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Materiality and the construction of Intersubjectivity: human-robot interaction In typical development and the use of the Objects in ASD children

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Chapter 1

General Introduction

*Una mente tutta logica è come un coltello tutto lama.
Fa sanguinare la mano che lo usa.*
(Rabindranath Tagore)

The aims of the present dissertation are to analyse, in children with typical and atypical development, the construction of the intersubjectivity through the use of objects in atypical development (ASD) and through the interaction with a humanoid robot in typical development. About the humanoid robots, the issue is to observe the possible attribution of human-like features to a robot that can make the human-robot interaction similar to the human-human interaction that is a classic intersubjective interaction because of the presence of two human subjects. This purpose is investigated considering two theoretical frameworks: 1) Theory of Mind that explain the construction of the intersubjectivity through the attribution of mental states to others; 2) Socio-material perspective which postulates that the construction of the intersubjectivity is mediated by objects in many cases. Thus, the question arises in this dissertation about the humanoid robot is: what happen when the mediator object (the robot) is also the interactive partner.

To achieve this purposes, the present thesis studies two main topics: 1) the interactional patterns with and the attribution of a mind to a robot by typically developing children; 2) the interactional patterns in atypical development - autistic children - in a child-adult interaction mediated by objects. The first topic is analysed in an innovative theoretical perspective and a through novel methodological approach, leading to an innovative understanding of the child-robot interaction. The theoretical perspective connects the role of Theory of Mind in HRI; the methodological approach observes children's decision-making strategies in the HRI, comparing these behavioural patterns when children interact with a human and with a robot. The second issue of the thesis is about the role of the object as mediator of the relationship between autistic children and adults. This is studied through the Socio-material perspective that hypothesised that material features of the objects and their intrinsic social qualities are strictly connected.

A useful psychological paradigm to investigate the construction of intersubjectivity is the Theory of Mind construct that will be briefly introduced; subsequently I will give an overview on Human-Robot

Interaction and, finally, I will conclude with some observations concerning the role of the objects in autism.

Theory of Mind or how understand the social world

Theory of Mind (ToM) represent one of the most important psychological constructs used in the last decades to interpret social interactions. ToM is the ability to understand one's own and other people's mental states (intentions, emotions, desires, beliefs), and to predict and interpret one's own and others' behaviours on the basis of such meta-representations (Premack and Woodruff, 1978; Wimmer and Perner, 1983; Perner and Wimmer, 1985). This definition highlights how the presence of the other is crucial for the comprehension of ourselves and for the interpretation of the relational world. The history of the ToM begins with the pioneering study of Premack and Woodruff (1978), titled "Does the Chimpanzee Have a Theory of Mind?". This study paved the way to study the ToM also in different agents, not only in humans but also in primates. They found that also the primates can use ToM ability to understand and predict the conspecific's and human's behaviours. These results allowed to study the ToM in an evolutionary perspective. In fact, Adolphs (2009) theorised about the phylogeny of social abilities, showing that our brain is a social brain that evolved from primates to humans.

Furthermore, developmental psychology study the changes that occur during children's development, showing the ontogenesis of this ability. ToM is not a monolithic construct, but it is a complex and multimodal ability that involved both cognitive and affective processes (Shamay-Tsoory & Aharon-Peretz, 2007; Kalbe et al., 2010).

Wellman (1991) hypothesised a ToM development from 3 to 7 years of age considering the understanding of mental states in the childhood. The author drawn a line of development: children in the early stage of development understand the non-epistemic states (desires, emotions and intentions) – between 3 and 4 years – and only late – between 4 and 7 years – the epistemic states. The epistemic states are the bases for the true and false belief understanding: this allows children to construct a meta-representation of their own and other's mind. Thus, considering the important of belief, in particular false belief, a pioneering study of Wimmer and Perner (1983) used for the first time the paradigm of the false belief task to study the ToM development. In this study the authors used the Unexpected Transfer Task in which a character has to ascribe a false belief of another character. The results showed that 4 - to 5 - year-old children can predict the actions of someone with a first order false beliefs referred to the first level of recursive thinking (i.e. "I think that you think"). These findings are supported by a meta-analytic study by Wellman, Cross and Watson (2001) that confirmed

that children begin to attribute a false belief starting from 4 years of age. In a second study Perner and Wimmer (1985) used a different task, the Ice-Cream Van, in order to analyse the second level of the recursive thinking (i.e. ‘I think that you think that she/he thinks’), that is the *second order false belief*. They found that 6- to 7- years-old children can understand this second level of representation. These findings show that the ‘sensible period’ for the emergence of the ToM is from 3 to 7 years of age and that it is acquired in a hierarchical way (Wellman, Cross and Watson, 2001). However, several studies show that the ToM is an ability that gradually develop from childhood to adulthood (Sommerville et al., 2013; Dumontheil et al., 2010; Apperly et al., 2012) and in the last years several studies investigate the modification of the ToM ability during the old age (Happé et al., 1998; Castelli et al., 2011; Saltzman et al., 2000).

Human-Robot Interaction: an interdisciplinary approach to investigate socio-cognitive abilities

“Human–Robot Interaction (HRI) is a field of study dedicated to understand, design, and evaluate robotic systems for use by or with humans” (Goodrich and Schultz, 2008, pp.1). The HRI derived from the Human-Computer Interaction (HCI) studies. The differences between HRI and HCI is that HRI uses robots that have physical human-like features (along a gradient from completely non-human like to a complete similarity with humans) and they can behave as humans (i.e., a robot can recognize and follow the eyes of a human or it can reply semi-autonomously to a human question). Thus, HRI not only implement behavioural patterns into robots but also design robots that can be perceived more human-like (Minato et al., 2004). In the last two decades HRI received more visibility especially related to the development of new theoretical approaches and technical skills in the robotics’ domain. For instance, in 2004 the Ishiguro’s Geminoid Project¹, in Japan, built androids which very closely resemble specific human “models” as a platform for research aimed at understanding humans, applying methods from engineering, cognitive science and neuroscience. Indeed, the robots can be used as a research tool in two different ways: 1) to use a robot in order to test human cognitive models, implementing algorithms that can simulate the human cognitive processes (Di Nuovo et al., 2013; De La Cruz et al., 2014; Whitaker, Colombo and Rand, 2018; Scassellati, 2003, 2005); 2) to use the robot as a possible partner in scenarios that implies the interaction with a human in order to observe social interactional patterns (Manzi, et al., 2018; Breazel et al., 2016; Moriguchi et al. 2011; Nishio et al., 2018; Sandoval et al., 2016). There are different theoretical approaches in HRI and in robotics; the

¹ For more information on the Geminoid Project: <http://www.geminoid.jp/en/index.html>

most interesting are: Developmental Robotics (Cangelosi and Schlesinger, 2015; Lungarella et al., 2003) and Developmental Cybernetics (Itakura 2008; Itakura, Okanda and Moriguchi, 2008).

Developmental Robotics is an emerging field of research that connects robotics, cognitive science and developmental sciences – in particular developmental psychology and developmental neuroscience (Di Nuovo et al., 2014; Di Nuovo et al., 2017). This field is focused on the implementation of robots that should be more autonomous, adaptable and sociable– the cognitive developmental studies are crucial in this respect – but to achieve this goal it is fundamental to employ models of human development in order to embed these models into robots. Thus, it is important the collaboration between engineers and developmental psychologists in order to design the models mentioned above (Asada et al., 2001; Lungarella et al., 2003). Developmental Robotics represents an innovative approach to the development of HRI: its statement is that robots can learn as children (Cangelosi and Schlesinger, 2015). Roboticians use algorithms, deriving from the Machine Learning field, to build cognitive models of psychological processes (Cangelosi and Riga, 2006; Cangelosi, 2010; Cangelosi et al., 2010). However, these models derive from the research in developmental psychology because it is fundamental to understand the trajectory of development of the psychological processes (i.e., ToM or linguistic development). Since robots should be social partners, Scassellati (1999, 2001, 2002) assumes that they have to possess a ToM. This is only a theoretical assumption because today technical innovation does not permit an implementation of a ToM into robots despite our knowledge about ToM development: an explanation is that ToM ability is a complex process that involves several cognitive and affective components.

Developmental Cybernetics connects Developmental Psychology and robotics, using the human development models in order to identify the most important behaviours that can promote HRI. This is the other side of the coin because, while the Developmental Robotics uses the models to make robots behave socially, Developmental Cybernetics studies which kind of behaviours should be implemented into robots in order to promote HRI. In particular, Developmental Cybernetics studies the development of social behaviour in infants in order to implement specific behaviours so that the robots can be treated as a companion. In the case of interactions between children and robots, we shift in the field of Child-Robot Interaction (often abbreviated as cHRI), which differs from HRI because the partner of the interaction, the child, presents an immature cognitive development (Belpame et al., 2013 a, b). cHRI is crucial for Developmental Cybernetics because of its futuristic hypotheses: in the next decades the robots can be introduced into human societies in different contexts among which the educational ones. In this case, the robots should be attractive for children: to reach this goal,

physical and behavioural characteristics should be more human-like. In 2018 one of the biggest Japanese educational projects introduces 500 humanoid robots (NAO robot, created by Aldebaran Robotics) in the Primary School in order to teach English to Japanese children². Moreover, several research programs use humanoid robots in different educational contexts (Chang et al., 2010; Belapme et al., 2016; Gordon et al., 2016; Kanda et al., 2007), highlighting, in a vygotskian approach, how robot can be use as scaffold. Developmental Cybernetics postulates that to build a social robot is important to study and to develop research knowledge about three main domains connected to the robot: Theory of Body (ToB), Theory of Communication (ToC) and Theory of Mind (ToM). The ToB hypothesises that a robot should move its arms, legs and head in a conventional mode. For instance, Morita and colleagues (2012) test children's and adults' reaction to conventional and unconventional movements of the body of a human and of a humanoid robot, showing that children extend their reaction to the unconventional movements both of human and humanoid robot respect to adults that are more activated when the unconventional movements are made by a humanoid robot. With regard to the domain of Theory of Communication, several studies show that an effective robot is a robot that can communicate in verbal and non-verbal way (Breazel at al., 2005; Brooks and Arkin, 2007; Mavridis, 2015). These researches generally highlight that a robot that can use non-verbal signals (i.e., facial expressions or gestures) to promote the human involvement in the interaction is perceived more as a companion than a robot that not communicate in such ways. For instance, Aaron and Mataric (2015) use a robot that communicate with a worker to achieve a goal, finding that the robot was perceived as a teammate more than a robot without communicative behaviours. The last, but not the least, domain of the Developmental Cybernetics is Theory of Mind: this is a crucial objective of Developmental Cybernetics because it hopes that in the future robots can interact in a way that can be perceived as having a mind. Nevertheless, as above mentioned, the implementation of ToM into robot is more a futuristic dream, while has been demonstrated that humans use their ToM ability to understand robots' behaviours. This a fundamental assumption that connects the different sections of this thesis. In fact, already Piaget (1929) uses the concept of animism suggesting that the human ability to ascribe intentionality to an object is an early infant's disposition. However, when we talk about robots, we refer to an animate object that appears and behaves in a human-like way. Thus, the ToM ability is a very useful psychological construct that can help to better to understand the human's tendency to ascribe mental states to a robot. In Chapter 1 it will be shown as humans, in a

² For more information is possible to access to the article by the following link:
https://rep.repubblica.it/pwa/generale/2018/09/24/news/giappone_robot_insegnano_inglese-207218720/?ref=RHRS-BH-I0-C6-P21-S1.6-T1

life-span perspective, tend to attribute minds to robots. Some research points out, in particular as regards childhood and adolescence, that the ascription of mental states changes with age (Manzi et al., 2017; Kahn et al., 2012). Chapter 2 shows that younger children tend to ascribe to robots more intentions and desires and less epistemic states than older children, in line with the ToM literature (Wellman, 2001). These findings highlight an important point for Developmental Cybernetics, and in general for developmental psychology, because they demonstrate that children perceive a robot as a partner that appear and behave like a human when they interact with it. Additionally, the children's ascription of a mind to a robot is the prerequisite for the establishment of the intersubjectivity. The concept of intersubjectivity captures the way a person understands and relates to another people and implies that exist a bridge between the knowledge of oneself and the one's own knowledge of others (Rochat, Passos-Ferreira and Salem, 2009). In the light of above, this is a crucial theoretical mark for the HRI because, if the intersubjectivity is the assumption of the interpersonal relationship in humans, the presence of this dimension in the human-robot interactions allows to interpret these interactions not only in a mere behavioural way but also in a relational way.

The use of the object in children's development: an overview on autism

The Autistic Spectrum Disorder (ASD) is a syndrome that can be characterized by an intellectual disability (DSM-5, 2013). The main symptoms of the ASD are: impairments in the social interaction (Baron-Cohen, 1997; Frith, 2003); impairments in the verbal and non-verbal communication (Mundy et al., 1987; Happé, 1995); stereotypical and repetitive behaviours, interests and activities (Bodfish et al., 2000; Boyd et al., 2010). Since ASD is a syndrome that affects all the psychological development, social and cognitive deficits are very heterogenous both for the complexity and severity of disease. These symptoms can emerge and change in different moment of development (Frith, 2003; Yirmiya and Charman, 2010). The repetitive behaviours and activities affect also the use of objects: some researchers report that this impairment can be detected already at 12 months of age (Ozonoff et al., 2008; McCleery et al., 2009). Ozonoff and colleagues (2008) found that 12-months-old children tend to use the object in a repetitive way. The use of the object needs to be studied from the sensorimotor development point of view because the object is present since the early stage of the children's development. More recently, several researches show that autistic children present atypical sensorimotor development and sensory perception that predicts the severity of symptoms especially in the area of communication at 24 months of age (Estes et al., 2015; Robertson and Baron-Cohen, 2017).

In the history of psychology, several psychologists studied the role of the object in the human development, such as Piaget, Vygotskji and Moscovici. Within his work, Piaget (1956; 1958; 1977) describes two different types of knowledge. The first type of knowledge origins through physical experience; such experience produces the knowledge of the properties of objects that are used. The second type of knowledge is gained through the logical-mathematical experience, which does not produce knowledge about the objects but about actions and their results. Thus, micro-genetic analysis, which aims to observe the temporal and qualitative aspects of the interactions, is a basic methodological condition for understanding the development of materiality. Despite this embryonic change of course the epistemological approach of Piaget remains anchored to the dualism of subject and reality.

Nevertheless Vygotskji (1962) uses another theoretical perspective: he considered the objects, named artefacts, as a fundamental component of human life. He suggests that humans use both material (i.e., a computer) and psychological (i.e., language) artefacts to interact. Adults use in a better way these artefacts and through their scaffolding 'teach' to children how to appropriately use them. In this respect, the artefacts represent human 'instruments' essential for the communication and interaction.

In these terms, the behaviour and the understanding of the processes of consciousness are closely dependent on the nature of the interaction of human and non-human components of this dialectic dyad. In the history of psychology, some the psychologists abandoned a dyadic approach in favour of a triadic perspective. The key aspect is no longer just the dyadic relationship, but what Moscovici (1976) defines triadic relationship. Moscovici proposes a ternary reading of facts and relations, and in fact replaces the two- term view, subject and object, with a three-term one: individual subject, social subject, and object. In other words, the Ego, the Other and the Object. This aspect assumes a constant exchange between the three elements of the triadic relationship. Such relationship may be conceived as static or dynamic, implying a simple "co-presence" or an "interaction" that can result in changes in thought and behaviour.

However, the theories presented above about the objects are based on a non-dialogical conception of the artefacts. In fact, Linell (2009) considers artefacts as external objects, according to a dialogical theory of the artefacts. The objects serve as anchoring points for intersubjectivity. Moreover, the author suggests that exist an interplay between the human ability of using artefacts and the external objects which possess a wide range of uses for humans. Thus, the objects are used by humans but also can change the humans perspective of the interactional world.

The objects are involved in several psychological mechanisms, such as joint attention and imitation that are largely studied in autism. The joint attention implicates at least the presence of two

partners and of an object that plays the role of the mediator of their interaction (Tomasello, 1995; Mundy and Gomes, 1998; Moore, Dunham and Dunham, 2014). Thus, the object is a protagonist of this human phenomenon, acquiring a crucial role in the interaction. Moreover, the studies on imitation distinguish between body gestures imitation and object actions imitation (Masur & Ritz, 1984; Snow, 1989), showing that the object is involved in the human development as a fundamental ‘non-living partner’ that has a role in a lot of psychological processes.

In the light of above, about children with typical development, the use of the object is a crucial element for the interactions (Rodriguez and Moreno, 2008; Barthélémy-Musso et al., 2013). In fact, Rodriguez and Moreno (2008) hypothesizes that children with typical development use the object in order to interact with adults: the adult has the role to teach to the child different uses of the object which, derive from the human society, Thus, the adult acquires the role of a scaffolder for the conventional use of the object (Moro, 2011, 2014). This approach is particularly interesting because the children and adult create an intersubjective space in which they can interact with each other through an object. Thus, the object is a mediator of the child-adult interaction. Moreover, as already highlighted in the previous paragraphs, the establishment of an intersubjectivity space is the basis of the of human interpersonal relationships.

In the view of the above, it is important to analyse the role of the object also in children with atypical development, in particular in autistic children because they present a distinctive pattern of interaction with the object (i.e., repetitive actions on the object) and are also characterized by social impairments which represent an obstacle for the establishment of interpersonal relationships. In fact, being social interaction impaired in autistic children is consequently impaired the interaction with the “social world of objects”. In the socio-material perspective (Iannaccone, 2015) the object is composed of material features and social components which coexisting the same object. Some autistic children show deficit in the use of the object: alterations in manipulation, observation, understanding and denomination. The object is a significant communicative mediator in social interaction between adults and children (Iannaccone, Savarese and Manzi, 2016). Thus, autistic children which do not present impairment in the use of the object show more social behaviours as pointing (Bernabei, Camaioni and Levi, 1998), imitation (Vanvuchelen et al., 2013) and joint attention (Mundy, 2016). For instance, joint attention is typified by subject-subject-object triangulation in which children alternate their eye gaze between the object and the other person (Trevvarthen and Hubley, 1978). In this respect, Chapter 3 and 4 deal with the role of the object as promoter of the child-adult interactions. Despite the identification of deficits in the expression of the most important early precursors for the social interaction, it has been observed that autistic children can use in specific ways the object that promote the intersubjectivity space. In Chapter 4 autistic children from 20 to 24

months of age exhibit specific sensorimotor patterns of use of objects (manipulation and exploration) that tend to involve the other partner – adults – to interact with the objects. Thus, also in the case of autistic children the object is a mediator of the relation with the adult. Moreover, Chapter 4 points out that autistic children that present a more complex and rhythmic patterns of interaction with the object present more social behaviours (i.e., joint attention and imitative actions).

These findings reveal the ability of autistic children to establish an intersubjectivity space, using the object as mediator of interactions with adults despite the evident social impairments that characterize this syndrome.

This Thesis

Chapter 1 is a review of the literature about the role of the Theory of Mind (ToM) in the Human-Robot Interaction (HRI) in a life-span perspective, showing that from the childhood to the adulthood humans can ascribe a mind to a robot, in particular to a humanoid robot. The HRI is analysed in two main domains: 1) mental states and actions; 2) physical human-like features. The first area highlights that a robot which behave like a human and use human-like cognitive processes promotes the attribution of a mind to a robot. Already in infancy some behaviours (i.e., eye-contact and goal directed actions) promote a better children's social involvement during the interaction with a robot. The robot human-likeness is effective in a life-span perspective. Moreover, the implementation of robots' human-like physical features (i.e. eyes, hands, legs etc) is a crucial goal for the promotion of a more complex human-robot interaction. However, it is also important for a robot to not be completely similar to a human since the risk of a perfect human-like appearance is the Uncanny Valley effect (Mori, 1970), in which the excessive similarity of a robot with humans can reduce the interaction. The main hypothesis is that through these technical innovations, concerning physical and behavioural features of a robot, humans construct an intersubjectivity space with a robot. This is possible because the recognition of a mind in a robot is the prerequisite because humans perceived it as social partner.

Chapter 2 is focuses on pre-schoolers' behaviour during the Ultimatum Game when they play with a human and a robot. In particular the study aims at analysing: the mental characteristics ascribed to the robot with respect to the human; children's behaviour at the UG when playing with the human and with the robot as proposers and receivers; children's justifications for their behaviour during the UG. To my knowledge, this is the first study which analyses children's behaviour during the UG, comparing human-human and human-robot interaction. In this respect, several tasks and tests were created *ad hoc*: 1) the Attribution of Mental State Scale (AMS) is a measure of mental states attribution that the child has to perform looking at pictures depicting a character; 2) to assess children's understanding of the first-order false belief, we introduced a new instrument, constituted by eight videos representing the classical story, introducing also the Robovie as a new character - we used a story similar to the classical *Unexpected Transfer* task as the script of the videos. The AMS results show that 5-year-old children recognize the robot as a different entity from the human. In fact, children ascribe mental states also to the robot, but they are different compared to the mental states attribute to the human. Nevertheless, children behaved similarly during the UG when playing with the human and with the robot, confirming a tendency to maximize gain. Additionally, children's

justifications at the UG showed that, independently on the interactive agent and on the role played (Proposer/Receiver), children tend to use ‘outcome’-based justifications to explain their behaviour for all divisions. This is the first qualitative evidence supporting the idea that, at the age considered, children mostly reason in economic/quantitative, homo-oeconomicus-like, terms. The almost total lack of equity and mentalization-based justifications of human unfair divisions further suggests an attempt of children to resolve a social cognitive conflict emerging from the discrepancy between a “socially-expected” fair behaviour and the actual “selfish” behaviour.

Chapter 3 presents an explorative study aimed at observing the quality of interactional patterns in child-adult interaction, using objects as key elements for the construction of intersubjectivity. This qualitative research is based on two theoretical perspectives: 1) Piaget's studies (1952, 1954), according to which children reach the conceptualization skills of objects in the fifth phase of the sensory-motor development; 2) studies that concern the canonical use of the objects, according to which the canonical functions of the objects are acquired as a normative phenomenon during social interactions (Tomasello, 2016), even if the cognitive understanding of these functions is a prerequisite. Several other studies show that canonical functions of the objects are acquired during child-adult interactions (Leontiev, 1981; Costall, 1997; Moro, 2011, 2014; Rodríguez & Moro, 1998; Sinha & Rodríguez, 2008). In this Chapter it will be analysed the manipulation of objects by children with autism spectrum disorder with the aim of showing how objects can be considered as active agents of interpersonal exchange between children and adults. The study adopts a socio-material interpretation, assuming that some interactional patterns, involving the manipulation of objects, can create a space that supports the child-adult relationship. The observations highlight that children present sensorial and realistic play and there are some children's behaviours (i.e., eye-contact) that show that the objects are concrete mediators for the construction of the intersubjective space in the interactions between children and adults. It has been observed in this study that children monitor adults' attention through eye contact or object manipulation. These actions are signs that the object becomes a mediator of mutual attention between the adult and the child: we called this kind of attention, “attention mediated by the object”.

Chapter 4 presents a brief report that investigates the role of the object as a factor that mediates the interaction between children and adults. We observed a group of autistic children in order to analyse if an object can be a promoter of social interactional functions: imitation, joint attention and pointing. The main focus of the study is to analyze in verbal ASD the understanding of social function intrinsic in the object through the use of material features of the object. In particular, the study evaluates the

relationship between the “interaction with/through object” (material features of the object) and three social functions classically impaired in ASD: pointing, imitation and joint attention. We observed a group of ASD children aged between the ending of the sensory-motor stage (24 months) and the beginning of the concrete operational stage (68 months). The group has been split in two sub-groups: group1 is composed of 18 children that act and interact through objects (for examples, balls, cars etc.). Indeed, children manipulate, observe, understand and sometimes give a definition of the object; group2 is composed of 25 children that do not act and interact through and with object. Group 1 shows more social functions (pointing, imitation and joint attention) than group 2 Autistic children which show a more complex use of the material features of the object and act and interact with and through object present more social functions. On the other hand, children which have alteration in the use of the object show fewer social functions. These differences depend on the children’s characteristics. In this study, the role of the object is a crucial element for the creation of the intersubjective space.

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Chapter 2

Theory of Mind and Humanoid Robots From a Lifespan Perspective

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Abstract

This mini-review focuses on some relevant issues concerning the relationship between Theory of Mind and humanoid robots. Humanoid robots are employed in different everyday-life contexts, so it seems relevant to question whether the relationships between human beings and humanoids can be characterized by a mode of interaction typical of the relationships between human beings, i.e., the attribution of mental states. Since Theory of Mind development continuously undergoes changes, from early childhood to late adulthood, a lifespan perspective was adopted. Contributions from the literature were analyzed by organizing them around the partition between ‘mental states and actions’ and ‘human-like features’. Finally, we considered the contribution that studying the human-robot interaction, within the paradigm of Theory of Mind, can give to the understanding of the intersubjective nature of this interaction.

Introduction

This contribution progresses from Turkle's (2004) opinion, which, reflecting on Steven Spielberg's movie, *AI*, exemplifies the most exquisite socio-relational issues of human–robot interaction:

. . .[S]cientists build a humanoid robot, David, who is programmed to love. David expresses this love to a woman who has adopted him as her child. In the discussion that followed the release of the film, emphasis usually fell on the question of whether such a robot could really be developed. People thereby passed over a deeper question. ... That question concerns...[w]hat kinds of people are we becoming as we develop more and more intimate relationships with machines? Today, we are faced with relational artifacts to which people respond in ways that have much in common with the mother in *A.I.* (p. 25).

For hundreds of years, the interest in human–robot interaction has occupied a space in the cultural productions of humankind. Today, we are witnessing a renewed interest in the human creation of a nonhuman alter ego. In particular, researchers are focusing their interest on social interactions with robots. Many scholars believe that a fundamental component of social interaction is the Theory of Mind (ToM; Wimmer & Perner, 1983). ToM is the ability to predict and interpret our own, and others', behavior on the basis of mental states. Herein we offer an overview of work that has focused on the study of human–robot interaction, in the context of ToM. In particular, we review studies investigating the attribution of mental states to robots in a lifespan perspective.

Without the claim of being chronologically exhaustive, we provide some examples of the pervasive interest in artificial partners in the history of humanity. Homer (2003), in the *Iliad* (XVIII, 573–579), told how Hephaestus, the god of fire, who needed help in his forges, built aides, similar to young men, who had hearts, voices, and life. Discussion of the more-or-less human characteristics of intelligent manmade machines has its most famous philosophical roots in the 17th and 18th centuries, in the debate around the works of Descartes and La Mettrie (Gunderson, 1964). Descartes equates animals with machines, but ascribes uniqueness to humans via the term, *cogito* (I think). On the contrary, La Mettrie extends the animal-machine analogy to humans, radicalizing the materialistic and mechanistic perspective.

The mechanical automaton was an attempt to build a human-like artifact, capable of replicating and repeating human activity. In the 13th century, Al-Jazari, an Arabic mechanical engineer, built a programmable device capable of playing sounds autonomously (Nadarajan, 2007). In the 15th

century, Leonardo da Vinci not only theorized on the possible robotic reproduction of an animal, but also advanced a project that attempted to mechanize the human being, with the mechanical knight of 1495 (Rosheim, 2006; Taddei, 2007).

A crucial qualitative leap into the anthropomorphization of machines is to ask whether robots can think, overcoming Cartesian dualism: the philosophical concept that asserts the existence of a separation between *res cogitans* and *res extensa* (i.e., respectively the mind and the body). From a psychological, and more intersubjective³, point of view, and for the purpose of this review, we can rephrase the question as: when will robots be able to make humans believe that they are human? In 1950, Turing published a seminal paper in which he imagined an imitation game with three participants. An interrogator asked questions of the other two participants and, based on the answers, had to guess who was a man and who was a woman. Then, without warning the interrogator, a computer would replace one of the participants. How long would it take to understand that the answers came from a machine, and not from a human being? According to Turing, during the imitation game, it would become increasingly difficult to distinguish the responses of a machine from those of a human (Turing, 1950).

Artistic creativity often anticipates scientific topics on the history of thought. There are many examples in literature and cinema about our subject. Let us remember Shelley (1830/1994), proposing the literary character of Frankenstein, or The Modern Prometheus⁴, destined for a much greater degree of notoriety thanks to the story's many cinematic adaptations. It is also worth mentioning Asimov (1983), who revisited the futuristic concept of a robot by conceiving it as a potential partner for supporting/replacing human activities.

³ The concept of intersubjectivity has various definitions, each of them highlighting different aspects: cognitive, affective, socio-cognitive. The various definitions have in common the idea that the meaning of the tasks and events that the person builds during development is not an operation in solitude but is the result of interaction with real or symbolic partners.

⁴ The story shows the human desire to create an immortal alter ego. The created alter ego turns out to be a monster. Dramatic events lead to the death of the monster's creator and then the monster itself. The monster suicides, explaining the evil deeds it has done while living with the contempt and rejection by humans. The fascination of this story consists in shaping the fears of both partners in this relationship.

Cinema has also represented – now as utopia, now as dystopia – the complexity of the robot’s relationship with humanoids. Fritz Lang’s *Metropolis* (1927) was the first movie to foreshadow the possibility that a robot could substitute for man in the hardest jobs, and that it could begin to interact with man in ways that went beyond any designed intentionality.

The iconic film *Blade Runner* (1982), drawing inspiration from Philip K. Dick’s *Do androids dream of electric sheep?* (1968), highlighted the risk of indistinguishability between

the creator of humanoids and his “children.” Freud (1919/1955) described the characteristics of a particular psychic experience with the experience of the “Perturbant” (*Unheimlich*-unfamiliar vs. *Heimlich*-familiar). Jentsch (1906, 1997) had already described this experience in relation to, for example, puppets and automatons. The latter consist of the uncertainty that a seemingly inanimate being is alive and, in a complementary way, that a living subject has the chance to be inanimate.

This phenomenon reappears in more recent literature as the “Uncanny Valley” experience. Mori (1970) described the sense of repulsion that can accompany interaction with humanoids whose appearance resembles, without being overly superimposed, that of a human (see also Mori, MacDorman, & Kageki, 2012). Another facet of the possible human–robot relationship worth mentioning is the one proposed by Spike Jonze’s *Her* (2013). The protagonist lives a true love story with an almost completely disincarnated artificial intelligence that manifests itself through a very sensual voice. Alongside this experience, the growing presence of anthropomorphic robots in everyday life, in educational, production, and welfare settings, raises several new issues – philosophical, ethical, political, economic, legal, and insurance⁵. While the anxiety about replacing men with robots in production situations, with the associated risk of unemployment and impoverishment, is not new, more recent discussions are about the status of robots, with respect to the new aforementioned issues (Floridi, 2017; Floridi & Sanders, 2004; see also the European Parliament Resolution of 16 February 2017).

In the case of robot-building for social purposes⁶, the extraordinary human capacity to invent and realize tools that integrate and expand the biologically-based abilities of our species (from work tools

⁵ To give just a few examples, think of the use of robots for assistance and companionship to the elderly, the educational and didactic use with children with typical and atypical development, and the execution of various activities in shopping centers, airports, and so forth.

⁶ The military is another area that makes extensive use of robotic engineering (just think of the recent massive use of drones in war). Although the psychological implications are multiple (attribution of responsibility, reliability of information, trust, etc.), we do not consider this field because there is no possibility of attributing mental states to the robot.

to sensory aids to external memory of electronic devices) has been driven in two directions. The first direction – developmental cybernetics (Itakura, 2008; Itakura, Okanda, & Moriguchi, 2008) – consists of creating a human-like system, with cognitive function (simulating psychological processes in the robot) and prosthetic functions (enhancing the function and life-style of persons). The second direction – developmental robotics – consists of the idea that robots can autonomously gain sensorimotor and mental capabilities with growing complexity, starting from intricate evolutionary principles (Cangelosi & Schlesinger, 2015). To date, developmental cybernetics aims to build robots that behave in a human-like way, while developmental robotics aims to build robots that develop in a human-like way. Based on these features, the two approaches are located at different points on a continuum that links interaction and relationship. Developmental cybernetics is closer to the relational dimension; in fact, it studies those human–robot exchanges in which the assumption of some form of subjectivity of the partners is involved. Let us think, for example, about the educational and welfare uses of intelligent machines, in which the dynamics associated with the use of prosthetic tools that improve quality of life are placed on the level of *hic et nunc* (here and now) interaction, without aiming at the construction of a relational story. Conversely, socio-relational dynamics value the level of the relationship (Gross et al., 2012; Tanaka, Cicourel, & Movellan, 2007). Developmental robotics is closer to the interactive dimension; it uses the interaction to study how a robot can develop new abilities, in a child-like fashion. For instance, consider the attempts at robotics modeling of the stages of language acquisition (Morse & Cangelosi, 2017), and the use of mutual imitation between humans and robots to promote the robot’s subsequent recognition of an interactive agent (Boucenna, Cohen, Meltzoff, Gaussier, & Chetouani, 2016).

We are interested in understanding how the attribution of mental states to robots evolves through the lifespan; therefore, we primarily analyze the studies conducted in the field of developmental cybernetics.

Why Robots Could Be Intended as Social Partners

From a psychological point of view, from the earliest moments and throughout one’s entire life, the possibility of establishing social exchanges involves the ability to recognize the other as being “like me” (Meltzoff, 2005; Meltzoff, 2007a, 2007b; Meltzoff, 2013; Meltzoff & Brooks, 2001). Infants can imitate facial movements, such as mouth opening and tongue protrusion (Meltzoff & Moore, 1977, 1983, 1989), and have visual acuity for human faces and stimuli, with characteristics similar to themselves (Johnson, Dziurawiec, Ellis, & Morton, 1991). Proto-conversations with the caregiver

root in these innate imitative mechanisms and, overall, the analysis of traits and characteristics of the relational partner contribute to building the intersubjective dimension underlying so many developmental acquisitions (Meltzoff, 2005; Meltzoff, 2007a, 2007b; Meltzoff, 2013). For this purpose, Trevarthen (1998) spoke of an innate specific human endowment that would guide us to the search for companionship, and put us in the condition of “understanding and using the intentions of other people in conversational talks of intentions, emotions, experiences, and meaning” (p. 16). According to Tronick, Als, Adamson, Wise, and Brazelton (1978), human beings experience the world in intersubjective terms. This trend is related to the tendency of children to first experience the world as if it were animated, and to make a distinction between animate and inanimate only later. This tendency is operationalized by the “still face” paradigm: the motionless face of the caregiver generates in the child a series of emotions from perplexity to anxiety, showing the infant’s expectation to interact with a human partner with an expressive, and therefore animated, face.

A fundamental question, therefore, is: what can the developmental research on human–robot interaction teach us about aspects, features, and cues that a robotic interactive partner must have to be recognized as “like-me?” This question has an epistemological basis. In fact, human–robot interaction represents a “technological gym” that specifies the social cues that must be implemented in a humanoid robot so that children of different ages recognize it and treat it as a social partner.

Below, we analyze contributions from the literature to the lifespan perspective in this regard, by organizing them around “mental states and actions” and “human-like features.” This division arises from the consideration that a representational ToM derives from the infants’ early understanding of the bodily cues of the mental states. In other words, the bodily roots of ToM remain through the lifespan, as the basis of more advanced representational mentalistic skills.

Mental States and Actions

Regarding the first element of the division that we set as the basis of robot attributions of features “like-me,” the research examines aspects of robotic actions that lead participants to believe that the actions imply mental states.

In this sense, a seminal study by Meltzoff (1995) investigated the reenactment of intended acts, performed by human beings versus robot-like devices, in a group of 18-month-old infants. An emerging sense of the person is revealed by the fact that infants did not reenact the action performed by the robot-like device, probably because they did not recognize its intentions and goals.

Itakura, Ishida, et al. (2008) studied this topic further, in children aged 24–35 months, and showed that the children were inclined to imitate goal-directed actions where the goal is not achieved; these failed actions implemented by a robot were imitated only when the robot's action was preceded by eye contact between the robot and an adult present at the scene. When the robot's eye contact with the adult was missing, the child did not mimic the robot's behavior. According to the authors, this evidence shows that it is not human-like morphology, but rather human-like behavior, through eye contact, that plays an important role in inducing children to imitate the goal-directed behavior of a nonhuman agent.

The theme of imitation of goal-directed actions relates to research on mirror neurons⁷, which seem to play an important role in understanding others' actions and, more generally, in social competence. On this basis, Moriguchi, Matsunaka, Itakura, and Hiraki (2012) initially elaborated that the actions are somehow related to perception, and that many human brain areas devoted to the execution of actions also function by observing other human actions, rather than robotic actions. The authors then built on this evidence through a research paradigm verifying whether, and how, actions taken by a human arm or a mechanical arm may somehow interfere with the child's search for an object. A human arm and a mechanical arm sought and found an object in position A. The object was then moved to position B. The child who was asked to look for the object attributed a kind of "retrospective trust" to the human arm, compared to the mechanical arm; in fact, the number of errors committed in the search for the object was higher when the human action preceded the search. The same result had already been obtained in a group of 3-year-olds (Moriguchi, Kanda, Ishiguro, & Itakura, 2010), suggesting that the presence of a mental simulation mechanism would only be activated when the children imitated human actions.

Okumura, Kanakogi, Kanda, Ishiguro, and Itakura (2013a) confirmed this in a paradigm that verified the ability to anticipate the appearance of an object, using the information from a human gaze, rather than a robotic gaze. Through the use of an eye tracker, gaze-following and object anticipation were measured in two groups of 10- and 12-month-old children. Both groups let themselves be guided by

⁷ The mirror neurons are a subset of neurons in the human brain that respond when an individual performs certain actions, and also when the same individual observes others performing the same movements. In other words, actions performed by one person can activate motor pathways in another's brain responsible for performing the same action. Mirror neurons, or mirror mechanism, provide a direct internal experience, and therefore understanding, of another person's act, intention, or emotion. Mirror neurons may also underlie the ability to imitate another's action, and thereby learn, making the mirror mechanism a bridge between individual brains for communication and connection on multiple levels (Rizzolatti, Fogassi, & Gallese 2006).

the human gaze and the robotic gaze; however, only the human gaze had an anticipation effect, and only for the 12-month-old children.

In the context of studies that analyze the importance of the perception of biological motion as the precursor of ToM (Frith & Frith, 1999), Breazeal et al. (2016) considered a group of 3- and 5-year-old children. Note that the ability to use a robotic informant with epistemic aims (name exotic, non-familiar animals for children) is strongly influenced by the nonverbal contingency of the informant (head movements, gaze shifts, arm movements, and facial movements) typical of human face-to-face interactions. From this perspective, Carter and Pelphrey (2006) explored, with functional Magnetic Resonance Imaging (fMRI), neural activations, corresponding to the perception of the movement of four different agents – human, robot, mechanical assembly, and grandfather clock – in 7- to 10-year-old children. The results showed different activations, according to the human-like nature of the perceived biological movement, that is, a motion made by a human or a robot. This brain network also included some components of the mirror neuron system. Replicating the evidence obtained on adults, these findings show that some portions of the neural circuit involved in the embodied simulation are recruited in the perception of the biological movement also enacted by a robot.

We now shift from studies that analyze indirect indicators of the attribution of human-like features to studies that explicitly analyze this attribution. Kahn et al. (2012) interviewed children aged 9, 12, and 15 years, and evaluated the attribution of social, mental, and moral features to robots previously observed in nine different interactive situations with the subject and the experimenter. The authors found an interesting developmental trend: 9- and 12-year-olds perceived the robotic partner as a more mental, social, and partially moral entity than did the 15-year-olds. Therefore, in the construction of robotic partners suitable for participants of preadolescent age, with different purposes (from play to education), it is important to analyze, in detail, what interactive features are strengthened, so that the robot is perceived as the holder of mental, social, and moral characteristics, even by teenagers. Similar results regarding the attribution of mentalistic features to robots, following the observation of goal-directed actions, were obtained using a semi-structured interview of participants aged between 5 and 16 years (Beran, Ramirez-Serrano, Kuzyk, Fior, & Nugent, 2011). The participants tended to attribute behavioral, cognitive, and affective features to robots observed in the execution of a block-stacking task, a construction game in which the robot stacked blocks of wood to form two towers. In carrying out these activities, the robot manifested autonomy through a series of behaviors, such as looking at the child's face, performing accidental actions, and so on. Reminiscent of Piagetian animism, there was also an effect of age such that younger children (under 12 years of age), more

than the older children, believed that robots possess a large number of human attributes (Piaget, 1954).

Chaminade et al. (2010) used behavioral and fMRI methods to explore emotion depiction (anger, joy, and disgust) in gestures acted by human beings and humanoid robots in a sample of young adults. Results showed higher emotion ratings for anger and disgust expressed by the human; no differences were found for joy. Neural evidence suggested less empathy from viewing the humanoid robot: in fact, the activation of the left anterior insula (perception of disgust) and the orbitofrontal cortex (perception of anger) was lower for robot stimuli than for human stimuli. Finally, the higher activation in the occipital and posterior temporal cortices with robot versus human stimuli probably arose from the additional visual processing linked to the perception of a behavior acted by the humanoid robot.

An ingenious way to look directly at the interaction between human and robot is to use economic interactive games. One of the most used interactive games is the Ultimatum Game: one player (responder) receives a monetary offer from another player (proposer), who has to divide the amount. The responder has the option of accepting or rejecting the offer. If the responder accepts the offer, the two participants split the sum of money; however, if the responder rejects the offer, both players receive nothing (Güth, Schmittberger, & Schwarze, 1982). Nishio, Ogawa, Kanakogi, Itakura, and Ishiguro (2012) had young adults play the Ultimatum Game with a robotic partner. Results showed that fairness-oriented behavior increased when “mentalizing stimuli” accompanied cues from the physical appearance of the robotic partner, such as the expression of utterances between experimental sessions (see also Castelli, Massaro, Sanfey, & Marchetti, 2010, for results in a sample of children with a human and a nonhuman partner).

Ultimately, the works presented in this section show that children and adults perceive an experience with an artificial partner as social when the artificial partner can express intentions and goals through behavioral cues that are typical of interactions among humans.

Human-Like Features

With regard to “human-like features,” the research focuses on the configuration of body features being indispensable to humanoid anthropomorphization. It seems that, very soon, human beings will be able to relate to robots according to a principle of similarity to themselves. A first question is

whether biological and psychological characteristics are attributed to robots similarly or differently from other living organisms, and other material entities. Kamewari, Kato, Kanda, Ishiguro, and Hiraki, (2005) showed that 6.5-month-old infants exhibited the ability to attribute agency to human and humanoid-robot motions, but not to a robot without a human-like appearance. A sophisticated teleological representation is assumed in interpreting actions during the early stages of an infant's life, insofar as the agents are human-like. This first result is strengthened by two studies that take into account two human features considered crucial in characterizing one's social nature – eyes and voice.

The first study by Okumura et al. (2013a) showed that the presence of eyes in a robot is crucial for 12-month-old children to have their attention directed by the movement of a robot. In fact, when a robot without eyes was set in motion, this movement was not as informative to the child. The authors interpreted this result by assuming that the presence of eyes was a crucial indicator for the attribution of a mind at this age. The second study by Okumura, Kanakogi, Kanda, Ishiguro, and Itakura (2013b) showed that, for children aged 12 months, the gaze of a robot can be effectively used to learn an object if it is accompanied by a verbalization (not a simple nonverbal sound).

Moving from the preverbal to the verbal age, results obtained by directly questioning the participants about the characteristics of the robots are consistent with the early propensity to attribute human-like characteristics to humanoids. With development, other elements, in addition to the look, become important in deciding whether a partner has human-like characteristics. Katayama, Katayama, Kitazaki, and Itakura (2010) compared humans, robots, animals, and cultural artifacts to study the possible recognition of biological and psychological features in robots by children aged 5 and 6 years, and by adults. While the adults' attributions were quite heterogeneous, both 5- and 6 year-olds attributed a variety of biological but not mentalistic features to robots. Somanader, Saylor, and Levin (2011) asked a sample of 4- and 5-year-olds about the presence of representational, biological and mechanical characteristics in a human being, and in cultural artifacts (i.e., a robot and a TV). They found that the children attributed more representational and biological features to the human being than to the cultural artifacts, and to the robot more than to the TV. They also found that such attributions were more likely to be given to the robot if they did not see that the robot was controlled by a remote. These data reverse the trend found in a previous study, by Saylor, Somanader, Levin, and Kawamura (2010), in which robots and other familiar artifacts, including a TV, were classified as the same thing in terms of biological and representational properties. The authors assumed that the difference between the results of the two studies was due to their efforts to formally anthropomorphize the robots.

Manzi et al. (2017) explored the mentalistic value of faces in anthropomorphic agents compared to human faces through a dichotomous morphing, or gradient, of progressive anthropomorphism. The authors showed that 7- and 9-year-old children ascribed more mental state (e.g., sensory, perceptive, emotive, will, imaginative, and epistemic attributes) to the human face than to a robotic face.

Fiore et al. (2013) explored which elements contributed to creating an impression of the social presence of an agent in a group of late teenagers. To this end, they analyzed the way human beings interpret social cues exhibited by robots, in terms of proxemic behavior (the distance that the robot travels within the human's space). This was investigated by placing the robot and the participant in a hallway-crossing scenario. In this scenario, the authors varied the level of proximity the robot would permit the human in establishing whether to cross paths, and if the robot waited until the participant had passed. The authors also measured the role of the gaze, performed at three levels of direction (congruent with the robot's movement, human-oriented, and variable). The results showed that the robot that waited until the participant passed was evaluated as an agent more socially present than the robot that crossed the path without waiting. Furthermore, gaze did not play a significant role as a social cue in this situation.

Krach et al. (2008) explored human-robot interaction with a group of young adults, using the interactive game the Prisoner's Dilemma and fMRI. In the game, two players must decide whether to cooperate with each other or defect. They may gain a defined sum of points, depending on their own, and their counterpart's decision. A unilateral win is maximized by defection, if the counterpart cooperates, but both players are punished if they defect. Relying on mutual cooperation involves the risk of being deceived. In this study, the game included four different partners, each with an increasing level of anthropomorphization (computer, functional robot, anthropomorphic robot, human). Anthropomorphization was operationalized by following Epley, Waytz, and Cacioppo (2007), who included cues relating explicitly to physical aspects and mental states (elicited agent knowledge, effectiveness motivation). Participants were asked to evaluate the game partner for fun, intelligence, competitiveness, and sympathy. Results showed a linearly increasing attribution of fun and intelligence as the partner appeared more human-like. Interestingly, the anthropomorphic robot and the human were perceived as equally competitive, and more competitive than the computer and the functional robot. Moreover, the authors of the study pointed out that higher levels of human-likeness

were positively correlated with a greater activation of the ToM network, that is, the brain areas⁸ that the literature has shown to be specifically recruited when people interact with a social partner.

Takahashi et al. (2014) focused on the neural bases of human–robot interaction when participants were involved in an economic interactive game (Matching Pennies) with several partners: human, human-like android, mechanical robot, interactive robot, and a computer. The game was played between two players: a participant and an opponent. They had to press a button corresponding to the left or the right side of their bodies. The win situation was reached only when the same side was selected by both participant and opponent. The partners were evaluated concerning two dimensions: mind-holderness (having mental functions) and mind-readerness (being intelligent). As predicted by game theory, the more robotic partners were thought to be mind-readers the more the human opponents changed their play strategies, increasing the level of entropy of exchanges through random choices. fMRI data showed the involvement of different subsets of the social brain, according to the attribution of mind-holderness (dorsal aspect of the temporoparietal junction, medial prefrontal and posterior paracingulate cortices) or mind-readerness (ventral temporoparietal junction and the temporal pole).

Broadbent et al. (2013) studied how the facial characteristics of a robot may influence recognition of the robot's qualities, such as mind, personality, and eeriness, using a sample of young adults involved in a simulated healthcare environment. They employed three robots, respectively showing lack of face, silver face, and human face. The results showed a clear preference for the robot with the human-like face, which was rated as having the most mind and personality, and the lowest eeriness. This specific result relates to the uncanny valley, demonstrating just how subtle the boundary is between a pleasant likeness to the human and a disquieting one.

Similarly, Martini, Gonzalez, and Wiese (2016) studied whether specific degrees of humanness were needed to attribute different typologies of internal states to non–human agents. Interestingly, they found that the threshold “having a mind” must be reached, before being able to ascribe any other kind of internal state. The more the non–human face resembled that of a human, the more this threshold was overcome.

⁸ The ToM network includes the medial prefrontal cortex (mPFC), parts of precuneus and posterior cingulate cortex, the temporoparietal junction (TPJ), the posterior superior temporal sulcus (pSTS) bilaterally; some studies also include the bilateral anterior temporal lobes and areas in the amygdala (Schurz, Radua, Aichhorn, Richlan, & Perner, 2014).

Considering the studies reviewed so far, it is useful to emphasize the great importance given to the face and eyes when considering the physical features capable of representing an agent in anthropomorphic terms. This evidence confirms the great amount of data from ethology, evolutionary psychology, and even studies of aesthetic perception, in support of the great power of the human face in creating a sense of social interaction (Brooks & Meltzoff, 2005; Call & Carpenter, 2001; Emery, 2000; Itakura, Agnetta, Hare, & Tomasello, 1999; Massaro et al., 2012; Moore & Corkum, 1998; Morales, Mundy, & Rojas, 1998; Savazzi et al., 2014; Slaughter & McConnell, 2003; Tomasello, Hare, & Fogleman, 2001; Tomasello, Hare, Lehmann, & Call, 2007).

In conclusion, the information presented in this section shows that interaction with artificial agents is more preferred, and perceived as human-like, when the artificial agent presents aesthetic features that reproduce those of humans, with particular relevance to face and gaze.

Human Beings and Robots: Preliminary Steps Toward Intersubjectivity

The studies reviewed identify features pertaining to mentalizing cues and physical appearance as important bases of the “like me” experience with humanoids. Recent research also suggests that Meltzoff’s (2007a, 2013) “like me” framework can be extended to encompass other dimensions on which human perceivers make “like me” attributions. These dimensions pertain to the nature of the interaction, and other, deeper factors that are just beginning to be explored. A minority of studies delineates an emerging trend of research in this field. These are investigations across the lifespan that consider the role of attitudes and expectations of the human partner, involved in different interactive contexts, in determining preferences and acceptance of the humanoid partner.

Meltzoff, Brooks, Shon, and Rao (2010) explored the hypothesis that 18-month-old infants may use information gained from observing human–robot interactions as evidence about whether the robot is a perceiver. The results showed that the infants attributed mind to the robot, based on the socially-communicative interactions the robot engaged in. This study also demonstrated that the nature of the interaction, and not only the robot’s behavior, mattered.

Tanaka et al. (2007) studied the relationship between 18- to 24-month-old children and a robot, through a long-life immersion technique (45 sessions of approximately 50 min each, spanning 5 months, in the children’s play area). One of the great problems of human–robot interaction is the

duration; long-term study is difficult. Children tire, even though they initially have great interest. The experiment aimed to verify relationship tenure for a time longer than the 10-hr barrier, comparing the employment of a robot able to manifest an entire repertoire of behavior (walking, head- moving, dancing, sitting down, standing up, lying down, hand gesturing, and giggling) to a robot able to manifest only predictable behavior. The relationship improved when the robot was programmed to manifest the entire repertoire of behaviors (27 sessions), worsened when the robot exhibited predictable behavior (15 sessions), and improved again when the robot began to manifest its entire repertoire. The development of socialization strategies correlated positively with frequency of contact with the robot.

Contextualizing the relationship in an educational setting, Movellan, Eckhardt, Virnes, and Rodriguez (2009) showed that interaction between 18- to 24-month-old toddlers and a low-cost sociable robot in an Early Childhood Education Center can significantly enhance word-learning. This evidence is promising, in view of the use of these humanoids with educational and didactic purposes, based on the intersubjective sharing of significant goal-oriented activities. Similarly, Tanaka and Matsuzoe (2012) employed a care-receiving robot to support foreign language learning in 3- to 6-year-old children. These authors showed that the care-receiving role, and not only the teaching role, could be successful in a teaching context. In fact, the condition in which a robot gave wrong answers improved the children's English verb acquisition more than the condition without the robot. Taking into account the relationship between peers, Westlund and Breazeal (2015) introduced a robot, programmed to behave as a peer, to a group of 4- to 6-year-old preschoolers in a storytelling context. The robot was able to lower its linguistic competence in order to match the child's current ability. The evidence showed that a storytelling robot capable of adapting to its partner in terms of language competence, was effective in supporting the oral language development of the child. Robots would seem to have educational skills not only as storytellers, but also as sympathetic listeners. Conti, Di Nuovo, Cirasa, and Di Nuovo (2017) compared a humanoid robot story- teller to a human teacher storyteller in a group of preschoolers. The authors evaluated how the storytellers' social behaviors influenced the children's memorization of the story. Results showed a similar performance in memorizing the details of the story when the storyteller was a robot or a human with an expressive behavior (expression of appropriate emotions with the body and with the voice). The expressive robot was even more efficient than a static inexpressive human storyteller (fixed gaze, motionless body, monotonous voice).

Park, Gelsomini, Lee, and Breazeal (2017) investigated the adaptive capacities of robots as listeners in: giving feedback that informed children about the presence of an active listener, given the abilities

of gazing, leaning forward, nodding, smiling, eye-widening to emulate eyebrow movement, and short utterances. The authors tested two robotic relational styles: a contingent style of the robot capable of reflecting the nonverbal behavior of the child; and a non-contingent style of the robot that emitted random, nonverbal behaviors. Based on children's gaze patterns, the results showed that the contingent robot most relationally engaged the children.

Human-robot interaction research ranges from ToM precursors to social skills of the elderly. Iwamura, Shiomi, Kanda, Ishiguro, and Hagita (2011) focused on the use of a robot by a group of elderly shoppers in a supermarket. They found that an assistive robot that also engaged in non-shopping-oriented conversation was preferred to a robot capable only of functionally oriented conversation. Sabelli, Kanda, and Hagita (2011) introduced a conversational robot into an elderly care setting for 3.5 months, and analyzed its main interactive exchanges with the elderly and the staff using an ethnographic methodology. Three of the six identified trends (basic social interaction, telling robot information, and emotional elements) pertained to the socio-relational/mentalistic dimension.

Again working on the relationship between robots and the elderly in a retirement village, Stafford, MacDonald, Jayawardena, Wegner, and Broadbent (2014) analyzed the attitudes to use mind agency, and attribute mind agency to the robots. The evidence showed that older people preferred to interact with robots to which they attributed less mind agency. These findings were rather counterintuitive because they question the presumed importance of mental state attribution in effective social exchanges. It is likely that the elderly were frightened by the robots because of an overestimation of their cognitive capacities which decreased with actual use.

Gross et al. (2012) presented preliminary results of the implementation of a companion robot for elderly people with Mild Cognitive Impairment (MCI). The evidence emphasized how satisfied the elderly were when interacting with a robot that could support them in executing daily tasks. This work opens up the use of robots in the context of caring for people with neurodegenerative diseases. It also places the importance of assessing the effectiveness of such long-term interventions (weeks or months), and fostering relationships with a truly autonomous robotic partner (hypothetically endowed with a wide behavioral repertoire), as the first point in the agenda for future research.

The studies presented in this section, many of which were conducted in extra-experimental settings, show the importance of a detailed analysis of the contexts in which human-robot interactions take place to fully understand the intersubjective nature of the human-robot interaction.

Conclusions

This review aimed to analyze human–robot interaction from two vantage points: (1) the human attribution of mental states to the robot and (2) the human recognition of the robot as “like-me.” The experience that the robot is “like me” is based mainly on the physical appearance of the robot, and its behavior; however, another aspect emerges that pertains neither to humans, nor to humanoids, but which is a characteristic of their encounters. This aspect is the intersubjective level of the exchange. This dimension contributes some design features of the humanoids, which cannot be conceived as simple artificial instruments for the extension of human abilities. The more a humanoid partner/companion can go beyond a functionally and mechanistically perfect performance, the more it seems “like me.” In other words, an exchange is especially meaningful if it happens with a partner with a human-like capacity to be engaged in somewhat unpredictable, intersubjective exchanges. From our point of view, this unpredictability depends on the subjective nature of the human knowledge and representations of the world. During social exchanges, partners share mental states and representations of the world. The construction of intersubjectivity is based on mutual recognition of the subjective nature of such states and of such representations.

In light of these considerations, this somewhat unpredictable meeting of minds can take different directions, and can be conceptualized in different ways. For example, it can be seen as the optimal level of frustration (Kohut, 1977). All human exchanges with significant partners are characterized by an alternation of gratification and frustration. However, this fact does not compromise human exchanges, provided that the frustration is remediable. A second possible way to conceive the somewhat unpredictable meeting of minds is that of the imperfect contingency (Bigelow, 1998). There is no optimum level of contingent responsiveness in early relationships with caregivers; rather each of us experiences an imperfect contingent responsiveness through parental interactions (i.e., the partners occasionally find the level of relational contingency adequate to the ongoing interaction). This responsiveness influences future exchanges with nonfamily partners. A further possible conceptualization is marked mirroring (Gergely, 2007; Gergely & Watson, 1996), which happens during a child’s affect-regulative interactions. The adult offers the child a reflection of an experience of the world, and of the emotional states of the child itself, and at the same time, the adult informs the child that this reflection is not expressing her/his own feelings. A final interesting conceptualization is offered by the work of Tronick and Beeghly (2011). They stated that interactions consist of a flow of matching and mismatching of meaning, and the reparation of mismatches to

matches. Intersubjective attunement would emerge from the experience of reparation, which in turn would create the experience of connection and shared states.

In the Vygotskijan theoretical framework, the unpredictability and possibility of relational mismatching takes on a particularly interesting form in the Zone of Proximal Development (“the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers”: Vygotsky, 1978, p. 86). In fact, cognitive discrepancy, if salient in intersubjective exchange, can become a powerful engine of learning and development. From this point of view, one of the most intriguing challenges for future humanoids is the possibility that they provide the partner stimuli, inputs, and interpretations that moderately surpass the present partner’s abilities, constructing bridges toward more advanced forms of understanding and capabilities. Looking at the future, our reflections allow us to glimpse the theme of technological singularity. It consists of the invention of a super-artificial intelligence that would result in a sudden “evolutionary” change, able in principle to overcome human intelligence (Eden, Moor, Soraker, & Steinhart, 2012). All this is possible if we consider the intersubjective nature of developmental and educational interactions in which both partners contribute to change and learning. ToM – which has as its core concept the “meeting of minds” – seems to us a theoretical perspective that is particularly well suited to understanding intersubjective interactions.

The end of the Blade Runner movie sums up this possible scenario of potentially open, flexible, and plastic exchanges between human beings and humanoids metaphorically. In fact, it shows as plausible a future of love between Rick Deckard, the replicant hunter, and Rachael, the first replicant without an a priori expiration date. Ultimately, the beauty of uncertainty, more than any other quality, made Rachel special, and therefore very humanlike.

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Chapter 3

It does not matter who you are: fairness in pre-schoolers interacting with human and robotic partners

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Abstract

The relationship between humans and robots is increasingly becoming focus of interest in many fields of research. The studies addressing the various dynamics underpinning the human-robot interaction have, up to date, mainly investigated this relationship analysing adults' behaviour when interacting with different forms of robotic agents. With this study, we present results assessing the human-robot interaction, in which children are the interactive partners. The child-robot interaction was studied – for the first time – observing thirty-one children aged 5 to 6 years playing the Ultimatum Game (UG) with either another child or with a humanoid robot. First, we found that children did recognize the robot as a distinct entity, as assessed through the children's attribution of mentalistic, emotional and physical properties to the interactive agents. Nevertheless, consistently with literature on adults, the results on the UG revealed a very similar behavioural approach when the child played with the other child and with the robot. We finally analysed the children's justifications for their behaviour at the ultimatum game and found that very young children tend to consider “fair” only the divisions that are exactly equal (5-5 divisions) and to justify them either in mere mathematical terms (outcome) or in terms of equity. These results are discussed in terms of Theory of Mind, as well as in light of developmental theories underpinning children's behaviour at the ultimatum game.

Introduction

The introduction of social robots - defined as “autonomous or semi-autonomous robots that interact and communicate with humans by following the behavioural norms expected by the people with whom the robot is intended to interact” (Bartneck & Forlizzi, 2004) - is deeply affecting our society in different fields of the human life. The robots used in industrial processes, for instance, are modifying the job roles and rules [Argote et al., 1983; Kang et al., 2008; Lin et al., 2011; see also European Union, 2017). Prospectively, the introduction of robots in other contexts, such as households, education, care assistance, manufacturing, etc., will also presumably have an increasingly significant effect on human activities and roles. In this perspective, several researches are working towards the implementation of robots in the attempt to make them increasingly similar to the human being [Asada et al., 2001; Di Salvo et al., 2002; Hoffman & Ju, 2014; Robins et al., 2005). The humanoid robots – the ultimate realization of such attempts – are characterized by human-like physical features, behaviours and cognitive processes. The mode and quality of the interaction between humanoid robots and humans will thus possibly change because of the robots’ similarities with humans that call to mind the idea of “they are more like-me” (Meltzoff & Brooks, 2001). The underlying rationale for the implementation of this new generation of robots is to create social partners in everyday life (Kanda et al., 2012), although the other side of the coin that researchers have to deal with in the robot human-likeness is the Uncanny Valley effect (Mori, 1970; Mori et al., 2012). This means that the more a robot has human features and behaves like a human, the more its “eeriness” will induce negative feelings in the interlocutor (Burleigh et al., 2013; Fink, 2012; Gray & Wegner, 2012; MacDorman, 2006; Mori et al., 2012; Sandoval et al., 2016; Scassellati, 2005).

Besides the contexts above mentioned, the implementation of robots is also aimed at aiding different scientific fields, such as anthropology, psychology, ethics, sociology, engineering, informatics, mathematics, physics, etc. (Saygin, 2011; Scassellati, 2003), for example, suggests that the use of the human-like robot could be useful for the study of typical and atypical human social development, allowing to test cognitive, behavioural and development models. In this sense, and from a multidisciplinary perspective, knowledge from developmental psychology is crucial to the implementation of these models since it contributes to the understanding and identification of the precursors underlying human sociality and their ontogenesis. In this respect, Itakura (2008) proposed a new research domain that connects developmental psychology and the study of human-robot interaction. This new investigation field was named Developmental Cybernetics (DC; 2008): it explores the child-robot interactions through the construction of theoretical frameworks that

characterize the design of the robot with the aim to facilitate these interactions (Itakura, 2008; Itakura et al., 2008b). Several studies used the Advanced Telecommunications Research Institute International (ATR) humanoid robot Robovie that can generate human-like behaviours (Ishiguro et al., 2001; Ishiguro et al., 2003). This humanoid robot has been used to test interactions with children in different contexts (Kahn et al., 2012; Kanda et al., 2004). Kanda and colleagues (2012), for example, introduced Robovie to 6th-graders to teach them how to use a Lego Mindstorms. This research showed how Robovie's human-like behaviours contribute to build a human-robot relationship, which goes beyond the more simple human-robot interaction.

Developmental Cybernetics hypothesizes that children can understand the non-human agent through mentalization, and that the construction of social intelligent agents could shed some light on the development processes and mechanisms of the child's mind (2008). In this respect, within the DC approach, Itakura (2008) proposes three abilities, which are critical for making a robot a social agent: Theory of Communication (Itakura, 2012; Itakura, 2013; Nitsch & Glassen, 2015), Theory of Body (Minato et al., 2006; Morita et al., 2012) and Theory of Mind (Itakura, 2008; Itakura et al., 2008a,b). With respect to the Theory of Mind (ToM), it has been proposed that ToM represents an important psychological ability for the study of the human-robot interaction [for a review, see Marchetti et al., 2018). In fact, ToM is essential for the development of social competences, in that it represents the ability to understand one's own and other people's mental states (intentions, emotions, desires, beliefs), and to predict and interpret one's own and others' behaviours on the basis of such meta-representations (Park et al., 2017; Piaget, 1929; White et al., 2009). Several ToM studies show that there are many different behaviours and cognitive processes that are linked to this human skill: imitation, joint attention, pointing, and gaze-following, just to mention a few. (Bandura, 1991; Brooks & Meltzoff, 2002; Camaioni et al., 2004; Charman et al., 2000; Meltzoff, & Gopnik, 1993; Meltzoff & Brooks, 2001).

The researches in the field of child-robot interaction have been increasing in the last decades. Generally, these researches explore what features should be implemented in the robot in order to establish a better interaction between humans and robots. Several studies have been conducted to analyse the effect of different ToM precursors on the interaction between humans and different non-human agents, including humanoid robots [Boucenna et al., 2014; Boucenna et al., 2016; Breazel et al., 2016; Chaminade et al., 2010; Fogassi et al., 2005; Itakura et al., 2008a; Kanngiesser et al., 2015; Meltzoff et al., 2010; Moriguchi et al., 2012; Mutlu et al., 2012; Okanda et al., 2013; Okumura et al., 2013; Rizzolatti et al., 2001; Sloane et al., 2012; Wellman et al., 2001). Generally, the results of

these studies have shown that children tend to attribute mental states to a humanoid robot (Beran et al., 2007; Breazeal et al., 2016; Kahn et al., 2004; Manzi et al., 2017; Moriguchi et al., 2012; Nishio et al., 2012; Park et al., 2017). Already Piaget (1929) suggested that children younger than six-years-old tend to attribute consciousness to objects - namely the capability to feel and perceive - and that children consider “alive” also the things that are inanimate for the adult, *if* these objects serve a function or are used to reach a goal: a phenomenon called animism. In their study, Katayama and colleagues (Katayama et al., 2010) showed that when five and six-years-old children had to attribute biological and psychological proprieties to a human or a robot, children generally discriminated between the two agents, though ascribing some human traits also to the robot. Thus, in line with Torta and colleagues (Torta et al., 2013) idea, when young children interact with artefacts, these acquire the status of relational artefacts: children believe the artefacts – like the robots – to be “alive” and to have an “intention”.

Interaction skills in social contexts are typically studied through use of interactive games deriving from the Game Theory (Camerer, 2013; Villani et al., 2013). One of such games is the Ultimatum Game (Güth & Kocher, 2014; Güth et al., 1982). Used with children, the Ultimatum Game (UG) serves to delineate development in terms of equity and negotiation ability in decision-making, thus focusing on sensitivity to fairness and aversion to inequality (Fehr & Schmidt, 1999). The UG involves interacting with at least another agent, and it is related to the development of ToM in that it activates the ability of mental comprehension, detection and anticipation of the other’s behaviour (Catelli et al., 2014a,b; Castelli et al., 2017; Hoffman & Ju, 2014; Lombardi et al., 2017; Marchetti et al., 2011; Marchetti et al., 2008; Massaro et al., 2017; Srinivasan et al., 2013; Turkle, 2004). In the UG, the subject can play as either the proposer or the receiver. In the *proposer* situation, the subject decides how to allocate resources; in the *receiver* situation, the subject decides whether to accept or refuse a proposed division of goods. The general rule underlying the UG is that the proposer makes an offer, proposing a certain division of goods between him or her and the other player. If the receiver refuses the offer, neither players get anything, whereas if the offer is accepted, both players obtain the proposed division. Using the UG, it is then possible to study interactive behaviour in reciprocal situations from a developmental perspective, comparing behaviour at different ages. Starting from infancy, some studies suggest that infants are responsive to an unequal resource distribution already at 19-month-olds (e.g., Seyama & Nagayama, 2007). Fehr and colleagues (2008) showed that sensitivity to fairness increases from 3 to 8 years of age, and that selfish behaviour decreases from 3-4 years to 5-6 years, although most of 5-6 year olds still tend to not share (78% of the sample).

Additionally, school age children (>7 years) generally behave more fairly when distributing resources and share more than younger children (Fehr et al., 2008;House et al., 2013).

Only few studies have employed the UG paradigm with robots, and – even so – uniquely in interaction with adults. There is in fact not research specifically addressing the relation between robot and children in a UG game. Research on adults generally shows that participants are more likely to behave in a similar fashion when playing the UG with another human or a robotic agent, and this similarity increases the more the robotic agent presents human-like features. Terada and Takeuchi (2017), for example, reported that rejection scores in the ultimatum game were higher in the case of a computer opponent than in the case of a human or robotic opponent, suggesting that people might treat a robot as a reciprocal partner as when playing with another human. Nishio and colleagues (2012) also tested university students while playing the UG with four different artificial agents, which differed in the degree of similarity with humans. In their study, there were four conditions: computer terminal (Computer condition), humanoid robot (Humanoid condition), android robot (Android condition) and human (Human condition). They included a mentalizing stimulus for each agent, which consisted of four shorts interactional sentences pronounced by each agent when meeting the subject, e.g., “how are things going?”. Furthermore, the authors administered a post-experimental questionnaire in order to test how participants perceived the agents (i.e., human likeness, or machine likeness). The authors examined the number of rejections of the agent’s proposals and the number of the agents’ fair and unfair proposals, both measures used as indicators of recognition of the agents as social entities. The results showed that, when the agent looked like a human, the fairness of the proposals and the refusal rate were similar to when interacting with a human, and particularly, when introducing the artificial agent after the interactional sentences. Additionally, Nitsch and Glassen (2015) analysed a group of young adults, who played the UG with a human agent and with a humanoid robot behaving so as to be perceived animated or apathetic. The results showed that the participants that played in the animated robot condition perceived the interactions more positively and human-like than in the apathetic condition. Robins and colleagues (Robins et al., 2005) also studied reciprocity in the human-robot interaction in a sample of young adults through the UG and the Prisoner Dilemma. The results showed that the participants were equally reciprocal with the human and the robot, despite the fact that the robots collaborated more with humans in the Prisoner Dilemma task, indicating that the human-human interactions are nevertheless privileged with respect to the human-robot interactions. Finally, Takagishi and colleagues (2010) examined the effect of different robots’ facial expressions in the UG, and showed that emotional expressions had an effect on the offers made by the participant to the robot compared to offers made to a computer displaying a simple line drawings face.

Altogether, the results from the studies here described suggest - in adult subjects - a proclivity to interact with robotic agents in a very similar fashion as when interacting with other humans.

As far as children's behaviour is concerned, there are no studies so far addressing children's decision making during an interactive and reciprocal social situation with a robot. In the present study, we made an attempt to fill this developmental gap exploring interactive behaviour during the UG when a child played with either another child (human agent) or with a robot (humanoid robot). Our sample children were aged five-to-six years. At this age, children show to have an acquired ToM capability of – at least - first order (Wardle et al., 2002). First order ToM entails a recursive thinking, which implies the meta-representation or the representation of a mental representation, of a low level of complexity, of the kind of: “I think that you think...”. In this respect, we hypothesized that children aged 5-6 years were able to discriminate between *agency* (human agent and humanoid robot) on the basis of mental states attribution. However, we were not able to advance any predictions in terms of differences in children's decision-making strategies when playing with a human and a robot, since no such literature exists specifically referred to the UG.

In this study, the children played both as proposers and as receivers. Additionally, children's performance on the UG task as a function of *agency* was evaluated against several socio-demographic, as well as, cognitive factors. Finally, an analysis of the children's justifications for their behaviour, both when playing as proposers and receivers, was carried out, outlining – for the first time – some response patterns that characterize the rationale underlying these children's game strategy.

Method

Participant

Thirty-three (33) Italian kindergarten children participated in the experiment. Two children were excluded from the study: one failed the First-Order ToM task and the other one failed the Inhibition task (see below). Data analysis was therefore carried out on 31 children (males=18, females=13; mean age = 70.8 months, SD=2.99). The children attended three different schools of Milan and Turin areas. The children's parents received a written explanation of the procedure of the study, the measurement items, and the materials used and gave written consent. Children were neither referred to social services nor reported by teachers for leaning and/or socio-relational difficulties. The study was

approved by the Local Ethic Committee (Università Cattolica del Sacro Cuore, Milan).

General Procedure and measures

The children were tested individually in a quiet room in the kindergartens. Administrations were carried out by a single researcher both in the morning and afternoon during normal activity. The children were assessed in two experimental sessions in different days within two weeks timeframe. The administration of the tasks in two independent sessions was done not to overly tire the children with an excessively long procedure as well as not to significantly disrupt the child's normal school activity.

In the first session, the children were administered the following tests: the First-Order False-Belief task, and two First-Order False-Belief videos, assessing first-order Theory of Mind; two Strange Stories, assessing advanced Theory of Mind; and the Attribution of Mental States scale. In the second session, the children were administered the following tests: the Family Affluence Scale, assessing the socioeconomic status; two executive functions tests, assessing the ability to inhibit behaviour and working memory; further two First-Order False-Belief videos; further two Strange Stories; and the Ultimatum Game, assessing fairness.

The tests were so distributed within sessions to balance the total time required to complete the whole battery, which was of approximately 45-50 minutes. In fact, each session lasted about 25 minutes. Within each session, the administration of the tests was randomized across children.

Socioeconomic status

To assess the children's socio-economic status, we used the Italian translation of the Family Affluence Scale (FAS; Boyce et al., 2006). This test is composed of four items measuring family wealth, and more specifically: 1) family car ownership (score range = 0–2); 2) own bedroom (range = 0–1); number of computers at home (range = 0–3); how many times they went on holiday during the past year (range = 0–3). The FAS total score was obtained adding up the four-item scores (total range = 0-9).

Executive functions (Inhibition and Working Memory)

We tested the children's executive functions using the Inhibition "A Developmental NEuroPSYchological Assessment" subtest (NEPSY II; Korkman et al., 2007), testing the ability to inhibit automatic responses in favour of novel responses and the ability to switch between response types. The child looks at a series of black and white shapes or arrows and names either the shape or direction or an alternate response, depending on the colour of the shape or arrow. In the present study, we used the combined scores of the Inhibition NEPSY-II subtest, which associates accuracy and speed of response.

Furthermore, we used the Backward Digit Span, testing working memory. Concerning the Backward Digit Span, the experimenter presented orally number sequences and the child was required to repeat them in reverse order. The test started with three sequences of two digits, gradually introducing triples of sequences of increasing length, to a maximum possible length of eight digits. The test stopped when the child failed all three sequences at the same length. The score was calculated as follows: children received 1 when they reversed at least two out of three sequences; if successful, the child passed to the next longer series, scoring 0.33 reserving at least one out of three sequences. The decimal scores were then summed to obtain the main score (e.g. $1+0.33 = 1.33$) until the children reached 1 (e.g. $1+0.33+0.33+0.33 = 2$), if necessary.

First-order false belief task

To assess first-order ToM, we used the story of the classical *Unexpected Transfer* task (Wimmer & Perner, 1983). The experimenter told the story using: two dolls (one male and one female), one ball, one box and one basket. The story is about two siblings playing with a ball in a room. One of the children puts the ball in a box and leaves the room. Meanwhile, the other child takes the ball out of the box, puts it in the basket and goes away. Finally, the first character comes back in the room and wants to play with the ball. At the end of the story the experimenter asks the child the following questions: "What is the first place where he will look for a teddy bear?" – referring to the first character (First-Order False Belief question); "Where did the child put the ball before going upstairs?" (control memory question); "Where is the ball really?" (Reality control question).

The answers to the two control questions (memory and reality) were used to filter the children's performance: children who did not pass them scored 0 and their performance on the First-Order False Belief question was not evaluated. If the children passed the control questions, the test question about the false belief scored 1 if correct and 0 if incorrect.

First-order false belief task: Video Stimuli

To assess children on the First-Order False Belief, we introduced – besides the commonly used task as described above – a new instrument, namely eight videos representing the classical story, this time introducing also the Robovie as a new character. More specifically, we used a story similar to the classical *Unexpected Transfer* task (Wimmer & Perner, 1983) as the script of the videos. The videos started presenting two characters (two children, two robots, or a child and a robot) in a room with two different boxes of a different colour (blue and pink) placed in front of them. Subsequently, one of the characters put a teddy bear under one box (the same for all videos) and then left the room. When the other character was alone in the room, he or she moved the teddy bear under the other box and left the room. Finally, the first character returned into the room to take the teddy bear. A voiceover narration described the story in each video.

The videos were recorded with five different actors: two children (C1 and C2) and three Robovies of different colours (White Robovie, WR; Green Robovie, GR; and Red Robovie, RR). Moreover, the five actors could play two different roles: the character who made the transfer (MtT) and the character who underwent the transfer (UtT). We used the WR for the human-robot videos and the other two Robovies (GR and RR) for the robot-robot videos. Thus, we videotaped eight different videos crossing the two children, the three Robovies, and the two roles. We created two different protocols, which were randomly assigned to the children. The first protocol was composed of four videos: 1) C1 playing the MtT role with C2; 2) C1 playing the MtT role with WR; 3) WR playing the MtT with C1; 4) GR playing the MtT with RR. The second protocol was composed of the following four videos: 1) C2 playing the MtT role with C1; 2) C2 playing the MtT role with WR; 3) WR playing the MtT with C2; 4) RR playing the MtT with GR. Within each protocol, the videos were presented randomly. We used the same scoring criteria as that used for the First-Order False Belief task (see above). The videos can be found in Electronic Supplementary Material.

At the end of the story, the experimenter asked to the child the following questions: “What is the first place where she will look for the teddy bear?” (First-Order False Belief question); two control questions (Memory and Reality as described above).

Strange Stories

We assessed the children's advanced ToM using the Strange Stories task (Happé, 1994; Westlund et al., 2017), whose Italian translation had been already used in other studies (Cattaneo et al., 2007; Lillard, 1994). This task evaluates the ability to make inferences about mental states by interpreting non-literal statements. We selected a subgroup of four mentalistic stories involving double bluffs, misunderstandings, white lies, and persuasion. After reading the stories, we asked the children to explain a character's behaviour without a time limit. The experimenter transcribed *ad verbatim* the child's answers. Scoring was based on the general guidelines (Westlund et al., 2017): 0 for incorrect answers, 1 for partially correct answers, and 2 for full and explicit answers. Two raters independently coded 30% of the responses. The inter-rater agreement was substantial (Cronbach's Alpha = .96). Disagreements were resolved through discussion between the raters. Total scores ranged from 0 to 8. The analysis of the children's performance on the strange stories showed a quite poor general performance. In fact, the children scored very low, ranging from 0 to 3 out of a total possible score of 8.

Attribution of States

The Attribution of States is a measure of states attribution that the child has to make looking at pictures depicting a character. The Attribution of States (AoF) is an *ad-hoc* questionnaire that was drawn from the questionnaire described in Martini and colleagues (Martini et al., 2016). This test was aimed at assessing what features the subject (the child) ascribed to the interactive agent (another child or the robot) in mental, emotional and physical terms. In this study, the experimenter first showed to the child two pictures depicting a child and a robot and then asked the child - as a control question - what was depicted in the picture (Reality question): if the child correctly recognized the child and the robot, the test went on; if the child responded incorrectly, the experimenter corrected the child making sure that he or she was fully aware of the agent's identity and then proceeded with the test. No children failed in the Reality question; that is, all of the children correctly recognized the child and the robot at first instance.

The presentation order of the two face pictures was randomized across children. After presenting the picture and asking the Reality question, the experimenter asked the child 25 questions referred to the agent's mental states. The child had to respond "Yes" or "No" to each question. The 25 questions were grouped in five different categories of mental states: Epistemic, Emotional, Desires and Intentions, Imaginative, and Perceptive. The total score was the sum of the "Yes" answers (score range = 0-25); the five partial scores were the sum of the "Yes" answer to each category (score range

= 0-5).

Ultimatum Game

A standard version of the Ultimatum Game (UG; Güth et al., 1982) was used to evaluate fairness. During the game, the child (playing as proponent) could decide how to distribute 10 stickers between him or her and a passive player, represented by a graphic representation of either a child – human agent (e.g., Castelli et al., 2010) or a robot. The graphic representation of the other child corresponded to a male figure when the child was a boy, whereas it represented a female when the child was a girl. The stickers depicted known animals by the children (e.g., dogs, cats, tigers, lions, birds, fishes, etc.). The minimum amount of stickers that could be offered during the game was 1, and the maximum amount was 9. After playing the UG, the child was actually given a final amount of stickers

During the UG, the children played one round as proposer and five rounds as responder, for a total of six rounds. Playing as proposer, the child could decide how to divide the stickers with the other child or the robot (graphic representation) and, playing as responder, the child could decide whether to accept or refuse the proposed division. In case of acceptance, both players received the respective proposed amounts; in case of refusal, neither player gained anything.

When playing as responder, each round (5 in total) corresponded to a specific type of proposal, ranging from a division of 5-5 (fair) to a division of 1-9 (highly unfair). The rounds were randomized across children. For each round, the child could accept or refuse the offered amount, receiving a score 1 in case of acceptance and 0 when refusing the offer. The total amount accepted was also calculated (range = 0-15) when the child played as receiver, which corresponded to the total gain for each child. Similarly, when playing as proposer, the total amount proposed was also calculated for each child (range= 0-9).

UG procedure

Before starting the game, the experimenter explained the game rules presenting four different examples in a graphic format: 1) an adult playing as proposer with a child, who accepted the offer; 2) an adult playing as proposer with a child, who refused the offer; 3) a robot playing as proposer with a child, who accepted the offer; 4) a robot playing as proposer with a child, who refused the offer.

During the game, the researcher played “the other child’s/robot’s” role, proposing, accepting, or refusing offers. The children’s performance at the Ultimatum Game was evaluated in a single session lasting approximately 10 minutes in total.

At the end of the game, the children were asked the reasons that they placed a certain offer (proposer) or accepted/refused a certain proposal (receiver). The children’s answers were classified according to three criteria: 1) outcome – the justification refers uniquely to the *amount offered or received* without commenting on or referring to the other player in mental terms (e.g., “because I like that he does not have anything and I have them all”; “because I wanted to win”); 2) equity – the justification includes terms that refer explicitly to the *construct* of equity, independently of whether the amount offered or received was equal or unequal (e.g., “because in this way we are even”; “because it was nicer to give him three and I like to share them”); 3) mentalistic – the justification includes terms that *refer to the other player in mental terms* (e.g., “because he would like me to receive more”; “he believed that I would win”)⁹.

Results and Discussion

All of the continuous variables were normally distributed with skewness between -1 and 1.

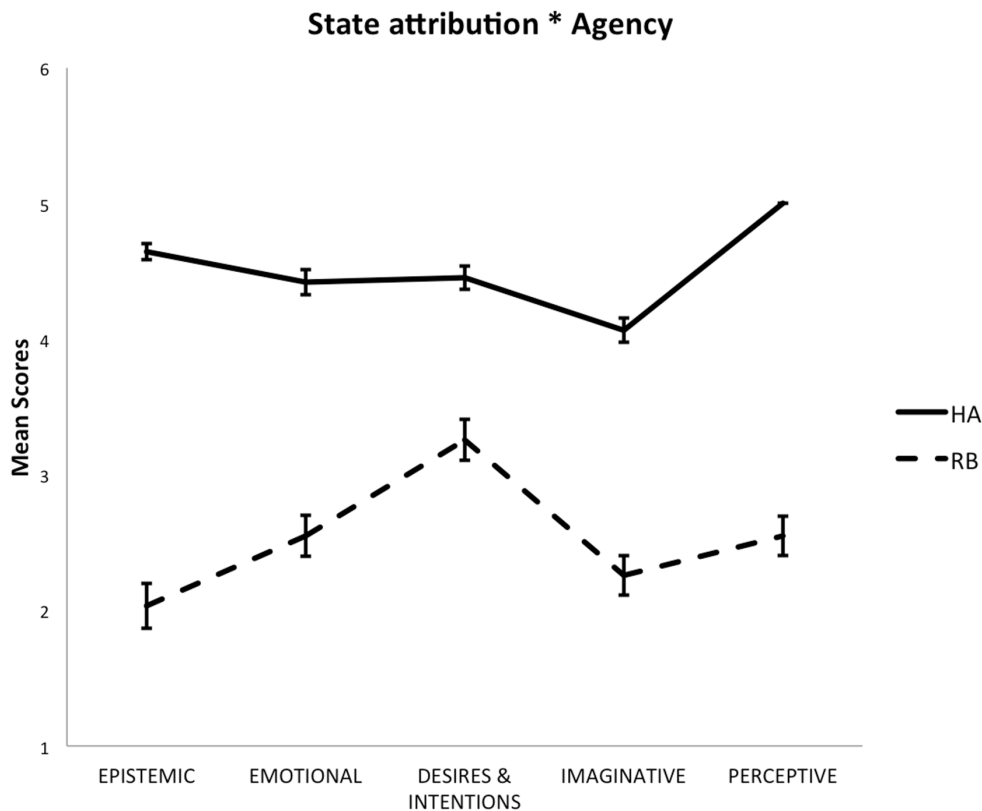
Attribution of States Scale

With this analysis, we compared the attribution of states - as described in the methods session - to the human agent (the other child) and to the robot. The inspection of the boxplots revealed a tendency towards maximum scores (5) in the case of state attribution to the human agent - particularly with respect to the perceptive state, where we observed a ceiling effect - and a normal distribution in the case of states attribution to the robot. A repeated measures general linear model (GLM) was carried out with five levels of *state* (epistemic, emotional, desires and intentions, imaginative, perceptive), and two levels of *agency* (human vs. robot) as the within groups factors. The results showed a main effect of *state* ($F_{4,120}=5.94$, $p<.0001$, $partial-\eta^2=.17$, $\delta=.98$), a main effect of *agency* (HA>RB; $F_{1,30}=53.82$, $p<.0001$, $partial-\eta^2=.64$, $\delta=.1$) and a significant interaction *state*agency* ($F_{4,120}=7.90$, $p<.0001$, $partial-\eta^2=.21$, $\delta=.1$). Post hoc analyses (Bonferroni corrected) showed that the states that scored higher were desires and intentions – which scored significantly higher than both epistemic

⁹ Ad verbatim translation from Italian.

($M_{diff}=.69, p<.01$) and imaginative ($M_{diff}=.52, p<.05$) – and perceptive state, that scored significantly higher than imaginative state ($M_{diff}=.61, p<.01$). Additionally, the analyses showed that the interaction effect stemmed primarily from differences between *states* within *agency* (HA, RB). More specifically, with respect to states attribution to HA, the epistemic state scored higher than imaginative state ($M_{diff}=.58, p<.01$); whereas the perceptive state scored higher than all the other states ($p<.05$) except for the epistemic state, which just failed to reach significance ($M_{diff}=.36, p=.055$). With respect to state attribution to RB, the results showed that desires and intentions received higher scores compared to the epistemic and imaginative states ($M_{diff}=1.23, M_{diff}=1.00$, respectively; $p<.001$). These results are summarized in Figure 1.

Figure 1: Mean scores obtained by the children during the attribution of states (epistemic, emotional, desires and intentions, imaginative, and perceptive) to the human agent (HA) and to the robot (RB). The bars represent the Standard Error of the mean.



The results on the attribution of states to HA and RB revealed that children clearly attributed different states on the basis of agency, with HA receiving higher scores on all states attribution compared to RB. This shows that children had a correct perception that the other child had epistemic and emotional

states, intentions and desires, an imagination and perceptive properties, which are different from that of a robot, therefore considering this latter as a distinct entity.

Within agency, children tended to ascribe poor imagination to both the child and the robot. This is in line with evidence showing that young children's imagination abilities mature gradually (Harris, 2000; Harris & Leivers, 2000; Lillard, 1994; Lillard, 2013). Interestingly, the differences observed within the attribution of states to the robot indicate that children tended to ascribe desires and intentions also to the robot, although to a significantly lesser extent than to the human agent. Desires and intentions attribution to the RB, in fact, received greater scores than all the other states, and substantially more than the epistemic and imaginative states. During video watching (see methods), the children observed the RB in action, and this may have led the children believe the robot as having intentions. In fact, also from a neurophysiological perspective, movement and intentions go hand in hand [see, for example, Gray & Wegnaer, 2012; Premack & Woodrouff, 1978) as also suggested by psychophysiological evidence with children (Cavallini et al., 2013). All the same, in the present study, while attributing intentions to the robot, the children ascribed to the robot a low ability to think, understand, and decide (epistemic attribution). These results, apparently in contrast, are on the other hand much in line with the idea of animism introduced above, and namely with young children's tendency to attribute a living soul to plants, inanimate objects, and natural phenomena, while being aware that these entities are non-living. The fact that this idea applies to objects only *if* these objects serve a function or are used to reach a goal (see Katayama et al., 2010; Perner & wimmer, 1985; Turkle, 2004], further supports the movement and intention interpretation just described (Chaminade et al., 2010; Sandoval et al., 2016).

Ultimatum Game

The main aim of the present study was to assess whether the child behaves differently when acting with a human agent or with a robot during an interactive situation. We therefore had the child playing the UG with either another child or with the robot, as both proposer and receiver.

Proposer

A t-test comparing the total amount offered to the other child or to the robot when the participant played as proposer showed no significant difference in the total amount offered (HA: $M=3.71$, $SE=.31$; RB: $M=3.55$, $SE=.35$; $p>.05$). Additionally, a high internal consistency (Cronbach $\alpha =.85$)

was observed between each individual child's behaviour when playing with the human agent or the robot. Table 1 reports the children's proposed divisions to HA and RB.

Table 1: Statistics of children's offers when playing as PROPOSERS; ns = not significant; na = not applicable.

	HA – RB	HA – RB	HA vs. RB
Proposed Division	N	%	Sign (<i>p</i>)*
1-9	0 – 0	0 – 0	na
2-8	0 – 0	0 – 0	na
3-7	0 – 1	0 – 3	na
4-6	5 – 5	16 – 16	ns
5-5	7 – 4	23 – 13	ns
6-4	9 – 7	29 – 23	ns
7-3	3 – 5	10 – 16	ns
8-2	2 – 3	7 – 10	ns
9-1	5 – 6	16 – 19	ns
tot	31 – 31	100 – 100	

**Wilcoxon rank test*

These results are in line with the literature [e.g., 28] showing that pre-schoolers tend to make offers that favour their own gain, although the frequency of children that made offers towards fairness (i.e., ranging between 4-6 and 6-4) was quite substantial (68% towards HA; 55% towards RB). Additionally, these results extend previous findings showing that five-year-old children's behaviour and game strategy is consistent independently of whether the child plays with another child or with a robot, in line with the large body of existing literature on adults, as fully introduced above.

Receiver

Within this analysis, we summed up all acceptances when the child played as receiver, therefore calculating the total amount gained by each child. A t-test comparing the total acceptances from the other child and the robot showed no differences in the total amount accepted as a function of *agency* ($t=.75$, $p>.05$), indicating that the children accepted similar amounts when playing with HA ($M=10.97$, $SE=.77$) and with RB ($M=10.45$, $SE=.95$). This result is congruent with the data above described, showing children's tendency to adopt a similar game strategy when playing with the other child or with the robot.

Specifically comparing the children's acceptances of each proposed division from HA and RB, our results confirmed no differences in the frequency of acceptances as a function of agency within division (for statistics, see Table 2). Additionally, comparing the frequency of acceptances between successive divisions for both HA and RB, the Wilcoxon test showed not significant differences for the child (i.e., 5-5 vs. 6-4; 6-4 vs. 7-3; etc.; $p > .05$), whereas we observed significant differences for the robot. More specifically, acceptances of the 6-4 division were significantly lower than acceptances of the 5-5 division (71% vs. 90%, $p < .01$), as well as acceptances of the 7-3 compared to the 6-4 divisions (52% vs. 71%, $p < .01$). This latter result shows a significant, although minor, tendency of children to accept slight unfair offers more from another child than from the robot.

Table 2: Comparison of refusals and acceptances of proposed divisions during the UG when the child played as receiver with another child (HA) and with the robot (RB) (N=31). *P-values* were non-significant (ns) at a value of .05.

		HA	RB	<i>HA vs RB</i>
Division		N (%)	N (%)	Sign (<i>p</i>)*
5-5	Refuse	3 (10)	3 (10)	ns
	Accept	28 (90)	28 (90)	
6-4	Refuse	7 (23)	9 (29)	ns
	Accept	24 (77)	22 (71)	
7-3	Refuse	12 (39)	15 (48)	ns
	Accept	19 (61)	16 (52)	
8-2	Refuse	16 (52)	13 (42)	ns
	Accept	15 (48)	18 (58)	
9-1	Refuse	14 (45)	15 (48)	ns
	Accept	17 (55)	16 (52)	

*McNemar's Test

Correlations

Pearson's correlations were carried out between the total scores at the ultimatum game when the child played with the other child and the robot, as both proposer and receiver. The results showed, as expected, a substantial correlation between the total amount proposed to the other child and the robot ($r^2 = .56$, $p < .01$), as well as a strong correlation between the total amount accepted by the other child and the robot ($r^2 = .49$, $p < .01$). Additionally, the scores obtained at the UG were further correlated with demographic, cognitive, and socio-economic variables: age (months); the child's gender; working memory scores; the ability to inhibit behaviour scores; the intentionality test scores; and the Family

Affluence Scale scores. These correlations are summarized in Table 3. In general, no significant correlations were observed between the scores obtained at the UG and any of these variables ($p > .05$).

Table 3: Correlation analysis between the total scores at the Ultimatum Game when the child played as proposer with a robot (1) and the child (2) and when the child played as receiver with the robot (3) and the child (4). These scores at the UG were correlated with demographic, cognitive, and socio-economic variables: Age (months); child's Gender; working memory (WM) scores; ability to inhibit behaviour (INHI) scores; Intentionality Test scores (IT); and Family Affluence Scale (FAS) scores.

Pearson Correlations

		1	2	3	4	Age	Gender	WM	INHI	IT	FAS
1)	Total Offer to the Child	1	,746**	0,298	0,179	0,218	-0,085	0,186	0,01	0,146	0,213
2)	Total Offer to the Robot		1	0,191	-0,015	0,224	-0,004	0,202	0,024	0,233	0,237
3)	Total Acceptance from the Child			1	,700**	0,069	0,285	0,151	0,293	0,354	0,165
4)	Total Acceptance from the Robot				1	0,047	0,329	0,251	-0,1	0,255	0,195

** Correlation is significant at the 0.01 level (2-tailed).

Analysis of the children's justifications at the UG

After the child played the UG in both the proposer and receiver roles, the experimenter asked him or her to explain the reasons for his or her division. The children's answers were classified as "outcome", "equity", or "mentalistic" (for details, see methods). Two independent judges evaluated the children's justifications.

Proposer

The inter-rater reliability scores were substantial both when assessing the child's justifications when playing with the other child (Cronbach's Alpha = .88) and when playing with the robot (Cronbach's Alpha = .91).

Analysing the frequencies of children who gave a specific justification to their behaviour for each division when making an offer, the results showed an even distribution of justification type (amount, equity) when the children offered a precise fair amount (division 5-5), whereas a skewed distribution of justification type toward "amount" when the children started placing offers that privileged their

own gain. This was independent of whether the child played with the HA or the RB. A summary of the frequency distribution of justification types for each proposed division is presented in Table 4A.

Receiver

The inter-rater reliability scores were calculated for each proposed division (5-5; 6-4; 7-3; 8-2; 9-1). The results showed substantial agreements both when assessing the child's acceptance/refusals justifications interacting with the other child (mean Cronbach's Alpha = .83; min=.82, max=.84) and with the robot (mean Cronbach's Alpha = .83; min=.80, max=.84).

With this analysis, we compared the frequency of children that provided a justification when accepting or refusing each proposed division. Justification types were different when the child received a 5-5 or a 6-4 division, independently of *agency* (HA, RB). When receiving a 5-5 division, the justifications were either based on "outcome" (HA: N=13; RB: N=14) or on "equity" (HA: N=18; RB: N =16); only one child presented a mentalization-based justification when interacting with the robot. When faced with a 6-4 division, the majority of children (HA: N=26; RB: N =28) presented a justification for their acceptance or refusal based on "outcome"; five children presented a justification based on "equity" and none based on "mentalization" when interacting with the other child; only one child presented a justification based on "equity" and two children a justification based on "mentalization" when interacting with the robot. A summary of the frequency distribution and statistics of acceptances and refusals of each proposed division and type of justification is presented in Table 4B. In general, these results suggest that, when children received a division proposal skewing towards unfairness, the equity and mentalization-based justifications decreased substantially ($\chi^2_{(4)}=16.47, p<.001$), in favour of the outcome-based justification.

The analysis of the children's justification for their behaviour - both when playing as proponents and when playing as receivers - indicates that children tend to regard fair (and hyperfair) divisions either in terms of outcome or in terms of equity-based reasoning, with an approximately equal split. When the division starts skewing, even slightly (i.e., 6-4 division), towards unfairness, the types of justifications offered remarkably bias towards an outcome-based reasoning. It is noteworthy observing that mentalistic-based justifications were very poor, if not even inexistent, in all proposed scenarios. This general behaviour was observed both when the child played with the other child and with the robot, indicating no differences in the type of reasoning underlying specific choices as a function of agency.

On the whole, the results on the UG suggest that children aged five years behave quite fairly, though showing a tendency towards favouring their own gain placing and accepting unfair – and even *very* unfair – divisions, in line with current literature describing pre-schoolers' behaviour during the UG (see, for example, Lombardi et al., 2017). Lack of behavioural differences as a function of agency (HA vs. RB) further appears to indicate that the children at this age tend to disregard to other's mind when making choices, following a very consistent strategy throughout the game on the basis of other criteria (e.g., tendency to maximise gains) or personal traits (e.g., disposition to fairness). This is particularly true if considering the fact that the robot was indeed considered an entity different from the human agent (the child), so as observed from the analysis of the states attribution described above. This idea of a much ego-centred behaviour is further supported by the analysis of the children's justifications for their decisions when placing specific offers (proposers) and when accepting or refusing certain offers (receivers). In fact, analysing the frequencies of children who gave a specific justification for their behaviour, the results showed an even distribution of justification type (amount, equity) when the children offered or accepted a fair amount both to/from another child and to/from the robot; whereas we observed a remarkably skewed outcome-based justification when the children offered or accepted/refused unfair divisions. These latter results are further discussed below.

General Discussion

This study investigated 5 year-olds' behaviour at the ultimatum game. The aim of this study was to compare young children's game strategy when they played with another child (human agent) and with a robot. The results showed that children's game strategy was very similar when playing with the other child and with the robot, independently of the role played (proposer or receiver). The children were quite conservative both when offering and accepting proposals, that is, the children generally tended to offer and to accept fair divisions (5-5), although almost half of children proposed and accepted also unfair divisions, ranging from 6-4 to 9-1. These results are in line with the developmental literature on UG. For example, Benenson and colleagues (2007) observed that children aged 4 years donated less than 6 and 9-years-old, showing that sensitivity to fairness increases with age. Furthermore, a recent research by Lombardi and colleagues (Lombardi et al., 2017) showed that, at 6 years, children displayed a more selfish behaviour than children aged 8 and 10 years, highlighting that younger children tend to maximize their gain accepting also unfair offers.

Importantly for the present purpose, no significant differences were observed between offers and

acceptances made to or received from the other child or the robot. In this respect, children's behaviour observed in this study when interacting with the robot is comparable to the adults' behaviour reported in several studies. Terada and Takeuchi (2017) for example, showed that, when playing the UG, adult participants took approximately the same time to decide how to distribute goods between a human and a robot. In the study by Kahn and colleagues Kahn et al., (2012), the frequency of acceptances and refusals became closer to that toward a human when the robot had more human-like features. Similar results were also found by Rosenthal-von der Pütten and Krämer (2014). On the whole, these results suggest that, when bargaining, the other player is regarded independently of agency: the other player's mind appears to be a reflection of our own mind and strategic thinking, whether or not the other has a mind at all, such as in the case of a robot.

With respect to the acceptance of offers made when the child played as receiver in the present study, although behaviour was comparable when the child played with another child or with the robot, it is worth noting that the results showed a significant, although minor, tendency of children to accept slight unfair offers more from another child than from the robot. In this respect, one may suggest that children's expectancy from a robot is to be a totally fair player – since it does not have a mind of its own that can work strategically. In this light, divergence from this initial expectation is less accepted compared to situations in which children play with a human peer. In this latter case, in fact, the other player (the human) - having a mind - is supposed to be able to apply a game strategy and, eventually, to be also unfair. Alternatively, but not mutually exclusive, one may suggest that the child believes to have a distinctive status compared to the robot that, as assessed through the test of attribution of states, is perceived as a different entity with respect to a child at all levels: epistemic, emotional, imaginative, and physical. Also in this light, unfair offers would be less accepted when made by a robot than by a peer.

Finally, with respect to the results from the analysis of the children's justifications at the UG, it is interesting to observe that the reasons provided by the children for their behavior, both when playing as proposers and responders, suggest that children aged 5 years tend to consider fair only a division that is exactly fair (5-5). A slight skewed division towards unfairness (i.e., 6-4) already falls within the range of categorization that characterizes very unfair proposals, regardless of whether the proposals are made or received. Additionally, it is noteworthy to observe that fair or slightly hyperfair divisions are typically justified in either outcome or equity terms, whereas unfair offers are mostly justified in terms of quantity. Mentalization-based justifications are poorly made for all divisions, although – in these cases – it is curious to observe that, when playing as proposer, mentalization–

based justifications are uniquely confined to the most fair divisions (4-5; 5-5; 6-4). In general, these observations may suggest that children, particularly in the case of unfair offers, tend to not use mentalization-based explanations in order to reduce the distress stemming from the discrepancy between a “socially-expected” equal behaviour and the actual “selfish” behaviour. This interpretation can be further extended to the outcome-based justifications predominantly used to explain unfair offers that, in a certain sense, may serve to resolve a social cognitive conflict [e.g., 3], ultimately reducing the distress caused by the experimenter’s explicit enquiry.

Concluding remarks and limitations of the study

This study showed for the first time that young children's fairness is not affected by whether the child plays with another child or with a robot. In particular, it appears that children's decisions during social interactions are self-centred and poorly oriented towards the other's mind. Future studies could address the same issue focussing on different ages so to highlight the development of behavior in late childhood, when higher mentalistic abilities are maturing and eventually acquired. Additionally, we showed that the analysis of the justifications of children's behavior may be enlightening with respect to the child's actual psychological understanding of constructs, such as that of fairness.

It is important to stress that the present results, and in particular those referring to the behavioural differences here reported when the child played as receiver with the other child and with the robot, need to be confirmed with a more ample sample. Confirmation of these results could highlight a distinctive attitude towards a non-human interactive partner that emerges quite early in childhood and that may change during adulthood.

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Chapter 4

Object Use in children with autism: Building with Blocks from a Piagetian Perspective

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Abstract

Aim: This study focused on the manipulation of objects by children with suspected autism spectrum disorder. The aim was to demonstrate how objects can be seen as active agents of interpersonal exchange in face-to-face interactions.

Participants: Three children with suspected autism spectrum disorder (aged 18, 20, and 24 months) were selected as representative of the sensorimotor stage of development.

Methods: Starting from Piaget's classical approach to the sensorimotor and symbolic developmental stages, the study moved toward a socio-material interpretation in which some patterns of interaction involving object manipulation seem to create a space that supports adult-child communication. In videotaped observations of verbal and non-verbal signs during an (organized) free play session, each child manipulated seven small blocks of colored plastic in the presence of an adult. The observations were informed by a checklist of 14 items, including eye contact and building a tower of toy blocks from section B of the CHAT (*CHecklist for Autism in Toddlers*) instrument.

results: Based on a broad Piagetian perspective and recent work in the field of socio-materiality, key observations included the following: (1) sensorimotor and realistic play was observed in all three children; (2) there were some intriguing indications that objects serve as concrete mediators in the intersubjective space between adult and child; (3) some of the children's attention patterns were visibly mediated by the object.

Discussion and conclusion: All three children exhibited a particular sequence of actions. First, they manipulated the blocks through active experimentation; second, there was an apparent pause, during which, the children were in fact examining the blocks to determine how best to continue the interaction; and finally, the children monitored adult attention by means of eye contact or by restarting manipulation of the blocks. As this last step in the sequence indicated that the object became a mediator of reciprocal attention, this interpersonal process was labeled "attention mediated by object."

Introduction

According to Piaget (1928, 1952, 1954), children with autism achieve object conceptualization skills by the fifth stage of sensorimotor development. As several studies advise caution in using the *stage* concept to describe typical and atypical psychological development, it seems useful to characterize these psychological processes in terms of specific activities that the child can plan and implement when acting on their physical and social environment. For example, as a predictive index, the number and type of different actions produced by children with autism during a recreational activity may not always follow the same stages as in typical development, and this can also be correlated with the severity of autistic functioning (McDuffie et al., 2015). In fact, while imitation difficulties may reflect a possible delay in psychological development, not all pre-scholars with autism have problems with imitation or symbolic play (Vanvuchelen et al., 2011). Within the broad line of research that raises questions concerning object canonicity, we identified some interesting elements related to the socio-material function of mediation during communication.

It is known that canonical functions of objects are introduced by other people present in the child's world (Leontiev, 1981; Costall, 1997; Rodríguez and Moro, 2008; Barthélémy-Musso et al., 2013). Indeed, Sinha (2009) suggests that the canonical functions of the object are acquired as a normative phenomenon during social interactions, although cognitive understanding of that status is a prerequisite. Additionally, Sinha (2015) (p. 12) points out that “the materiality of meaning and meaningfulness of materiality is central to approaches in cognitive science emphasizing the importance of objects in extended cognitive embodiment.” In particular, there is evidence that canonical functions are acquired during child–adult interactions (Rodríguez and Moro, 1998; Sinha and Rodríguez, 2008; Moro, 2011, 2014). Several studies have reported how, under certain conditions (for example, impaired interpersonal relations or attentional focus), objects become mediators of social interaction (Williams et al., 1999; Dimitrova, 2014; Moro, 2014). Cárdenas et al. (2014) highlighted the importance of the reciprocal nature of these interactions by showing how they emerge from communicative and triadic contexts (adult–child–object). The crucial role of the adult in the acquisition of object use is observable from early infancy (Moreno-Núñez et al., 2017). Moreover, during child–object–adult interaction, the child's visual attention is more focused when interacting with an experienced caregiver than with an unfamiliar adult (Miller et al., 2009; Miller and Gros-Louis, 2013). Miller and Gros-Louis (2017) also showed that the child's attention is influenced by partner social style. Tomasello et al. (1993) and Tomasello (2016) highlighted different kinds of learning, such as imitative, instructed, and collaborative. For instance, imitation is important for

learning that involves others and objects, as it facilitates understanding of the normative expectations of a given cultural group (Tomasello, 2016). Sinha (2009) suggested that children apprehend canonical functions primarily by cognitive means, thereby accessing the normative identity of the cultural group. Bruckner and Yoder (2007) reported that, even among children with autism, object use can be linked to emergent functions in the preoperational stage, such as imitation and attention to the other person.

Most of the existing research suggests that imitation is impaired in children with autism (Charman and Baron-Cohen, 1994; Rogers, 1999; Rogers et al., 2003; Williams et al., 2004). Indeed, Smith and Bryson (2007) noted that children with autism exhibit difficulty in imitating any unconventional use of objects but are able to imitate canonical object use. By imitating this canonical use, children with autism access part of the cultural group's heritage. With respect to manipulative play activities, Kanner (1943) was among the first to note that, despite differences and limitations, children with autism exhibit a number of functions related to the use of canonical and non-canonical objects. Trevarthen and Hubley (1978) described the dynamics informing subject–subject–object triangulation (the theory of “secondary intersubjective tuning”). Typical children alternate their eye gaze between the object being viewed and the other person, so engendering joint attention. However, in atypical development, and especially for those on the autistic spectrum, an abnormality has been observed in the development of behaviors related to joint attention. Palacios and Rodríguez (2015) showed that in typical children aged 9–15 months, the symbolic use of an object develops within a triadic context. Ungerer and Sigman (1981) assessed the use of everyday objects in a group of children with autism ranging in age from 39 to 74 months in a structured and free play session and found that most were unable to use an object according to its designated function. Williams et al. (2005) interviewed parents of 10 children with autism (MA = 62.2 months; SD = 19.9) who reported problems relating to the use of an object, such as an interest in some unusual aspect of the object, an unusual way of using the object, or difficulty in generalizing object use. Custance et al. (2014) suggested that imitative deficits in children with autism can be reduced by means of object-related activities, especially if there are no time limits on use of the object. Object-related activities promote joint attention, motor imitation, and intentional communication with a social partner (Bruckner and Yoder, 2007), and there is evidence that interventions focused on play involving different objects can promote social and imitative behaviors (Brown and Murray, 2001; Stahmer et al., 2003; Lee et al., 2017). Swettenham et al. (1998) observed three types of attentional behavior: (1) between an object and another object, (2) between an object and a person, and (3) between one person and another. Children with autism showed relatively more attention to interactions between an object and another

object. In our recent studies, we have observed the important role of the object in activating attention in the child with autism, and we describe the phenomenon as “attention mediated by the object,” which may be a precursor of joint attention (Iannaccone et al., 2016; Manzi and Savarese, 2017; Savarese et al., 2017).

The observational study reported here incorporates a sociomaterial perspective, referring in particular to the mediating role that objects seem to assume in the interaction between children and adults, which has to date been neglected in the scientific literature. Using a selected set of objects, the study analyzed the child with autism’s ability to manipulate those objects and to evaluate their symbolic use. Starting from presentation of the object, a further objective was to identify the type of game engaged in by the child. During interaction with an adult, we observed first whether there was eye contact; second, whether this changed how the child used the object; and third, whether the canonical use of the object was an important element in the child–adult interaction.

Material and Methods

Participants

We used the tower building item from section B of the “CHecklist for Autism in Toddlers instrument” (*CHAT*; Baron-Cohen et al., 1992). It was developed to help identify children who are at risk of developing social-communication disorders (scoring “high risk of autism”). It was administered to filter participants and one child aged 22 months did not pass this item. Children aged 18 months are capable of tertiary circular reactions and can stop and restart a sequence of actions at any intermediate step, which is crucial in building a tower of blocks. Children older than 18 months can use symbolic mental representations. The selected age range, therefore, allowed us to observe the early development of symbolic functions.

The study’s participants were three non-verbal male children with suspected autism spectrum disorder. The suspected diagnosis of autism was identified through the use of the CHAT instrument.

Their different ages encompassed the transition from sensorimotor to preoperational stage; participant 1 was aged 18 months, participant 2 was aged 20 months, and participant 3 was aged 24 months.

Methods

The study employed videotaped observations (with one camera) of verbal and non-verbal signs during an organized free play session, in which each child played with seven small blocks of colored plastic in the presence of an adult (a different experimenter was used for each observation). The observations were conducted on the basis of a checklist consisting of 14 items (see Appendix A), including eye contact and the building of a tower of toy blocks from section B of the CHAT procedure.

The blocks were selected not only because of their use in the CHAT procedure but also in accordance with the empirical tradition of Piaget (1962) and Reifel (1984), who have shown the importance of toy blocks in the child's cognitive development. The interaction sequences from the video recordings were transcribed in full for microgenetic and semiotic analysis, primarily examining the children's non-verbal signs (gestures and posture) during interactions with the objects. Adult intervention was also analyzed in terms of non-verbal signs (gestures and posture), again focusing on sequences of microgenetic and semiotic actions. Sequences were selected using the following criteria: the presence of gestures, actions, or both, where (1) the adult intervened and the object became a mediator of the interaction, and (2) the object mediated the attention between child and adult. The observations of child and adult occurred simultaneously.

Ethical issues

This study was carried out in accordance with the recommendations of AIP (Associazione Italiana di Psicologia), and all of the children's parents gave written informed consent in accordance with the Declaration of Helsinki. As there is as yet no psychological ethics committee at the University of Salerno, the protocol was approved by the external experts group from the University's "Centro di Counseling Psicologico" (Counseling Center). While the Center is not specifically responsible for ethical approval, the external experts group supervises research carried out by psychological researchers at the University. In Italy, few universities have a psychological ethics committee, and these generally offer degree courses in psychology or have a psychology department or institute. The University of Salerno has not activated degree courses in psychology and has no such department. We would like to thank the external experts, Dr Oreste Fasano (Psychologist), Dr Nadia Pecoraro (Psychologist), and Dr Monica Mollo (Lecturer in Psychology).

Results

The interactions with the blocks helped to observe behaviors that related to the blocks' physical attributes and the child's competence to establish relations with them. This playful manipulation of

objects probably helps planning and coordinated action, stimulating and strengthening the child's ability to interact with the outside world. At the same time, these activities allow children to imagine new construction scenarios (Harris, 2000). In the presence of potential partners or competitors (children or adults), the child's management of play activities and their implementation of communication strategies can also be observed. For example, the 18-month-old touched and handled all seven blocks, the 21-month-old touched and handled six blocks, and the 24-month-old touched and mechanically stacked all seven blocks.

Based on their independent observations, the two researchers agreed that the three children's symbolic use of objects (see **Table 1**) could be assigned to the first level of symbolic play as proposed by McCune-Nicolich (1981), based on Piaget's sequence (1972), because the children played using sensorimotor schemes. In addition, unlike the 24-month-old, the 18- and 20-month-old played a realistic game. Pretend and symbolic play was not observed in any of the three children's behaviors.

Table 1. *Use of Objects*

	Child 1: 18 months	Child 2: 20 months	Child 3: 24 months
Realistic play	Yes	Yes	No
Pretend play	No	No	No
Symbolic play	No	No	No

Based on observations of the "Can the child build a tower of blocks?" item in section B of the CHAT instrument (see **Table 2**), it was established that all three children used the objects in a manner similar to that described by Piaget as part of the manipulative activities of sensorimotor functioning. The children showed active exploratory behaviors as the toy blocks were manipulated, sorted, and stacked.

Table 2. *CHAT Section B: non-key items.*

	Child 1: 18 months	Child 2: 20 months	Child 3: 24 months
Tower of Blocks	Yes	Yes	Yes
Eye-Contact	Yes	Yes	No

In observations of the Eye Contact item of CHAT section B, the 18- and 20-month-old made visual contact with the adult, but the 24-month-old showed no eye contact. In the child-object- adult or

simple child–object interactions excerpted below, a set of seven colored plastic blocks was placed in front of the child. Transcription commenced when the child began to manipulate the blocks.

Observational results

In this section, we describe the observations we made of children with autism in relation to the types of object use (see **Table 1**). Crucial episodes were selected to illustrate the characteristics of the interactions between the children and the adults.

Generally, adults help children to interact with objects. In the observation of Child 1, the child was able to perform a complex series of actions on the object during the interaction. The child grabbed the object, manipulated it to orient it, dropped it, balanced it, and connected the different objects by stacking them. Here, the adult's help was crucial, as the elements of the child's interaction with the object were changed; at the same time, the object became a mediator in transforming the interactive arrangement between the child and the adult. The adult's hand in direct contact with the object became a source of interest to the child, who focused on this subject–object hybrid.

Observation 1. Child 1. Difficulties in the use of the material features of the object induced the intervention of the adult.

The child cries because the blocks he had begun to stack fall; while he cries, he holds two blocks in his hands and tries to put them on a block on the table. The adult comes over and gets behind the child. The child tries to lay block 1 but fails because he is shaken by tears. The adult places the existing block in a better way. The child looks attentively at the adult's hand and places block 1. The adult takes block 1 with the child and helps to place it in the right position in balancing it.

(...) With his hand, the adult moves block 4 (stacked by the child) to achieve better balance. The child observes the adult's hand. The child leaves block in his left hand alone and, continuing to watch the stacked blocks, extends his right arm to grab block 6. He places block 5 onto block 4 and, without looking, tries to grab block 6.

The child's initial frustration on being unable to stack the blocks led to an intervention by the adult, who was seated on the ground behind the child. The adult intervened when the child played with the blocks, and the object became a mediator of interactions and interpersonal activity.

Observation 2. Child 1. The previous help of the adult activated the attention of the child.

Once block 4 is in his left hand, he stretches his right arm and grabs block 5 before positioning block 4. While watching block 5, the child places block 4 and leaves it on block 3a; in the meantime, he brings block 5 closer to his body. After leaving block 4, the child takes a step back to turn to the adult, and they look at each other.

(...) He places block 6 onto block 5 and leaves it. Having left block 6, he turns to the adult, and they look at each other.

The child continued to play with the blocks, which became a mediator of attention between the child and the adult. After his intervention, the adult facilitated the stronger relational attractiveness of the object, as it became a transformative element in the initial environmental arrangement.

Observation 3. Child 1. The child used the material features of the object correctly after the intervention of the adult.

The child stretches his right hand and grabs block 4. The child then passes block 4 to his left hand, no longer looking at block 4 and directing his gaze to block 5. Meanwhile, the child keeps block 5 in his right hand. Holding the new block, the child turns to the stacked blocks and simultaneously raises his right hand (with block 5). He raises both arms above his head and grabs block 5 with both hands.

The child combined the object's socio-material properties by combining the material properties of the object with the social structures inherent in the object itself.

Furthermore, a series of interesting gestures was observed in the child-object interaction. When the child took the block and raised it over his head, even though the blocks on which the held block was to be placed were much lower in height, the child may have been planning to build a much higher structure with different characteristics to the existing one. One may take these behaviors as possible evidence of an imaginative process. This can also be seen as an explanation of the socio-material link, as imagining a structure beyond what is immediately present may indicate the child's ability to combine the material properties of objects. As the adult intervened, he became an example for the activity of the child. In the child-adult interaction, the object became a mediator of attention.

In the observation of Child 2, the child's manipulative skill was organized in a complex series of actions. He eyed the objects, planned to grab and stack them, rotated the objects in both hands, left, and again grabbed the objects. The material characteristics of the objects were explored. The adult intervened when the child played with the blocks, and the clock (the object) became the mediator for the joint attention of the child and the adult.

Observation 4. Child 2. The child began to actively explore the objects.

The child moves the blocks in front of him (almost shuffling them), watching them carefully. Still looking at the five blocks in front of him, he moves his right hand and touches block 1, which is not present in his visual field.

The child explored the material features of the blocks, and through these actions, which blended complex activities, the child seemed to experience the object adapting and being adapted by its constituent elements. In building a tower of blocks, the child's aims and imaginative action planning appeared to converge. Thus, even though a symbolic game could not be identified, it seems that sensorimotor play and realistic play were present.

Observation 5. Child 2. The child used the material features of the object.

He raises block 1, keeping his eyes on it while grabbing block 2 with his left hand. He turns block 2 around, changing the side that rests on the ground; in the meantime, his right hand brings block 1, moves it in the air, and passes it over block 2. He is about to place block 1 but brings it back close to himself, touching it with his left hand and resting it on block 2.

Here, the child experienced the features of the object. The adult intervened several times during these child-object interactions. The subject-object hybrid identified during the observation of Child 1 is also present here. During the first stage, the child's attention was focused on the transformative mediation of the subject-object hybrid, highlighting how this inextricable relationship drives the modification of the initial environmental arrangement. The child's actions can be seen to occur in a synchronic and harmonic circle of the imitation of the adult's actions.

Observation 6. Child 2. The socio-material features emerged during the child-adult interaction.

The adult places his hand in the child's visual field by moving a block over to him; putting it onto the floor, the adult begins to stack the block. Throughout the sequence, the child is

attracted by the adult's hand manipulating the block. He directs his gaze to block 1 and grabs it; continuing to watch it, he takes it with both hands. The adult begins to stack the blocks. The child manipulates block 1, which he holds in his two hands. He rests block 1 and leaves it. Directing his gaze to the blocks in front of him, he watches the adult, who stacks blocks.

(...) The adult takes the blocks that the child had put in rows and stacks them on top of each other. The child again takes block 4 with both hands. The child carefully observes the adult's movements while stacking. Still with block 4 in his right hand, crawling and with momentum, the child approaches the blocks stacked by the adult. The child grabs block with both hands, looks at it, and manipulates it. He turns block 4 in the direction that seems to enable stacking. He watches the blocks being stacked by the adult and, with his right hand, places block 4 onto the stack of blocks.

The subject/adult-object hybrid appeared to represent the transformation of the subject/adult-object-subject/child relationship, leading to revised planning of the action and thereby structuring of general aims. As well as becoming a mediator of the child's exploration of the surrounding environment, the object also rewrote the relational terms. This last step seems to follow the socio-material perspective, as the social structure of the object was intertwined with its material characteristics.

In observation of Child 3's sequence of actions, the attractiveness of the object overrode the ability to create a contact area with the adult who remained peripheral, or as a mere spectator of the child's construction. Actions have a regularity of performance: blocks are looked at, the hand gets ready to grab, the arm is stretched out to get to the object, the object is grabbed, the child identifies where to put the object, and eventually rests it in balance for stacking.

Observation 7. Child 3. The child used only the material features of the objects.

The child grasps block 1 with his right hand and rests it on a raised board, which has a width equal to the side of the block. He looks closely at block 1 and grabs it with both hands as if to be sure it is in balance. He pulls his right hand away from block 1 and, holding himself with his left hand, leans over the board to see what is there. He directs his eyes to where the blocks are located. He lowers himself, leaning with his left hand on the board and gripping block 2 with his right hand. He gets up and, watching block 1, rests block 2 onto block 1. He removes his right hand from block 2, lowers his body to take block 3, and grabs it with his right hand. He gets up and places it onto block 2, leaving block 3.

Following this regularity of actions, which converged in a purposeful activity, we can assume that the child has completed the main stages of sensory–motor skill development and understood the object’s material characteristics. Additionally, the social function inherent to the object appears to be linked to its use.

In fact, the building of the tower was achieved through structured planning and with a constant imaginative tendency. What is lacking seems to be an understanding of the possibility to use the object as a social agent, because the adult was present only as a spectator.

Based on the regularity of actions that converged in purposeful activity, we can assume that Child 3 had completed the main stages of sensorimotor skill development and was able to understand the object’s material characteristics. Further, the objects’ inherent social functions appeared to be linked to their use. In fact, the building of the tower was achieved through structured planning and with a constant imaginative tendency. The adult did not intervene when the child played. In the child–adult interaction, what seemed to be lacking is an understanding of the possibility of using objects as social agents, as the adult was present only as a spectator.

Searching for constants in analyzing the filmed sequences of the three children, their successive actions were identified; initially, each actively manipulated all the blocks. This activity preceded an apparent break, but during that phase, the child observed the objects to determine how to continue. Immediately thereafter, the child either sought the adult’s attention through eye contact or resumed the interrupted object manipulation.

At the beginning of the game, the children moved, shook, and turned the items several times, and this correlated with activation of their hand movements. Here, we probably witnessed the typical secondary circular reactions of the sensorimotor stage. After the break and the search for mutual attention and/or eye contact with the adult, the children then proceeded (by trial and error) to build the tower of blocks, modifying their existing schemes in so doing. This was indicative of tertiary circular reactions.

Discussion and Conclusions

Consistent with a theoretical perspective emphasizing the role of social and material dimensions in psychological development and activities (Iannaccone, 2015), our analysis highlights two important implications in our observations of object manipulation. First, consistent with the Piagetian

perspective, the observations highlighted object manipulation and action planning identifying the presence of secondary and tertiary circular reactions (Piaget, 1972). In relation to the game, invoking the McCune-Nicolich model (1981), all the children exhibited sensorimotor play, in which the object was manipulated and understood in terms of its material characteristics.

The second implication relates to how, in some action sequences, the material and social characteristics of the objects contributed to shaping partner interactions between child and adult. This aligns with several empirical studies of the social uses of objects (conventional, canonical, and symbolic) (John-Steiner and Mahn, 1996; Moro, 2011). In such interpersonal situations, the activities of participants (child and adult) are clearly affected by the setting's physical and social affordances. In particular, during child–parent interactions (Moro, 2014), triadic child– object–adult interactions (Moro, 2011) seem to create relevant socio-material scenarios that frame communicational activities. In our observations, two of the three children in fact exhibited a kind of object management mode that seemed to replace eye contact with the adult. In some sequences of actions, child and adult managed to coordinate action planning through object manipulation, child exploratory activity, and adult scaffolding. For example, the child observed and touched the objects to encourage play activities; the adult touched the object with his hand, and this action frequently became a source of interest for the child. The child looked for the adult's attention through eye contact, and the child began to manipulate the object. In activities of these kinds, it seems evident that the objects can serve as mediators in communicative interactions with the adult. As well as taking into account the social function of objects, the observed children were already considering the socio-material characteristics of the play situation, as adults and children engaged in managing a kind of “socio-material space” as proposed by Rodríguez et al. (2015). In fact, from the first year of life, adults produce a shared space with objects that serve as effective tools of communication with children. Our findings in relation to the object as a tool for adult–child interaction align with Moreno-Núñez et al. (2017), confirming that the first shared understandings between adult and child take place around the object and its uses. Finally, in considering these first results, we can imagine relevant challenges for a new developmental psychology based on further related research.

Our observations of these interactions do not focus on direct joint attention but identify a kind of psychological process that we call “activity mediated by the object.” Unlike Tomasello (1995), we consider the object itself as mediator, not only of the mutual attention between adult and child but of the dynamic relational exchange between partners.

In conclusion, our study reported the preliminary results of a larger analysis. In considering these first results, we can imagine relevant challenges for the developmental psychology of children with autism. Consistent with the results of studies on children with typical development, our study on children with autism shows that the socio-material features of objects represent factors that mediate the construction of child–adult interactions. Starting from the first intervention of an adult, an object becomes a mediator and promoter of interpersonal activities and space.

Ethic Statement

This study was carried out in accordance with the recommendations of AIP (Associazione Italiana di Psicologia), and all of the children’s parents gave written informed consent in accordance with the Declaration of Helsinki. As there is as yet no psychological ethics committee at the University of Salerno, the protocol was approved by the external experts group from the University’s “Centro di Counseling Psicologico” (Counselling Centre). While the Centre is not specifically responsible for ethics approval, the external experts group supervise research carried out by psychological researchers at the University. In Italy, few universities have a psychological ethics committee, and these generally offer degree courses in psychology or have a psychology department or institute. The University of Salerno has not activated degree courses in psychology and has no such department. We would like to thank the external experts, Dr Oreste Fasano (Psychologist), Dr Nadia Pecoraro (Psychologist), and Dr Monica Mollo (Lecturer in Psychology).

Author Contributions

The introduction was written by AI. The observational analysis was written by FM. The discussion of the results and the conclusions were written by GS.

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Chapter 5

Social Functions in Autistic Children and Interaction with/through Object: A Brief Report

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Abstract

The aim is to analyse the social functions of pointing, of imitation and of joint attention in presence of the object for the autistic children. We have built an ad-hoc observation check-list and we have conducted 43 observations with verbal ASD-affected children aged between 2 years and 6 years. The results show that a better use of the object is correlated to the manifestation of social functions analysed.

Introduction

In a socio-material perspective (Iannaccone, 2015), the object is composed of material features and social components coexisting together. Considering that the social interaction is impaired in autistic children; consequently, the interaction with the “social world of objects” is impaired as well (Iannaccone, et al., 2016). Some autistic children show deficits in the use of objects: alterations in manipulation, exploration and describing. Thus, autistic children which do not present impairment in the use of the object show more social functions than impaired children (Trevvarthen & Hubley, 1978; Tomasello, 1995; 2016).

The three social functions, pointing, imitation and joint attention analysed in the study and they all have in common the presence of the object in their definition. Thus, our aim is to analyse these functions not only taking into account the development of these by the autistic child, but also what role plays the object specifically in social and relational terms.

Method

We have built an ad-hoc observation check-list inquiring on 9 areas (each of which has specifying under-questions), which refer to 9 psychological theory constructs developed by the literature on autism and object. The main objective of this check-list is that of describing characteristics and socio-material functions of the object with reference to autistic subjects. In this check-list, there are different psychological constructs, but here we have analysed in detail three constructs: declarative function, imitation and attention. As we can see the check-list was made of different constructs but we will analyse these other constructs in future.

During each observation, an educator following the child for rehabilitation was present and the educator completed the check-list. Each observation lasted 26 minutes on average and has been transcribed on an ad-hoc check-list.

Children have been observed while interacting with an object, a small-sized plastic toy, they had chosen from a set of objects, for instance, toy cars, trains, toy animals and others. When we refer to “acted and interacted with and through the object” we arranged different constructs of the check-list, such as: Understanding of the use of the object, interaction through the objects etc. Which are the constructs refer to the manipulation, exploration and describing.

We carried out 43 observations with verbal ASD-affected children aged between the end of the sensory-motor stage (24 months) and the start of the pre- operational stage (68 months, namely 6 years). Moreover, the literature shows some results showing a link between a better use of the object

and those functions that emerge during the pre-operating period, such as imitation and attention to the other (Bruckner & Yoder, 2007).

We were two samples. The first sample composed of 18 children who acted and interacted with and through the object while the second sample composed of 25 children who acted and interacted with and through the object.

Results

Regarding the association between the sample 1 and the declarative function (Figure 1) shows that the 66.7% of the sample present this association while the sample 2 shows that only the 24% present this association.

Indeed, it is possible also for autistic children to use the imperative function of pointing, as for typical development children, and pointing is often the ground- breaking of a full declarative function (Camaioni et al., 2003).

Regarding the association between the sample 1 and the imitation (Figure 2) shows that the 94.4% of the sample present this association while the sample 2 shows that only the 60% present this association.

Concerning imitation, it has been suggested that the specific imitation deficit of autism could be reduced or even eliminated with the use of activities linked to objects (Vanvuchelen et al., 2013; Custance et al., 2014), especially when no timelines in the use of objects are given.

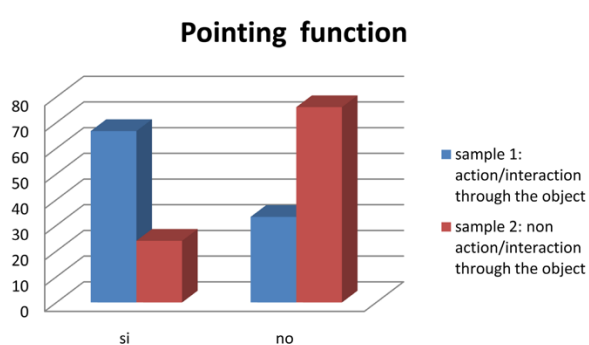


Figure 1. Pointing function

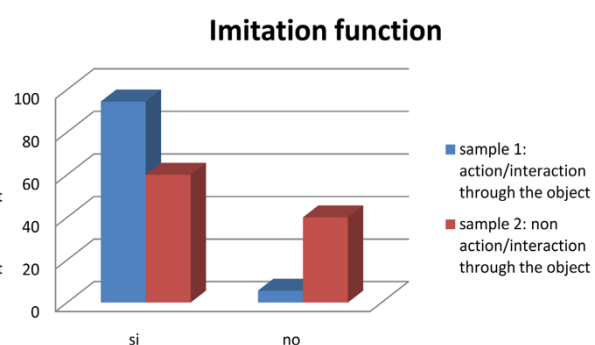


Figure 2. Imitation function

This would favour a higher joint attention, motor imitation and intentional communication with a social partner (Swettenham et al., 1998).

Regarding the association between the sample 1 and the Joint attention (Figure 3) shows that the 61.1% of the sample present this association while the sample 2 shows that only the 32% present this association.

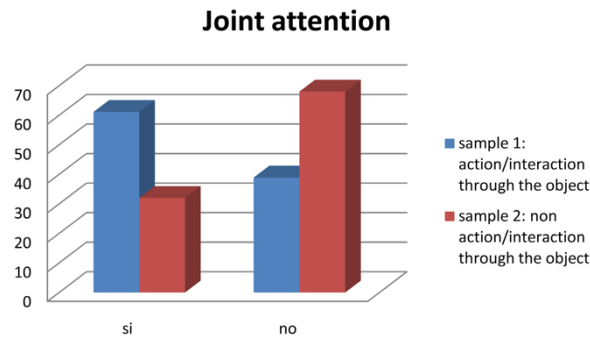


Figure 3. Attention to the adult function

Lastly, regarding joint attention it has been proved that manipulation of material objects can address the child's attention and favour the joint attention with both adults and peers (Korkiakangas & Rae, 2013).

Conclusion

The socio-material features of the object represent factors that mediate the construction of the interaction with the adult. Social functions contribute to this process are: the declarative function (relating to pointing), the imitative function, the function of joint attention.

In line with the literature (Bruckner & Yoder, 2007) on the child with typical development, our study with autistic children shows a link between a better use of the object and these functions that emerge during the pre-operating period, such as imitation and attention for interacting with people.

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Chapter 6

General Discussion

The aims of this thesis were: 1) to explore the intersubjectivity space that a child can establish with an object (the robot) that is also the interactive partner during the interactions; 2) to observe the role of the object as mediator of the child-adult interaction and as promoter of the construction of the intersubjectivity space. The first topic has been investigated in children with typical development while the second topic has been explored in children with atypical development, i.e. autistic children.

In this respect, there were designed two different interactional scenarios to evaluate the intersubjectivity: 1) concerning typical development it has been used an interactional situation involving humanoid robot in order to test the decision-making processes; 2) regarding autistic children the use of the object has been observed during an interaction with an adult mediated by an object, testing the role of the object as mediator and promoter of the interaction. The first situation, involving an innovative field of research, needed a review of the literature in order to understand which role can be assumed by the robot during the interactions with a human. Thus, it was important to analyse if human can ascribe a mind – mental states – to a robot, in particular in a life-span perspective in order to observe changes during the human development. The second scenarios used an original perspective to examine the interaction between autistic children and adults, showing that autistic children, despite their impairments in different areas of development, can create an intersubjective space with the adults. However, this is evident when child and adult use an object as mediator of this interaction.

The findings emerged from these scenarios arise two main questions:

Can a child treat a humanoid robot similarly to a human partner?

Futurologists hypothesised that in the next years robots will be introduced in different contexts of our everyday life such as household, elderly assistance, education etc, modifying the job market but also our social interactions. For instance, the use of robots in the educational context are inspiring new educational program. Moreover, children will be more conscious of the existence of the robots because robots become part of their everyday experience. Several studies underline the need to implement physical and behavioural features in order to make robots more sociable, promoting better

interactions. From Chapter 1 results that subjects ascribe mental states to a humanoid robot. However, the attribution of a mind is not similar at all ages, but it changes during the life-span. For instance, a recent study of Manzi and colleagues (2017) showed that children from 5 to 9 years of age distinguish a human from a robot as regards the attribution of mental states, in particular children ascribe different mental states to a robot at different age: younger children ascribe more emotional states compare to older children. However, several researches in the field of educational robotics show that children treat a robot as a companion and scaffolder in the educational contexts. These findings are evident in the study presented in Chapter 2. In fact, 5-years-old children ascribe less mental states to a robot compared to a human but despite these differences, they use similar strategy with human and robot when they play in an interactive game. This is a fundamental result because it means that children can treat a robot similarly to a human. Moreover, another innovative result of the study is the analyses of children justifications given to the Ultimatum Game. We observed that children tend to use justifications based on the outcome and not on the basis of mentalistic terms both for human and robot, showing how children behave like maximisers – according with the homo-oeconomicus theory – when they interact both with human and robot. In the human condition, children's justifications based on the 'outcome' given to the unfair divisions, both as a proponent and as a receiver, could be explained as the attempt to resolve a cognitive and social conflict (expected "social" fair behaviour VS real "selfish" behaviour). Moreover, in the robot condition, children's justifications based on mentalistic terms to unfair divisions, both as a proponent and as a receiver, can be explained as the social norms of equity might be less relevant (robot = "not perfectly like-me").

The literature review in Chapter 2 and the data of Chapter 3 represent an important finding for the HRI and cHRI because it is possible to infer that humans – from childhood to old age - tend to ascribe a mind to a robot and that besides 5-years-old children tend to treat a robot as social partner, using similar cognitive strategies both for human and for robot.

In conclusion, robots can be considered 'like-me' (Meltzoff, 2005, 2007a, 2007b, 2013) but it depends from: 1) the age of human partner interacting with a robot; 2) the methodological procedures, and particularly the nature offline (i.e., the AMS questionnaire used in Chapter 3) or online (i.e., the modified version of the Ultimatum Game used in Chapter 3) of the tasks employed; These final observations lead to reflect on the instruments used in research and this is even more important when the topic of research is new such as the HRI. In fact, it is essential to combine both offline and online measures, but also it is important use together ecological and laboratory tasks.

Can an object be a mediator and a promoter of the child-adult interaction also for autistic children?

We live in a social world composed by humans and objects. In the history of Psychology, the human-human interactions were largely investigated but few studies analysed the human-human interaction mediated by objects. In this regard, Piaget (1952, 1954) highlighted that children discover the world of the objects through a sensorimotor activity, which constitutes the basis of the cognitive development. Vygotskji (1962, 1978) showed that children with typical development use artefacts to interact with others, acquiring their knowledge about objects through the interaction with a scaffolder (peers or adults). Moreover, Moscovici (1976) examined the interpersonal relationships in a triadic perspective, highlighting that humans and objects are strictly connected. However, Linell (2009) proposed a dialogical interpretation of the objects, suggesting that it is important to understand the objects as external referent that can change human's perspective of the world. Several studies showed that an adult can be a scaffolder for the acquisition of the use of the objects in children with typical development (Moro, 2014). In Chapter 4 and 5 we demonstrated that also children with atypical development, in particular autistic children, can use the object to construct an intersubjectivity space during the interaction with the adult. The objects in these interactions acts as mediators of the child-adult interaction, creating a specific intersubjective space in which autistic children, despite their social impairments, are able of some social performances (i.e., ocular contact).

In Chapter 4 the results seem to demonstrate that the socio-material features of objects represent a key-element that mediates the construction of child–adult interactions, becoming a mediator and promoter of interpersonal activities and space. Chapter 5 shows a link between a better use of the object and the presence of social behaviors that emerge during the pre-operational stage, such as imitation and attention. However, it is important to highlight that the use of the object and the presence of social abilities largely vary in each autistic child because autism is a spectrum disorder that implies a wide range of phenotypes. Thus, the construction of intersubjectivity space has to consider the specific subjects of the interaction and their interpretation of the objects.

These findings lead to the conclusion that to understand how children with typical development interpret the use of the objects it is important that adults ‘share’ the child’s perspective in order to create an intersubjective space. If it is crucial in typical development, then it becomes even more essential in atypical development, in particular in autism that is a spectrum of disorders that imply a different kind of impairments in several areas of development. In fact, the adult has to consider that each autistic child constructs the intersubjectivity space in a subjective way, using all her/his skills.

In general, both as regards typical and atypical development, the adult should accept that each artefact is always reinterpreted by the child in a triadic relationship through a continuous and dynamic construction of the intersubjectivity.

Conclusion

The majority of the psychological research is inspired by everyday experiences and so I will try to give some examples of the key points of this thesis, starting from my life.

I am writing my thesis using my computer right now and its battery is almost discharged. I am saying “Why you do this to me?”. Despite my prayers, my computer will switch off if I will not put it in charge. What does this situation mean? I am ascribing intentions to my computer, in particular the intentions to turn off itself.

I remind that in UK when I was learning how to use a robot, I was staying in the Lab hours and hours without talk to anybody and so I was starting to talk to the robot, ‘praying’ it to work in the right way. It obviously continued to not work and to not reply to my questions and prayers (fortunately!).

I bought a toy for a son of two friends of mine when he was 6-moths-old. Then these friends moved to USA and sometimes we Skyped, but I did not see them for a long time. This summer when I came back to my hometown, I saw them after three years and the child still had the toy and when the mother said him that I bought it for him he smiled and give me the toy to play together.

The above examples highlight the two main points of this thesis: 1) we can ascribe mental qualities also to objects that have not ‘really’ a mind because we tend to project our internal states onto the external world; 2) we are fully immerse in a world of objects that give us the opportunity to create an interaction with another person beyond the time.

To attempt a tentative conclusion, the purpose of this thesis was to show that when humans build objects - from the classic ones to the more technological ones - they also achieve two further important objectives: to facilitate social interactions and to create an intersubjectivity space that includes both human and non-human partners. I sincerely hope my efforts have at least partially succeeded.

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Materiality and the construction of Intersubjectivity: human-robot interaction In typical development and the use of the Objects in ASD children

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Chapter 1

General Introduction

*Una mente tutta logica è come un coltello tutto lama.
Fa sanguinare la mano che lo usa.*
(Rabindranath Tagore)

The aims of the present dissertation are to analyse, in children with typical and atypical development, the construction of the intersubjectivity through the use of objects in atypical development (ASD) and through the interaction with a humanoid robot in typical development. About the humanoid robots, the issue is to observe the possible attribution of human-like features to a robot that can make the human-robot interaction similar to the human-human interaction that is a classic intersubjective interaction because of the presence of two human subjects. This purpose is investigated considering two theoretical frameworks: 1) Theory of Mind that explain the construction of the intersubjectivity through the attribution of mental states to others; 2) Socio-material perspective which postulates that the construction of the intersubjectivity is mediated by objects in many cases. Thus, the question arises in this dissertation about the humanoid robot is: what happen when the mediator object (the robot) is also the interactive partner.

To achieve this purposes, the present thesis studies two main topics: 1) the interactional patterns with and the attribution of a mind to a robot by typically developing children; 2) the interactional patterns in atypical development - autistic children - in a child-adult interaction mediated by objects. The first topic is analysed in an innovative theoretical perspective and a through novel methodological approach, leading to an innovative understanding of the child-robot interaction. The theoretical perspective connects the role of Theory of Mind in HRI; the methodological approach observes children's decision-making strategies in the HRI, comparing these behavioural patterns when children interact with a human and with a robot. The second issue of the thesis is about the role of the object as mediator of the relationship between autistic children and adults. This is studied through the Socio-material perspective that hypothesised that material features of the objects and their intrinsic social qualities are strictly connected.

A useful psychological paradigm to investigate the construction of intersubjectivity is the Theory of Mind construct that will be briefly introduced; subsequently I will give an overview on Human-Robot

Interaction and, finally, I will conclude with some observations concerning the role of the objects in autism.

Theory of Mind or how understand the social world

Theory of Mind (ToM) represent one of the most important psychological constructs used in the last decades to interpret social interactions. ToM is the ability to understand one's own and other people's mental states (intentions, emotions, desires, beliefs), and to predict and interpret one's own and others' behaviours on the basis of such meta-representations (Premack and Woodruff, 1978; Wimmer and Perner, 1983; Perner and Wimmer, 1985). This definition highlights how the presence of the other is crucial for the comprehension of ourselves and for the interpretation of the relational world. The history of the ToM begins with the pioneering study of Premack and Woodruff (1978), titled "Does the Chimpanzee Have a Theory of Mind?". This study paved the way to study the ToM also in different agents, not only in humans but also in primates. They found that also the primates can use ToM ability to understand and predict the conspecific's and human's behaviours. These results allowed to study the ToM in an evolutionary perspective. In fact, Adolphs (2009) theorised about the phylogeny of social abilities, showing that our brain is a social brain that evolved from primates to humans.

Furthermore, developmental psychology study the changes that occur during children's development, showing the ontogenesis of this ability. ToM is not a monolithic construct, but it is a complex and multimodal ability that involved both cognitive and affective processes (Shamay-Tsoory & Aharon-Peretz, 2007; Kalbe et al., 2010).

Wellman (1991) hypothesised a ToM development from 3 to 7 years of age considering the understanding of mental states in the childhood. The author drawn a line of development: children in the early stage of development understand the non-epistemic states (desires, emotions and intentions) – between 3 and 4 years – and only late – between 4 and 7 years – the epistemic states. The epistemic states are the bases for the true and false belief understanding: this allows children to construct a meta-representation of their own and other's mind. Thus, considering the important of belief, in particular false belief, a pioneering study of Wimmer and Perner (1983) used for the first time the paradigm of the false belief task to study the ToM development. In this study the authors used the Unexpected Transfer Task in which a character has to ascribe a false belief of another character. The results showed that 4 - to 5 - year-old children can predict the actions of someone with a first order false beliefs referred to the first level of recursive thinking (i.e. "I think that you think"). These findings are supported by a meta-analytic study by Wellman, Cross and Watson (2001) that confirmed

that children begin to attribute a false belief starting from 4 years of age. In a second study Perner and Wimmer (1985) used a different task, the Ice-Cream Van, in order to analyse the second level of the recursive thinking (i.e. ‘I think that you think that she/he thinks’), that is the *second order false belief*. They found that 6- to 7- years-old children can understand this second level of representation. These findings show that the ‘sensible period’ for the emergence of the ToM is from 3 to 7 years of age and that it is acquired in a hierarchical way (Wellman, Cross and Watson, 2001). However, several studies show that the ToM is an ability that gradually develop from childhood to adulthood (Sommerville et al., 2013; Dumontheil et al., 2010; Apperly et al., 2012) and in the last years several studies investigate the modification of the ToM ability during the old age (Happé et al., 1998; Castelli et al., 2011; Saltzman et al., 2000).

Human-Robot Interaction: an interdisciplinary approach to investigate socio-cognitive abilities

“Human–Robot Interaction (HRI) is a field of study dedicated to understand, design, and evaluate robotic systems for use by or with humans” (Goodrich and Schultz, 2008, pp.1). The HRI derived from the Human-Computer Interaction (HCI) studies. The differences between HRI and HCI is that HRI uses robots that have physical human-like features (along a gradient from completely non-human like to a complete similarity with humans) and they can behave as humans (i.e., a robot can recognize and follow the eyes of a human or it can reply semi-autonomously to a human question). Thus, HRI not only implement behavioural patterns into robots but also design robots that can be perceived more human-like (Minato et al., 2004). In the last two decades HRI received more visibility especially related to the development of new theoretical approaches and technical skills in the robotics’ domain. For instance, in 2004 the Ishiguro’s Geminoid Project¹, in Japan, built androids which very closely resemble specific human “models” as a platform for research aimed at understanding humans, applying methods from engineering, cognitive science and neuroscience. Indeed, the robots can be used as a research tool in two different ways: 1) to use a robot in order to test human cognitive models, implementing algorithms that can simulate the human cognitive processes (Di Nuovo et al., 2013; De La Cruz et al., 2014; Whitaker, Colombo and Rand, 2018; Scassellati, 2003, 2005); 2) to use the robot as a possible partner in scenarios that implies the interaction with a human in order to observe social interactional patterns (Manzi, et al., 2018; Breazel et al., 2016; Moriguchi et al. 2011; Nishio et al., 2018; Sandoval et al., 2016). There are different theoretical approaches in HRI and in robotics; the

¹ For more information on the Geminoid Project: <http://www.geminoid.jp/en/index.html>

most interesting are: Developmental Robotics (Cangelosi and Schlesinger, 2015; Lungarella et al., 2003) and Developmental Cybernetics (Itakura 2008; Itakura, Okanda and Moriguchi, 2008).

Developmental Robotics is an emerging field of research that connects robotics, cognitive science and developmental sciences – in particular developmental psychology and developmental neuroscience (Di Nuovo et al., 2014; Di Nuovo et al., 2017). This field is focused on the implementation of robots that should be more autonomous, adaptable and sociable– the cognitive developmental studies are crucial in this respect – but to achieve this goal it is fundamental to employ models of human development in order to embed these models into robots. Thus, it is important the collaboration between engineers and developmental psychologists in order to design the models mentioned above (Asada et al., 2001; Lungarella et al., 2003). Developmental Robotics represents an innovative approach to the development of HRI: its statement is that robots can learn as children (Cangelosi and Schlesinger, 2015). Roboticians use algorithms, deriving from the Machine Learning field, to build cognitive models of psychological processes (Cangelosi and Riga, 2006; Cangelosi, 2010; Cangelosi et al., 2010). However, these models derive from the research in developmental psychology because it is fundamental to understand the trajectory of development of the psychological processes (i.e., ToM or linguistic development). Since robots should be social partners, Scassellati (1999, 2001, 2002) assumes that they have to possess a ToM. This is only a theoretical assumption because today technical innovation does not permit an implementation of a ToM into robots despite our knowledge about ToM development: an explanation is that ToM ability is a complex process that involves several cognitive and affective components.

Developmental Cybernetics connects Developmental Psychology and robotics, using the human development models in order to identify the most important behaviours that can promote HRI. This is the other side of the coin because, while the Developmental Robotics uses the models to make robots behave socially, Developmental Cybernetics studies which kind of behaviours should be implemented into robots in order to promote HRI. In particular, Developmental Cybernetics studies the development of social behaviour in infants in order to implement specific behaviours so that the robots can be treated as a companion. In the case of interactions between children and robots, we shift in the field of Child-Robot Interaction (often abbreviated as cHRI), which differs from HRI because the partner of the interaction, the child, presents an immature cognitive development (Belpame et al., 2013 a, b). cHRI is crucial for Developmental Cybernetics because of its futuristic hypotheses: in the next decades the robots can be introduced into human societies in different contexts among which the educational ones. In this case, the robots should be attractive for children: to reach this goal,

physical and behavioural characteristics should be more human-like. In 2018 one of the biggest Japanese educational projects introduces 500 humanoid robots (NAO robot, created by Aldebaran Robotics) in the Primary School in order to teach English to Japanese children². Moreover, several research programs use humanoid robots in different educational contexts (Chang et al., 2010; Belapme et al., 2016; Gordon et al., 2016; Kanda et al., 2007), highlighting, in a vygotskian approach, how robot can be use as scaffold. Developmental Cybernetics postulates that to build a social robot is important to study and to develop research knowledge about three main domains connected to the robot: Theory of Body (ToB), Theory of Communication (ToC) and Theory of Mind (ToM). The ToB hypothesises that a robot should move its arms, legs and head in a conventional mode. For instance, Morita and colleagues (2012) test children's and adults' reaction to conventional and unconventional movements of the body of a human and of a humanoid robot, showing that children extend their reaction to the unconventional movements both of human and humanoid robot respect to adults that are more activated when the unconventional movements are made by a humanoid robot. With regard to the domain of Theory of Communication, several studies show that an effective robot is a robot that can communicate in verbal and non-verbal way (Breazel at al., 2005; Brooks and Arkin, 2007; Mavridis, 2015). These researches generally highlight that a robot that can use non-verbal signals (i.e., facial expressions or gestures) to promote the human involvement in the interaction is perceived more as a companion than a robot that not communicate in such ways. For instance, Aaron and Mataric (2015) use a robot that communicate with a worker to achieve a goal, finding that the robot was perceived as a teammate more than a robot without communicative behaviours. The last, but not the least, domain of the Developmental Cybernetics is Theory of Mind: this is a crucial objective of Developmental Cybernetics because it hopes that in the future robots can interact in a way that can be perceived as having a mind. Nevertheless, as above mentioned, the implementation of ToM into robot is more a futuristic dream, while has been demonstrated that humans use their ToM ability to understand robots' behaviours. This a fundamental assumption that connects the different sections of this thesis. In fact, already Piaget (1929) uses the concept of animism suggesting that the human ability to ascribe intentionality to an object is an early infant's disposition. However, when we talk about robots, we refer to an animate object that appears and behaves in a human-like way. Thus, the ToM ability is a very useful psychological construct that can help to better to understand the human's tendency to ascribe mental states to a robot. In Chapter 1 it will be shown as humans, in a

² For more information is possible to access to the article by the following link:
https://rep.repubblica.it/pwa/generale/2018/09/24/news/giappone_robot_insegnano_inglese-207218720/?ref=RHRS-BH-I0-C6-P21-S1.6-T1

life-span perspective, tend to attribute minds to robots. Some research points out, in particular as regards childhood and adolescence, that the ascription of mental states changes with age (Manzi et al., 2017; Kahn et al., 2012). Chapter 2 shows that younger children tend to ascribe to robots more intentions and desires and less epistemic states than older children, in line with the ToM literature (Wellman, 2001). These findings highlight an important point for Developmental Cybernetics, and in general for developmental psychology, because they demonstrate that children perceive a robot as a partner that appear and behave like a human when they interact with it. Additionally, the children's ascription of a mind to a robot is the prerequisite for the establishment of the intersubjectivity. The concept of intersubjectivity captures the way a person understands and relates to another people and implies that exist a bridge between the knowledge of oneself and the one's own knowledge of others (Rochat, Passos-Ferreira and Salem, 2009). In the light of above, this is a crucial theoretical mark for the HRI because, if the intersubjectivity is the assumption of the interpersonal relationship in humans, the presence of this dimension in the human-robot interactions allows to interpret these interactions not only in a mere behavioural way but also in a relational way.

The use of the object in children's development: an overview on autism

The Autistic Spectrum Disorder (ASD) is a syndrome that can be characterized by an intellectual disability (DSM-5, 2013). The main symptoms of the ASD are: impairments in the social interaction (Baron-Cohen, 1997; Frith, 2003); impairments in the verbal and non-verbal communication (Mundy et al., 1987; Happé, 1995); stereotypical and repetitive behaviours, interests and activities (Bodfish et al., 2000; Boyd et al., 2010). Since ASD is a syndrome that affects all the psychological development, social and cognitive deficits are very heterogenous both for the complexity and severity of disease. These symptoms can emerge and change in different moment of development (Frith, 2003; Yirmiya and Charman, 2010). The repetitive behaviours and activities affect also the use of objects: some researchers report that this impairment can be detected already at 12 months of age (Ozonoff et al., 2008; McCleery et al., 2009). Ozonoff and colleagues (2008) found that 12-months-old children tend to use the object in a repetitive way. The use of the object needs to be studied from the sensorimotor development point of view because the object is present since the early stage of the children's development. More recently, several researches show that autistic children present atypical sensorimotor development and sensory perception that predicts the severity of symptoms especially in the area of communication at 24 months of age (Estes et al., 2015; Robertson and Baron-Cohen, 2017).

In the history of psychology, several psychologists studied the role of the object in the human development, such as Piaget, Vygotskji and Moscovici. Within his work, Piaget (1956; 1958; 1977) describes two different types of knowledge. The first type of knowledge origins through physical experience; such experience produces the knowledge of the properties of objects that are used. The second type of knowledge is gained through the logical-mathematical experience, which does not produce knowledge about the objects but about actions and their results. Thus, micro-genetic analysis, which aims to observe the temporal and qualitative aspects of the interactions, is a basic methodological condition for understanding the development of materiality. Despite this embryonic change of course the epistemological approach of Piaget remains anchored to the dualism of subject and reality.

Nevertheless Vygotskji (1962) uses another theoretical perspective: he considered the objects, named artefacts, as a fundamental component of human life. He suggests that humans use both material (i.e., a computer) and psychological (i.e., language) artefacts to interact. Adults use in a better way these artefacts and through their scaffolding 'teach' to children how to appropriately use them. In this respect, the artefacts represent human 'instruments' essential for the communication and interaction.

In these terms, the behaviour and the understanding of the processes of consciousness are closely dependent on the nature of the interaction of human and non-human components of this dialectic dyad. In the history of psychology, some the psychologists abandoned a dyadic approach in favour of a triadic perspective. The key aspect is no longer just the dyadic relationship, but what Moscovici (1976) defines triadic relationship. Moscovici proposes a ternary reading of facts and relations, and in fact replaces the two- term view, subject and object, with a three-term one: individual subject, social subject, and object. In other words, the Ego, the Other and the Object. This aspect assumes a constant exchange between the three elements of the triadic relationship. Such relationship may be conceived as static or dynamic, implying a simple "co-presence" or an "interaction" that can result in changes in thought and behaviour.

However, the theories presented above about the objects are based on a non-dialogical conception of the artefacts. In fact, Linell (2009) considers artefacts as external objects, according to a dialogical theory of the artefacts. The objects serve as anchoring points for intersubjectivity. Moreover, the author suggests that exist an interplay between the human ability of using artefacts and the external objects which possess a wide range of uses for humans. Thus, the objects are used by humans but also can change the humans perspective of the interactional world.

The objects are involved in several psychological mechanisms, such as joint attention and imitation that are largely studied in autism. The joint attention implicates at least the presence of two

partners and of an object that plays the role of the mediator of their interaction (Tomasello, 1995; Mundy and Gomes, 1998; Moore, Dunham and Dunham, 2014). Thus, the object is a protagonist of this human phenomenon, acquiring a crucial role in the interaction. Moreover, the studies on imitation distinguish between body gestures imitation and object actions imitation (Masur & Ritz, 1984; Snow, 1989), showing that the object is involved in the human development as a fundamental ‘non-living partner’ that has a role in a lot of psychological processes.

In the light of above, about children with typical development, the use of the object is a crucial element for the interactions (Rodriguez and Moreno, 2008; Barthélémy-Musso et al., 2013). In fact, Rodriguez and Moreno (2008) hypothesizes that children with typical development use the object in order to interact with adults: the adult has the role to teach to the child different uses of the object which, derive from the human society, Thus, the adult acquires the role of a scaffolder for the conventional use of the object (Moro, 2011, 2014). This approach is particularly interesting because the children and adult create an intersubjective space in which they can interact with each other through an object. Thus, the object is a mediator of the child-adult interaction. Moreover, as already highlighted in the previous paragraphs, the establishment of an intersubjectivity space is the basis of the of human interpersonal relationships.

In the view of the above, it is important to analyse the role of the object also in children with atypical development, in particular in autistic children because they present a distinctive pattern of interaction with the object (i.e., repetitive actions on the object) and are also characterized by social impairments which represent an obstacle for the establishment of interpersonal relationships. In fact, being social interaction impaired in autistic children is consequently impaired the interaction with the “social world of objects”. In the socio-material perspective (Iannaccone, 2015) the object is composed of material features and social components which coexisting the same object. Some autistic children show deficit in the use of the object: alterations in manipulation, observation, understanding and denomination. The object is a significant communicative mediator in social interaction between adults and children (Iannaccone, Savarese and Manzi, 2016). Thus, autistic children which do not present impairment in the use of the object show more social behaviours as pointing (Bernabei, Camaioni and Levi, 1998), imitation (Vanvuchelen et al., 2013) and joint attention (Mundy, 2016). For instance, joint attention is typified by subject-subject-object triangulation in which children alternate their eye gaze between the object and the other person (Trevarthen and Hubley, 1978). In this respect, Chapter 3 and 4 deal with the role of the object as promoter of the child-adult interactions. Despite the identification of deficits in the expression of the most important early precursors for the social interaction, it has been observed that autistic children can use in specific ways the object that promote the intersubjectivity space. In Chapter 4 autistic children from 20 to 24

months of age exhibit specific sensorimotor patterns of use of objects (manipulation and exploration) that tend to involve the other partner – adults – to interact with the objects. Thus, also in the case of autistic children the object is a mediator of the relation with the adult. Moreover, Chapter 4 points out that autistic children that present a more complex and rhythmic patterns of interaction with the object present more social behaviours (i.e., joint attention and imitative actions).

These findings reveal the ability of autistic children to establish an intersubjectivity space, using the object as mediator of interactions with adults despite the evident social impairments that characterize this syndrome.

This Thesis

Chapter 1 is a review of the literature about the role of the Theory of Mind (ToM) in the Human-Robot Interaction (HRI) in a life-span perspective, showing that from the childhood to the adulthood humans can ascribe a mind to a robot, in particular to a humanoid robot. The HRI is analysed in two main domains: 1) mental states and actions; 2) physical human-like features. The first area highlights that a robot which behave like a human and use human-like cognitive processes promotes the attribution of a mind to a robot. Already in infancy some behaviours (i.e., eye-contact and goal directed actions) promote a better children's social involvement during the interaction with a robot. The robot human-likeness is effective in a life-span perspective. Moreover, the implementation of robots' human-like physical features (i.e. eyes, hands, legs etc) is a crucial goal for the promotion of a more complex human-robot interaction. However, it is also important for a robot to not be completely similar to a human since the risk of a perfect human-like appearance is the Uncanny Valley effect (Mori, 1970), in which the excessive similarity of a robot with humans can reduce the interaction. The main hypothesis is that through these technical innovations, concerning physical and behavioural features of a robot, humans construct an intersubjectivity space with a robot. This is possible because the recognition of a mind in a robot is the prerequisite because humans perceived it as social partner.

Chapter 2 is focuses on pre-schoolers' behaviour during the Ultimatum Game when they play with a human and a robot. In particular the study aims at analysing: the mental characteristics ascribed to the robot with respect to the human; children's behaviour at the UG when playing with the human and with the robot as proposers and receivers; children's justifications for their behaviour during the UG. To my knowledge, this is the first study which analyses children's behaviour during the UG, comparing human-human and human-robot interaction. In this respect, several tasks and tests were created *ad hoc*: 1) the Attribution of Mental State Scale (AMS) is a measure of mental states attribution that the child has to perform looking at pictures depicting a character; 2) to assess children's understanding of the first-order false belief, we introduced a new instrument, constituted by eight videos representing the classical story, introducing also the Robovie as a new character - we used a story similar to the classical *Unexpected Transfer* task as the script of the videos. The AMS results show that 5-year-old children recognize the robot as a different entity from the human. In fact, children ascribe mental states also to the robot, but they are different compared to the mental states attribute to the human. Nevertheless, children behaved similarly during the UG when playing with the human and with the robot, confirming a tendency to maximize gain. Additionally, children's

justifications at the UG showed that, independently on the interactive agent and on the role played (Proposer/Receiver), children tend to use ‘outcome’-based justifications to explain their behaviour for all divisions. This is the first qualitative evidence supporting the idea that, at the age considered, children mostly reason in economic/quantitative, homo-oeconomicus-like, terms. The almost total lack of equity and mentalization-based justifications of human unfair divisions further suggests an attempt of children to resolve a social cognitive conflict emerging from the discrepancy between a “socially-expected” fair behaviour and the actual “selfish” behaviour.

Chapter 3 presents an explorative study aimed at observing the quality of interactional patterns in child-adult interaction, using objects as key elements for the construction of intersubjectivity. This qualitative research is based on two theoretical perspectives: 1) Piaget's studies (1952, 1954), according to which children reach the conceptualization skills of objects in the fifth phase of the sensory-motor development; 2) studies that concern the canonical use of the objects, according to which the canonical functions of the objects are acquired as a normative phenomenon during social interactions (Tomasello, 2016), even if the cognitive understanding of these functions is a prerequisite. Several other studies show that canonical functions of the objects are acquired during child-adult interactions (Leontiev, 1981; Costall, 1997; Moro, 2011, 2014; Rodríguez & Moro, 1998; Sinha & Rodríguez, 2008). In this Chapter it will be analysed the manipulation of objects by children with autism spectrum disorder with the aim of showing how objects can be considered as active agents of interpersonal exchange between children and adults. The study adopts a socio-material interpretation, assuming that some interactional patterns, involving the manipulation of objects, can create a space that supports the child-adult relationship. The observations highlight that children present sensorial and realistic play and there are some children's behaviours (i.e., eye-contact) that show that the objects are concrete mediators for the construction of the intersubjective space in the interactions between children and adults. It has been observed in this study that children monitor adults' attention through eye contact or object manipulation. These actions are signs that the object becomes a mediator of mutual attention between the adult and the child: we called this kind of attention, “attention mediated by the object”.

Chapter 4 presents a brief report that investigates the role of the object as a factor that mediates the interaction between children and adults. We observed a group of autistic children in order to analyse if an object can be a promoter of social interactional functions: imitation, joint attention and pointing. The main focus of the study is to analyze in verbal ASD the understanding of social function intrinsic in the object through the use of material features of the object. In particular, the study evaluates the

relationship between the “interaction with/through object” (material features of the object) and three social functions classically impaired in ASD: pointing, imitation and joint attention. We observed a group of ASD children aged between the ending of the sensory-motor stage (24 months) and the beginning of the concrete operational stage (68 months). The group has been split in two sub-groups: group1 is composed of 18 children that act and interact through objects (for examples, balls, cars etc.). Indeed, children manipulate, observe, understand and sometimes give a definition of the object; group2 is composed of 25 children that do not act and interact through and with object. Group 1 shows more social functions (pointing, imitation and joint attention) than group 2 Autistic children which show a more complex use of the material features of the object and act and interact with and through object present more social functions. On the other hand, children which have alteration in the use of the object show fewer social functions. These differences depend on the children’s characteristics. In this study, the role of the object is a crucial element for the creation of the intersubjective space.

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Chapter 2

Theory of Mind and Humanoid Robots From a Lifespan Perspective

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Abstract

This mini-review focuses on some relevant issues concerning the relationship between Theory of Mind and humanoid robots. Humanoid robots are employed in different everyday-life contexts, so it seems relevant to question whether the relationships between human beings and humanoids can be characterized by a mode of interaction typical of the relationships between human beings, i.e., the attribution of mental states. Since Theory of Mind development continuously undergoes changes, from early childhood to late adulthood, a lifespan perspective was adopted. Contributions from the literature were analyzed by organizing them around the partition between ‘mental states and actions’ and ‘human-like features’. Finally, we considered the contribution that studying the human-robot interaction, within the paradigm of Theory of Mind, can give to the understanding of the intersubjective nature of this interaction.

Introduction

This contribution progresses from Turkle's (2004) opinion, which, reflecting on Steven Spielberg's movie, *AI*, exemplifies the most exquisite socio-relational issues of human–robot interaction:

. . .[S]cientists build a humanoid robot, David, who is programmed to love. David expresses this love to a woman who has adopted him as her child. In the discussion that followed the release of the film, emphasis usually fell on the question of whether such a robot could really be developed. People thereby passed over a deeper question. ... That question concerns...[w]hat kinds of people are we becoming as we develop more and more intimate relationships with machines? Today, we are faced with relational artifacts to which people respond in ways that have much in common with the mother in *A.I.* (p. 25).

For hundreds of years, the interest in human–robot interaction has occupied a space in the cultural productions of humankind. Today, we are witnessing a renewed interest in the human creation of a nonhuman alter ego. In particular, researchers are focusing their interest on social interactions with robots. Many scholars believe that a fundamental component of social interaction is the Theory of Mind (ToM; Wimmer & Perner, 1983). ToM is the ability to predict and interpret our own, and others', behavior on the basis of mental states. Herein we offer an overview of work that has focused on the study of human–robot interaction, in the context of ToM. In particular, we review studies investigating the attribution of mental states to robots in a lifespan perspective.

Without the claim of being chronologically exhaustive, we provide some examples of the pervasive interest in artificial partners in the history of humanity. Homer (2003), in the *Iliad* (XVIII, 573–579), told how Hephaestus, the god of fire, who needed help in his forges, built aides, similar to young men, who had hearts, voices, and life. Discussion of the more-or-less human characteristics of intelligent manmade machines has its most famous philosophical roots in the 17th and 18th centuries, in the debate around the works of Descartes and La Mettrie (Gunderson, 1964). Descartes equates animals with machines, but ascribes uniqueness to humans via the term, *cogito* (I think). On the contrary, La Mettrie extends the animal-machine analogy to humans, radicalizing the materialistic and mechanistic perspective.

The mechanical automaton was an attempt to build a human-like artifact, capable of replicating and repeating human activity. In the 13th century, Al-Jazari, an Arabic mechanical engineer, built a programmable device capable of playing sounds autonomously (Nadarajan, 2007). In the 15th

century, Leonardo da Vinci not only theorized on the possible robotic reproduction of an animal, but also advanced a project that attempted to mechanize the human being, with the mechanical knight of 1495 (Rosheim, 2006; Taddei, 2007).

A crucial qualitative leap into the anthropomorphization of machines is to ask whether robots can think, overcoming Cartesian dualism: the philosophical concept that asserts the existence of a separation between *res cogitans* and *res extensa* (i.e., respectively the mind and the body). From a psychological, and more intersubjective³, point of view, and for the purpose of this review, we can rephrase the question as: when will robots be able to make humans believe that they are human? In 1950, Turing published a seminal paper in which he imagined an imitation game with three participants. An interrogator asked questions of the other two participants and, based on the answers, had to guess who was a man and who was a woman. Then, without warning the interrogator, a computer would replace one of the participants. How long would it take to understand that the answers came from a machine, and not from a human being? According to Turing, during the imitation game, it would become increasingly difficult to distinguish the responses of a machine from those of a human (Turing, 1950).

Artistic creativity often anticipates scientific topics on the history of thought. There are many examples in literature and cinema about our subject. Let us remember Shelley (1830/1994), proposing the literary character of Frankenstein, or The Modern Prometheus⁴, destined for a much greater degree of notoriety thanks to the story's many cinematic adaptations. It is also worth mentioning Asimov (1983), who revisited the futuristic concept of a robot by conceiving it as a potential partner for supporting/replacing human activities.

³ The concept of intersubjectivity has various definitions, each of them highlighting different aspects: cognitive, affective, socio-cognitive. The various definitions have in common the idea that the meaning of the tasks and events that the person builds during development is not an operation in solitude but is the result of interaction with real or symbolic partners.

⁴ The story shows the human desire to create an immortal alter ego. The created alter ego turns out to be a monster. Dramatic events lead to the death of the monster's creator and then the monster itself. The monster suicides, explaining the evil deeds it has done while living with the contempt and rejection by humans. The fascination of this story consists in shaping the fears of both partners in this relationship.

Cinema has also represented – now as utopia, now as dystopia – the complexity of the robot’s relationship with humanoids. Fritz Lang’s *Metropolis* (1927) was the first movie to foreshadow the possibility that a robot could substitute for man in the hardest jobs, and that it could begin to interact with man in ways that went beyond any designed intentionality.

The iconic film *Blade Runner* (1982), drawing inspiration from Philip K. Dick’s *Do androids dream of electric sheep?* (1968), highlighted the risk of indistinguishability between

the creator of humanoids and his “children.” Freud (1919/1955) described the characteristics of a particular psychic experience with the experience of the “Perturbant” (*Unheimlich*-unfamiliar vs. *Heimlich*-familiar). Jentsch (1906, 1997) had already described this experience in relation to, for example, puppets and automatons. The latter consist of the uncertainty that a seemingly inanimate being is alive and, in a complementary way, that a living subject has the chance to be inanimate.

This phenomenon reappears in more recent literature as the “Uncanny Valley” experience. Mori (1970) described the sense of repulsion that can accompany interaction with humanoids whose appearance resembles, without being overly superimposed, that of a human (see also Mori, MacDorman, & Kageki, 2012). Another facet of the possible human–robot relationship worth mentioning is the one proposed by Spike Jonze’s *Her* (2013). The protagonist lives a true love story with an almost completely disincarnated artificial intelligence that manifests itself through a very sensual voice. Alongside this experience, the growing presence of anthropomorphic robots in everyday life, in educational, production, and welfare settings, raises several new issues – philosophical, ethical, political, economic, legal, and insurance⁵. While the anxiety about replacing men with robots in production situations, with the associated risk of unemployment and impoverishment, is not new, more recent discussions are about the status of robots, with respect to the new aforementioned issues (Floridi, 2017; Floridi & Sanders, 2004; see also the European Parliament Resolution of 16 February 2017).

In the case of robot-building for social purposes⁶, the extraordinary human capacity to invent and realize tools that integrate and expand the biologically-based abilities of our species (from work tools

⁵ To give just a few examples, think of the use of robots for assistance and companionship to the elderly, the educational and didactic use with children with typical and atypical development, and the execution of various activities in shopping centers, airports, and so forth.

⁶ The military is another area that makes extensive use of robotic engineering (just think of the recent massive use of drones in war). Although the psychological implications are multiple (attribution of responsibility, reliability of information, trust, etc.), we do not consider this field because there is no possibility of attributing mental states to the robot.

to sensory aids to external memory of electronic devices) has been driven in two directions. The first direction – developmental cybernetics (Itakura, 2008; Itakura, Okanda, & Moriguchi, 2008) – consists of creating a human-like system, with cognitive function (simulating psychological processes in the robot) and prosthetic functions (enhancing the function and life-style of persons). The second direction – developmental robotics – consists of the idea that robots can autonomously gain sensorimotor and mental capabilities with growing complexity, starting from intricate evolutionary principles (Cangelosi & Schlesinger, 2015). To date, developmental cybernetics aims to build robots that behave in a human-like way, while developmental robotics aims to build robots that develop in a human-like way. Based on these features, the two approaches are located at different points on a continuum that links interaction and relationship. Developmental cybernetics is closer to the relational dimension; in fact, it studies those human–robot exchanges in which the assumption of some form of subjectivity of the partners is involved. Let us think, for example, about the educational and welfare uses of intelligent machines, in which the dynamics associated with the use of prosthetic tools that improve quality of life are placed on the level of *hic et nunc* (here and now) interaction, without aiming at the construction of a relational story. Conversely, socio-relational dynamics value the level of the relationship (Gross et al., 2012; Tanaka, Cicourel, & Movellan, 2007). Developmental robotics is closer to the interactive dimension; it uses the interaction to study how a robot can develop new abilities, in a child-like fashion. For instance, consider the attempts at robotics modeling of the stages of language acquisition (Morse & Cangelosi, 2017), and the use of mutual imitation between humans and robots to promote the robot’s subsequent recognition of an interactive agent (Boucenna, Cohen, Meltzoff, Gaussier, & Chetouani, 2016).

We are interested in understanding how the attribution of mental states to robots evolves through the lifespan; therefore, we primarily analyze the studies conducted in the field of developmental cybernetics.

Why Robots Could Be Intended as Social Partners

From a psychological point of view, from the earliest moments and throughout one’s entire life, the possibility of establishing social exchanges involves the ability to recognize the other as being “like me” (Meltzoff, 2005; Meltzoff, 2007a, 2007b; Meltzoff, 2013; Meltzoff & Brooks, 2001). Infants can imitate facial movements, such as mouth opening and tongue protrusion (Meltzoff & Moore, 1977, 1983, 1989), and have visual acuity for human faces and stimuli, with characteristics similar to themselves (Johnson, Dziurawiec, Ellis, & Morton, 1991). Proto-conversations with the caregiver

root in these innate imitative mechanisms and, overall, the analysis of traits and characteristics of the relational partner contribute to building the intersubjective dimension underlying so many developmental acquisitions (Meltzoff, 2005; Meltzoff, 2007a, 2007b; Meltzoff, 2013). For this purpose, Trevarthen (1998) spoke of an innate specific human endowment that would guide us to the search for companionship, and put us in the condition of “understanding and using the intentions of other people in conversational talks of intentions, emotions, experiences, and meaning” (p. 16). According to Tronick, Als, Adamson, Wise, and Brazelton (1978), human beings experience the world in intersubjective terms. This trend is related to the tendency of children to first experience the world as if it were animated, and to make a distinction between animate and inanimate only later. This tendency is operationalized by the “still face” paradigm: the motionless face of the caregiver generates in the child a series of emotions from perplexity to anxiety, showing the infant’s expectation to interact with a human partner with an expressive, and therefore animated, face.

A fundamental question, therefore, is: what can the developmental research on human–robot interaction teach us about aspects, features, and cues that a robotic interactive partner must have to be recognized as “like-me?” This question has an epistemological basis. In fact, human–robot interaction represents a “technological gym” that specifies the social cues that must be implemented in a humanoid robot so that children of different ages recognize it and treat it as a social partner.

Below, we analyze contributions from the literature to the lifespan perspective in this regard, by organizing them around “mental states and actions” and “human-like features.” This division arises from the consideration that a representational ToM derives from the infants’ early understanding of the bodily cues of the mental states. In other words, the bodily roots of ToM remain through the lifespan, as the basis of more advanced representational mentalistic skills.

Mental States and Actions

Regarding the first element of the division that we set as the basis of robot attributions of features “like-me,” the research examines aspects of robotic actions that lead participants to believe that the actions imply mental states.

In this sense, a seminal study by Meltzoff (1995) investigated the reenactment of intended acts, performed by human beings versus robot-like devices, in a group of 18-month-old infants. An emerging sense of the person is revealed by the fact that infants did not reenact the action performed by the robot-like device, probably because they did not recognize its intentions and goals.

Itakura, Ishida, et al. (2008) studied this topic further, in children aged 24–35 months, and showed that the children were inclined to imitate goal-directed actions where the goal is not achieved; these failed actions implemented by a robot were imitated only when the robot's action was preceded by eye contact between the robot and an adult present at the scene. When the robot's eye contact with the adult was missing, the child did not mimic the robot's behavior. According to the authors, this evidence shows that it is not human-like morphology, but rather human-like behavior, through eye contact, that plays an important role in inducing children to imitate the goal-directed behavior of a nonhuman agent.

The theme of imitation of goal-directed actions relates to research on mirror neurons⁷, which seem to play an important role in understanding others' actions and, more generally, in social competence. On this basis, Moriguchi, Matsunaka, Itakura, and Hiraki (2012) initially elaborated that the actions are somehow related to perception, and that many human brain areas devoted to the execution of actions also function by observing other human actions, rather than robotic actions. The authors then built on this evidence through a research paradigm verifying whether, and how, actions taken by a human arm or a mechanical arm may somehow interfere with the child's search for an object. A human arm and a mechanical arm sought and found an object in position A. The object was then moved to position B. The child who was asked to look for the object attributed a kind of "retrospective trust" to the human arm, compared to the mechanical arm; in fact, the number of errors committed in the search for the object was higher when the human action preceded the search. The same result had already been obtained in a group of 3-year-olds (Moriguchi, Kanda, Ishiguro, & Itakura, 2010), suggesting that the presence of a mental simulation mechanism would only be activated when the children imitated human actions.

Okumura, Kanakogi, Kanda, Ishiguro, and Itakura (2013a) confirmed this in a paradigm that verified the ability to anticipate the appearance of an object, using the information from a human gaze, rather than a robotic gaze. Through the use of an eye tracker, gaze-following and object anticipation were measured in two groups of 10- and 12-month-old children. Both groups let themselves be guided by

⁷ The mirror neurons are a subset of neurons in the human brain that respond when an individual performs certain actions, and also when the same individual observes others performing the same movements. In other words, actions performed by one person can activate motor pathways in another's brain responsible for performing the same action. Mirror neurons, or mirror mechanism, provide a direct internal experience, and therefore understanding, of another person's act, intention, or emotion. Mirror neurons may also underlie the ability to imitate another's action, and thereby learn, making the mirror mechanism a bridge between individual brains for communication and connection on multiple levels (Rizzolatti, Fogassi, & Gallese 2006).

the human gaze and the robotic gaze; however, only the human gaze had an anticipation effect, and only for the 12-month-old children.

In the context of studies that analyze the importance of the perception of biological motion as the precursor of ToM (Frith & Frith, 1999), Breazeal et al. (2016) considered a group of 3- and 5-year-old children. Note that the ability to use a robotic informant with epistemic aims (name exotic, non-familiar animals for children) is strongly influenced by the nonverbal contingency of the informant (head movements, gaze shifts, arm movements, and facial movements) typical of human face-to-face interactions. From this perspective, Carter and Pelphrey (2006) explored, with functional Magnetic Resonance Imaging (fMRI), neural activations, corresponding to the perception of the movement of four different agents – human, robot, mechanical assembly, and grandfather clock – in 7- to 10-year-old children. The results showed different activations, according to the human-like nature of the perceived biological movement, that is, a motion made by a human or a robot. This brain network also included some components of the mirror neuron system. Replicating the evidence obtained on adults, these findings show that some portions of the neural circuit involved in the embodied simulation are recruited in the perception of the biological movement also enacted by a robot.

We now shift from studies that analyze indirect indicators of the attribution of human-like features to studies that explicitly analyze this attribution. Kahn et al. (2012) interviewed children aged 9, 12, and 15 years, and evaluated the attribution of social, mental, and moral features to robots previously observed in nine different interactive situations with the subject and the experimenter. The authors found an interesting developmental trend: 9- and 12-year-olds perceived the robotic partner as a more mental, social, and partially moral entity than did the 15-year-olds. Therefore, in the construction of robotic partners suitable for participants of preadolescent age, with different purposes (from play to education), it is important to analyze, in detail, what interactive features are strengthened, so that the robot is perceived as the holder of mental, social, and moral characteristics, even by teenagers. Similar results regarding the attribution of mentalistic features to robots, following the observation of goal-directed actions, were obtained using a semi-structured interview of participants aged between 5 and 16 years (Beran, Ramirez-Serrano, Kuzyk, Fior, & Nugent, 2011). The participants tended to attribute behavioral, cognitive, and affective features to robots observed in the execution of a block-stacking task, a construction game in which the robot stacked blocks of wood to form two towers. In carrying out these activities, the robot manifested autonomy through a series of behaviors, such as looking at the child's face, performing accidental actions, and so on. Reminiscent of Piagetian animism, there was also an effect of age such that younger children (under 12 years of age), more

than the older children, believed that robots possess a large number of human attributes (Piaget, 1954).

Chaminade et al. (2010) used behavioral and fMRI methods to explore emotion depiction (anger, joy, and disgust) in gestures acted by human beings and humanoid robots in a sample of young adults. Results showed higher emotion ratings for anger and disgust expressed by the human; no differences were found for joy. Neural evidence suggested less empathy from viewing the humanoid robot: in fact, the activation of the left anterior insula (perception of disgust) and the orbitofrontal cortex (perception of anger) was lower for robot stimuli than for human stimuli. Finally, the higher activation in the occipital and posterior temporal cortices with robot versus human stimuli probably arose from the additional visual processing linked to the perception of a behavior acted by the humanoid robot.

An ingenious way to look directly at the interaction between human and robot is to use economic interactive games. One of the most used interactive games is the Ultimatum Game: one player (responder) receives a monetary offer from another player (proposer), who has to divide the amount. The responder has the option of accepting or rejecting the offer. If the responder accepts the offer, the two participants split the sum of money; however, if the responder rejects the offer, both players receive nothing (Güth, Schmittberger, & Schwarze, 1982). Nishio, Ogawa, Kanakogi, Itakura, and Ishiguro (2012) had young adults play the Ultimatum Game with a robotic partner. Results showed that fairness-oriented behavior increased when “mentalizing stimuli” accompanied cues from the physical appearance of the robotic partner, such as the expression of utterances between experimental sessions (see also Castelli, Massaro, Sanfey, & Marchetti, 2010, for results in a sample of children with a human and a nonhuman partner).

Ultimately, the works presented in this section show that children and adults perceive an experience with an artificial partner as social when the artificial partner can express intentions and goals through behavioral cues that are typical of interactions among humans.

Human-Like Features

With regard to “human-like features,” the research focuses on the configuration of body features being indispensable to humanoid anthropomorphization. It seems that, very soon, human beings will be able to relate to robots according to a principle of similarity to themselves. A first question is

whether biological and psychological characteristics are attributed to robots similarly or differently from other living organisms, and other material entities. Kamewari, Kato, Kanda, Ishiguro, and Hiraki, (2005) showed that 6.5-month-old infants exhibited the ability to attribute agency to human and humanoid-robot motions, but not to a robot without a human-like appearance. A sophisticated teleological representation is assumed in interpreting actions during the early stages of an infant's life, insofar as the agents are human-like. This first result is strengthened by two studies that take into account two human features considered crucial in characterizing one's social nature – eyes and voice.

The first study by Okumura et al. (2013a) showed that the presence of eyes in a robot is crucial for 12-month-old children to have their attention directed by the movement of a robot. In fact, when a robot without eyes was set in motion, this movement was not as informative to the child. The authors interpreted this result by assuming that the presence of eyes was a crucial indicator for the attribution of a mind at this age. The second study by Okumura, Kanakogi, Kanda, Ishiguro, and Itakura (2013b) showed that, for children aged 12 months, the gaze of a robot can be effectively used to learn an object if it is accompanied by a verbalization (not a simple nonverbal sound).

Moving from the preverbal to the verbal age, results obtained by directly questioning the participants about the characteristics of the robots are consistent with the early propensity to attribute human-like characteristics to humanoids. With development, other elements, in addition to the look, become important in deciding whether a partner has human-like characteristics. Katayama, Katayama, Kitazaki, and Itakura (2010) compared humans, robots, animals, and cultural artifacts to study the possible recognition of biological and psychological features in robots by children aged 5 and 6 years, and by adults. While the adults' attributions were quite heterogeneous, both 5- and 6 year-olds attributed a variety of biological but not mentalistic features to robots. Somanader, Saylor, and Levin (2011) asked a sample of 4- and 5-year-olds about the presence of representational, biological and mechanical characteristics in a human being, and in cultural artifacts (i.e., a robot and a TV). They found that the children attributed more representational and biological features to the human being than to the cultural artifacts, and to the robot more than to the TV. They also found that such attributions were more likely to be given to the robot if they did not see that the robot was controlled by a remote. These data reverse the trend found in a previous study, by Saylor, Somanader, Levin, and Kawamura (2010), in which robots and other familiar artifacts, including a TV, were classified as the same thing in terms of biological and representational properties. The authors assumed that the difference between the results of the two studies was due to their efforts to formally anthropomorphize the robots.

Manzi et al. (2017) explored the mentalistic value of faces in anthropomorphic agents compared to human faces through a dichotomous morphing, or gradient, of progressive anthropomorphism. The authors showed that 7- and 9-year-old children ascribed more mental state (e.g., sensory, perceptive, emotive, will, imaginative, and epistemic attributes) to the human face than to a robotic face.

Fiore et al. (2013) explored which elements contributed to creating an impression of the social presence of an agent in a group of late teenagers. To this end, they analyzed the way human beings interpret social cues exhibited by robots, in terms of proxemic behavior (the distance that the robot travels within the human's space). This was investigated by placing the robot and the participant in a hallway-crossing scenario. In this scenario, the authors varied the level of proximity the robot would permit the human in establishing whether to cross paths, and if the robot waited until the participant had passed. The authors also measured the role of the gaze, performed at three levels of direction (congruent with the robot's movement, human-oriented, and variable). The results showed that the robot that waited until the participant passed was evaluated as an agent more socially present than the robot that crossed the path without waiting. Furthermore, gaze did not play a significant role as a social cue in this situation.

Krach et al. (2008) explored human-robot interaction with a group of young adults, using the interactive game the Prisoner's Dilemma and fMRI. In the game, two players must decide whether to cooperate with each other or defect. They may gain a defined sum of points, depending on their own, and their counterpart's decision. A unilateral win is maximized by defection, if the counterpart cooperates, but both players are punished if they defect. Relying on mutual cooperation involves the risk of being deceived. In this study, the game included four different partners, each with an increasing level of anthropomorphization (computer, functional robot, anthropomorphic robot, human). Anthropomorphization was operationalized by following Epley, Waytz, and Cacioppo (2007), who included cues relating explicitly to physical aspects and mental states (elicited agent knowledge, effectiveness motivation). Participants were asked to evaluate the game partner for fun, intelligence, competitiveness, and sympathy. Results showed a linearly increasing attribution of fun and intelligence as the partner appeared more human-like. Interestingly, the anthropomorphic robot and the human were perceived as equally competitive, and more competitive than the computer and the functional robot. Moreover, the authors of the study pointed out that higher levels of human-likeness

were positively correlated with a greater activation of the ToM network, that is, the brain areas⁸ that the literature has shown to be specifically recruited when people interact with a social partner.

Takahashi et al. (2014) focused on the neural bases of human–robot interaction when participants were involved in an economic interactive game (Matching Pennies) with several partners: human, human-like android, mechanical robot, interactive robot, and a computer. The game was played between two players: a participant and an opponent. They had to press a button corresponding to the left or the right side of their bodies. The win situation was reached only when the same side was selected by both participant and opponent. The partners were evaluated concerning two dimensions: mind-holderness (having mental functions) and mind-readerness (being intelligent). As predicted by game theory, the more robotic partners were thought to be mind-readers the more the human opponents changed their play strategies, increasing the level of entropy of exchanges through random choices. fMRI data showed the involvement of different subsets of the social brain, according to the attribution of mind-holderness (dorsal aspect of the temporoparietal junction, medial prefrontal and posterior paracingulate cortices) or mind-readerness (ventral temporoparietal junction and the temporal pole).

Broadbent et al. (2013) studied how the facial characteristics of a robot may influence recognition of the robot's qualities, such as mind, personality, and eeriness, using a sample of young adults involved in a simulated healthcare environment. They employed three robots, respectively showing lack of face, silver face, and human face. The results showed a clear preference for the robot with the human-like face, which was rated as having the most mind and personality, and the lowest eeriness. This specific result relates to the uncanny valley, demonstrating just how subtle the boundary is between a pleasant likeness to the human and a disquieting one.

Similarly, Martini, Gonzalez, and Wiese (2016) studied whether specific degrees of humanness were needed to attribute different typologies of internal states to non–human agents. Interestingly, they found that the threshold “having a mind” must be reached, before being able to ascribe any other kind of internal state. The more the non–human face resembled that of a human, the more this threshold was overcome.

⁸ The ToM network includes the medial prefrontal cortex (mPFC), parts of precuneus and posterior cingulate cortex, the temporoparietal junction (TPJ), the posterior superior temporal sulcus (pSTS) bilaterally; some studies also include the bilateral anterior temporal lobes and areas in the amygdala (Schurz, Radua, Aichhorn, Richlan, & Perner, 2014).

Considering the studies reviewed so far, it is useful to emphasize the great importance given to the face and eyes when considering the physical features capable of representing an agent in anthropomorphic terms. This evidence confirms the great amount of data from ethology, evolutionary psychology, and even studies of aesthetic perception, in support of the great power of the human face in creating a sense of social interaction (Brooks & Meltzoff, 2005; Call & Carpenter, 2001; Emery, 2000; Itakura, Agnetta, Hare, & Tomasello, 1999; Massaro et al., 2012; Moore & Corkum, 1998; Morales, Mundy, & Rojas, 1998; Savazzi et al., 2014; Slaughter & McConnell, 2003; Tomasello, Hare, & Fogleman, 2001; Tomasello, Hare, Lehmann, & Call, 2007).

In conclusion, the information presented in this section shows that interaction with artificial agents is more preferred, and perceived as human-like, when the artificial agent presents aesthetic features that reproduce those of humans, with particular relevance to face and gaze.

Human Beings and Robots: Preliminary Steps Toward Intersubjectivity

The studies reviewed identify features pertaining to mentalizing cues and physical appearance as important bases of the “like me” experience with humanoids. Recent research also suggests that Meltzoff’s (2007a, 2013) “like me” framework can be extended to encompass other dimensions on which human perceivers make “like me” attributions. These dimensions pertain to the nature of the interaction, and other, deeper factors that are just beginning to be explored. A minority of studies delineates an emerging trend of research in this field. These are investigations across the lifespan that consider the role of attitudes and expectations of the human partner, involved in different interactive contexts, in determining preferences and acceptance of the humanoid partner.

Meltzoff, Brooks, Shon, and Rao (2010) explored the hypothesis that 18-month-old infants may use information gained from observing human–robot interactions as evidence about whether the robot is a perceiver. The results showed that the infants attributed mind to the robot, based on the socially-communicative interactions the robot engaged in. This study also demonstrated that the nature of the interaction, and not only the robot’s behavior, mattered.

Tanaka et al. (2007) studied the relationship between 18- to 24-month-old children and a robot, through a long-life immersion technique (45 sessions of approximately 50 min each, spanning 5 months, in the children’s play area). One of the great problems of human–robot interaction is the

duration; long-term study is difficult. Children tire, even though they initially have great interest. The experiment aimed to verify relationship tenure for a time longer than the 10-hr barrier, comparing the employment of a robot able to manifest an entire repertoire of behavior (walking, head- moving, dancing, sitting down, standing up, lying down, hand gesturing, and giggling) to a robot able to manifest only predictable behavior. The relationship improved when the robot was programmed to manifest the entire repertoire of behaviors (27 sessions), worsened when the robot exhibited predictable behavior (15 sessions), and improved again when the robot began to manifest its entire repertoire. The development of socialization strategies correlated positively with frequency of contact with the robot.

Contextualizing the relationship in an educational setting, Movellan, Eckhardt, Virnes, and Rodriguez (2009) showed that interaction between 18- to 24-month-old toddlers and a low-cost sociable robot in an Early Childhood Education Center can significantly enhance word-learning. This evidence is promising, in view of the use of these humanoids with educational and didactic purposes, based on the intersubjective sharing of significant goal-oriented activities. Similarly, Tanaka and Matsuzoe (2012) employed a care-receiving robot to support foreign language learning in 3- to 6-year-old children. These authors showed that the care-receiving role, and not only the teaching role, could be successful in a teaching context. In fact, the condition in which a robot gave wrong answers improved the children's English verb acquisition more than the condition without the robot. Taking into account the relationship between peers, Westlund and Breazeal (2015) introduced a robot, programmed to behave as a peer, to a group of 4- to 6-year-old preschoolers in a storytelling context. The robot was able to lower its linguistic competence in order to match the child's current ability. The evidence showed that a storytelling robot capable of adapting to its partner in terms of language competence, was effective in supporting the oral language development of the child. Robots would seem to have educational skills not only as storytellers, but also as sympathetic listeners. Conti, Di Nuovo, Cirasa, and Di Nuovo (2017) compared a humanoid robot story- teller to a human teacher storyteller in a group of preschoolers. The authors evaluated how the storytellers' social behaviors influenced the children's memorization of the story. Results showed a similar performance in memorizing the details of the story when the storyteller was a robot or a human with an expressive behavior (expression of appropriate emotions with the body and with the voice). The expressive robot was even more efficient than a static inexpressive human storyteller (fixed gaze, motionless body, monotonous voice).

Park, Gelsomini, Lee, and Breazeal (2017) investigated the adaptive capacities of robots as listeners in: giving feedback that informed children about the presence of an active listener, given the abilities

of gazing, leaning forward, nodding, smiling, eye-widening to emulate eyebrow movement, and short utterances. The authors tested two robotic relational styles: a contingent style of the robot capable of reflecting the nonverbal behavior of the child; and a non-contingent style of the robot that emitted random, nonverbal behaviors. Based on children's gaze patterns, the results showed that the contingent robot most relationally engaged the children.

Human-robot interaction research ranges from ToM precursors to social skills of the elderly. Iwamura, Shiomi, Kanda, Ishiguro, and Hagita (2011) focused on the use of a robot by a group of elderly shoppers in a supermarket. They found that an assistive robot that also engaged in non-shopping-oriented conversation was preferred to a robot capable only of functionally oriented conversation. Sabelli, Kanda, and Hagita (2011) introduced a conversational robot into an elderly care setting for 3.5 months, and analyzed its main interactive exchanges with the elderly and the staff using an ethnographic methodology. Three of the six identified trends (basic social interaction, telling robot information, and emotional elements) pertained to the socio-relational/mentalistic dimension.

Again working on the relationship between robots and the elderly in a retirement village, Stafford, MacDonald, Jayawardena, Wegner, and Broadbent (2014) analyzed the attitudes to use mind agency, and attribute mind agency to the robots. The evidence showed that older people preferred to interact with robots to which they attributed less mind agency. These findings were rather counterintuitive because they question the presumed importance of mental state attribution in effective social exchanges. It is likely that the elderly were frightened by the robots because of an overestimation of their cognitive capacities which decreased with actual use.

Gross et al. (2012) presented preliminary results of the implementation of a companion robot for elderly people with Mild Cognitive Impairment (MCI). The evidence emphasized how satisfied the elderly were when interacting with a robot that could support them in executing daily tasks. This work opens up the use of robots in the context of caring for people with neurodegenerative diseases. It also places the importance of assessing the effectiveness of such long-term interventions (weeks or months), and fostering relationships with a truly autonomous robotic partner (hypothetically endowed with a wide behavioral repertoire), as the first point in the agenda for future research.

The studies presented in this section, many of which were conducted in extra-experimental settings, show the importance of a detailed analysis of the contexts in which human-robot interactions take place to fully understand the intersubjective nature of the human-robot interaction.

Conclusions

This review aimed to analyze human–robot interaction from two vantage points: (1) the human attribution of mental states to the robot and (2) the human recognition of the robot as “like-me.” The experience that the robot is “like me” is based mainly on the physical appearance of the robot, and its behavior; however, another aspect emerges that pertains neither to humans, nor to humanoids, but which is a characteristic of their encounters. This aspect is the intersubjective level of the exchange. This dimension contributes some design features of the humanoids, which cannot be conceived as simple artificial instruments for the extension of human abilities. The more a humanoid partner/companion can go beyond a functionally and mechanistically perfect performance, the more it seems “like me.” In other words, an exchange is especially meaningful if it happens with a partner with a human-like capacity to be engaged in somewhat unpredictable, intersubjective exchanges. From our point of view, this unpredictability depends on the subjective nature of the human knowledge and representations of the world. During social exchanges, partners share mental states and representations of the world. The construction of intersubjectivity is based on mutual recognition of the subjective nature of such states and of such representations.

In light of these considerations, this somewhat unpredictable meeting of minds can take different directions, and can be conceptualized in different ways. For example, it can be seen as the optimal level of frustration (Kohut, 1977). All human exchanges with significant partners are characterized by an alternation of gratification and frustration. However, this fact does not compromise human exchanges, provided that the frustration is remediable. A second possible way to conceive the somewhat unpredictable meeting of minds is that of the imperfect contingency (Bigelow, 1998). There is no optimum level of contingent responsiveness in early relationships with caregivers; rather each of us experiences an imperfect contingent responsiveness through parental interactions (i.e., the partners occasionally find the level of relational contingency adequate to the ongoing interaction). This responsiveness influences future exchanges with nonfamily partners. A further possible conceptualization is marked mirroring (Gergely, 2007; Gergely & Watson, 1996), which happens during a child’s affect-regulative interactions. The adult offers the child a reflection of an experience of the world, and of the emotional states of the child itself, and at the same time, the adult informs the child that this reflection is not expressing her/his own feelings. A final interesting conceptualization is offered by the work of Tronick and Beeghly (2011). They stated that interactions consist of a flow of matching and mismatching of meaning, and the reparation of mismatches to

matches. Intersubjective attunement would emerge from the experience of reparation, which in turn would create the experience of connection and shared states.

In the Vygotskijan theoretical framework, the unpredictability and possibility of relational mismatching takes on a particularly interesting form in the Zone of Proximal Development (“the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers”: Vygotsky, 1978, p. 86). In fact, cognitive discrepancy, if salient in intersubjective exchange, can become a powerful engine of learning and development. From this point of view, one of the most intriguing challenges for future humanoids is the possibility that they provide the partner stimuli, inputs, and interpretations that moderately surpass the present partner’s abilities, constructing bridges toward more advanced forms of understanding and capabilities. Looking at the future, our reflections allow us to glimpse the theme of technological singularity. It consists of the invention of a super-artificial intelligence that would result in a sudden “evolutionary” change, able in principle to overcome human intelligence (Eden, Moor, Soraker, & Steinhart, 2012). All this is possible if we consider the intersubjective nature of developmental and educational interactions in which both partners contribute to change and learning. ToM – which has as its core concept the “meeting of minds” – seems to us a theoretical perspective that is particularly well suited to understanding intersubjective interactions.

The end of the Blade Runner movie sums up this possible scenario of potentially open, flexible, and plastic exchanges between human beings and humanoids metaphorically. In fact, it shows as plausible a future of love between Rick Deckard, the replicant hunter, and Rachael, the first replicant without an a priori expiration date. Ultimately, the beauty of uncertainty, more than any other quality, made Rachel special, and therefore very humanlike.

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Chapter 3

It does not matter who you are: fairness in pre-schoolers interacting with human and robotic partners

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Abstract

The relationship between humans and robots is increasingly becoming focus of interest in many fields of research. The studies addressing the various dynamics underpinning the human-robot interaction have, up to date, mainly investigated this relationship analysing adults' behaviour when interacting with different forms of robotic agents. With this study, we present results assessing the human-robot interaction, in which children are the interactive partners. The child-robot interaction was studied – for the first time – observing thirty-one children aged 5 to 6 years playing the Ultimatum Game (UG) with either another child or with a humanoid robot. First, we found that children did recognize the robot as a distinct entity, as assessed through the children's attribution of mentalistic, emotional and physical properties to the interactive agents. Nevertheless, consistently with literature on adults, the results on the UG revealed a very similar behavioural approach when the child played with the other child and with the robot. We finally analysed the children's justifications for their behaviour at the ultimatum game and found that very young children tend to consider “fair” only the divisions that are exactly equal (5-5 divisions) and to justify them either in mere mathematical terms (outcome) or in terms of equity. These results are discussed in terms of Theory of Mind, as well as in light of developmental theories underpinning children's behaviour at the ultimatum game.

Introduction

The introduction of social robots - defined as “autonomous or semi-autonomous robots that interact and communicate with humans by following the behavioural norms expected by the people with whom the robot is intended to interact” (Bartneck & Forlizzi, 2004) - is deeply affecting our society in different fields of the human life. The robots used in industrial processes, for instance, are modifying the job roles and rules [Argote et al., 1983; Kang et al., 2008; Lin et al., 2011; see also European Union, 2017). Prospectively, the introduction of robots in other contexts, such as households, education, care assistance, manufacturing, etc., will also presumably have an increasingly significant effect on human activities and roles. In this perspective, several researches are working towards the implementation of robots in the attempt to make them increasingly similar to the human being [Asada et al., 2001; Di Salvo et al., 2002; Hoffman & Ju, 2014; Robins et al., 2005). The humanoid robots – the ultimate realization of such attempts – are characterized by human-like physical features, behaviours and cognitive processes. The mode and quality of the interaction between humanoid robots and humans will thus possibly change because of the robots’ similarities with humans that call to mind the idea of “they are more like-me” (Meltzoff & Brooks, 2001). The underlying rationale for the implementation of this new generation of robots is to create social partners in everyday life (Kanda et al., 2012), although the other side of the coin that researchers have to deal with in the robot human-likeness is the Uncanny Valley effect (Mori, 1970; Mori et al., 2012). This means that the more a robot has human features and behaves like a human, the more its “eeriness” will induce negative feelings in the interlocutor (Burleigh et al., 2013; Fink, 2012; Gray & Wegner, 2012; MacDorman, 2006; Mori et al., 2012; Sandoval et al., 2016; Scassellati, 2005).

Besides the contexts above mentioned, the implementation of robots is also aimed at aiding different scientific fields, such as anthropology, psychology, ethics, sociology, engineering, informatics, mathematics, physics, etc. (Saygin, 2011; Scassellati, 2003), for example, suggests that the use of the human-like robot could be useful for the study of typical and atypical human social development, allowing to test cognitive, behavioural and development models. In this sense, and from a multidisciplinary perspective, knowledge from developmental psychology is crucial to the implementation of these models since it contributes to the understanding and identification of the precursors underlying human sociality and their ontogenesis. In this respect, Itakura (2008) proposed a new research domain that connects developmental psychology and the study of human-robot interaction. This new investigation field was named Developmental Cybernetics (DC; 2008): it explores the child-robot interactions through the construction of theoretical frameworks that

characterize the design of the robot with the aim to facilitate these interactions (Itakura, 2008; Itakura et al., 2008b). Several studies used the Advanced Telecommunications Research Institute International (ATR) humanoid robot Robovie that can generate human-like behaviours (Ishiguro et al., 2001; Ishiguro et al., 2003). This humanoid robot has been used to test interactions with children in different contexts (Kahn et al., 2012; Kanda et al., 2004). Kanda and colleagues (2012), for example, introduced Robovie to 6th-graders to teach them how to use a Lego Mindstorms. This research showed how Robovie's human-like behaviours contribute to build a human-robot relationship, which goes beyond the more simple human-robot interaction.

Developmental Cybernetics hypothesizes that children can understand the non-human agent through mentalization, and that the construction of social intelligent agents could shed some light on the development processes and mechanisms of the child's mind (2008). In this respect, within the DC approach, Itakura (2008) proposes three abilities, which are critical for making a robot a social agent: Theory of Communication (Itakura, 2012; Itakura, 2013; Nitsch & Glassen, 2015), Theory of Body (Minato et al., 2006; Morita et al., 2012) and Theory of Mind (Itakura, 2008; Itakura et al., 2008a,b). With respect to the Theory of Mind (ToM), it has been proposed that ToM represents an important psychological ability for the study of the human-robot interaction [for a review, see Marchetti et al., 2018). In fact, ToM is essential for the development of social competences, in that it represents the ability to understand one's own and other people's mental states (intentions, emotions, desires, beliefs), and to predict and interpret one's own and others' behaviours on the basis of such meta-representations (Park et al., 2017; Piaget, 1929; White et al., 2009). Several ToM studies show that there are many different behaviours and cognitive processes that are linked to this human skill: imitation, joint attention, pointing, and gaze-following, just to mention a few. (Bandura, 1991; Brooks & Meltzoff, 2002; Camaioni et al., 2004; Charman et al., 2000; Meltzoff, & Gopnik, 1993; Meltzoff & Brooks, 2001).

The researches in the field of child-robot interaction have been increasing in the last decades. Generally, these researches explore what features should be implemented in the robot in order to establish a better interaction between humans and robots. Several studies have been conducted to analyse the effect of different ToM precursors on the interaction between humans and different non-human agents, including humanoid robots [Boucenna et al., 2014; Boucenna et al., 2016; Breazel et al., 2016; Chaminade et al., 2010; Fogassi et al., 2005; Itakura et al., 2008a; Kanngiesser et al., 2015; Meltzoff et al., 2010; Moriguchi et al., 2012; Mutlu et al., 2012; Okanda et al., 2013; Okumura et al., 2013; Rizzolatti et al., 2001; Sloane et al., 2012; Wellman et al., 2001). Generally, the results of

these studies have shown that children tend to attribute mental states to a humanoid robot (Beran et al., 2007; Breazeal et al., 2016; Kahn et al., 2004; Manzi et al., 2017; Moriguchi et al., 2012; Nishio et al., 2012; Park et al., 2017). Already Piaget (1929) suggested that children younger than six-years-old tend to attribute consciousness to objects - namely the capability to feel and perceive - and that children consider “alive” also the things that are inanimate for the adult, *if* these objects serve a function or are used to reach a goal: a phenomenon called animism. In their study, Katayama and colleagues (Katayama et al., 2010) showed that when five and six-years-old children had to attribute biological and psychological proprieties to a human or a robot, children generally discriminated between the two agents, though ascribing some human traits also to the robot. Thus, in line with Torta and colleagues (Torta et al., 2013) idea, when young children interact with artefacts, these acquire the status of relational artefacts: children believe the artefacts – like the robots – to be “alive” and to have an “intention”.

Interaction skills in social contexts are typically studied through use of interactive games deriving from the Game Theory (Camerer, 2013; Villani et al., 2013). One of such games is the Ultimatum Game (Güth & Kocher, 2014; Güth et al., 1982). Used with children, the Ultimatum Game (UG) serves to delineate development in terms of equity and negotiation ability in decision-making, thus focusing on sensitivity to fairness and aversion to inequality (Fehr & Schmidt, 1999). The UG involves interacting with at least another agent, and it is related to the development of ToM in that it activates the ability of mental comprehension, detection and anticipation of the other’s behaviour (Catelli et al., 2014a,b; Castelli et al., 2017; Hoffman & Ju, 2014; Lombardi et al., 2017; Marchetti et al., 2011; Marchetti et al., 2008; Massaro et al., 2017; Srinivasan et al., 2013; Turkle, 2004). In the UG, the subject can play as either the proposer or the receiver. In the *proposer* situation, the subject decides how to allocate resources; in the *receiver* situation, the subject decides whether to accept or refuse a proposed division of goods. The general rule underlying the UG is that the proposer makes an offer, proposing a certain division of goods between him or her and the other player. If the receiver refuses the offer, neither players get anything, whereas if the offer is accepted, both players obtain the proposed division. Using the UG, it is then possible to study interactive behaviour in reciprocal situations from a developmental perspective, comparing behaviour at different ages. Starting from infancy, some studies suggest that infants are responsive to an unequal resource distribution already at 19-month-olds (e.g., Seyama & Nagayama, 2007). Fehr and colleagues (2008) showed that sensitivity to fairness increases from 3 to 8 years of age, and that selfish behaviour decreases from 3-4 years to 5-6 years, although most of 5-6 year olds still tend to not share (78% of the sample).

Additionally, school age children (>7 years) generally behave more fairly when distributing resources and share more than younger children (Fehr et al., 2008;House et al., 2013).

Only few studies have employed the UG paradigm with robots, and – even so – uniquely in interaction with adults. There is in fact not research specifically addressing the relation between robot and children in a UG game. Research on adults generally shows that participants are more likely to behave in a similar fashion when playing the UG with another human or a robotic agent, and this similarity increases the more the robotic agent presents human-like features. Terada and Takeuchi (2017), for example, reported that rejection scores in the ultimatum game were higher in the case of a computer opponent than in the case of a human or robotic opponent, suggesting that people might treat a robot as a reciprocal partner as when playing with another human. Nishio and colleagues (2012) also tested university students while playing the UG with four different artificial agents, which differed in the degree of similarity with humans. In their study, there were four conditions: computer terminal (Computer condition), humanoid robot (Humanoid condition), android robot (Android condition) and human (Human condition). They included a mentalizing stimulus for each agent, which consisted of four shorts interactional sentences pronounced by each agent when meeting the subject, e.g., “how are things going?”. Furthermore, the authors administered a post-experimental questionnaire in order to test how participants perceived the agents (i.e., human likeness, or machine likeness). The authors examined the number of rejections of the agent’s proposals and the number of the agents’ fair and unfair proposals, both measures used as indicators of recognition of the agents as social entities. The results showed that, when the agent looked like a human, the fairness of the proposals and the refusal rate were similar to when interacting with a human, and particularly, when introducing the artificial agent after the interactional sentences. Additionally, Nitsch and Glassen (2015) analysed a group of young adults, who played the UG with a human agent and with a humanoid robot behaving so as to be perceived animated or apathetic. The results showed that the participants that played in the animated robot condition perceived the interactions more positively and human-like than in the apathetic condition. Robins and colleagues (Robins et al., 2005) also studied reciprocity in the human-robot interaction in a sample of young adults through the UG and the Prisoner Dilemma. The results showed that the participants were equally reciprocal with the human and the robot, despite the fact that the robots collaborated more with humans in the Prisoner Dilemma task, indicating that the human-human interactions are nevertheless privileged with respect to the human-robot interactions. Finally, Takagishi and colleagues (2010) examined the effect of different robots’ facial expressions in the UG, and showed that emotional expressions had an effect on the offers made by the participant to the robot compared to offers made to a computer displaying a simple line drawings face.

Altogether, the results from the studies here described suggest - in adult subjects - a proclivity to interact with robotic agents in a very similar fashion as when interacting with other humans.

As far as children's behaviour is concerned, there are no studies so far addressing children's decision making during an interactive and reciprocal social situation with a robot. In the present study, we made an attempt to fill this developmental gap exploring interactive behaviour during the UG when a child played with either another child (human agent) or with a robot (humanoid robot). Our sample children were aged five-to-six years. At this age, children show to have an acquired ToM capability of – at least - first order (Wardle et al., 2002). First order ToM entails a recursive thinking, which implies the meta-representation or the representation of a mental representation, of a low level of complexity, of the kind of: “I think that you think...”. In this respect, we hypothesized that children aged 5-6 years were able to discriminate between *agency* (human agent and humanoid robot) on the basis of mental states attribution. However, we were not able to advance any predictions in terms of differences in children's decision-making strategies when playing with a human and a robot, since no such literature exists specifically referred to the UG.

In this study, the children played both as proposers and as receivers. Additionally, children's performance on the UG task as a function of *agency* was evaluated against several socio-demographic, as well as, cognitive factors. Finally, an analysis of the children's justifications for their behaviour, both when playing as proposers and receivers, was carried out, outlining – for the first time – some response patterns that characterize the rationale underlying these children's game strategy.

Method

Participant

Thirty-three (33) Italian kindergarten children participated in the experiment. Two children were excluded from the study: one failed the First-Order ToM task and the other one failed the Inhibition task (see below). Data analysis was therefore carried out on 31 children (males=18, females=13; mean age = 70.8 months, SD=2.99). The children attended three different schools of Milan and Turin areas. The children's parents received a written explanation of the procedure of the study, the measurement items, and the materials used and gave written consent. Children were neither referred to social services nor reported by teachers for leaning and/or socio-relational difficulties. The study was

approved by the Local Ethic Committee (Università Cattolica del Sacro Cuore, Milan).

General Procedure and measures

The children were tested individually in a quiet room in the kindergartens. Administrations were carried out by a single researcher both in the morning and afternoon during normal activity. The children were assessed in two experimental sessions in different days within two weeks timeframe. The administration of the tasks in two independent sessions was done not to overly tire the children with an excessively long procedure as well as not to significantly disrupt the child's normal school activity.

In the first session, the children were administered the following tests: the First-Order False-Belief task, and two First-Order False-Belief videos, assessing first-order Theory of Mind; two Strange Stories, assessing advanced Theory of Mind; and the Attribution of Mental States scale. In the second session, the children were administered the following tests: the Family Affluence Scale, assessing the socioeconomic status; two executive functions tests, assessing the ability to inhibit behaviour and working memory; further two First-Order False-Belief videos; further two Strange Stories; and the Ultimatum Game, assessing fairness.

The tests were so distributed within sessions to balance the total time required to complete the whole battery, which was of approximately 45-50 minutes. In fact, each session lasted about 25 minutes. Within each session, the administration of the tests was randomized across children.

Socioeconomic status

To assess the children's socio-economic status, we used the Italian translation of the Family Affluence Scale (FAS; Boyce et al., 2006). This test is composed of four items measuring family wealth, and more specifically: 1) family car ownership (score range = 0–2); 2) own bedroom (range = 0–1); number of computers at home (range = 0–3); how many times they went on holiday during the past year (range = 0–3). The FAS total score was obtained adding up the four-item scores (total range = 0-9).

Executive functions (Inhibition and Working Memory)

We tested the children's executive functions using the Inhibition "A Developmental NEuroPSYchological Assessment" subtest (NEPSY II; Korkman et al., 2007), testing the ability to inhibit automatic responses in favour of novel responses and the ability to switch between response types. The child looks at a series of black and white shapes or arrows and names either the shape or direction or an alternate response, depending on the colour of the shape or arrow. In the present study, we used the combined scores of the Inhibition NEPSY-II subtest, which associates accuracy and speed of response.

Furthermore, we used the Backward Digit Span, testing working memory. Concerning the Backward Digit Span, the experimenter presented orally number sequences and the child was required to repeat them in reverse order. The test started with three sequences of two digits, gradually introducing triples of sequences of increasing length, to a maximum possible length of eight digits. The test stopped when the child failed all three sequences at the same length. The score was calculated as follows: children received 1 when they reversed at least two out of three sequences; if successful, the child passed to the next longer series, scoring 0.33 reserving at least one out of three sequences. The decimal scores were then summed to obtain the main score (e.g. $1+0.33 = 1.33$) until the children reached 1 (e.g. $1+0.33+0.33+0.33 = 2$), if necessary.

First-order false belief task

To assess first-order ToM, we used the story of the classical *Unexpected Transfer* task (Wimmer & Perner, 1983). The experimenter told the story using: two dolls (one male and one female), one ball, one box and one basket. The story is about two siblings playing with a ball in a room. One of the children puts the ball in a box and leaves the room. Meanwhile, the other child takes the ball out of the box, puts it in the basket and goes away. Finally, the first character comes back in the room and wants to play with the ball. At the end of the story the experimenter asks the child the following questions: "What is the first place where he will look for a teddy bear?" – referring to the first character (First-Order False Belief question); "Where did the child put the ball before going upstairs?" (control memory question); "Where is the ball really?" (Reality control question).

The answers to the two control questions (memory and reality) were used to filter the children's performance: children who did not pass them scored 0 and their performance on the First-Order False Belief question was not evaluated. If the children passed the control questions, the test question about the false belief scored 1 if correct and 0 if incorrect.

First-order false belief task: Video Stimuli

To assess children on the First-Order False Belief, we introduced – besides the commonly used task as described above – a new instrument, namely eight videos representing the classical story, this time introducing also the Robovie as a new character. More specifically, we used a story similar to the classical *Unexpected Transfer* task (Wimmer & Perner, 1983) as the script of the videos. The videos started presenting two characters (two children, two robots, or a child and a robot) in a room with two different boxes of a different colour (blue and pink) placed in front of them. Subsequently, one of the characters put a teddy bear under one box (the same for all videos) and then left the room. When the other character was alone in the room, he or she moved the teddy bear under the other box and left the room. Finally, the first character returned into the room to take the teddy bear. A voiceover narration described the story in each video.

The videos were recorded with five different actors: two children (C1 and C2) and three Robovies of different colours (White Robovie, WR; Green Robovie, GR; and Red Robovie, RR). Moreover, the five actors could play two different roles: the character who made the transfer (MtT) and the character who underwent the transfer (UtT). We used the WR for the human-robot videos and the other two Robovies (GR and RR) for the robot-robot videos. Thus, we videotaped eight different videos crossing the two children, the three Robovies, and the two roles. We created two different protocols, which were randomly assigned to the children. The first protocol was composed of four videos: 1) C1 playing the MtT role with C2; 2) C1 playing the MtT role with WR; 3) WR playing the MtT with C1; 4) GR playing the MtT with RR. The second protocol was composed of the following four videos: 1) C2 playing the MtT role with C1; 2) C2 playing the MtT role with WR; 3) WR playing the MtT with C2; 4) RR playing the MtT with GR. Within each protocol, the videos were presented randomly. We used the same scoring criteria as that used for the First-Order False Belief task (see above). The videos can be found in Electronic Supplementary Material.

At the end of the story, the experimenter asked to the child the following questions: “What is the first place where she will look for the teddy bear?” (First-Order False Belief question); two control questions (Memory and Reality as described above).

Strange Stories

We assessed the children's advanced ToM using the Strange Stories task (Happé, 1994; Westlund et al., 2017), whose Italian translation had been already used in other studies (Cattaneo et al., 2007; Lillard, 1994). This task evaluates the ability to make inferences about mental states by interpreting non-literal statements. We selected a subgroup of four mentalistic stories involving double bluffs, misunderstandings, white lies, and persuasion. After reading the stories, we asked the children to explain a character's behaviour without a time limit. The experimenter transcribed *ad verbatim* the child's answers. Scoring was based on the general guidelines (Westlund et al., 2017): 0 for incorrect answers, 1 for partially correct answers, and 2 for full and explicit answers. Two raters independently coded 30% of the responses. The inter-rater agreement was substantial (Cronbach's Alpha = .96). Disagreements were resolved through discussion between the raters. Total scores ranged from 0 to 8. The analysis of the children's performance on the strange stories showed a quite poor general performance. In fact, the children scored very low, ranging from 0 to 3 out of a total possible score of 8.

Attribution of States

The Attribution of States is a measure of states attribution that the child has to make looking at pictures depicting a character. The Attribution of States (AoF) is an *ad-hoc* questionnaire that was drawn from the questionnaire described in Martini and colleagues (Martini et al., 2016). This test was aimed at assessing what features the subject (the child) ascribed to the interactive agent (another child or the robot) in mental, emotional and physical terms. In this study, the experimenter first showed to the child two pictures depicting a child and a robot and then asked the child - as a control question - what was depicted in the picture (Reality question): if the child correctly recognized the child and the robot, the test went on; if the child responded incorrectly, the experimenter corrected the child making sure that he or she was fully aware of the agent's identity and then proceeded with the test. No children failed in the Reality question; that is, all of the children correctly recognized the child and the robot at first instance.

The presentation order of the two face pictures was randomized across children. After presenting the picture and asking the Reality question, the experimenter asked the child 25 questions referred to the agent's mental states. The child had to respond "Yes" or "No" to each question. The 25 questions were grouped in five different categories of mental states: Epistemic, Emotional, Desires and Intentions, Imaginative, and Perceptive. The total score was the sum of the "Yes" answers (score range = 0-25); the five partial scores were the sum of the "Yes" answer to each category (score range

= 0-5).

Ultimatum Game

A standard version of the Ultimatum Game (UG; Güth et al., 1982) was used to evaluate fairness. During the game, the child (playing as proponent) could decide how to distribute 10 stickers between him or her and a passive player, represented by a graphic representation of either a child – human agent (e.g., Castelli et al., 2010) or a robot. The graphic representation of the other child corresponded to a male figure when the child was a boy, whereas it represented a female when the child was a girl. The stickers depicted known animals by the children (e.g., dogs, cats, tigers, lions, birds, fishes, etc.). The minimum amount of stickers that could be offered during the game was 1, and the maximum amount was 9. After playing the UG, the child was actually given a final amount of stickers

During the UG, the children played one round as proposer and five rounds as responder, for a total of six rounds. Playing as proposer, the child could decide how to divide the stickers with the other child or the robot (graphic representation) and, playing as responder, the child could decide whether to accept or refuse the proposed division. In case of acceptance, both players received the respective proposed amounts; in case of refusal, neither player gained anything.

When playing as responder, each round (5 in total) corresponded to a specific type of proposal, ranging from a division of 5-5 (fair) to a division of 1-9 (highly unfair). The rounds were randomized across children. For each round, the child could accept or refuse the offered amount, receiving a score 1 in case of acceptance and 0 when refusing the offer. The total amount accepted was also calculated (range = 0-15) when the child played as receiver, which corresponded to the total gain for each child. Similarly, when playing as proposer, the total amount proposed was also calculated for each child (range= 0-9).

UG procedure

Before starting the game, the experimenter explained the game rules presenting four different examples in a graphic format: 1) an adult playing as proposer with a child, who accepted the offer; 2) an adult playing as proposer with a child, who refused the offer; 3) a robot playing as proposer with a child, who accepted the offer; 4) a robot playing as proposer with a child, who refused the offer.

During the game, the researcher played “the other child’s/robot’s” role, proposing, accepting, or refusing offers. The children’s performance at the Ultimatum Game was evaluated in a single session lasting approximately 10 minutes in total.

At the end of the game, the children were asked the reasons that they placed a certain offer (proposer) or accepted/refused a certain proposal (receiver). The children’s answers were classified according to three criteria: 1) outcome – the justification refers uniquely to the *amount offered or received* without commenting on or referring to the other player in mental terms (e.g., “because I like that he does not have anything and I have them all”; “because I wanted to win”); 2) equity – the justification includes terms that refer explicitly to the *construct* of equity, independently of whether the amount offered or received was equal or unequal (e.g., “because in this way we are even”; “because it was nicer to give him three and I like to share them”); 3) mentalistic – the justification includes terms that *refer to the other player in mental terms* (e.g., “because he would like me to receive more”; “he believed that I would win”)⁹.

Results and Discussion

All of the continuous variables were normally distributed with skewness between -1 and 1.

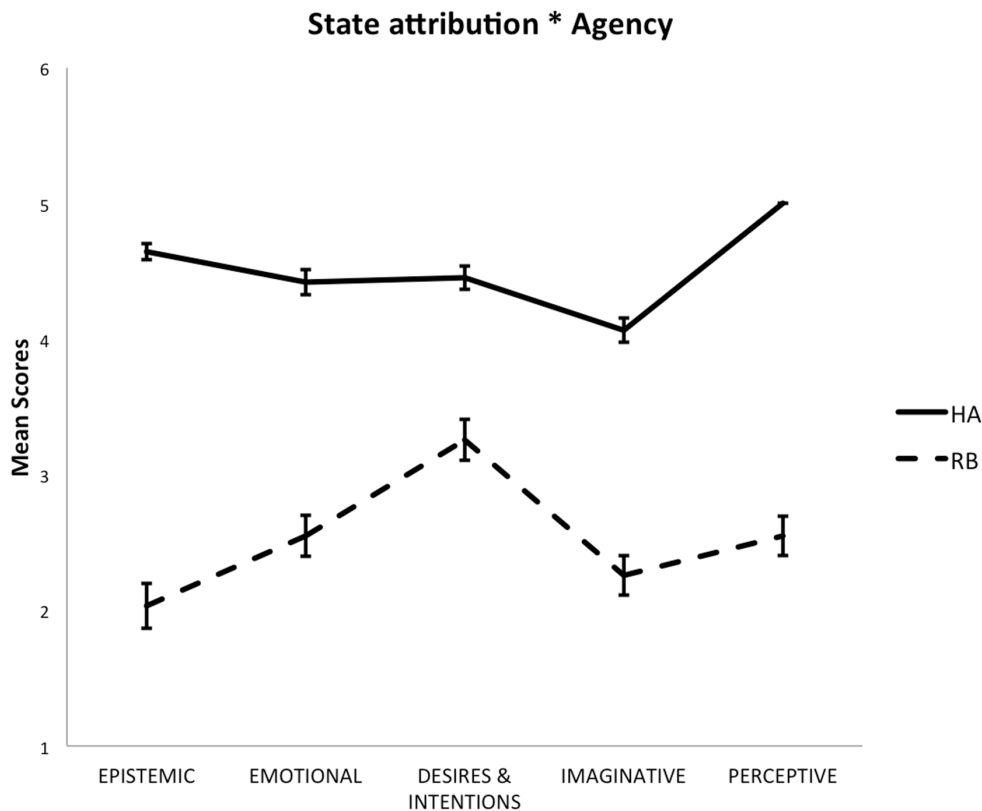
Attribution of States Scale

With this analysis, we compared the attribution of states - as described in the methods session - to the human agent (the other child) and to the robot. The inspection of the boxplots revealed a tendency towards maximum scores (5) in the case of state attribution to the human agent - particularly with respect to the perceptive state, where we observed a ceiling effect - and a normal distribution in the case of states attribution to the robot. A repeated measures general linear model (GLM) was carried out with five levels of *state* (epistemic, emotional, desires and intentions, imaginative, perceptive), and two levels of *agency* (human vs. robot) as the within groups factors. The results showed a main effect of *state* ($F_{4,120}=5.94$, $p<.0001$, $partial-\eta^2=.17$, $\delta=.98$), a main effect of *agency* (HA>RB; $F_{1,30}=53.82$, $p<.0001$, $partial-\eta^2=.64$, $\delta=.1$) and a significant interaction *state*agency* ($F_{4,120}=7.90$, $p<.0001$, $partial-\eta^2=.21$, $\delta=.1$). Post hoc analyses (Bonferroni corrected) showed that the states that scored higher were desires and intentions – which scored significantly higher than both epistemic

⁹ Ad verbatim translation from Italian.

($M_{diff}=.69, p<.01$) and imaginative ($M_{diff}=.52, p<.05$) – and perceptive state, that scored significantly higher than imaginative state ($M_{diff}=.61, p<.01$). Additionally, the analyses showed that the interaction effect stemmed primarily from differences between *states* within *agency* (HA, RB). More specifically, with respect to states attribution to HA, the epistemic state scored higher than imaginative state ($M_{diff}=.58, p<.01$); whereas the perceptive state scored higher than all the other states ($p<.05$) except for the epistemic state, which just failed to reach significance ($M_{diff}=.36, p=.055$). With respect to state attribution to RB, the results showed that desires and intentions received higher scores compared to the epistemic and imaginative states ($M_{diff}=1.23, M_{diff}=1.00$, respectively; $p<.001$). These results are summarized in Figure 1.

Figure 1: Mean scores obtained by the children during the attribution of states (epistemic, emotional, desires and intentions, imaginative, and perceptive) to the human agent (HA) and to the robot (RB). The bars represent the Standard Error of the mean.



The results on the attribution of states to HA and RB revealed that children clearly attributed different states on the basis of agency, with HA receiving higher scores on all states attribution compared to RB. This shows that children had a correct perception that the other child had epistemic and emotional

states, intentions and desires, an imagination and perceptive properties, which are different from that of a robot, therefore considering this latter as a distinct entity.

Within agency, children tended to ascribe poor imagination to both the child and the robot. This is in line with evidence showing that young children's imagination abilities mature gradually (Harris, 2000; Harris & Leivers, 2000; Lillard, 1994; Lillard, 2013). Interestingly, the differences observed within the attribution of states to the robot indicate that children tended to ascribe desires and intentions also to the robot, although to a significantly lesser extent than to the human agent. Desires and intentions attribution to the RB, in fact, received greater scores than all the other states, and substantially more than the epistemic and imaginative states. During video watching (see methods), the children observed the RB in action, and this may have led the children believe the robot as having intentions. In fact, also from a neurophysiological perspective, movement and intentions go hand in hand [see, for example, Gray & Wegnaer, 2012; Premack & Woodruff, 1978) as also suggested by psychophysiological evidence with children (Cavallini et al., 2013). All the same, in the present study, while attributing intentions to the robot, the children ascribed to the robot a low ability to think, understand, and decide (epistemic attribution). These results, apparently in contrast, are on the other hand much in line with the idea of animism introduced above, and namely with young children's tendency to attribute a living soul to plants, inanimate objects, and natural phenomena, while being aware that these entities are non-living. The fact that this idea applies to objects only *if* these objects serve a function or are used to reach a goal (see Katayama et al., 2010; Perner & wimmer, 1985; Turkle, 2004], further supports the movement and intention interpretation just described (Chaminade et al., 2010; Sandoval et al., 2016).

Ultimatum Game

The main aim of the present study was to assess whether the child behaves differently when acting with a human agent or with a robot during an interactive situation. We therefore had the child playing the UG with either another child or with the robot, as both proposer and receiver.

Proposer

A t-test comparing the total amount offered to the other child or to the robot when the participant played as proposer showed no significant difference in the total amount offered (HA: $M=3.71$, $SE=.31$; RB: $M=3.55$, $SE=.35$; $p>.05$). Additionally, a high internal consistency (Cronbach $\alpha =.85$)

was observed between each individual child's behaviour when playing with the human agent or the robot. Table 1 reports the children's proposed divisions to HA and RB.

Table 1: Statistics of children's offers when playing as PROPOSERS; ns = not significant; na = not applicable.

	HA – RB	HA – RB	HA vs. RB
Proposed Division	N	%	Sign (<i>p</i>)*
1-9	0 – 0	0 – 0	na
2-8	0 – 0	0 – 0	na
3-7	0 – 1	0 – 3	na
4-6	5 – 5	16 – 16	ns
5-5	7 – 4	23 – 13	ns
6-4	9 – 7	29 – 23	ns
7-3	3 – 5	10 – 16	ns
8-2	2 – 3	7 – 10	ns
9-1	5 – 6	16 – 19	ns
tot	31 – 31	100 – 100	

**Wilcoxon rank test*

These results are in line with the literature [e.g., 28] showing that pre-schoolers tend to make offers that favour their own gain, although the frequency of children that made offers towards fairness (i.e., ranging between 4-6 and 6-4) was quite substantial (68% towards HA; 55% towards RB). Additionally, these results extend previous findings showing that five-year-old children's behaviour and game strategy is consistent independently of whether the child plays with another child or with a robot, in line with the large body of existing literature on adults, as fully introduced above.

Receiver

Within this analysis, we summed up all acceptances when the child played as receiver, therefore calculating the total amount gained by each child. A t-test comparing the total acceptances from the other child and the robot showed no differences in the total amount accepted as a function of *agency* ($t=.75$, $p>.05$), indicating that the children accepted similar amounts when playing with HA ($M=10.97$, $SE=.77$) and with RB ($M=10.45$, $SE=.95$). This result is congruent with the data above described, showing children's tendency to adopt a similar game strategy when playing with the other child or with the robot.

Specifically comparing the children's acceptances of each proposed division from HA and RB, our results confirmed no differences in the frequency of acceptances as a function of agency within division (for statistics, see Table 2). Additionally, comparing the frequency of acceptances between successive divisions for both HA and RB, the Wilcoxon test showed not significant differences for the child (i.e., 5-5 vs. 6-4; 6-4 vs. 7-3; etc.; $p > .05$), whereas we observed significant differences for the robot. More specifically, acceptances of the 6-4 division were significantly lower than acceptances of the 5-5 division (71% vs. 90%, $p < .01$), as well as acceptances of the 7-3 compared to the 6-4 divisions (52% vs. 71%, $p < .01$). This latter result shows a significant, although minor, tendency of children to accept slight unfair offers more from another child than from the robot.

Table 2: Comparison of refusals and acceptances of proposed divisions during the UG when the child played as receiver with another child (HA) and with the robot (RB) (N=31). *P-values* were non-significant (ns) at a value of .05.

		HA	RB	<i>HA vs RB</i>
Division		N (%)	N (%)	Sign (<i>p</i>)*
5-5	Refuse	3 (10)	3 (10)	ns
	Accept	28 (90)	28 (90)	
6-4	Refuse	7 (23)	9 (29)	ns
	Accept	24 (77)	22 (71)	
7-3	Refuse	12 (39)	15 (48)	ns
	Accept	19 (61)	16 (52)	
8-2	Refuse	16 (52)	13 (42)	ns
	Accept	15 (48)	18 (58)	
9-1	Refuse	14 (45)	15 (48)	ns
	Accept	17 (55)	16 (52)	

*McNemar's Test

Correlations

Pearson's correlations were carried out between the total scores at the ultimatum game when the child played with the other child and the robot, as both proposer and receiver. The results showed, as expected, a substantial correlation between the total amount proposed to the other child and the robot ($r^2 = .56$, $p < .01$), as well as a strong correlation between the total amount accepted by the other child and the robot ($r^2 = .49$, $p < .01$). Additionally, the scores obtained at the UG were further correlated with demographic, cognitive, and socio-economic variables: age (months); the child's gender; working memory scores; the ability to inhibit behaviour scores; the intentionality test scores; and the Family

Affluence Scale scores. These correlations are summarized in Table 3. In general, no significant correlations were observed between the scores obtained at the UG and any of these variables ($p > .05$).

Table 3: Correlation analysis between the total scores at the Ultimatum Game when the child played as proposer with a robot (1) and the child (2) and when the child played as receiver with the robot (3) and the child (4). These scores at the UG were correlated with demographic, cognitive, and socio-economic variables: Age (months); child's Gender; working memory (WM) scores; ability to inhibit behaviour (INHI) scores; Intentionality Test scores (IT); and Family Affluence Scale (FAS) scores.

Pearson Correlations

		1	2	3	4	Age	Gender	WM	INHI	IT	FAS
1)	Total Offer to the Child	1	,746**	0,298	0,179	0,218	-0,085	0,186	0,01	0,146	0,213
2)	Total Offer to the Robot		1	0,191	-0,015	0,224	-0,004	0,202	0,024	0,233	0,237
3)	Total Acceptance from the Child			1	,700**	0,069	0,285	0,151	0,293	0,354	0,165
4)	Total Acceptance from the Robot				1	0,047	0,329	0,251	-0,1	0,255	0,195

** Correlation is significant at the 0.01 level (2-tailed).

Analysis of the children's justifications at the UG

After the child played the UG in both the proposer and receiver roles, the experimenter asked him or her to explain the reasons for his or her division. The children's answers were classified as "outcome", "equity", or "mentalistic" (for details, see methods). Two independent judges evaluated the children's justifications.

Proposer

The inter-rater reliability scores were substantial both when assessing the child's justifications when playing with the other child (Cronbach's Alpha = .88) and when playing with the robot (Cronbach's Alpha = .91).

Analysing the frequencies of children who gave a specific justification to their behaviour for each division when making an offer, the results showed an even distribution of justification type (amount, equity) when the children offered a precise fair amount (division 5-5), whereas a skewed distribution of justification type toward "amount" when the children started placing offers that privileged their

own gain. This was independent of whether the child played with the HA or the RB. A summary of the frequency distribution of justification types for each proposed division is presented in Table 4A.

Receiver

The inter-rater reliability scores were calculated for each proposed division (5-5; 6-4; 7-3; 8-2; 9-1). The results showed substantial agreements both when assessing the child's acceptance/refusals justifications interacting with the other child (mean Cronbach's Alpha = .83; min=.82, max=.84) and with the robot (mean Cronbach's Alpha = .83; min=.80, max=.84).

With this analysis, we compared the frequency of children that provided a justification when accepting or refusing each proposed division. Justification types were different when the child received a 5-5 or a 6-4 division, independently of *agency* (HA, RB). When receiving a 5-5 division, the justifications were either based on "outcome" (HA: N=13; RB: N=14) or on "equity" (HA: N=18; RB: N =16); only one child presented a mentalization-based justification when interacting with the robot. When faced with a 6-4 division, the majority of children (HA: N=26; RB: N =28) presented a justification for their acceptance or refusal based on "outcome"; five children presented a justification based on "equity" and none based on "mentalization" when interacting with the other child; only one child presented a justification based on "equity" and two children a justification based on "mentalization" when interacting with the robot. A summary of the frequency distribution and statistics of acceptances and refusals of each proposed division and type of justification is presented in Table 4B. In general, these results suggest that, when children received a division proposal skewing towards unfairness, the equity and mentalization-based justifications decreased substantially ($\chi^2_{(4)}=16.47, p<.001$), in favour of the outcome-based justification.

The analysis of the children's justification for their behaviour - both when playing as proponents and when playing as receivers - indicates that children tend to regard fair (and hyperfair) divisions either in terms of outcome or in terms of equity-based reasoning, with an approximately equal split. When the division starts skewing, even slightly (i.e., 6-4 division), towards unfairness, the types of justifications offered remarkably bias towards an outcome-based reasoning. It is noteworthy observing that mentalistic-based justifications were very poor, if not even inexistent, in all proposed scenarios. This general behaviour was observed both when the child played with the other child and with the robot, indicating no differences in the type of reasoning underlying specific choices as a function of agency.

On the whole, the results on the UG suggest that children aged five years behave quite fairly, though showing a tendency towards favouring their own gain placing and accepting unfair – and even *very* unfair – divisions, in line with current literature describing pre-schoolers' behaviour during the UG (see, for example, Lombardi et al., 2017). Lack of behavioural differences as a function of agency (HA vs. RB) further appears to indicate that the children at this age tend to disregard to other's mind when making choices, following a very consistent strategy throughout the game on the basis of other criteria (e.g., tendency to maximise gains) or personal traits (e.g., disposition to fairness). This is particularly true if considering the fact that the robot was indeed considered an entity different from the human agent (the child), so as observed from the analysis of the states attribution described above. This idea of a much ego-centred behaviour is further supported by the analysis of the children's justifications for their decisions when placing specific offers (proposers) and when accepting or refusing certain offers (receivers). In fact, analysing the frequencies of children who gave a specific justification for their behaviour, the results showed an even distribution of justification type (amount, equity) when the children offered or accepted a fair amount both to/from another child and to/from the robot; whereas we observed a remarkably skewed outcome-based justification when the children offered or accepted/refused unfair divisions. These latter results are further discussed below.

General Discussion

This study investigated 5 year-olds' behaviour at the ultimatum game. The aim of this study was to compare young children's game strategy when they played with another child (human agent) and with a robot. The results showed that children's game strategy was very similar when playing with the other child and with the robot, independently of the role played (proposer or receiver). The children were quite conservative both when offering and accepting proposals, that is, the children generally tended to offer and to accept fair divisions (5-5), although almost half of children proposed and accepted also unfair divisions, ranging from 6-4 to 9-1. These results are in line with the developmental literature on UG. For example, Benenson and colleagues (2007) observed that children aged 4 years donated less than 6 and 9-years-old, showing that sensitivity to fairness increases with age. Furthermore, a recent research by Lombardi and colleagues (Lombardi et al., 2017) showed that, at 6 years, children displayed a more selfish behaviour than children aged 8 and 10 years, highlighting that younger children tend to maximize their gain accepting also unfair offers.

Importantly for the present purpose, no significant differences were observed between offers and

acceptances made to or received from the other child or the robot. In this respect, children's behaviour observed in this study when interacting with the robot is comparable to the adults' behaviour reported in several studies. Terada and Takeuchi (2017) for example, showed that, when playing the UG, adult participants took approximately the same time to decide how to distribute goods between a human and a robot. In the study by Kahn and colleagues Kahn et al., (2012), the frequency of acceptances and refusals became closer to that toward a human when the robot had more human-like features. Similar results were also found by Rosenthal-von der Pütten and Krämer (2014). On the whole, these results suggest that, when bargaining, the other player is regarded independently of agency: the other player's mind appears to be a reflection of our own mind and strategic thinking, whether or not the other has a mind at all, such as in the case of a robot.

With respect to the acceptance of offers made when the child played as receiver in the present study, although behaviour was comparable when the child played with another child or with the robot, it is worth noting that the results showed a significant, although minor, tendency of children to accept slight unfair offers more from another child than from the robot. In this respect, one may suggest that children's expectancy from a robot is to be a totally fair player – since it does not have a mind of its own that can work strategically. In this light, divergence from this initial expectation is less accepted compared to situations in which children play with a human peer. In this latter case, in fact, the other player (the human) - having a mind - is supposed to be able to apply a game strategy and, eventually, to be also unfair. Alternatively, but not mutually exclusive, one may suggest that the child believes to have a distinctive status compared to the robot that, as assessed through the test of attribution of states, is perceived as a different entity with respect to a child at all levels: epistemic, emotional, imaginative, and physical. Also in this light, unfair offers would be less accepted when made by a robot than by a peer.

Finally, with respect to the results from the analysis of the children's justifications at the UG, it is interesting to observe that the reasons provided by the children for their behavior, both when playing as proposers and responders, suggest that children aged 5 years tend to consider fair only a division that is exactly fair (5-5). A slight skewed division towards unfairness (i.e., 6-4) already falls within the range of categorization that characterizes very unfair proposals, regardless of whether the proposals are made or received. Additionally, it is noteworthy to observe that fair or slightly hyperfair divisions are typically justified in either outcome or equity terms, whereas unfair offers are mostly justified in terms of quantity. Mentalization-based justifications are poorly made for all divisions, although – in these cases – it is curious to observe that, when playing as proposer, mentalization–

based justifications are uniquely confined to the most fair divisions (4-5; 5-5; 6-4). In general, these observations may suggest that children, particularly in the case of unfair offers, tend to not use mentalization-based explanations in order to reduce the distress stemming from the discrepancy between a “socially-expected” equal behaviour and the actual “selfish” behaviour. This interpretation can be further extended to the outcome-based justifications predominantly used to explain unfair offers that, in a certain sense, may serve to resolve a social cognitive conflict [e.g., 3], ultimately reducing the distress caused by the experimenter’s explicit enquiry.

Concluding remarks and limitations of the study

This study showed for the first time that young children's fairness is not affected by whether the child plays with another child or with a robot. In particular, it appears that children's decisions during social interactions are self-centred and poorly oriented towards the other's mind. Future studies could address the same issue focussing on different ages so to highlight the development of behavior in late childhood, when higher mentalistic abilities are maturing and eventually acquired. Additionally, we showed that the analysis of the justifications of children's behavior may be enlightening with respect to the child's actual psychological understanding of constructs, such as that of fairness.

It is important to stress that the present results, and in particular those referring to the behavioural differences here reported when the child played as receiver with the other child and with the robot, need to be confirmed with a more ample sample. Confirmation of these results could highlight a distinctive attitude towards a non-human interactive partner that emerges quite early in childhood and that may change during adulthood.

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Chapter 4

Object Use in children with autism: Building with Blocks from a Piagetian Perspective

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Abstract

Aim: This study focused on the manipulation of objects by children with suspected autism spectrum disorder. The aim was to demonstrate how objects can be seen as active agents of interpersonal exchange in face-to-face interactions.

Participants: Three children with suspected autism spectrum disorder (aged 18, 20, and 24 months) were selected as representative of the sensorimotor stage of development.

Methods: Starting from Piaget's classical approach to the sensorimotor and symbolic developmental stages, the study moved toward a socio-material interpretation in which some patterns of interaction involving object manipulation seem to create a space that supports adult-child communication. In videotaped observations of verbal and non-verbal signs during an (organized) free play session, each child manipulated seven small blocks of colored plastic in the presence of an adult. The observations were informed by a checklist of 14 items, including eye contact and building a tower of toy blocks from section B of the CHAT (*CHecklist for Autism in Toddlers*) instrument.

results: Based on a broad Piagetian perspective and recent work in the field of socio-materiality, key observations included the following: (1) sensorimotor and realistic play was observed in all three children; (2) there were some intriguing indications that objects serve as concrete mediators in the intersubjective space between adult and child; (3) some of the children's attention patterns were visibly mediated by the object.

Discussion and conclusion: All three children exhibited a particular sequence of actions. First, they manipulated the blocks through active experimentation; second, there was an apparent pause, during which, the children were in fact examining the blocks to determine how best to continue the interaction; and finally, the children monitored adult attention by means of eye contact or by restarting manipulation of the blocks. As this last step in the sequence indicated that the object became a mediator of reciprocal attention, this interpersonal process was labeled "attention mediated by object."

Introduction

According to Piaget (1928, 1952, 1954), children with autism achieve object conceptualization skills by the fifth stage of sensorimotor development. As several studies advise caution in using the *stage* concept to describe typical and atypical psychological development, it seems useful to characterize these psychological processes in terms of specific activities that the child can plan and implement when acting on their physical and social environment. For example, as a predictive index, the number and type of different actions produced by children with autism during a recreational activity may not always follow the same stages as in typical development, and this can also be correlated with the severity of autistic functioning (McDuffie et al., 2015). In fact, while imitation difficulties may reflect a possible delay in psychological development, not all pre-scholars with autism have problems with imitation or symbolic play (Vanvuchelen et al., 2011). Within the broad line of research that raises questions concerning object canonicity, we identified some interesting elements related to the socio-material function of mediation during communication.

It is known that canonical functions of objects are introduced by other people present in the child's world (Leontiev, 1981; Costall, 1997; Rodríguez and Moro, 2008; Barthélémy-Musso et al., 2013). Indeed, Sinha (2009) suggests that the canonical functions of the object are acquired as a normative phenomenon during social interactions, although cognitive understanding of that status is a prerequisite. Additionally, Sinha (2015) (p. 12) points out that “the materiality of meaning and meaningfulness of materiality is central to approaches in cognitive science emphasizing the importance of objects in extended cognitive embodiment.” In particular, there is evidence that canonical functions are acquired during child–adult interactions (Rodríguez and Moro, 1998; Sinha and Rodríguez, 2008; Moro, 2011, 2014). Several studies have reported how, under certain conditions (for example, impaired interpersonal relations or attentional focus), objects become mediators of social interaction (Williams et al., 1999; Dimitrova, 2014; Moro, 2014). Cárdenas et al. (2014) highlighted the importance of the reciprocal nature of these interactions by showing how they emerge from communicative and triadic contexts (adult–child–object). The crucial role of the adult in the acquisition of object use is observable from early infancy (Moreno-Núñez et al., 2017). Moreover, during child–object–adult interaction, the child's visual attention is more focused when interacting with an experienced caregiver than with an unfamiliar adult (Miller et al., 2009; Miller and Gros-Louis, 2013). Miller and Gros-Louis (2017) also showed that the child's attention is influenced by partner social style. Tomasello et al. (1993) and Tomasello (2016) highlighted different kinds of learning, such as imitative, instructed, and collaborative. For instance, imitation is important for

learning that involves others and objects, as it facilitates understanding of the normative expectations of a given cultural group (Tomasello, 2016). Sinha (2009) suggested that children apprehend canonical functions primarily by cognitive means, thereby accessing the normative identity of the cultural group. Bruckner and Yoder (2007) reported that, even among children with autism, object use can be linked to emergent functions in the preoperational stage, such as imitation and attention to the other person.

Most of the existing research suggests that imitation is impaired in children with autism (Charman and Baron-Cohen, 1994; Rogers, 1999; Rogers et al., 2003; Williams et al., 2004). Indeed, Smith and Bryson (2007) noted that children with autism exhibit difficulty in imitating any unconventional use of objects but are able to imitate canonical object use. By imitating this canonical use, children with autism access part of the cultural group's heritage. With respect to manipulative play activities, Kanner (1943) was among the first to note that, despite differences and limitations, children with autism exhibit a number of functions related to the use of canonical and non-canonical objects. Trevarthen and Hubley (1978) described the dynamics informing subject–subject–object triangulation (the theory of “secondary intersubjective tuning”). Typical children alternate their eye gaze between the object being viewed and the other person, so engendering joint attention. However, in atypical development, and especially for those on the autistic spectrum, an abnormality has been observed in the development of behaviors related to joint attention. Palacios and Rodríguez (2015) showed that in typical children aged 9–15 months, the symbolic use of an object develops within a triadic context. Ungerer and Sigman (1981) assessed the use of everyday objects in a group of children with autism ranging in age from 39 to 74 months in a structured and free play session and found that most were unable to use an object according to its designated function. Williams et al. (2005) interviewed parents of 10 children with autism (MA = 62.2 months; SD = 19.9) who reported problems relating to the use of an object, such as an interest in some unusual aspect of the object, an unusual way of using the object, or difficulty in generalizing object use. Custance et al. (2014) suggested that imitative deficits in children with autism can be reduced by means of object-related activities, especially if there are no time limits on use of the object. Object-related activities promote joint attention, motor imitation, and intentional communication with a social partner (Bruckner and Yoder, 2007), and there is evidence that interventions focused on play involving different objects can promote social and imitative behaviors (Brown and Murray, 2001; Stahmer et al., 2003; Lee et al., 2017). Swettenham et al. (1998) observed three types of attentional behavior: (1) between an object and another object, (2) between an object and a person, and (3) between one person and another. Children with autism showed relatively more attention to interactions between an object and another

object. In our recent studies, we have observed the important role of the object in activating attention in the child with autism, and we describe the phenomenon as “attention mediated by the object,” which may be a precursor of joint attention (Iannaccone et al., 2016; Manzi and Savarese, 2017; Savarese et al., 2017).

The observational study reported here incorporates a sociomaterial perspective, referring in particular to the mediating role that objects seem to assume in the interaction between children and adults, which has to date been neglected in the scientific literature. Using a selected set of objects, the study analyzed the child with autism’s ability to manipulate those objects and to evaluate their symbolic use. Starting from presentation of the object, a further objective was to identify the type of game engaged in by the child. During interaction with an adult, we observed first whether there was eye contact; second, whether this changed how the child used the object; and third, whether the canonical use of the object was an important element in the child–adult interaction.

Material and Methods

Participants

We used the tower building item from section B of the “CHecklist for Autism in Toddlers instrument” (*CHAT*; Baron-Cohen et al., 1992). It was developed to help identify children who are at risk of developing social-communication disorders (scoring “high risk of autism”). It was administered to filter participants and one child aged 22 months did not pass this item. Children aged 18 months are capable of tertiary circular reactions and can stop and restart a sequence of actions at any intermediate step, which is crucial in building a tower of blocks. Children older than 18 months can use symbolic mental representations. The selected age range, therefore, allowed us to observe the early development of symbolic functions.

The study’s participants were three non-verbal male children with suspected autism spectrum disorder. The suspected diagnosis of autism was identified through the use of the CHAT instrument.

Their different ages encompassed the transition from sensorimotor to preoperational stage; participant 1 was aged 18 months, participant 2 was aged 20 months, and participant 3 was aged 24 months.

Methods

The study employed videotaped observations (with one camera) of verbal and non-verbal signs during an organized free play session, in which each child played with seven small blocks of colored plastic in the presence of an adult (a different experimenter was used for each observation). The observations were conducted on the basis of a checklist consisting of 14 items (see Appendix A), including eye contact and the building of a tower of toy blocks from section B of the CHAT procedure.

The blocks were selected not only because of their use in the CHAT procedure but also in accordance with the empirical tradition of Piaget (1962) and Reifel (1984), who have shown the importance of toy blocks in the child's cognitive development. The interaction sequences from the video recordings were transcribed in full for microgenetic and semiotic analysis, primarily examining the children's non-verbal signs (gestures and posture) during interactions with the objects. Adult intervention was also analyzed in terms of non-verbal signs (gestures and posture), again focusing on sequences of microgenetic and semiotic actions. Sequences were selected using the following criteria: the presence of gestures, actions, or both, where (1) the adult intervened and the object became a mediator of the interaction, and (2) the object mediated the attention between child and adult. The observations of child and adult occurred simultaneously.

Ethical issues

This study was carried out in accordance with the recommendations of AIP (Associazione Italiana di Psicologia), and all of the children's parents gave written informed consent in accordance with the Declaration of Helsinki. As there is as yet no psychological ethics committee at the University of Salerno, the protocol was approved by the external experts group from the University's "Centro di Counseling Psicologico" (Counseling Center). While the Center is not specifically responsible for ethical approval, the external experts group supervises research carried out by psychological researchers at the University. In Italy, few universities have a psychological ethics committee, and these generally offer degree courses in psychology or have a psychology department or institute. The University of Salerno has not activated degree courses in psychology and has no such department. We would like to thank the external experts, Dr Oreste Fasano (Psychologist), Dr Nadia Pecoraro (Psychologist), and Dr Monica Mollo (Lecturer in Psychology).

Results

The interactions with the blocks helped to observe behaviors that related to the blocks' physical attributes and the child's competence to establish relations with them. This playful manipulation of

objects probably helps planning and coordinated action, stimulating and strengthening the child's ability to interact with the outside world. At the same time, these activities allow children to imagine new construction scenarios (Harris, 2000). In the presence of potential partners or competitors (children or adults), the child's management of play activities and their implementation of communication strategies can also be observed. For example, the 18-month-old touched and handled all seven blocks, the 21-month-old touched and handled six blocks, and the 24-month-old touched and mechanically stacked all seven blocks.

Based on their independent observations, the two researchers agreed that the three children's symbolic use of objects (see **Table 1**) could be assigned to the first level of symbolic play as proposed by McCune-Nicolich (1981), based on Piaget's sequence (1972), because the children played using sensorimotor schemes. In addition, unlike the 24-month-old, the 18- and 20-month-old played a realistic game. Pretend and symbolic play was not observed in any of the three children's behaviors.

Table 1. *Use of Objects*

	Child 1: 18 months	Child 2: 20 months	Child 3: 24 months
Realistic play	Yes	Yes	No
Pretend play	No	No	No
Symbolic play	No	No	No

Based on observations of the "Can the child build a tower of blocks?" item in section B of the CHAT instrument (see **Table 2**), it was established that all three children used the objects in a manner similar to that described by Piaget as part of the manipulative activities of sensorimotor functioning. The children showed active exploratory behaviors as the toy blocks were manipulated, sorted, and stacked.

Table 2. *CHAT Section B: non-key items.*

	Child 1: 18 months	Child 2: 20 months	Child 3: 24 months
Tower of Blocks	Yes	Yes	Yes
Eye-Contact	Yes	Yes	No

In observations of the Eye Contact item of CHAT section B, the 18- and 20-month-old made visual contact with the adult, but the 24-month-old showed no eye contact. In the child-object- adult or

simple child–object interactions excerpted below, a set of seven colored plastic blocks was placed in front of the child. Transcription commenced when the child began to manipulate the blocks.

Observational results

In this section, we describe the observations we made of children with autism in relation to the types of object use (see **Table 1**). Crucial episodes were selected to illustrate the characteristics of the interactions between the children and the adults.

Generally, adults help children to interact with objects. In the observation of Child 1, the child was able to perform a complex series of actions on the object during the interaction. The child grabbed the object, manipulated it to orient it, dropped it, balanced it, and connected the different objects by stacking them. Here, the adult's help was crucial, as the elements of the child's interaction with the object were changed; at the same time, the object became a mediator in transforming the interactive arrangement between the child and the adult. The adult's hand in direct contact with the object became a source of interest to the child, who focused on this subject–object hybrid.

Observation 1. Child 1. Difficulties in the use of the material features of the object induced the intervention of the adult.

The child cries because the blocks he had begun to stack fall; while he cries, he holds two blocks in his hands and tries to put them on a block on the table. The adult comes over and gets behind the child. The child tries to lay block 1 but fails because he is shaken by tears. The adult places the existing block in a better way. The child looks attentively at the adult's hand and places block 1. The adult takes block 1 with the child and helps to place it in the right position in balancing it.

(...) With his hand, the adult moves block 4 (stacked by the child) to achieve better balance. The child observes the adult's hand. The child leaves block in his left hand alone and, continuing to watch the stacked blocks, extends his right arm to grab block 6. He places block 5 onto block 4 and, without looking, tries to grab block 6.

The child's initial frustration on being unable to stack the blocks led to an intervention by the adult, who was seated on the ground behind the child. The adult intervened when the child played with the blocks, and the object became a mediator of interactions and interpersonal activity.

Observation 2. Child 1. The previous help of the adult activated the attention of the child.

Once block 4 is in his left hand, he stretches his right arm and grabs block 5 before positioning block 4. While watching block 5, the child places block 4 and leaves it on block 3a; in the meantime, he brings block 5 closer to his body. After leaving block 4, the child takes a step back to turn to the adult, and they look at each other.

(...) He places block 6 onto block 5 and leaves it. Having left block 6, he turns to the adult, and they look at each other.

The child continued to play with the blocks, which became a mediator of attention between the child and the adult. After his intervention, the adult facilitated the stronger relational attractiveness of the object, as it became a transformative element in the initial environmental arrangement.

Observation 3. Child 1. The child used the material features of the object correctly after the intervention of the adult.

The child stretches his right hand and grabs block 4. The child then passes block 4 to his left hand, no longer looking at block 4 and directing his gaze to block 5. Meanwhile, the child keeps block 5 in his right hand. Holding the new block, the child turns to the stacked blocks and simultaneously raises his right hand (with block 5). He raises both arms above his head and grabs block 5 with both hands.

The child combined the object's socio-material properties by combining the material properties of the object with the social structures inherent in the object itself.

Furthermore, a series of interesting gestures was observed in the child-object interaction. When the child took the block and raised it over his head, even though the blocks on which the held block was to be placed were much lower in height, the child may have been planning to build a much higher structure with different characteristics to the existing one. One may take these behaviors as possible evidence of an imaginative process. This can also be seen as an explanation of the socio-material link, as imagining a structure beyond what is immediately present may indicate the child's ability to combine the material properties of objects. As the adult intervened, he became an example for the activity of the child. In the child-adult interaction, the object became a mediator of attention.

In the observation of Child 2, the child's manipulative skill was organized in a complex series of actions. He eyed the objects, planned to grab and stack them, rotated the objects in both hands, left, and again grabbed the objects. The material characteristics of the objects were explored. The adult intervened when the child played with the blocks, and the clock (the object) became the mediator for the joint attention of the child and the adult.

Observation 4. Child 2. The child began to actively explore the objects.

The child moves the blocks in front of him (almost shuffling them), watching them carefully. Still looking at the five blocks in front of him, he moves his right hand and touches block 1, which is not present in his visual field.

The child explored the material features of the blocks, and through these actions, which blended complex activities, the child seemed to experience the object adapting and being adapted by its constituent elements. In building a tower of blocks, the child's aims and imaginative action planning appeared to converge. Thus, even though a symbolic game could not be identified, it seems that sensorimotor play and realistic play were present.

Observation 5. Child 2. The child used the material features of the object.

He raises block 1, keeping his eyes on it while grabbing block 2 with his left hand. He turns block 2 around, changing the side that rests on the ground; in the meantime, his right hand brings block 1, moves it in the air, and passes it over block 2. He is about to place block 1 but brings it back close to himself, touching it with his left hand and resting it on block 2.

Here, the child experienced the features of the object. The adult intervened several times during these child-object interactions. The subject-object hybrid identified during the observation of Child 1 is also present here. During the first stage, the child's attention was focused on the transformative mediation of the subject-object hybrid, highlighting how this inextricable relationship drives the modification of the initial environmental arrangement. The child's actions can be seen to occur in a synchronic and harmonic circle of the imitation of the adult's actions.

Observation 6. Child 2. The socio-material features emerged during the child-adult interaction.

The adult places his hand in the child's visual field by moving a block over to him; putting it onto the floor, the adult begins to stack the block. Throughout the sequence, the child is

attracted by the adult's hand manipulating the block. He directs his gaze to block 1 and grabs it; continuing to watch it, he takes it with both hands. The adult begins to stack the blocks. The child manipulates block 1, which he holds in his two hands. He rests block 1 and leaves it. Directing his gaze to the blocks in front of him, he watches the adult, who stacks blocks.

(...) The adult takes the blocks that the child had put in rows and stacks them on top of each other. The child again takes block 4 with both hands. The child carefully observes the adult's movements while stacking. Still with block 4 in his right hand, crawling and with momentum, the child approaches the blocks stacked by the adult. The child grabs block with both hands, looks at it, and manipulates it. He turns block 4 in the direction that seems to enable stacking. He watches the blocks being stacked by the adult and, with his right hand, places block 4 onto the stack of blocks.

The subject/adult-object hybrid appeared to represent the transformation of the subject/adult-object-subject/child relationship, leading to revised planning of the action and thereby structuring of general aims. As well as becoming a mediator of the child's exploration of the surrounding environment, the object also rewrote the relational terms. This last step seems to follow the socio-material perspective, as the social structure of the object was intertwined with its material characteristics.

In observation of Child 3's sequence of actions, the attractiveness of the object overrode the ability to create a contact area with the adult who remained peripheral, or as a mere spectator of the child's construction. Actions have a regularity of performance: blocks are looked at, the hand gets ready to grab, the arm is stretched out to get to the object, the object is grabbed, the child identifies where to put the object, and eventually rests it in balance for stacking.

Observation 7. Child 3. The child used only the material features of the objects.

The child grasps block 1 with his right hand and rests it on a raised board, which has a width equal to the side of the block. He looks closely at block 1 and grabs it with both hands as if to be sure it is in balance. He pulls his right hand away from block 1 and, holding himself with his left hand, leans over the board to see what is there. He directs his eyes to where the blocks are located. He lowers himself, leaning with his left hand on the board and gripping block 2 with his right hand. He gets up and, watching block 1, rests block 2 onto block 1. He removes his right hand from block 2, lowers his body to take block 3, and grabs it with his right hand. He gets up and places it onto block 2, leaving block 3.

Following this regularity of actions, which converged in a purposeful activity, we can assume that the child has completed the main stages of sensory–motor skill development and understood the object’s material characteristics. Additionally, the social function inherent to the object appears to be linked to its use.

In fact, the building of the tower was achieved through structured planning and with a constant imaginative tendency. What is lacking seems to be an understanding of the possibility to use the object as a social agent, because the adult was present only as a spectator.

Based on the regularity of actions that converged in purposeful activity, we can assume that Child 3 had completed the main stages of sensorimotor skill development and was able to understand the object’s material characteristics. Further, the objects’ inherent social functions appeared to be linked to their use. In fact, the building of the tower was achieved through structured planning and with a constant imaginative tendency. The adult did not intervene when the child played. In the child–adult interaction, what seemed to be lacking is an understanding of the possibility of using objects as social agents, as the adult was present only as a spectator.

Searching for constants in analyzing the filmed sequences of the three children, their successive actions were identified; initially, each actively manipulated all the blocks. This activity preceded an apparent break, but during that phase, the child observed the objects to determine how to continue. Immediately thereafter, the child either sought the adult’s attention through eye contact or resumed the interrupted object manipulation.

At the beginning of the game, the children moved, shook, and turned the items several times, and this correlated with activation of their hand movements. Here, we probably witnessed the typical secondary circular reactions of the sensorimotor stage. After the break and the search for mutual attention and/or eye contact with the adult, the children then proceeded (by trial and error) to build the tower of blocks, modifying their existing schemes in so doing. This was indicative of tertiary circular reactions.

Discussion and Conclusions

Consistent with a theoretical perspective emphasizing the role of social and material dimensions in psychological development and activities (Iannaccone, 2015), our analysis highlights two important implications in our observations of object manipulation. First, consistent with the Piagetian

perspective, the observations highlighted object manipulation and action planning identifying the presence of secondary and tertiary circular reactions (Piaget, 1972). In relation to the game, invoking the McCune-Nicolich model (1981), all the children exhibited sensorimotor play, in which the object was manipulated and understood in terms of its material characteristics.

The second implication relates to how, in some action sequences, the material and social characteristics of the objects contributed to shaping partner interactions between child and adult. This aligns with several empirical studies of the social uses of objects (conventional, canonical, and symbolic) (John-Steiner and Mahn, 1996; Moro, 2011). In such interpersonal situations, the activities of participants (child and adult) are clearly affected by the setting's physical and social affordances. In particular, during child–parent interactions (Moro, 2014), triadic child– object–adult interactions (Moro, 2011) seem to create relevant socio-material scenarios that frame communicational activities. In our observations, two of the three children in fact exhibited a kind of object management mode that seemed to replace eye contact with the adult. In some sequences of actions, child and adult managed to coordinate action planning through object manipulation, child exploratory activity, and adult scaffolding. For example, the child observed and touched the objects to encourage play activities; the adult touched the object with his hand, and this action frequently became a source of interest for the child. The child looked for the adult's attention through eye contact, and the child began to manipulate the object. In activities of these kinds, it seems evident that the objects can serve as mediators in communicative interactions with the adult. As well as taking into account the social function of objects, the observed children were already considering the socio-material characteristics of the play situation, as adults and children engaged in managing a kind of “socio-material space” as proposed by Rodríguez et al. (2015). In fact, from the first year of life, adults produce a shared space with objects that serve as effective tools of communication with children. Our findings in relation to the object as a tool for adult–child interaction align with Moreno-Núñez et al. (2017), confirming that the first shared understandings between adult and child take place around the object and its uses. Finally, in considering these first results, we can imagine relevant challenges for a new developmental psychology based on further related research.

Our observations of these interactions do not focus on direct joint attention but identify a kind of psychological process that we call “activity mediated by the object.” Unlike Tomasello (1995), we consider the object itself as mediator, not only of the mutual attention between adult and child but of the dynamic relational exchange between partners.

In conclusion, our study reported the preliminary results of a larger analysis. In considering these first results, we can imagine relevant challenges for the developmental psychology of children with autism. Consistent with the results of studies on children with typical development, our study on children with autism shows that the socio-material features of objects represent factors that mediate the construction of child–adult interactions. Starting from the first intervention of an adult, an object becomes a mediator and promoter of interpersonal activities and space.

Ethic Statement

This study was carried out in accordance with the recommendations of AIP (Associazione Italiana di Psicologia), and all of the children’s parents gave written informed consent in accordance with the Declaration of Helsinki. As there is as yet no psychological ethics committee at the University of Salerno, the protocol was approved by the external experts group from the University’s “Centro di Counseling Psicologico” (Counselling Centre). While the Centre is not specifically responsible for ethics approval, the external experts group supervise research carried out by psychological researchers at the University. In Italy, few universities have a psychological ethics committee, and these generally offer degree courses in psychology or have a psychology department or institute. The University of Salerno has not activated degree courses in psychology and has no such department. We would like to thank the external experts, Dr Oreste Fasano (Psychologist), Dr Nadia Pecoraro (Psychologist), and Dr Monica Mollo (Lecturer in Psychology).

Author Contributions

The introduction was written by AI. The observational analysis was written by FM. The discussion of the results and the conclusions were written by GS.

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Chapter 5

Social Functions in Autistic Children and Interaction with/through Object: A Brief Report

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Abstract

The aim is to analyse the social functions of pointing, of imitation and of joint attention in presence of the object for the autistic children. We have built an ad-hoc observation check-list and we have conducted 43 observations with verbal ASD-affected children aged between 2 years and 6 years. The results show that a better use of the object is correlated to the manifestation of social functions analysed.

Introduction

In a socio-material perspective (Iannaccone, 2015), the object is composed of material features and social components coexisting together. Considering that the social interaction is impaired in autistic children; consequently, the interaction with the “social world of objects” is impaired as well (Iannaccone, et al., 2016). Some autistic children show deficits in the use of objects: alterations in manipulation, exploration and describing. Thus, autistic children which do not present impairment in the use of the object show more social functions than impaired children (Trevvarthen & Hubley, 1978; Tomasello, 1995; 2016).

The three social functions, pointing, imitation and joint attention analysed in the study and they all have in common the presence of the object in their definition. Thus, our aim is to analyse these functions not only taking into account the development of these by the autistic child, but also what role plays the object specifically in social and relational terms.

Method

We have built an ad-hoc observation check-list inquiring on 9 areas (each of which has specifying under-questions), which refer to 9 psychological theory constructs developed by the literature on autism and object. The main objective of this check-list is that of describing characteristics and socio-material functions of the object with reference to autistic subjects. In this check-list, there are different psychological constructs, but here we have analysed in detail three constructs: declarative function, imitation and attention. As we can see the check-list was made of different constructs but we will analyse these other constructs in future.

During each observation, an educator following the child for rehabilitation was present and the educator completed the check-list. Each observation lasted 26 minutes on average and has been transcribed on an ad-hoc check-list.

Children have been observed while interacting with an object, a small-sized plastic toy, they had chosen from a set of objects, for instance, toy cars, trains, toy animals and others. When we refer to “acted and interacted with and through the object” we arranged different constructs of the check-list, such as: Understanding of the use of the object, interaction through the objects etc. Which are the constructs refer to the manipulation, exploration and describing.

We carried out 43 observations with verbal ASD-affected children aged between the end of the sensory-motor stage (24 months) and the start of the pre- operational stage (68 months, namely 6 years). Moreover, the literature shows some results showing a link between a better use of the object

and those functions that emerge during the pre-operating period, such as imitation and attention to the other (Bruckner & Yoder, 2007).

We were two samples. The first sample composed of 18 children who acted and interacted with and through the object while the second sample composed of 25 children who acted and interacted with and through the object.

Results

Regarding the association between the sample 1 and the declarative function (Figure 1) shows that the 66.7% of the sample present this association while the sample 2 shows that only the 24% present this association.

Indeed, it is possible also for autistic children to use the imperative function of pointing, as for typical development children, and pointing is often the ground- breaking of a full declarative function (Camaioni et al., 2003).

Regarding the association between the sample 1 and the imitation (Figure 2) shows that the 94.4% of the sample present this association while the sample 2 shows that only the 60% present this association.

Concerning imitation, it has been suggested that the specific imitation deficit of autism could be reduced or even eliminated with the use of activities linked to objects (Vanvuchelen et al., 2013; Custance et al., 2014), especially when no timelines in the use of objects are given.

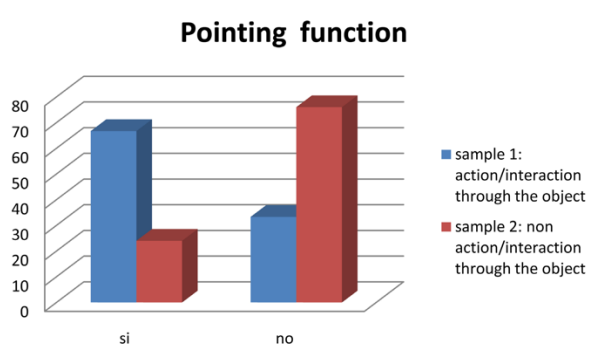


Figure 1. Pointing function

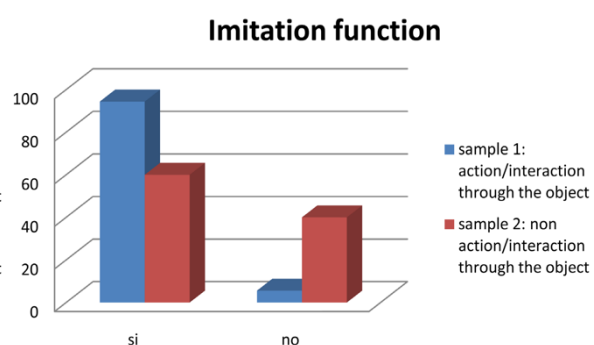


Figure 2. Imitation function

This would favour a higher joint attention, motor imitation and intentional communication with a social partner (Swettenham et al., 1998).

Regarding the association between the sample 1 and the Joint attention (Figure 3) shows that the 61.1% of the sample present this association while the sample 2 shows that only the 32% present this association.

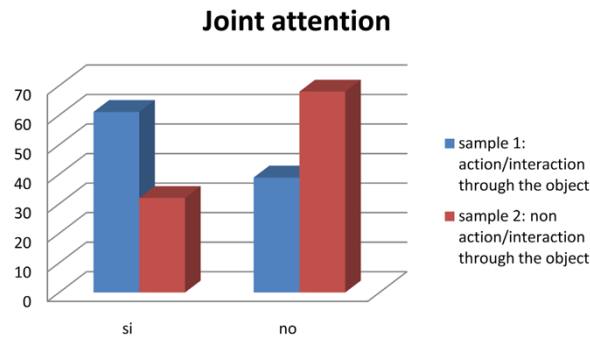


Figure 3. Attention to the adult function

Lastly, regarding joint attention it has been proved that manipulation of material objects can address the child's attention and favour the joint attention with both adults and peers (Korkiakangas & Rae, 2013).

Conclusion

The socio-material features of the object represent factors that mediate the construction of the interaction with the adult. Social functions contribute to this process are: the declarative function (relating to pointing), the imitative function, the function of joint attention.

In line with the literature (Bruckner & Yoder, 2007) on the child with typical development, our study with autistic children shows a link between a better use of the object and these functions that emerge during the pre-operating period, such as imitation and attention for interacting with people.

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Chapter 6

General Discussion

The aims of this thesis were: 1) to explore the intersubjectivity space that a child can establish with an object (the robot) that is also the interactive partner during the interactions; 2) to observe the role of the object as mediator of the child-adult interaction and as promoter of the construction of the intersubjectivity space. The first topic has been investigated in children with typical development while the second topic has been explored in children with atypical development, i.e. autistic children.

In this respect, there were designed two different interactional scenarios to evaluate the intersubjectivity: 1) concerning typical development it has been used an interactional situation involving humanoid robot in order to test the decision-making processes; 2) regarding autistic children the use of the object has been observed during an interaction with an adult mediated by an object, testing the role of the object as mediator and promoter of the interaction. The first situation, involving an innovative field of research, needed a review of the literature in order to understand which role can be assumed by the robot during the interactions with a human. Thus, it was important to analyse if human can ascribe a mind – mental states – to a robot, in particular in a life-span perspective in order to observe changes during the human development. The second scenarios used an original perspective to examine the interaction between autistic children and adults, showing that autistic children, despite their impairments in different areas of development, can create an intersubjective space with the adults. However, this is evident when child and adult use an object as mediator of this interaction.

The findings emerged from these scenarios arise two main questions:

Can a child treat a humanoid robot similarly to a human partner?

Futurologists hypothesised that in the next years robots will be introduced in different contexts of our everyday life such as household, elderly assistance, education etc, modifying the job market but also our social interactions. For instance, the use of robots in the educational context are inspiring new educational program. Moreover, children will be more conscious of the existence of the robots because robots become part of their everyday experience. Several studies underline the need to implement physical and behavioural features in order to make robots more sociable, promoting better

interactions. From Chapter 1 results that subjects ascribe mental states to a humanoid robot. However, the attribution of a mind is not similar at all ages, but it changes during the life-span. For instance, a recent study of Manzi and colleagues (2017) showed that children from 5 to 9 years of age distinguish a human from a robot as regards the attribution of mental states, in particular children ascribe different mental states to a robot at different age: younger children ascribe more emotional states compare to older children. However, several researches in the field of educational robotics show that children treat a robot as a companion and scaffolder in the educational contexts. These findings are evident in the study presented in Chapter 2. In fact, 5-years-old children ascribe less mental states to a robot compared to a human but despite these differences, they use similar strategy with human and robot when they play in an interactive game. This is a fundamental result because it means that children can treat a robot similarly to a human. Moreover, another innovative result of the study is the analyses of children justifications given to the Ultimatum Game. We observed that children tend to use justifications based on the outcome and not on the basis of mentalistic terms both for human and robot, showing how children behave like maximisers – according with the homo-oeconomicus theory – when they interact both with human and robot. In the human condition, children's justifications based on the 'outcome' given to the unfair divisions, both as a proponent and as a receiver, could be explained as the attempt to resolve a cognitive and social conflict (expected "social" fair behaviour VS real "selfish" behaviour). Moreover, in the robot condition, children's justifications based on mentalistic terms to unfair divisions, both as a proponent and as a receiver, can be explained as the social norms of equity might be less relevant (robot = "not perfectly like-me").

The literature review in Chapter 2 and the data of Chapter 3 represent an important finding for the HRI and cHRI because it is possible to infer that humans – from childhood to old age - tend to ascribe a mind to a robot and that besides 5-years-old children tend to treat a robot as social partner, using similar cognitive strategies both for human and for robot.

In conclusion, robots can be considered 'like-me' (Meltzoff, 2005, 2007a, 2007b, 2013) but it depends from: 1) the age of human partner interacting with a robot; 2) the methodological procedures, and particularly the nature offline (i.e., the AMS questionnaire used in Chapter 3) or online (i.e., the modified version of the Ultimatum Game used in Chapter 3) of the tasks employed; These final observations lead to reflect on the instruments used in research and this is even more important when the topic of research is new such as the HRI. In fact, it is essential to combine both offline and online measures, but also it is important use together ecological and laboratory tasks.

Can an object be a mediator and a promoter of the child-adult interaction also for autistic children?

We live in a social world composed by humans and objects. In the history of Psychology, the human-human interactions were largely investigated but few studies analysed the human-human interaction mediated by objects. In this regard, Piaget (1952, 1954) highlighted that children discover the world of the objects through a sensorimotor activity, which constitutes the basis of the cognitive development. Vygotskji (1962, 1978) showed that children with typical development use artefacts to interact with others, acquiring their knowledge about objects through the interaction with a scaffolder (peers or adults). Moreover, Moscovici (1976) examined the interpersonal relationships in a triadic perspective, highlighting that humans and objects are strictly connected. However, Linell (2009) proposed a dialogical interpretation of the objects, suggesting that it is important to understand the objects as external referent that can change human's perspective of the world. Several studies showed that an adult can be a scaffolder for the acquisition of the use of the objects in children with typical development (Moro, 2014). In Chapter 4 and 5 we demonstrated that also children with atypical development, in particular autistic children, can use the object to construct an intersubjectivity space during the interaction with the adult. The objects in these interactions acts as mediators of the child-adult interaction, creating a specific intersubjective space in which autistic children, despite their social impairments, are able of some social performances (i.e., ocular contact).

In Chapter 4 the results seem to demonstrate that the socio-material features of objects represent a key-element that mediates the construction of child–adult interactions, becoming a mediator and promoter of interpersonal activities and space. Chapter 5 shows a link between a better use of the object and the presence of social behaviors that emerge during the pre-operational stage, such as imitation and attention. However, it is important to highlight that the use of the object and the presence of social abilities largely vary in each autistic child because autism is a spectrum disorder that implies a wide range of phenotypes. Thus, the construction of intersubjectivity space has to consider the specific subjects of the interaction and their interpretation of the objects.

These findings lead to the conclusion that to understand how children with typical development interpret the use of the objects it is important that adults ‘share’ the child’s perspective in order to create an intersubjective space. If it is crucial in typical development, then it becomes even more essential in atypical development, in particular in autism that is a spectrum of disorders that imply a different kind of impairments in several areas of development. In fact, the adult has to consider that each autistic child constructs the intersubjectivity space in a subjective way, using all her/his skills.

In general, both as regards typical and atypical development, the adult should accept that each artefact is always reinterpreted by the child in a triadic relationship through a continuous and dynamic construction of the intersubjectivity.

Conclusion

The majority of the psychological research is inspired by everyday experiences and so I will try to give some examples of the key points of this thesis, starting from my life.

I am writing my thesis using my computer right now and its battery is almost discharged. I am saying “Why you do this to me?”. Despite my prayers, my computer will switch off if I will not put it in charge. What does this situation mean? I am ascribing intentions to my computer, in particular the intentions to turn off itself.

I remind that in UK when I was learning how to use a robot, I was staying in the Lab hours and hours without talk to anybody and so I was starting to talk to the robot, ‘praying’ it to work in the right way. It obviously continued to not work and to not reply to my questions and prayers (fortunately!).

I bought a toy for a son of two friends of mine when he was 6-moths-old. Then these friends moved to USA and sometimes we Skyped, but I did not see them for a long time. This summer when I came back to my hometown, I saw them after three years and the child still had the toy and when the mother said him that I bought it for him he smiled and give me the toy to play together.

The above examples highlight the two main points of this thesis: 1) we can ascribe mental qualities also to objects that have not ‘really’ a mind because we tend to project our internal states onto the external world; 2) we are fully immerse in a world of objects that give us the opportunity to create an interaction with another person beyond the time.

To attempt a tentative conclusion, the purpose of this thesis was to show that when humans build objects - from the classic ones to the more technological ones - they also achieve two further important objectives: to facilitate social interactions and to create an intersubjectivity space that includes both human and non-human partners. I sincerely hope my efforts have at least partially succeeded.

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Materiality and the construction of Intersubjectivity: human-robot interaction In typical development and the use of the Objects in ASD children

Federico Manzi

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Chapter 1

General Introduction

*Una mente tutta logica è come un coltello tutto lama.
Fa sanguinare la mano che lo usa.
(Rabindranath Tagore)*

The aims of the present dissertation are to analyse, in children with typical and atypical development, the construction of the intersubjectivity through the use of objects in atypical development (ASD) and through the interaction with a humanoid robot in typical development. About the humanoid robots, the issue is to observe the possible attribution of human-like features to a robot that can make the human-robot interaction similar to the human-human interaction that is a classic intersubjective interaction because of the presence of two human subjects. This purpose is investigated considering two theoretical frameworks: 1) Theory of Mind that explain the construction of the intersubjectivity through the attribution of mental states to others; 2) Socio-material perspective which postulates that the construction of the intersubjectivity is mediated by objects in many cases. Thus, the question arises in this dissertation about the humanoid robot is: what happen when the mediator object (the robot) is also the interactive partner.

To achieve this purposes, the present thesis studies two main topics: 1) the interactional patterns with and the attribution of a mind to a robot by typically developing children; 2) the interactional patterns in atypical development - autistic children - in a child-adult interaction mediated by objects. The first topic is analysed in an innovative theoretical perspective and a through novel methodological approach, leading to an innovative understanding of the child-robot interaction. The theoretical perspective connects the role of Theory of Mind in HRI; the methodological approach observes children's decision-making strategies in the HRI, comparing these behavioural patterns when children interact with a human and with a robot. The second issue of the thesis is about the role of the object as mediator of the relationship between autistic children and adults. This is studied through the Socio-material perspective that hypothesised that material features of the objects and their intrinsic social qualities are strictly connected.

A useful psychological paradigm to investigate the construction of intersubjectivity is the Theory of Mind construct that will be briefly introduced; subsequently I will give an overview on Human-Robot

Interaction and, finally, I will conclude with some observations concerning the role of the objects in autism.

Theory of Mind or how understand the social world

Theory of Mind (ToM) represent one of the most important psychological constructs used in the last decades to interpret social interactions. ToM is the ability to understand one's own and other people's mental states (intentions, emotions, desires, beliefs), and to predict and interpret one's own and others' behaviours on the basis of such meta-representations (Premack and Woodruff, 1978; Wimmer and Perner, 1983; Perner and Wimmer, 1985). This definition highlights how the presence of the other is crucial for the comprehension of ourselves and for the interpretation of the relational world. The history of the ToM begins with the pioneering study of Premack and Woodruff (1978), titled "Does the Chimpanzee Have a Theory of Mind?". This study paved the way to study the ToM also in different agents, not only in humans but also in primates. They found that also the primates can use ToM ability to understand and predict the conspecific's and human's behaviours. These results allowed to study the ToM in an evolutionary perspective. In fact, Adolphs (2009) theorised about the phylogeny of social abilities, showing that our brain is a social brain that evolved from primates to humans.

Furthermore, developmental psychology study the changes that occur during children's development, showing the ontogenesis of this ability. ToM is not a monolithic construct, but it is a complex and multimodal ability that involved both cognitive and affective processes (Shamay-Tsoory & Aharon-Peretz, 2007; Kalbe et al., 2010).

Wellman (1991) hypothesised a ToM development from 3 to 7 years of age considering the understanding of mental states in the childhood. The author drawn a line of development: children in the early stage of development understand the non-epistemic states (desires, emotions and intentions) – between 3 and 4 years – and only late – between 4 and 7 years – the epistemic states. The epistemic states are the bases for the true and false belief understanding: this allows children to construct a meta-representation of their own and other's mind. Thus, considering the important of belief, in particular false belief, a pioneering study of Wimmer and Perner (1983) used for the first time the paradigm of the false belief task to study the ToM development. In this study the authors used the Unexpected Transfer Task in which a character has to ascribe a false belief of another character. The results showed that 4 - to 5 - year-old children can predict the actions of someone with a first order false beliefs referred to the first level of recursive thinking (i.e. "I think that you think"). These findings are supported by a meta-analytic study by Wellman, Cross and Watson (2001) that confirmed

that children begin to attribute a false belief starting from 4 years of age. In a second study Perner and Wimmer (1985) used a different task, the Ice-Cream Van, in order to analyse the second level of the recursive thinking (i.e. ‘I think that you think that she/he thinks’), that is the *second order false belief*. They found that 6- to 7- years-old children can understand this second level of representation. These findings show that the ‘sensible period’ for the emergence of the ToM is from 3 to 7 years of age and that it is acquired in a hierarchical way (Wellman, Cross and Watson, 2001). However, several studies show that the ToM is an ability that gradually develop from childhood to adulthood (Sommerville et al., 2013; Dumontheil et al., 2010; Apperly et al., 2012) and in the last years several studies investigate the modification of the ToM ability during the old age (Happé et al., 1998; Castelli et al., 2011; Saltzman et al., 2000).

Human-Robot Interaction: an interdisciplinary approach to investigate socio-cognitive abilities

“Human–Robot Interaction (HRI) is a field of study dedicated to understand, design, and evaluate robotic systems for use by or with humans” (Goodrich and Schultz, 2008, pp.1). The HRI derived from the Human-Computer Interaction (HCI) studies. The differences between HRI and HCI is that HRI uses robots that have physical human-like features (along a gradient from completely non-human like to a complete similarity with humans) and they can behave as humans (i.e., a robot can recognize and follow the eyes of a human or it can reply semi-autonomously to a human question). Thus, HRI not only implement behavioural patterns into robots but also design robots that can be perceived more human-like (Minato et al., 2004). In the last two decades HRI received more visibility especially related to the development of new theoretical approaches and technical skills in the robotics’ domain. For instance, in 2004 the Ishiguro’s Geminoid Project¹, in Japan, built androids which very closely resemble specific human “models” as a platform for research aimed at understanding humans, applying methods from engineering, cognitive science and neuroscience. Indeed, the robots can be used as a research tool in two different ways: 1) to use a robot in order to test human cognitive models, implementing algorithms that can simulate the human cognitive processes (Di Nuovo et al., 2013; De La Cruz et al., 2014; Whitaker, Colombo and Rand, 2018; Scassellati, 2003, 2005); 2) to use the robot as a possible partner in scenarios that implies the interaction with a human in order to observe social interactional patterns (Manzi, et al., 2018; Breazel et al., 2016; Moriguchi et al. 2011; Nishio et al., 2018; Sandoval et al., 2016). There are different theoretical approaches in HRI and in robotics; the

¹ For more information on the Geminoid Project: <http://www.geminoid.jp/en/index.html>

most interesting are: Developmental Robotics (Cangelosi and Schlesinger, 2015; Lungarella et al., 2003) and Developmental Cybernetics (Itakura 2008; Itakura, Okanda and Moriguchi, 2008).

Developmental Robotics is an emerging field of research that connects robotics, cognitive science and developmental sciences – in particular developmental psychology and developmental neuroscience (Di Nuovo et al., 2014; Di Nuovo et al., 2017). This field is focused on the implementation of robots that should be more autonomous, adaptable and sociable– the cognitive developmental studies are crucial in this respect – but to achieve this goal it is fundamental to employ models of human development in order to embed these models into robots. Thus, it is important the collaboration between engineers and developmental psychologists in order to design the models mentioned above (Asada et al., 2001; Lungarella et al., 2003). Developmental Robotics represents an innovative approach to the development of HRI: its statement is that robots can learn as children (Cangelosi and Schlesinger, 2015). Roboticians use algorithms, deriving from the Machine Learning field, to build cognitive models of psychological processes (Cangelosi and Riga, 2006; Cangelosi, 2010; Cangelosi et al., 2010). However, these models derive from the research in developmental psychology because it is fundamental to understand the trajectory of development of the psychological processes (i.e., ToM or linguistic development). Since robots should be social partners, Scassellati (1999, 2001, 2002) assumes that they have to possess a ToM. This is only a theoretical assumption because today technical innovation does not permit an implementation of a ToM into robots despite our knowledge about ToM development: an explanation is that ToM ability is a complex process that involves several cognitive and affective components.

Developmental Cybernetics connects Developmental Psychology and robotics, using the human development models in order to identify the most important behaviours that can promote HRI. This is the other side of the coin because, while the Developmental Robotics uses the models to make robots behave socially, Developmental Cybernetics studies which kind of behaviours should be implemented into robots in order to promote HRI. In particular, Developmental Cybernetics studies the development of social behaviour in infants in order to implement specific behaviours so that the robots can be treated as a companion. In the case of interactions between children and robots, we shift in the field of Child-Robot Interaction (often abbreviated as cHRI), which differs from HRI because the partner of the interaction, the child, presents an immature cognitive development (Belpame et al., 2013 a, b). cHRI is crucial for Developmental Cybernetics because of its futuristic hypotheses: in the next decades the robots can be introduced into human societies in different contexts among which the educational ones. In this case, the robots should be attractive for children: to reach this goal,

physical and behavioural characteristics should be more human-like. In 2018 one of the biggest Japanese educational projects introduces 500 humanoid robots (NAO robot, created by Aldebaran Robotics) in the Primary School in order to teach English to Japanese children². Moreover, several research programs use humanoid robots in different educational contexts (Chang et al., 2010; Belapme et al., 2016; Gordon et al., 2016; Kanda et al., 2007), highlighting, in a vygotskian approach, how robot can be use as scaffold. Developmental Cybernetics postulates that to build a social robot is important to study and to develop research knowledge about three main domains connected to the robot: Theory of Body (ToB), Theory of Communication (ToC) and Theory of Mind (ToM). The ToB hypothesises that a robot should move its arms, legs and head in a conventional mode. For instance, Morita and colleagues (2012) test children's and adults' reaction to conventional and unconventional movements of the body of a human and of a humanoid robot, showing that children extend their reaction to the unconventional movements both of human and humanoid robot respect to adults that are more activated when the unconventional movements are made by a humanoid robot. With regard to the domain of Theory of Communication, several studies show that an effective robot is a robot that can communicate in verbal and non-verbal way (Breazel at al., 2005; Brooks and Arkin, 2007; Mavridis, 2015). These researches generally highlight that a robot that can use non-verbal signals (i.e., facial expressions or gestures) to promote the human involvement in the interaction is perceived more as a companion than a robot that not communicate in such ways. For instance, Aaron and Mataric (2015) use a robot that communicate with a worker to achieve a goal, finding that the robot was perceived as a teammate more than a robot without communicative behaviours. The last, but not the least, domain of the Developmental Cybernetics is Theory of Mind: this is a crucial objective of Developmental Cybernetics because it hopes that in the future robots can interact in a way that can be perceived as having a mind. Nevertheless, as above mentioned, the implementation of ToM into robot is more a futuristic dream, while has been demonstrated that humans use their ToM ability to understand robots' behaviours. This a fundamental assumption that connects the different sections of this thesis. In fact, already Piaget (1929) uses the concept of animism suggesting that the human ability to ascribe intentionality to an object is an early infant's disposition. However, when we talk about robots, we refer to an animate object that appears and behaves in a human-like way. Thus, the ToM ability is a very useful psychological construct that can help to better to understand the human's tendency to ascribe mental states to a robot. In Chapter 1 it will be shown as humans, in a

² For more information is possible to access to the article by the following link:
https://rep.repubblica.it/pwa/generale/2018/09/24/news/giappone_robot_insegnano_inglese-207218720/?ref=RHRS-BH-I0-C6-P21-S1.6-T1

life-span perspective, tend to attribute minds to robots. Some research points out, in particular as regards childhood and adolescence, that the ascription of mental states changes with age (Manzi et al., 2017; Kahn et al., 2012). Chapter 2 shows that younger children tend to ascribe to robots more intentions and desires and less epistemic states than older children, in line with the ToM literature (Wellman, 2001). These findings highlight an important point for Developmental Cybernetics, and in general for developmental psychology, because they demonstrate that children perceive a robot as a partner that appear and behave like a human when they interact with it. Additionally, the children's ascription of a mind to a robot is the prerequisite for the establishment of the intersubjectivity. The concept of intersubjectivity captures the way a person understands and relates to another people and implies that exist a bridge between the knowledge of oneself and the one's own knowledge of others (Rochat, Passos-Ferreira and Salem, 2009). In the light of above, this is a crucial theoretical mark for the HRI because, if the intersubjectivity is the assumption of the interpersonal relationship in humans, the presence of this dimension in the human-robot interactions allows to interpret these interactions not only in a mere behavioural way but also in a relational way.

The use of the object in children's development: an overview on autism

The Autistic Spectrum Disorder (ASD) is a syndrome that can be characterized by an intellectual disability (DSM-5, 2013). The main symptoms of the ASD are: impairments in the social interaction (Baron-Cohen, 1997; Frith, 2003); impairments in the verbal and non-verbal communication (Mundy et al., 1987; Happé, 1995); stereotypical and repetitive behaviours, interests and activities (Bodfish et al., 2000; Boyd et al., 2010). Since ASD is a syndrome that affects all the psychological development, social and cognitive deficits are very heterogenous both for the complexity and severity of disease. These symptoms can emerge and change in different moment of development (Frith, 2003; Yirmiya and Charman, 2010). The repetitive behaviours and activities affect also the use of objects: some researchers report that this impairment can be detected already at 12 months of age (Ozonoff et al., 2008; McCleery et al., 2009). Ozonoff and colleagues (2008) found that 12-months-old children tend to use the object in a repetitive way. The use of the object needs to be studied from the sensorimotor development point of view because the object is present since the early stage of the children's development. More recently, several researches show that autistic children present atypical sensorimotor development and sensory perception that predicts the severity of symptoms especially in the area of communication at 24 months of age (Estes et al., 2015; Robertson and Baron-Cohen, 2017).

In the history of psychology, several psychologists studied the role of the object in the human development, such as Piaget, Vygotskji and Moscovici. Within his work, Piaget (1956; 1958; 1977) describes two different types of knowledge. The first type of knowledge origins through physical experience; such experience produces the knowledge of the properties of objects that are used. The second type of knowledge is gained through the logical-mathematical experience, which does not produce knowledge about the objects but about actions and their results. Thus, micro-genetic analysis, which aims to observe the temporal and qualitative aspects of the interactions, is a basic methodological condition for understanding the development of materiality. Despite this embryonic change of course the epistemological approach of Piaget remains anchored to the dualism of subject and reality.

Nevertheless Vygotskji (1962) uses another theoretical perspective: he considered the objects, named artefacts, as a fundamental component of human life. He suggests that humans use both material (i.e., a computer) and psychological (i.e., language) artefacts to interact. Adults use in a better way these artefacts and through their scaffolding 'teach' to children how to appropriately use them. In this respect, the artefacts represent human 'instruments' essential for the communication and interaction.

In these terms, the behaviour and the understanding of the processes of consciousness are closely dependent on the nature of the interaction of human and non-human components of this dialectic dyad. In the history of psychology, some the psychologists abandoned a dyadic approach in favour of a triadic perspective. The key aspect is no longer just the dyadic relationship, but what Moscovici (1976) defines triadic relationship. Moscovici proposes a ternary reading of facts and relations, and in fact replaces the two- term view, subject and object, with a three-term one: individual subject, social subject, and object. In other words, the Ego, the Other and the Object. This aspect assumes a constant exchange between the three elements of the triadic relationship. Such relationship may be conceived as static or dynamic, implying a simple "co-presence" or an "interaction" that can result in changes in thought and behaviour.

However, the theories presented above about the objects are based on a non-dialogical conception of the artefacts. In fact, Linell (2009) considers artefacts as external objects, according to a dialogical theory of the artefacts. The objects serve as anchoring points for intersubjectivity. Moreover, the author suggests that exist an interplay between the human ability of using artefacts and the external objects which possess a wide range of uses for humans. Thus, the objects are used by humans but also can change the humans perspective of the interactional world.

The objects are involved in several psychological mechanisms, such as joint attention and imitation that are largely studied in autism. The joint attention implicates at least the presence of two

partners and of an object that plays the role of the mediator of their interaction (Tomasello, 1995; Mundy and Gomes, 1998; Moore, Dunham and Dunham, 2014). Thus, the object is a protagonist of this human phenomenon, acquiring a crucial role in the interaction. Moreover, the studies on imitation distinguish between body gestures imitation and object actions imitation (Masur & Ritz, 1984; Snow, 1989), showing that the object is involved in the human development as a fundamental ‘non-living partner’ that has a role in a lot of psychological processes.

In the light of above, about children with typical development, the use of the object is a crucial element for the interactions (Rodriguez and Moreno, 2008; Barthélémy-Musso et al., 2013). In fact, Rodriguez and Moreno (2008) hypothesizes that children with typical development use the object in order to interact with adults: the adult has the role to teach to the child different uses of the object which, derive from the human society, Thus, the adult acquires the role of a scaffolder for the conventional use of the object (Moro, 2011, 2014). This approach is particularly interesting because the children and adult create an intersubjective space in which they can interact with each other through an object. Thus, the object is a mediator of the child-adult interaction. Moreover, as already highlighted in the previous paragraphs, the establishment of an intersubjectivity space is the basis of the of human interpersonal relationships.

In the view of the above, it is important to analyse the role of the object also in children with atypical development, in particular in autistic children because they present a distinctive pattern of interaction with the object (i.e., repetitive actions on the object) and are also characterized by social impairments which represent an obstacle for the establishment of interpersonal relationships. In fact, being social interaction impaired in autistic children is consequently impaired the interaction with the “social world of objects”. In the socio-material perspective (Iannaccone, 2015) the object is composed of material features and social components which coexisting the same object. Some autistic children show deficit in the use of the object: alterations in manipulation, observation, understanding and denomination. The object is a significant communicative mediator in social interaction between adults and children (Iannaccone, Savarese and Manzi, 2016). Thus, autistic children which do not present impairment in the use of the object show more social behaviours as pointing (Bernabei, Camaioni and Levi, 1998), imitation (Vanvuchelen et al., 2013) and joint attention (Mundy, 2016). For instance, joint attention is typified by subject-subject-object triangulation in which children alternate their eye gaze between the object and the other person (Trevvarthen and Hubley, 1978). In this respect, Chapter 3 and 4 deal with the role of the object as promoter of the child-adult interactions. Despite the identification of deficits in the expression of the most important early precursors for the social interaction, it has been observed that autistic children can use in specific ways the object that promote the intersubjectivity space. In Chapter 4 autistic children from 20 to 24

months of age exhibit specific sensorimotor patterns of use of objects (manipulation and exploration) that tend to involve the other partner – adults – to interact with the objects. Thus, also in the case of autistic children the object is a mediator of the relation with the adult. Moreover, Chapter 4 points out that autistic children that present a more complex and rhythmic patterns of interaction with the object present more social behaviours (i.e., joint attention and imitative actions).

These findings reveal the ability of autistic children to establish an intersubjectivity space, using the object as mediator of interactions with adults despite the evident social impairments that characterize this syndrome.

This Thesis

Chapter 1 is a review of the literature about the role of the Theory of Mind (ToM) in the Human-Robot Interaction (HRI) in a life-span perspective, showing that from the childhood to the adulthood humans can ascribe a mind to a robot, in particular to a humanoid robot. The HRI is analysed in two main domains: 1) mental states and actions; 2) physical human-like features. The first area highlights that a robot which behave like a human and use human-like cognitive processes promotes the attribution of a mind to a robot. Already in infancy some behaviours (i.e., eye-contact and goal directed actions) promote a better children's social involvement during the interaction with a robot. The robot human-likeness is effective in a life-span perspective. Moreover, the implementation of robots' human-like physical features (i.e. eyes, hands, legs etc) is a crucial goal for the promotion of a more complex human-robot interaction. However, it is also important for a robot to not be completely similar to a human since the risk of a perfect human-like appearance is the Uncanny Valley effect (Mori, 1970), in which the excessive similarity of a robot with humans can reduce the interaction. The main hypothesis is that through these technical innovations, concerning physical and behavioural features of a robot, humans construct an intersubjectivity space with a robot. This is possible because the recognition of a mind in a robot is the prerequisite because humans perceived it as social partner.

Chapter 2 is focuses on pre-schoolers' behaviour during the Ultimatum Game when they play with a human and a robot. In particular the study aims at analysing: the mental characteristics ascribed to the robot with respect to the human; children's behaviour at the UG when playing with the human and with the robot as proposers and receivers; children's justifications for their behaviour during the UG. To my knowledge, this is the first study which analyses children's behaviour during the UG, comparing human-human and human-robot interaction. In this respect, several tasks and tests were created *ad hoc*: 1) the Attribution of Mental State Scale (AMS) is a measure of mental states attribution that the child has to perform looking at pictures depicting a character; 2) to assess children's understanding of the first-order false belief, we introduced a new instrument, constituted by eight videos representing the classical story, introducing also the Robovie as a new character - we used a story similar to the classical *Unexpected Transfer* task as the script of the videos. The AMS results show that 5-year-old children recognize the robot as a different entity from the human. In fact, children ascribe mental states also to the robot, but they are different compared to the mental states attribute to the human. Nevertheless, children behaved similarly during the UG when playing with the human and with the robot, confirming a tendency to maximize gain. Additionally, children's

justifications at the UG showed that, independently on the interactive agent and on the role played (Proposer/Receiver), children tend to use ‘outcome’-based justifications to explain their behaviour for all divisions. This is the first qualitative evidence supporting the idea that, at the age considered, children mostly reason in economic/quantitative, homo-oeconomicus-like, terms. The almost total lack of equity and mentalization-based justifications of human unfair divisions further suggests an attempt of children to resolve a social cognitive conflict emerging from the discrepancy between a “socially-expected” fair behaviour and the actual “selfish” behaviour.

Chapter 3 presents an explorative study aimed at observing the quality of interactional patterns in child-adult interaction, using objects as key elements for the construction of intersubjectivity. This qualitative research is based on two theoretical perspectives: 1) Piaget's studies (1952, 1954), according to which children reach the conceptualization skills of objects in the fifth phase of the sensory-motor development; 2) studies that concern the canonical use of the objects, according to which the canonical functions of the objects are acquired as a normative phenomenon during social interactions (Tomasello, 2016), even if the cognitive understanding of these functions is a prerequisite. Several other studies show that canonical functions of the objects are acquired during child-adult interactions (Leontiev, 1981; Costall, 1997; Moro, 2011, 2014; Rodríguez & Moro, 1998; Sinha & Rodríguez, 2008). In this Chapter it will be analysed the manipulation of objects by children with autism spectrum disorder with the aim of showing how objects can be considered as active agents of interpersonal exchange between children and adults. The study adopts a socio-material interpretation, assuming that some interactional patterns, involving the manipulation of objects, can create a space that supports the child-adult relationship. The observations highlight that children present sensorial and realistic play and there are some children's behaviours (i.e., eye-contact) that show that the objects are concrete mediators for the construction of the intersubjective space in the interactions between children and adults. It has been observed in this study that children monitor adults' attention through eye contact or object manipulation. These actions are signs that the object becomes a mediator of mutual attention between the adult and the child: we called this kind of attention, “attention mediated by the object”.

Chapter 4 presents a brief report that investigates the role of the object as a factor that mediates the interaction between children and adults. We observed a group of autistic children in order to analyse if an object can be a promoter of social interactional functions: imitation, joint attention and pointing. The main focus of the study is to analyze in verbal ASD the understanding of social function intrinsic in the object through the use of material features of the object. In particular, the study evaluates the

relationship between the “interaction with/through object” (material features of the object) and three social functions classically impaired in ASD: pointing, imitation and joint attention. We observed a group of ASD children aged between the ending of the sensory-motor stage (24 months) and the beginning of the concrete operational stage (68 months). The group has been split in two sub-groups: group1 is composed of 18 children that act and interact through objects (for examples, balls, cars etc.). Indeed, children manipulate, observe, understand and sometimes give a definition of the object; group2 is composed of 25 children that do not act and interact through and with object. Group 1 shows more social functions (pointing, imitation and joint attention) than group 2 Autistic children which show a more complex use of the material features of the object and act and interact with and through object present more social functions. On the other hand, children which have alteration in the use of the object show fewer social functions. These differences depend on the children’s characteristics. In this study, the role of the object is a crucial element for the creation of the intersubjective space.

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Chapter 2

Theory of Mind and Humanoid Robots From a Lifespan Perspective

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Abstract

This mini-review focuses on some relevant issues concerning the relationship between Theory of Mind and humanoid robots. Humanoid robots are employed in different everyday-life contexts, so it seems relevant to question whether the relationships between human beings and humanoids can be characterized by a mode of interaction typical of the relationships between human beings, i.e., the attribution of mental states. Since Theory of Mind development continuously undergoes changes, from early childhood to late adulthood, a lifespan perspective was adopted. Contributions from the literature were analyzed by organizing them around the partition between ‘mental states and actions’ and ‘human-like features’. Finally, we considered the contribution that studying the human-robot interaction, within the paradigm of Theory of Mind, can give to the understanding of the intersubjective nature of this interaction.

Introduction

This contribution progresses from Turkle's (2004) opinion, which, reflecting on Steven Spielberg's movie, *AI*, exemplifies the most exquisite socio-relational issues of human–robot interaction:

. . .[S]cientists build a humanoid robot, David, who is programmed to love. David expresses this love to a woman who has adopted him as her child. In the discussion that followed the release of the film, emphasis usually fell on the question of whether such a robot could really be developed. People thereby passed over a deeper question. ... That question concerns...[w]hat kinds of people are we becoming as we develop more and more intimate relationships with machines? Today, we are faced with relational artifacts to which people respond in ways that have much in common with the mother in *A.I.* (p. 25).

For hundreds of years, the interest in human–robot interaction has occupied a space in the cultural productions of humankind. Today, we are witnessing a renewed interest in the human creation of a nonhuman alter ego. In particular, researchers are focusing their interest on social interactions with robots. Many scholars believe that a fundamental component of social interaction is the Theory of Mind (ToM; Wimmer & Perner, 1983). ToM is the ability to predict and interpret our own, and others', behavior on the basis of mental states. Herein we offer an overview of work that has focused on the study of human–robot interaction, in the context of ToM. In particular, we review studies investigating the attribution of mental states to robots in a lifespan perspective.

Without the claim of being chronologically exhaustive, we provide some examples of the pervasive interest in artificial partners in the history of humanity. Homer (2003), in the *Iliad* (XVIII, 573–579), told how Hephaestus, the god of fire, who needed help in his forges, built aides, similar to young men, who had hearts, voices, and life. Discussion of the more-or-less human characteristics of intelligent manmade machines has its most famous philosophical roots in the 17th and 18th centuries, in the debate around the works of Descartes and La Mettrie (Gunderson, 1964). Descartes equates animals with machines, but ascribes uniqueness to humans via the term, *cogito* (I think). On the contrary, La Mettrie extends the animal-machine analogy to humans, radicalizing the materialistic and mechanistic perspective.

The mechanical automaton was an attempt to build a human-like artifact, capable of replicating and repeating human activity. In the 13th century, Al-Jazari, an Arabic mechanical engineer, built a programmable device capable of playing sounds autonomously (Nadarajan, 2007). In the 15th

century, Leonardo da Vinci not only theorized on the possible robotic reproduction of an animal, but also advanced a project that attempted to mechanize the human being, with the mechanical knight of 1495 (Rosheim, 2006; Taddei, 2007).

A crucial qualitative leap into the anthropomorphization of machines is to ask whether robots can think, overcoming Cartesian dualism: the philosophical concept that asserts the existence of a separation between *res cogitans* and *res extensa* (i.e., respectively the mind and the body). From a psychological, and more intersubjective³, point of view, and for the purpose of this review, we can rephrase the question as: when will robots be able to make humans believe that they are human? In 1950, Turing published a seminal paper in which he imagined an imitation game with three participants. An interrogator asked questions of the other two participants and, based on the answers, had to guess who was a man and who was a woman. Then, without warning the interrogator, a computer would replace one of the participants. How long would it take to understand that the answers came from a machine, and not from a human being? According to Turing, during the imitation game, it would become increasingly difficult to distinguish the responses of a machine from those of a human (Turing, 1950).

Artistic creativity often anticipates scientific topics on the history of thought. There are many examples in literature and cinema about our subject. Let us remember Shelley (1830/1994), proposing the literary character of Frankenstein, or The Modern Prometheus⁴, destined for a much greater degree of notoriety thanks to the story's many cinematic adaptations. It is also worth mentioning Asimov (1983), who revisited the futuristic concept of a robot by conceiving it as a potential partner for supporting/replacing human activities.

³ The concept of intersubjectivity has various definitions, each of them highlighting different aspects: cognitive, affective, socio-cognitive. The various definitions have in common the idea that the meaning of the tasks and events that the person builds during development is not an operation in solitude but is the result of interaction with real or symbolic partners.

⁴ The story shows the human desire to create an immortal alter ego. The created alter ego turns out to be a monster. Dramatic events lead to the death of the monster's creator and then the monster itself. The monster suicides, explaining the evil deeds it has done while living with the contempt and rejection by humans. The fascination of this story consists in shaping the fears of both partners in this relationship.

Cinema has also represented – now as utopia, now as dystopia – the complexity of the robot’s relationship with humanoids. Fritz Lang’s *Metropolis* (1927) was the first movie to foreshadow the possibility that a robot could substitute for man in the hardest jobs, and that it could begin to interact with man in ways that went beyond any designed intentionality.

The iconic film *Blade Runner* (1982), drawing inspiration from Philip K. Dick’s *Do androids dream of electric sheep?* (1968), highlighted the risk of indistinguishability between

the creator of humanoids and his “children.” Freud (1919/1955) described the characteristics of a particular psychic experience with the experience of the “Perturbant” (*Unheimlich*-unfamiliar vs. *Heimlich*-familiar). Jentsch (1906, 1997) had already described this experience in relation to, for example, puppets and automatons. The latter consist of the uncertainty that a seemingly inanimate being is alive and, in a complementary way, that a living subject has the chance to be inanimate.

This phenomenon reappears in more recent literature as the “Uncanny Valley” experience. Mori (1970) described the sense of repulsion that can accompany interaction with humanoids whose appearance resembles, without being overly superimposed, that of a human (see also Mori, MacDorman, & Kageki, 2012). Another facet of the possible human–robot relationship worth mentioning is the one proposed by Spike Jonze’s *Her* (2013). The protagonist lives a true love story with an almost completely disincarnated artificial intelligence that manifests itself through a very sensual voice. Alongside this experience, the growing presence of anthropomorphic robots in everyday life, in educational, production, and welfare settings, raises several new issues – philosophical, ethical, political, economic, legal, and insurance⁵. While the anxiety about replacing men with robots in production situations, with the associated risk of unemployment and impoverishment, is not new, more recent discussions are about the status of robots, with respect to the new aforementioned issues (Floridi, 2017; Floridi & Sanders, 2004; see also the European Parliament Resolution of 16 February 2017).

In the case of robot-building for social purposes⁶, the extraordinary human capacity to invent and realize tools that integrate and expand the biologically-based abilities of our species (from work tools

⁵ To give just a few examples, think of the use of robots for assistance and companionship to the elderly, the educational and didactic use with children with typical and atypical development, and the execution of various activities in shopping centers, airports, and so forth.

⁶ The military is another area that makes extensive use of robotic engineering (just think of the recent massive use of drones in war). Although the psychological implications are multiple (attribution of responsibility, reliability of information, trust, etc.), we do not consider this field because there is no possibility of attributing mental states to the robot.

to sensory aids to external memory of electronic devices) has been driven in two directions. The first direction – developmental cybernetics (Itakura, 2008; Itakura, Okanda, & Moriguchi, 2008) – consists of creating a human-like system, with cognitive function (simulating psychological processes in the robot) and prosthetic functions (enhancing the function and life-style of persons). The second direction – developmental robotics – consists of the idea that robots can autonomously gain sensorimotor and mental capabilities with growing complexity, starting from intricate evolutionary principles (Cangelosi & Schlesinger, 2015). To date, developmental cybernetics aims to build robots that behave in a human-like way, while developmental robotics aims to build robots that develop in a human-like way. Based on these features, the two approaches are located at different points on a continuum that links interaction and relationship. Developmental cybernetics is closer to the relational dimension; in fact, it studies those human–robot exchanges in which the assumption of some form of subjectivity of the partners is involved. Let us think, for example, about the educational and welfare uses of intelligent machines, in which the dynamics associated with the use of prosthetic tools that improve quality of life are placed on the level of *hic et nunc* (here and now) interaction, without aiming at the construction of a relational story. Conversely, socio-relational dynamics value the level of the relationship (Gross et al., 2012; Tanaka, Cicourel, & Movellan, 2007). Developmental robotics is closer to the interactive dimension; it uses the interaction to study how a robot can develop new abilities, in a child-like fashion. For instance, consider the attempts at robotics modeling of the stages of language acquisition (Morse & Cangelosi, 2017), and the use of mutual imitation between humans and robots to promote the robot’s subsequent recognition of an interactive agent (Boucenna, Cohen, Meltzoff, Gaussier, & Chetouani, 2016).

We are interested in understanding how the attribution of mental states to robots evolves through the lifespan; therefore, we primarily analyze the studies conducted in the field of developmental cybernetics.

Why Robots Could Be Intended as Social Partners

From a psychological point of view, from the earliest moments and throughout one’s entire life, the possibility of establishing social exchanges involves the ability to recognize the other as being “like me” (Meltzoff, 2005; Meltzoff, 2007a, 2007b; Meltzoff, 2013; Meltzoff & Brooks, 2001). Infants can imitate facial movements, such as mouth opening and tongue protrusion (Meltzoff & Moore, 1977, 1983, 1989), and have visual acuity for human faces and stimuli, with characteristics similar to themselves (Johnson, Dziurawiec, Ellis, & Morton, 1991). Proto-conversations with the caregiver

root in these innate imitative mechanisms and, overall, the analysis of traits and characteristics of the relational partner contribute to building the intersubjective dimension underlying so many developmental acquisitions (Meltzoff, 2005; Meltzoff, 2007a, 2007b; Meltzoff, 2013). For this purpose, Trevarthen (1998) spoke of an innate specific human endowment that would guide us to the search for companionship, and put us in the condition of “understanding and using the intentions of other people in conversational talks of intentions, emotions, experiences, and meaning” (p. 16). According to Tronick, Als, Adamson, Wise, and Brazelton (1978), human beings experience the world in intersubjective terms. This trend is related to the tendency of children to first experience the world as if it were animated, and to make a distinction between animate and inanimate only later. This tendency is operationalized by the “still face” paradigm: the motionless face of the caregiver generates in the child a series of emotions from perplexity to anxiety, showing the infant’s expectation to interact with a human partner with an expressive, and therefore animated, face.

A fundamental question, therefore, is: what can the developmental research on human–robot interaction teach us about aspects, features, and cues that a robotic interactive partner must have to be recognized as “like-me?” This question has an epistemological basis. In fact, human–robot interaction represents a “technological gym” that specifies the social cues that must be implemented in a humanoid robot so that children of different ages recognize it and treat it as a social partner.

Below, we analyze contributions from the literature to the lifespan perspective in this regard, by organizing them around “mental states and actions” and “human-like features.” This division arises from the consideration that a representational ToM derives from the infants’ early understanding of the bodily cues of the mental states. In other words, the bodily roots of ToM remain through the lifespan, as the basis of more advanced representational mentalistic skills.

Mental States and Actions

Regarding the first element of the division that we set as the basis of robot attributions of features “like-me,” the research examines aspects of robotic actions that lead participants to believe that the actions imply mental states.

In this sense, a seminal study by Meltzoff (1995) investigated the reenactment of intended acts, performed by human beings versus robot-like devices, in a group of 18-month-old infants. An emerging sense of the person is revealed by the fact that infants did not reenact the action performed by the robot-like device, probably because they did not recognize its intentions and goals.

Itakura, Ishida, et al. (2008) studied this topic further, in children aged 24–35 months, and showed that the children were inclined to imitate goal-directed actions where the goal is not achieved; these failed actions implemented by a robot were imitated only when the robot's action was preceded by eye contact between the robot and an adult present at the scene. When the robot's eye contact with the adult was missing, the child did not mimic the robot's behavior. According to the authors, this evidence shows that it is not human-like morphology, but rather human-like behavior, through eye contact, that plays an important role in inducing children to imitate the goal-directed behavior of a nonhuman agent.

The theme of imitation of goal-directed actions relates to research on mirror neurons⁷, which seem to play an important role in understanding others' actions and, more generally, in social competence. On this basis, Moriguchi, Matsunaka, Itakura, and Hiraki (2012) initially elaborated that the actions are somehow related to perception, and that many human brain areas devoted to the execution of actions also function by observing other human actions, rather than robotic actions. The authors then built on this evidence through a research paradigm verifying whether, and how, actions taken by a human arm or a mechanical arm may somehow interfere with the child's search for an object. A human arm and a mechanical arm sought and found an object in position A. The object was then moved to position B. The child who was asked to look for the object attributed a kind of "retrospective trust" to the human arm, compared to the mechanical arm; in fact, the number of errors committed in the search for the object was higher when the human action preceded the search. The same result had already been obtained in a group of 3-year-olds (Moriguchi, Kanda, Ishiguro, & Itakura, 2010), suggesting that the presence of a mental simulation mechanism would only be activated when the children imitated human actions.

Okumura, Kanakogi, Kanda, Ishiguro, and Itakura (2013a) confirmed this in a paradigm that verified the ability to anticipate the appearance of an object, using the information from a human gaze, rather than a robotic gaze. Through the use of an eye tracker, gaze-following and object anticipation were measured in two groups of 10- and 12-month-old children. Both groups let themselves be guided by

⁷ The mirror neurons are a subset of neurons in the human brain that respond when an individual performs certain actions, and also when the same individual observes others performing the same movements. In other words, actions performed by one person can activate motor pathways in another's brain responsible for performing the same action. Mirror neurons, or mirror mechanism, provide a direct internal experience, and therefore understanding, of another person's act, intention, or emotion. Mirror neurons may also underlie the ability to imitate another's action, and thereby learn, making the mirror mechanism a bridge between individual brains for communication and connection on multiple levels (Rizzolatti, Fogassi, & Gallese 2006).

the human gaze and the robotic gaze; however, only the human gaze had an anticipation effect, and only for the 12-month-old children.

In the context of studies that analyze the importance of the perception of biological motion as the precursor of ToM (Frith & Frith, 1999), Breazeal et al. (2016) considered a group of 3- and 5-year-old children. Note that the ability to use a robotic informant with epistemic aims (name exotic, non-familiar animals for children) is strongly influenced by the nonverbal contingency of the informant (head movements, gaze shifts, arm movements, and facial movements) typical of human face-to-face interactions. From this perspective, Carter and Pelphrey (2006) explored, with functional Magnetic Resonance Imaging (fMRI), neural activations, corresponding to the perception of the movement of four different agents – human, robot, mechanical assembly, and grandfather clock – in 7- to 10-year-old children. The results showed different activations, according to the human-like nature of the perceived biological movement, that is, a motion made by a human or a robot. This brain network also included some components of the mirror neuron system. Replicating the evidence obtained on adults, these findings show that some portions of the neural circuit involved in the embodied simulation are recruited in the perception of the biological movement also enacted by a robot.

We now shift from studies that analyze indirect indicators of the attribution of human-like features to studies that explicitly analyze this attribution. Kahn et al. (2012) interviewed children aged 9, 12, and 15 years, and evaluated the attribution of social, mental, and moral features to robots previously observed in nine different interactive situations with the subject and the experimenter. The authors found an interesting developmental trend: 9- and 12-year-olds perceived the robotic partner as a more mental, social, and partially moral entity than did the 15-year-olds. Therefore, in the construction of robotic partners suitable for participants of preadolescent age, with different purposes (from play to education), it is important to analyze, in detail, what interactive features are strengthened, so that the robot is perceived as the holder of mental, social, and moral characteristics, even by teenagers. Similar results regarding the attribution of mentalistic features to robots, following the observation of goal-directed actions, were obtained using a semi-structured interview of participants aged between 5 and 16 years (Beran, Ramirez-Serrano, Kuzyk, Fior, & Nugent, 2011). The participants tended to attribute behavioral, cognitive, and affective features to robots observed in the execution of a block-stacking task, a construction game in which the robot stacked blocks of wood to form two towers. In carrying out these activities, the robot manifested autonomy through a series of behaviors, such as looking at the child's face, performing accidental actions, and so on. Reminiscent of Piagetian animism, there was also an effect of age such that younger children (under 12 years of age), more

than the older children, believed that robots possess a large number of human attributes (Piaget, 1954).

Chaminade et al. (2010) used behavioral and fMRI methods to explore emotion depiction (anger, joy, and disgust) in gestures acted by human beings and humanoid robots in a sample of young adults. Results showed higher emotion ratings for anger and disgust expressed by the human; no differences were found for joy. Neural evidence suggested less empathy from viewing the humanoid robot: in fact, the activation of the left anterior insula (perception of disgust) and the orbitofrontal cortex (perception of anger) was lower for robot stimuli than for human stimuli. Finally, the higher activation in the occipital and posterior temporal cortices with robot versus human stimuli probably arose from the additional visual processing linked to the perception of a behavior acted by the humanoid robot.

An ingenious way to look directly at the interaction between human and robot is to use economic interactive games. One of the most used interactive games is the Ultimatum Game: one player (responder) receives a monetary offer from another player (proposer), who has to divide the amount. The responder has the option of accepting or rejecting the offer. If the responder accepts the offer, the two participants split the sum of money; however, if the responder rejects the offer, both players receive nothing (Güth, Schmittberger, & Schwarze, 1982). Nishio, Ogawa, Kanakogi, Itakura, and Ishiguro (2012) had young adults play the Ultimatum Game with a robotic partner. Results showed that fairness-oriented behavior increased when “mentalizing stimuli” accompanied cues from the physical appearance of the robotic partner, such as the expression of utterances between experimental sessions (see also Castelli, Massaro, Sanfey, & Marchetti, 2010, for results in a sample of children with a human and a nonhuman partner).

Ultimately, the works presented in this section show that children and adults perceive an experience with an artificial partner as social when the artificial partner can express intentions and goals through behavioral cues that are typical of interactions among humans.

Human-Like Features

With regard to “human-like features,” the research focuses on the configuration of body features being indispensable to humanoid anthropomorphization. It seems that, very soon, human beings will be able to relate to robots according to a principle of similarity to themselves. A first question is

whether biological and psychological characteristics are attributed to robots similarly or differently from other living organisms, and other material entities. Kamewari, Kato, Kanda, Ishiguro, and Hiraki, (2005) showed that 6.5-month-old infants exhibited the ability to attribute agency to human and humanoid-robot motions, but not to a robot without a human-like appearance. A sophisticated teleological representation is assumed in interpreting actions during the early stages of an infant's life, insofar as the agents are human-like. This first result is strengthened by two studies that take into account two human features considered crucial in characterizing one's social nature – eyes and voice.

The first study by Okumura et al. (2013a) showed that the presence of eyes in a robot is crucial for 12-month-old children to have their attention directed by the movement of a robot. In fact, when a robot without eyes was set in motion, this movement was not as informative to the child. The authors interpreted this result by assuming that the presence of eyes was a crucial indicator for the attribution of a mind at this age. The second study by Okumura, Kanakogi, Kanda, Ishiguro, and Itakura (2013b) showed that, for children aged 12 months, the gaze of a robot can be effectively used to learn an object if it is accompanied by a verbalization (not a simple nonverbal sound).

Moving from the preverbal to the verbal age, results obtained by directly questioning the participants about the characteristics of the robots are consistent with the early propensity to attribute human-like characteristics to humanoids. With development, other elements, in addition to the look, become important in deciding whether a partner has human-like characteristics. Katayama, Katayama, Kitazaki, and Itakura (2010) compared humans, robots, animals, and cultural artifacts to study the possible recognition of biological and psychological features in robots by children aged 5 and 6 years, and by adults. While the adults' attributions were quite heterogeneous, both 5- and 6 year-olds attributed a variety of biological but not mentalistic features to robots. Somanader, Saylor, and Levin (2011) asked a sample of 4- and 5-year-olds about the presence of representational, biological and mechanical characteristics in a human being, and in cultural artifacts (i.e., a robot and a TV). They found that the children attributed more representational and biological features to the human being than to the cultural artifacts, and to the robot more than to the TV. They also found that such attributions were more likely to be given to the robot if they did not see that the robot was controlled by a remote. These data reverse the trend found in a previous study, by Saylor, Somanader, Levin, and Kawamura (2010), in which robots and other familiar artifacts, including a TV, were classified as the same thing in terms of biological and representational properties. The authors assumed that the difference between the results of the two studies was due to their efforts to formally anthropomorphize the robots.

Manzi et al. (2017) explored the mentalistic value of faces in anthropomorphic agents compared to human faces through a dichotomous morphing, or gradient, of progressive anthropomorphism. The authors showed that 7- and 9-year-old children ascribed more mental state (e.g., sensory, perceptive, emotive, will, imaginative, and epistemic attributes) to the human face than to a robotic face.

Fiore et al. (2013) explored which elements contributed to creating an impression of the social presence of an agent in a group of late teenagers. To this end, they analyzed the way human beings interpret social cues exhibited by robots, in terms of proxemic behavior (the distance that the robot travels within the human's space). This was investigated by placing the robot and the participant in a hallway-crossing scenario. In this scenario, the authors varied the level of proximity the robot would permit the human in establishing whether to cross paths, and if the robot waited until the participant had passed. The authors also measured the role of the gaze, performed at three levels of direction (congruent with the robot's movement, human-oriented, and variable). The results showed that the robot that waited until the participant passed was evaluated as an agent more socially present than the robot that crossed the path without waiting. Furthermore, gaze did not play a significant role as a social cue in this situation.

Krach et al. (2008) explored human-robot interaction with a group of young adults, using the interactive game the Prisoner's Dilemma and fMRI. In the game, two players must decide whether to cooperate with each other or defect. They may gain a defined sum of points, depending on their own, and their counterpart's decision. A unilateral win is maximized by defection, if the counterpart cooperates, but both players are punished if they defect. Relying on mutual cooperation involves the risk of being deceived. In this study, the game included four different partners, each with an increasing level of anthropomorphization (computer, functional robot, anthropomorphic robot, human). Anthropomorphization was operationalized by following Epley, Waytz, and Cacioppo (2007), who included cues relating explicitly to physical aspects and mental states (elicited agent knowledge, effectiveness motivation). Participants were asked to evaluate the game partner for fun, intelligence, competitiveness, and sympathy. Results showed a linearly increasing attribution of fun and intelligence as the partner appeared more human-like. Interestingly, the anthropomorphic robot and the human were perceived as equally competitive, and more competitive than the computer and the functional robot. Moreover, the authors of the study pointed out that higher levels of human-likeness

were positively correlated with a greater activation of the ToM network, that is, the brain areas⁸ that the literature has shown to be specifically recruited when people interact with a social partner.

Takahashi et al. (2014) focused on the neural bases of human–robot interaction when participants were involved in an economic interactive game (Matching Pennies) with several partners: human, human-like android, mechanical robot, interactive robot, and a computer. The game was played between two players: a participant and an opponent. They had to press a button corresponding to the left or the right side of their bodies. The win situation was reached only when the same side was selected by both participant and opponent. The partners were evaluated concerning two dimensions: mind-holderness (having mental functions) and mind-readerness (being intelligent). As predicted by game theory, the more robotic partners were thought to be mind-readers the more the human opponents changed their play strategies, increasing the level of entropy of exchanges through random choices. fMRI data showed the involvement of different subsets of the social brain, according to the attribution of mind-holderness (dorsal aspect of the temporoparietal junction, medial prefrontal and posterior paracingulate cortices) or mind-readerness (ventral temporoparietal junction and the temporal pole).

Broadbent et al. (2013) studied how the facial characteristics of a robot may influence recognition of the robot's qualities, such as mind, personality, and eeriness, using a sample of young adults involved in a simulated healthcare environment. They employed three robots, respectively showing lack of face, silver face, and human face. The results showed a clear preference for the robot with the human-like face, which was rated as having the most mind and personality, and the lowest eeriness. This specific result relates to the uncanny valley, demonstrating just how subtle the boundary is between a pleasant likeness to the human and a disquieting one.

Similarly, Martini, Gonzalez, and Wiese (2016) studied whether specific degrees of humanness were needed to attribute different typologies of internal states to non–human agents. Interestingly, they found that the threshold “having a mind” must be reached, before being able to ascribe any other kind of internal state. The more the non–human face resembled that of a human, the more this threshold was overcome.

⁸ The ToM network includes the medial prefrontal cortex (mPFC), parts of precuneus and posterior cingulate cortex, the temporoparietal junction (TPJ), the posterior superior temporal sulcus (pSTS) bilaterally; some studies also include the bilateral anterior temporal lobes and areas in the amygdala (Schurz, Radua, Aichhorn, Richlan, & Perner, 2014).

Considering the studies reviewed so far, it is useful to emphasize the great importance given to the face and eyes when considering the physical features capable of representing an agent in anthropomorphic terms. This evidence confirms the great amount of data from ethology, evolutionary psychology, and even studies of aesthetic perception, in support of the great power of the human face in creating a sense of social interaction (Brooks & Meltzoff, 2005; Call & Carpenter, 2001; Emery, 2000; Itakura, Agnetta, Hare, & Tomasello, 1999; Massaro et al., 2012; Moore & Corkum, 1998; Morales, Mundy, & Rojas, 1998; Savazzi et al., 2014; Slaughter & McConnell, 2003; Tomasello, Hare, & Fogleman, 2001; Tomasello, Hare, Lehmann, & Call, 2007).

In conclusion, the information presented in this section shows that interaction with artificial agents is more preferred, and perceived as human-like, when the artificial agent presents aesthetic features that reproduce those of humans, with particular relevance to face and gaze.

Human Beings and Robots: Preliminary Steps Toward Intersubjectivity

The studies reviewed identify features pertaining to mentalizing cues and physical appearance as important bases of the “like me” experience with humanoids. Recent research also suggests that Meltzoff’s (2007a, 2013) “like me” framework can be extended to encompass other dimensions on which human perceivers make “like me” attributions. These dimensions pertain to the nature of the interaction, and other, deeper factors that are just beginning to be explored. A minority of studies delineates an emerging trend of research in this field. These are investigations across the lifespan that consider the role of attitudes and expectations of the human partner, involved in different interactive contexts, in determining preferences and acceptance of the humanoid partner.

Meltzoff, Brooks, Shon, and Rao (2010) explored the hypothesis that 18-month-old infants may use information gained from observing human–robot interactions as evidence about whether the robot is a perceiver. The results showed that the infants attributed mind to the robot, based on the socially-communicative interactions the robot engaged in. This study also demonstrated that the nature of the interaction, and not only the robot’s behavior, mattered.

Tanaka et al. (2007) studied the relationship between 18- to 24-month-old children and a robot, through a long-life immersion technique (45 sessions of approximately 50 min each, spanning 5 months, in the children’s play area). One of the great problems of human–robot interaction is the

duration; long-term study is difficult. Children tire, even though they initially have great interest. The experiment aimed to verify relationship tenure for a time longer than the 10-hr barrier, comparing the employment of a robot able to manifest an entire repertoire of behavior (walking, head- moving, dancing, sitting down, standing up, lying down, hand gesturing, and giggling) to a robot able to manifest only predictable behavior. The relationship improved when the robot was programmed to manifest the entire repertoire of behaviors (27 sessions), worsened when the robot exhibited predictable behavior (15 sessions), and improved again when the robot began to manifest its entire repertoire. The development of socialization strategies correlated positively with frequency of contact with the robot.

Contextualizing the relationship in an educational setting, Movellan, Eckhardt, Virnes, and Rodriguez (2009) showed that interaction between 18- to 24-month-old toddlers and a low-cost sociable robot in an Early Childhood Education Center can significantly enhance word-learning. This evidence is promising, in view of the use of these humanoids with educational and didactic purposes, based on the intersubjective sharing of significant goal-oriented activities. Similarly, Tanaka and Matsuzoe (2012) employed a care-receiving robot to support foreign language learning in 3- to 6-year-old children. These authors showed that the care-receiving role, and not only the teaching role, could be successful in a teaching context. In fact, the condition in which a robot gave wrong answers improved the children's English verb acquisition more than the condition without the robot. Taking into account the relationship between peers, Westlund and Breazeal (2015) introduced a robot, programmed to behave as a peer, to a group of 4- to 6-year-old preschoolers in a storytelling context. The robot was able to lower its linguistic competence in order to match the child's current ability. The evidence showed that a storytelling robot capable of adapting to its partner in terms of language competence, was effective in supporting the oral language development of the child. Robots would seem to have educational skills not only as storytellers, but also as sympathetic listeners. Conti, Di Nuovo, Cirasa, and Di Nuovo (2017) compared a humanoid robot story- teller to a human teacher storyteller in a group of preschoolers. The authors evaluated how the storytellers' social behaviors influenced the children's memorization of the story. Results showed a similar performance in memorizing the details of the story when the storyteller was a robot or a human with an expressive behavior (expression of appropriate emotions with the body and with the voice). The expressive robot was even more efficient than a static inexpressive human storyteller (fixed gaze, motionless body, monotonous voice).

Park, Gelsomini, Lee, and Breazeal (2017) investigated the adaptive capacities of robots as listeners in: giving feedback that informed children about the presence of an active listener, given the abilities

of gazing, leaning forward, nodding, smiling, eye-widening to emulate eyebrow movement, and short utterances. The authors tested two robotic relational styles: a contingent style of the robot capable of reflecting the nonverbal behavior of the child; and a non-contingent style of the robot that emitted random, nonverbal behaviors. Based on children's gaze patterns, the results showed that the contingent robot most relationally engaged the children.

Human-robot interaction research ranges from ToM precursors to social skills of the elderly. Iwamura, Shiomi, Kanda, Ishiguro, and Hagita (2011) focused on the use of a robot by a group of elderly shoppers in a supermarket. They found that an assistive robot that also engaged in non-shopping-oriented conversation was preferred to a robot capable only of functionally oriented conversation. Sabelli, Kanda, and Hagita (2011) introduced a conversational robot into an elderly care setting for 3.5 months, and analyzed its main interactive exchanges with the elderly and the staff using an ethnographic methodology. Three of the six identified trends (basic social interaction, telling robot information, and emotional elements) pertained to the socio-relational/mentalistic dimension.

Again working on the relationship between robots and the elderly in a retirement village, Stafford, MacDonald, Jayawardena, Wegner, and Broadbent (2014) analyzed the attitudes to use mind agency, and attribute mind agency to the robots. The evidence showed that older people preferred to interact with robots to which they attributed less mind agency. These findings were rather counterintuitive because they question the presumed importance of mental state attribution in effective social exchanges. It is likely that the elderly were frightened by the robots because of an overestimation of their cognitive capacities which decreased with actual use.

Gross et al. (2012) presented preliminary results of the implementation of a companion robot for elderly people with Mild Cognitive Impairment (MCI). The evidence emphasized how satisfied the elderly were when interacting with a robot that could support them in executing daily tasks. This work opens up the use of robots in the context of caring for people with neurodegenerative diseases. It also places the importance of assessing the effectiveness of such long-term interventions (weeks or months), and fostering relationships with a truly autonomous robotic partner (hypothetically endowed with a wide behavioral repertoire), as the first point in the agenda for future research.

The studies presented in this section, many of which were conducted in extra-experimental settings, show the importance of a detailed analysis of the contexts in which human-robot interactions take place to fully understand the intersubjective nature of the human-robot interaction.

Conclusions

This review aimed to analyze human–robot interaction from two vantage points: (1) the human attribution of mental states to the robot and (2) the human recognition of the robot as “like-me.” The experience that the robot is “like me” is based mainly on the physical appearance of the robot, and its behavior; however, another aspect emerges that pertains neither to humans, nor to humanoids, but which is a characteristic of their encounters. This aspect is the intersubjective level of the exchange. This dimension contributes some design features of the humanoids, which cannot be conceived as simple artificial instruments for the extension of human abilities. The more a humanoid partner/companion can go beyond a functionally and mechanistically perfect performance, the more it seems “like me.” In other words, an exchange is especially meaningful if it happens with a partner with a human-like capacity to be engaged in somewhat unpredictable, intersubjective exchanges. From our point of view, this unpredictability depends on the subjective nature of the human knowledge and representations of the world. During social exchanges, partners share mental states and representations of the world. The construction of intersubjectivity is based on mutual recognition of the subjective nature of such states and of such representations.

In light of these considerations, this somewhat unpredictable meeting of minds can take different directions, and can be conceptualized in different ways. For example, it can be seen as the optimal level of frustration (Kohut, 1977). All human exchanges with significant partners are characterized by an alternation of gratification and frustration. However, this fact does not compromise human exchanges, provided that the frustration is remediable. A second possible way to conceive the somewhat unpredictable meeting of minds is that of the imperfect contingency (Bigelow, 1998). There is no optimum level of contingent responsiveness in early relationships with caregivers; rather each of us experiences an imperfect contingent responsiveness through parental interactions (i.e., the partners occasionally find the level of relational contingency adequate to the ongoing interaction). This responsiveness influences future exchanges with nonfamily partners. A further possible conceptualization is marked mirroring (Gergely, 2007; Gergely & Watson, 1996), which happens during a child’s affect-regulative interactions. The adult offers the child a reflection of an experience of the world, and of the emotional states of the child itself, and at the same time, the adult informs the child that this reflection is not expressing her/his own feelings. A final interesting conceptualization is offered by the work of Tronick and Beeghly (2011). They stated that interactions consist of a flow of matching and mismatching of meaning, and the reparation of mismatches to

matches. Intersubjective attunement would emerge from the experience of reparation, which in turn would create the experience of connection and shared states.

In the Vygotskijan theoretical framework, the unpredictability and possibility of relational mismatching takes on a particularly interesting form in the Zone of Proximal Development (“the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers”: Vygotsky, 1978, p. 86). In fact, cognitive discrepancy, if salient in intersubjective exchange, can become a powerful engine of learning and development. From this point of view, one of the most intriguing challenges for future humanoids is the possibility that they provide the partner stimuli, inputs, and interpretations that moderately surpass the present partner’s abilities, constructing bridges toward more advanced forms of understanding and capabilities. Looking at the future, our reflections allow us to glimpse the theme of technological singularity. It consists of the invention of a super-artificial intelligence that would result in a sudden “evolutionary” change, able in principle to overcome human intelligence (Eden, Moor, Soraker, & Steinhart, 2012). All this is possible if we consider the intersubjective nature of developmental and educational interactions in which both partners contribute to change and learning. ToM – which has as its core concept the “meeting of minds” – seems to us a theoretical perspective that is particularly well suited to understanding intersubjective interactions.

The end of the Blade Runner movie sums up this possible scenario of potentially open, flexible, and plastic exchanges between human beings and humanoids metaphorically. In fact, it shows as plausible a future of love between Rick Deckard, the replicant hunter, and Rachael, the first replicant without an a priori expiration date. Ultimately, the beauty of uncertainty, more than any other quality, made Rachel special, and therefore very humanlike.

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Chapter 3

It does not matter who you are: fairness in pre-schoolers interacting with human and robotic partners

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Abstract

The relationship between humans and robots is increasingly becoming focus of interest in many fields of research. The studies addressing the various dynamics underpinning the human-robot interaction have, up to date, mainly investigated this relationship analysing adults' behaviour when interacting with different forms of robotic agents. With this study, we present results assessing the human-robot interaction, in which children are the interactive partners. The child-robot interaction was studied – for the first time – observing thirty-one children aged 5 to 6 years playing the Ultimatum Game (UG) with either another child or with a humanoid robot. First, we found that children did recognize the robot as a distinct entity, as assessed through the children's attribution of mentalistic, emotional and physical properties to the interactive agents. Nevertheless, consistently with literature on adults, the results on the UG revealed a very similar behavioural approach when the child played with the other child and with the robot. We finally analysed the children's justifications for their behaviour at the ultimatum game and found that very young children tend to consider “fair” only the divisions that are exactly equal (5-5 divisions) and to justify them either in mere mathematical terms (outcome) or in terms of equity. These results are discussed in terms of Theory of Mind, as well as in light of developmental theories underpinning children's behaviour at the ultimatum game.

Introduction

The introduction of social robots - defined as “autonomous or semi-autonomous robots that interact and communicate with humans by following the behavioural norms expected by the people with whom the robot is intended to interact” (Bartneck & Forlizzi, 2004) - is deeply affecting our society in different fields of the human life. The robots used in industrial processes, for instance, are modifying the job roles and rules [Argote et al., 1983; Kang et al., 2008; Lin et al., 2011; see also European Union, 2017). Prospectively, the introduction of robots in other contexts, such as households, education, care assistance, manufacturing, etc., will also presumably have an increasingly significant effect on human activities and roles. In this perspective, several researches are working towards the implementation of robots in the attempt to make them increasingly similar to the human being [Asada et al., 2001; Di Salvo et al., 2002; Hoffman & Ju, 2014; Robins et al., 2005). The humanoid robots – the ultimate realization of such attempts – are characterized by human-like physical features, behaviours and cognitive processes. The mode and quality of the interaction between humanoid robots and humans will thus possibly change because of the robots’ similarities with humans that call to mind the idea of “they are more like-me” (Meltzoff & Brooks, 2001). The underlying rationale for the implementation of this new generation of robots is to create social partners in everyday life (Kanda et al., 2012), although the other side of the coin that researchers have to deal with in the robot human-likeness is the Uncanny Valley effect (Mori, 1970; Mori et al., 2012). This means that the more a robot has human features and behaves like a human, the more its “eeriness” will induce negative feelings in the interlocutor (Burleigh et al., 2013; Fink, 2012; Gray & Wegner, 2012; MacDorman, 2006; Mori et al., 2012; Sandoval et al., 2016; Scassellati, 2005).

Besides the contexts above mentioned, the implementation of robots is also aimed at aiding different scientific fields, such as anthropology, psychology, ethics, sociology, engineering, informatics, mathematics, physics, etc. (Saygin, 2011; Scassellati, 2003), for example, suggests that the use of the human-like robot could be useful for the study of typical and atypical human social development, allowing to test cognitive, behavioural and development models. In this sense, and from a multidisciplinary perspective, knowledge from developmental psychology is crucial to the implementation of these models since it contributes to the understanding and identification of the precursors underlying human sociality and their ontogenesis. In this respect, Itakura (2008) proposed a new research domain that connects developmental psychology and the study of human-robot interaction. This new investigation field was named Developmental Cybernetics (DC; 2008): it explores the child-robot interactions through the construction of theoretical frameworks that

characterize the design of the robot with the aim to facilitate these interactions (Itakura, 2008; Itakura et al., 2008b). Several studies used the Advanced Telecommunications Research Institute International (ATR) humanoid robot Robovie that can generate human-like behaviours (Ishiguro et al., 2001; Ishiguro et al., 2003). This humanoid robot has been used to test interactions with children in different contexts (Kahn et al., 2012; Kanda et al., 2004). Kanda and colleagues (2012), for example, introduced Robovie to 6th-graders to teach them how to use a Lego Mindstorms. This research showed how Robovie's human-like behaviours contribute to build a human-robot relationship, which goes beyond the more simple human-robot interaction.

Developmental Cybernetics hypothesizes that children can understand the non-human agent through mentalization, and that the construction of social intelligent agents could shed some light on the development processes and mechanisms of the child's mind (2008). In this respect, within the DC approach, Itakura (2008) proposes three abilities, which are critical for making a robot a social agent: Theory of Communication (Itakura, 2012; Itakura, 2013; Nitsch & Glassen, 2015), Theory of Body (Minato et al., 2006; Morita et al., 2012) and Theory of Mind (Itakura, 2008; Itakura et al., 2008a,b). With respect to the Theory of Mind (ToM), it has been proposed that ToM represents an important psychological ability for the study of the human-robot interaction [for a review, see Marchetti et al., 2018). In fact, ToM is essential for the development of social competences, in that it represents the ability to understand one's own and other people's mental states (intentions, emotions, desires, beliefs), and to predict and interpret one's own and others' behaviours on the basis of such meta-representations (Park et al., 2017; Piaget, 1929; White et al., 2009). Several ToM studies show that there are many different behaviours and cognitive processes that are linked to this human skill: imitation, joint attention, pointing, and gaze-following, just to mention a few. (Bandura, 1991; Brooks & Meltzoff, 2002; Camaioni et al., 2004; Charman et al., 2000; Meltzoff, & Gopnik, 1993; Meltzoff & Brooks, 2001).

The researches in the field of child-robot interaction have been increasing in the last decades. Generally, these researches explore what features should be implemented in the robot in order to establish a better interaction between humans and robots. Several studies have been conducted to analyse the effect of different ToM precursors on the interaction between humans and different non-human agents, including humanoid robots [Boucenna et al., 2014; Boucenna et al., 2016; Breazel et al., 2016; Chaminade et al., 2010; Fogassi et al., 2005; Itakura et al., 2008a; Kanngiesser et al., 2015; Meltzoff et al., 2010; Moriguchi et al., 2012; Mutlu et al., 2012; Okanda et al., 2013; Okumura et al., 2013; Rizzolatti et al., 2001; Sloane et al., 2012; Wellman et al., 2001). Generally, the results of

these studies have shown that children tend to attribute mental states to a humanoid robot (Beran et al., 2007; Breazeal et al., 2016; Kahn et al., 2004; Manzi et al., 2017; Moriguchi et al., 2012; Nishio et al., 2012; Park et al., 2017). Already Piaget (1929) suggested that children younger than six-years-old tend to attribute consciousness to objects - namely the capability to feel and perceive - and that children consider “alive” also the things that are inanimate for the adult, *if* these objects serve a function or are used to reach a goal: a phenomenon called animism. In their study, Katayama and colleagues (Katayama et al., 2010) showed that when five and six-years-old children had to attribute biological and psychological proprieties to a human or a robot, children generally discriminated between the two agents, though ascribing some human traits also to the robot. Thus, in line with Torta and colleagues (Torta et al., 2013) idea, when young children interact with artefacts, these acquire the status of relational artefacts: children believe the artefacts – like the robots – to be “alive” and to have an “intention”.

Interaction skills in social contexts are typically studied through use of interactive games deriving from the Game Theory (Camerer, 2013; Villani et al., 2013). One of such games is the Ultimatum Game (Güth & Kocher, 2014; Güth et al., 1982). Used with children, the Ultimatum Game (UG) serves to delineate development in terms of equity and negotiation ability in decision-making, thus focusing on sensitivity to fairness and aversion to inequality (Fehr & Schmidt, 1999). The UG involves interacting with at least another agent, and it is related to the development of ToM in that it activates the ability of mental comprehension, detection and anticipation of the other’s behaviour (Catelli et al., 2014a,b; Castelli et al., 2017; Hoffman & Ju, 2014; Lombardi et al., 2017; Marchetti et al., 2011; Marchetti et al., 2008; Massaro et al., 2017; Srinivasan et al., 2013; Turkle, 2004). In the UG, the subject can play as either the proposer or the receiver. In the *proposer* situation, the subject decides how to allocate resources; in the *receiver* situation, the subject decides whether to accept or refuse a proposed division of goods. The general rule underlying the UG is that the proposer makes an offer, proposing a certain division of goods between him or her and the other player. If the receiver refuses the offer, neither players get anything, whereas if the offer is accepted, both players obtain the proposed division. Using the UG, it is then possible to study interactive behaviour in reciprocal situations from a developmental perspective, comparing behaviour at different ages. Starting from infancy, some studies suggest that infants are responsive to an unequal resource distribution already at 19-month-olds (e.g., Seyama & Nagayama, 2007). Fehr and colleagues (2008) showed that sensitivity to fairness increases from 3 to 8 years of age, and that selfish behaviour decreases from 3-4 years to 5-6 years, although most of 5-6 year olds still tend to not share (78% of the sample).

Additionally, school age children (>7 years) generally behave more fairly when distributing resources and share more than younger children (Fehr et al., 2008;House et al., 2013).

Only few studies have employed the UG paradigm with robots, and – even so – uniquely in interaction with adults. There is in fact not research specifically addressing the relation between robot and children in a UG game. Research on adults generally shows that participants are more likely to behave in a similar fashion when playing the UG with another human or a robotic agent, and this similarity increases the more the robotic agent presents human-like features. Terada and Takeuchi (2017), for example, reported that rejection scores in the ultimatum game were higher in the case of a computer opponent than in the case of a human or robotic opponent, suggesting that people might treat a robot as a reciprocal partner as when playing with another human. Nishio and colleagues (2012) also tested university students while playing the UG with four different artificial agents, which differed in the degree of similarity with humans. In their study, there were four conditions: computer terminal (Computer condition), humanoid robot (Humanoid condition), android robot (Android condition) and human (Human condition). They included a mentalizing stimulus for each agent, which consisted of four shorts interactional sentences pronounced by each agent when meeting the subject, e.g., “how are things going?”. Furthermore, the authors administered a post-experimental questionnaire in order to test how participants perceived the agents (i.e., human likeness, or machine likeness). The authors examined the number of rejections of the agent’s proposals and the number of the agents’ fair and unfair proposals, both measures used as indicators of recognition of the agents as social entities. The results showed that, when the agent looked like a human, the fairness of the proposals and the refusal rate were similar to when interacting with a human, and particularly, when introducing the artificial agent after the interactional sentences. Additionally, Nitsch and Glassen (2015) analysed a group of young adults, who played the UG with a human agent and with a humanoid robot behaving so as to be perceived animated or apathetic. The results showed that the participants that played in the animated robot condition perceived the interactions more positively and human-like than in the apathetic condition. Robins and colleagues (Robins et al., 2005) also studied reciprocity in the human-robot interaction in a sample of young adults through the UG and the Prisoner Dilemma. The results showed that the participants were equally reciprocal with the human and the robot, despite the fact that the robots collaborated more with humans in the Prisoner Dilemma task, indicating that the human-human interactions are nevertheless privileged with respect to the human-robot interactions. Finally, Takagishi and colleagues (2010) examined the effect of different robots’ facial expressions in the UG, and showed that emotional expressions had an effect on the offers made by the participant to the robot compared to offers made to a computer displaying a simple line drawings face.

Altogether, the results from the studies here described suggest - in adult subjects - a proclivity to interact with robotic agents in a very similar fashion as when interacting with other humans.

As far as children's behaviour is concerned, there are no studies so far addressing children's decision making during an interactive and reciprocal social situation with a robot. In the present study, we made an attempt to fill this developmental gap exploring interactive behaviour during the UG when a child played with either another child (human agent) or with a robot (humanoid robot). Our sample children were aged five-to-six years. At this age, children show to have an acquired ToM capability of – at least - first order (Wardle et al., 2002). First order ToM entails a recursive thinking, which implies the meta-representation or the representation of a mental representation, of a low level of complexity, of the kind of: “I think that you think...”. In this respect, we hypothesized that children aged 5-6 years were able to discriminate between *agency* (human agent and humanoid robot) on the basis of mental states attribution. However, we were not able to advance any predictions in terms of differences in children's decision-making strategies when playing with a human and a robot, since no such literature exists specifically referred to the UG.

In this study, the children played both as proposers and as receivers. Additionally, children's performance on the UG task as a function of *agency* was evaluated against several socio-demographic, as well as, cognitive factors. Finally, an analysis of the children's justifications for their behaviour, both when playing as proposers and receivers, was carried out, outlining – for the first time – some response patterns that characterize the rationale underlying these children's game strategy.

Method

Participant

Thirty-three (33) Italian kindergarten children participated in the experiment. Two children were excluded from the study: one failed the First-Order ToM task and the other one failed the Inhibition task (see below). Data analysis was therefore carried out on 31 children (males=18, females=13; mean age = 70.8 months, SD=2.99). The children attended three different schools of Milan and Turin areas. The children's parents received a written explanation of the procedure of the study, the measurement items, and the materials used and gave written consent. Children were neither referred to social services nor reported by teachers for leaning and/or socio-relational difficulties. The study was

approved by the Local Ethic Committee (Università Cattolica del Sacro Cuore, Milan).

General Procedure and measures

The children were tested individually in a quiet room in the kindergartens. Administrations were carried out by a single researcher both in the morning and afternoon during normal activity. The children were assessed in two experimental sessions in different days within two weeks timeframe. The administration of the tasks in two independent sessions was done not to overly tire the children with an excessively long procedure as well as not to significantly disrupt the child's normal school activity.

In the first session, the children were administered the following tests: the First-Order False-Belief task, and two First-Order False-Belief videos, assessing first-order Theory of Mind; two Strange Stories, assessing advanced Theory of Mind; and the Attribution of Mental States scale. In the second session, the children were administered the following tests: the Family Affluence Scale, assessing the socioeconomic status; two executive functions tests, assessing the ability to inhibit behaviour and working memory; further two First-Order False-Belief videos; further two Strange Stories; and the Ultimatum Game, assessing fairness.

The tests were so distributed within sessions to balance the total time required to complete the whole battery, which was of approximately 45-50 minutes. In fact, each session lasted about 25 minutes. Within each session, the administration of the tests was randomized across children.

Socioeconomic status

To assess the children's socio-economic status, we used the Italian translation of the Family Affluence Scale (FAS; Boyce et al., 2006). This test is composed of four items measuring family wealth, and more specifically: 1) family car ownership (score range = 0–2); 2) own bedroom (range = 0–1); number of computers at home (range = 0–3); how many times they went on holiday during the past year (range = 0–3). The FAS total score was obtained adding up the four-item scores (total range = 0-9).

Executive functions (Inhibition and Working Memory)

We tested the children's executive functions using the Inhibition "A Developmental NEuroPSYchological Assessment" subtest (NEPSY II; Korkman et al., 2007), testing the ability to inhibit automatic responses in favour of novel responses and the ability to switch between response types. The child looks at a series of black and white shapes or arrows and names either the shape or direction or an alternate response, depending on the colour of the shape or arrow. In the present study, we used the combined scores of the Inhibition NEPSY-II subtest, which associates accuracy and speed of response.

Furthermore, we used the Backward Digit Span, testing working memory. Concerning the Backward Digit Span, the experimenter presented orally number sequences and the child was required to repeat them in reverse order. The test started with three sequences of two digits, gradually introducing triples of sequences of increasing length, to a maximum possible length of eight digits. The test stopped when the child failed all three sequences at the same length. The score was calculated as follows: children received 1 when they reversed at least two out of three sequences; if successful, the child passed to the next longer series, scoring 0.33 reserving at least one out of three sequences. The decimal scores were then summed to obtain the main score (e.g. $1+0.33 = 1.33$) until the children reached 1 (e.g. $1+0.33+0.33+0.33 = 2$), if necessary.

First-order false belief task

To assess first-order ToM, we used the story of the classical *Unexpected Transfer* task (Wimmer & Perner, 1983). The experimenter told the story using: two dolls (one male and one female), one ball, one box and one basket. The story is about two siblings playing with a ball in a room. One of the children puts the ball in a box and leaves the room. Meanwhile, the other child takes the ball out of the box, puts it in the basket and goes away. Finally, the first character comes back in the room and wants to play with the ball. At the end of the story the experimenter asks the child the following questions: "What is the first place where he will look for a teddy bear?" – referring to the first character (First-Order False Belief question); "Where did the child put the ball before going upstairs?" (control memory question); "Where is the ball really?" (Reality control question).

The answers to the two control questions (memory and reality) were used to filter the children's performance: children who did not pass them scored 0 and their performance on the First-Order False Belief question was not evaluated. If the children passed the control questions, the test question about the false belief scored 1 if correct and 0 if incorrect.

First-order false belief task: Video Stimuli

To assess children on the First-Order False Belief, we introduced – besides the commonly used task as described above – a new instrument, namely eight videos representing the classical story, this time introducing also the Robovie as a new character. More specifically, we used a story similar to the classical *Unexpected Transfer* task (Wimmer & Perner, 1983) as the script of the videos. The videos started presenting two characters (two children, two robots, or a child and a robot) in a room with two different boxes of a different colour (blue and pink) placed in front of them. Subsequently, one of the characters put a teddy bear under one box (the same for all videos) and then left the room. When the other character was alone in the room, he or she moved the teddy bear under the other box and left the room. Finally, the first character returned into the room to take the teddy bear. A voiceover narration described the story in each video.

The videos were recorded with five different actors: two children (C1 and C2) and three Robovies of different colours (White Robovie, WR; Green Robovie, GR; and Red Robovie, RR). Moreover, the five actors could play two different roles: the character who made the transfer (MtT) and the character who underwent the transfer (UtT). We used the WR for the human-robot videos and the other two Robovies (GR and RR) for the robot-robot videos. Thus, we videotaped eight different videos crossing the two children, the three Robovies, and the two roles. We created two different protocols, which were randomly assigned to the children. The first protocol was composed of four videos: 1) C1 playing the MtT role with C2; 2) C1 playing the MtT role with WR; 3) WR playing the MtT with C1; 4) GR playing the MtT with RR. The second protocol was composed of the following four videos: 1) C2 playing the MtT role with C1; 2) C2 playing the MtT role with WR; 3) WR playing the MtT with C2; 4) RR playing the MtT with GR. Within each protocol, the videos were presented randomly. We used the same scoring criteria as that used for the First-Order False Belief task (see above). The videos can be found in Electronic Supplementary Material.

At the end of the story, the experimenter asked to the child the following questions: “What is the first place where she will look for the teddy bear?” (First-Order False Belief question); two control questions (Memory and Reality as described above).

Strange Stories

We assessed the children's advanced ToM using the Strange Stories task (Happé, 1994; Westlund et al., 2017), whose Italian translation had been already used in other studies (Cattaneo et al., 2007; Lillard, 1994). This task evaluates the ability to make inferences about mental states by interpreting non-literal statements. We selected a subgroup of four mentalistic stories involving double bluffs, misunderstandings, white lies, and persuasion. After reading the stories, we asked the children to explain a character's behaviour without a time limit. The experimenter transcribed *ad verbatim* the child's answers. Scoring was based on the general guidelines (Westlund et al., 2017): 0 for incorrect answers, 1 for partially correct answers, and 2 for full and explicit answers. Two raters independently coded 30% of the responses. The inter-rater agreement was substantial (Cronbach's Alpha = .96). Disagreements were resolved through discussion between the raters. Total scores ranged from 0 to 8. The analysis of the children's performance on the strange stories showed a quite poor general performance. In fact, the children scored very low, ranging from 0 to 3 out of a total possible score of 8.

Attribution of States

The Attribution of States is a measure of states attribution that the child has to make looking at pictures depicting a character. The Attribution of States (AoF) is an *ad-hoc* questionnaire that was drawn from the questionnaire described in Martini and colleagues (Martini et al., 2016). This test was aimed at assessing what features the subject (the child) ascribed to the interactive agent (another child or the robot) in mental, emotional and physical terms. In this study, the experimenter first showed to the child two pictures depicting a child and a robot and then asked the child - as a control question - what was depicted in the picture (Reality question): if the child correctly recognized the child and the robot, the test went on; if the child responded incorrectly, the experimenter corrected the child making sure that he or she was fully aware of the agent's identity and then proceeded with the test. No children failed in the Reality question; that is, all of the children correctly recognized the child and the robot at first instance.

The presentation order of the two face pictures was randomized across children. After presenting the picture and asking the Reality question, the experimenter asked the child 25 questions referred to the agent's mental states. The child had to respond "Yes" or "No" to each question. The 25 questions were grouped in five different categories of mental states: Epistemic, Emotional, Desires and Intentions, Imaginative, and Perceptive. The total score was the sum of the "Yes" answers (score range = 0-25); the five partial scores were the sum of the "Yes" answer to each category (score range

= 0-5).

Ultimatum Game

A standard version of the Ultimatum Game (UG; Güth et al., 1982) was used to evaluate fairness. During the game, the child (playing as proponent) could decide how to distribute 10 stickers between him or her and a passive player, represented by a graphic representation of either a child – human agent (e.g., Castelli et al., 2010) or a robot. The graphic representation of the other child corresponded to a male figure when the child was a boy, whereas it represented a female when the child was a girl. The stickers depicted known animals by the children (e.g., dogs, cats, tigers, lions, birds, fishes, etc.). The minimum amount of stickers that could be offered during the game was 1, and the maximum amount was 9. After playing the UG, the child was actually given a final amount of stickers

During the UG, the children played one round as proposer and five rounds as responder, for a total of six rounds. Playing as proposer, the child could decide how to divide the stickers with the other child or the robot (graphic representation) and, playing as responder, the child could decide whether to accept or refuse the proposed division. In case of acceptance, both players received the respective proposed amounts; in case of refusal, neither player gained anything.

When playing as responder, each round (5 in total) corresponded to a specific type of proposal, ranging from a division of 5-5 (fair) to a division of 1-9 (highly unfair). The rounds were randomized across children. For each round, the child could accept or refuse the offered amount, receiving a score 1 in case of acceptance and 0 when refusing the offer. The total amount accepted was also calculated (range = 0-15) when the child played as receiver, which corresponded to the total gain for each child. Similarly, when playing as proposer, the total amount proposed was also calculated for each child (range= 0-9).

UG procedure

Before starting the game, the experimenter explained the game rules presenting four different examples in a graphic format: 1) an adult playing as proposer with a child, who accepted the offer; 2) an adult playing as proposer with a child, who refused the offer; 3) a robot playing as proposer with a child, who accepted the offer; 4) a robot playing as proposer with a child, who refused the offer.

During the game, the researcher played “the other child’s/robot’s” role, proposing, accepting, or refusing offers. The children’s performance at the Ultimatum Game was evaluated in a single session lasting approximately 10 minutes in total.

At the end of the game, the children were asked the reasons that they placed a certain offer (proposer) or accepted/refused a certain proposal (receiver). The children’s answers were classified according to three criteria: 1) outcome – the justification refers uniquely to the *amount offered or received* without commenting on or referring to the other player in mental terms (e.g., “because I like that he does not have anything and I have them all”; “because I wanted to win”); 2) equity – the justification includes terms that refer explicitly to the *construct* of equity, independently of whether the amount offered or received was equal or unequal (e.g., “because in this way we are even”; “because it was nicer to give him three and I like to share them”); 3) mentalistic – the justification includes terms that *refer to the other player in mental terms* (e.g., “because he would like me to receive more”; “he believed that I would win”)⁹.

Results and Discussion

All of the continuous variables were normally distributed with skewness between -1 and 1.

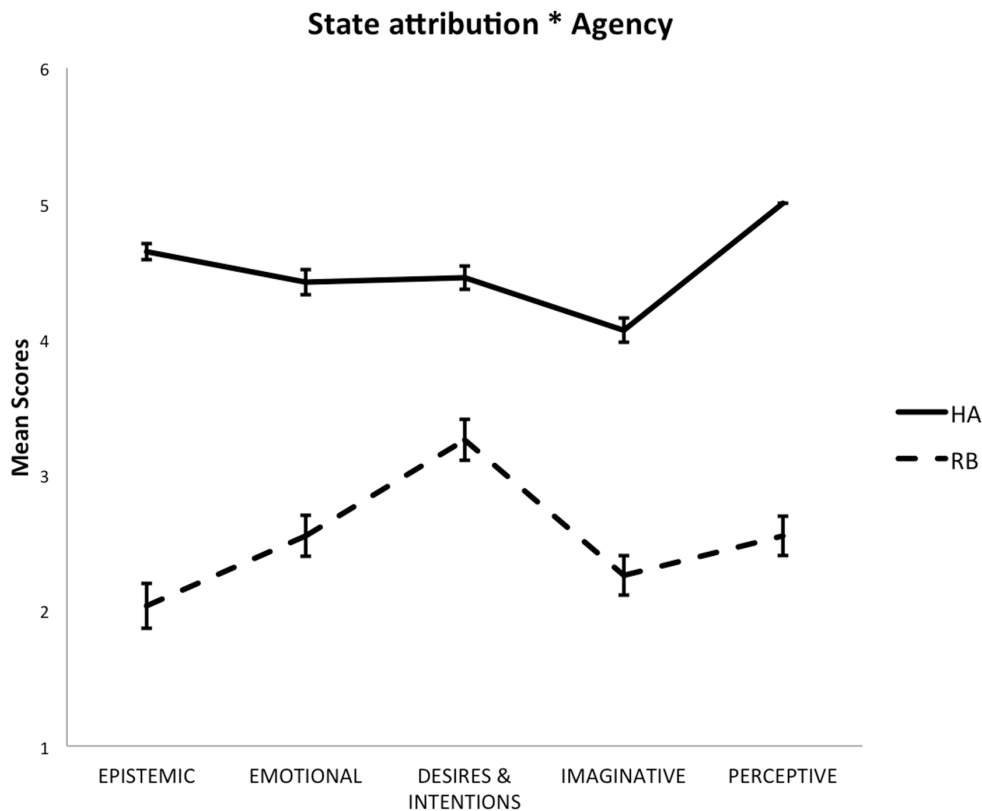
Attribution of States Scale

With this analysis, we compared the attribution of states - as described in the methods session - to the human agent (the other child) and to the robot. The inspection of the boxplots revealed a tendency towards maximum scores (5) in the case of state attribution to the human agent - particularly with respect to the perceptive state, where we observed a ceiling effect - and a normal distribution in the case of states attribution to the robot. A repeated measures general linear model (GLM) was carried out with five levels of *state* (epistemic, emotional, desires and intentions, imaginative, perceptive), and two levels of *agency* (human vs. robot) as the within groups factors. The results showed a main effect of *state* ($F_{4,120}=5.94$, $p<.0001$, $partial-\eta^2=.17$, $\delta=.98$), a main effect of *agency* (HA>RB; $F_{1,30}=53.82$, $p<.0001$, $partial-\eta^2=.64$, $\delta=.1$) and a significant interaction *state*agency* ($F_{4,120}=7.90$, $p<.0001$, $partial-\eta^2=.21$, $\delta=.1$). Post hoc analyses (Bonferroni corrected) showed that the states that scored higher were desires and intentions – which scored significantly higher than both epistemic

⁹ Ad verbatim translation from Italian.

($M_{diff}=.69, p<.01$) and imaginative ($M_{diff}=.52, p<.05$) – and perceptive state, that scored significantly higher than imaginative state ($M_{diff}=.61, p<.01$). Additionally, the analyses showed that the interaction effect stemmed primarily from differences between *states* within *agency* (HA, RB). More specifically, with respect to states attribution to HA, the epistemic state scored higher than imaginative state ($M_{diff}=.58, p<.01$); whereas the perceptive state scored higher than all the other states ($p<.05$) except for the epistemic state, which just failed to reach significance ($M_{diff}=.36, p=.055$). With respect to state attribution to RB, the results showed that desires and intentions received higher scores compared to the epistemic and imaginative states ($M_{diff}=1.23, M_{diff}=1.00$, respectively; $p<.001$). These results are summarized in Figure 1.

Figure 1: Mean scores obtained by the children during the attribution of states (epistemic, emotional, desires and intentions, imaginative, and perceptive) to the human agent (HA) and to the robot (RB). The bars represent the Standard Error of the mean.



The results on the attribution of states to HA and RB revealed that children clearly attributed different states on the basis of agency, with HA receiving higher scores on all states attribution compared to RB. This shows that children had a correct perception that the other child had epistemic and emotional

states, intentions and desires, an imagination and perceptive properties, which are different from that of a robot, therefore considering this latter as a distinct entity.

Within agency, children tended to ascribe poor imagination to both the child and the robot. This is in line with evidence showing that young children's imagination abilities mature gradually (Harris, 2000; Harris & Leivers, 2000; Lillard, 1994; Lillard, 2013). Interestingly, the differences observed within the attribution of states to the robot indicate that children tended to ascribe desires and intentions also to the robot, although to a significantly lesser extent than to the human agent. Desires and intentions attribution to the RB, in fact, received greater scores than all the other states, and substantially more than the epistemic and imaginative states. During video watching (see methods), the children observed the RB in action, and this may have led the children believe the robot as having intentions. In fact, also from a neurophysiological perspective, movement and intentions go hand in hand [see, for example, Gray & Wegnaer, 2012; Premack & Woodruff, 1978] as also suggested by psychophysiological evidence with children (Cavallini et al., 2013). All the same, in the present study, while attributing intentions to the robot, the children ascribed to the robot a low ability to think, understand, and decide (epistemic attribution). These results, apparently in contrast, are on the other hand much in line with the idea of animism introduced above, and namely with young children's tendency to attribute a living soul to plants, inanimate objects, and natural phenomena, while being aware that these entities are non-living. The fact that this idea applies to objects only *if* these objects serve a function or are used to reach a goal (see Katayama et al., 2010; Perner & wimmer, 1985; Turkle, 2004], further supports the movement and intention interpretation just described (Chaminade et al., 2010; Sandoval et al., 2016).

Ultimatum Game

The main aim of the present study was to assess whether the child behaves differently when acting with a human agent or with a robot during an interactive situation. We therefore had the child playing the UG with either another child or with the robot, as both proposer and receiver.

Proposer

A t-test comparing the total amount offered to the other child or to the robot when the participant played as proposer showed no significant difference in the total amount offered (HA: $M=3.71$, $SE=.31$; RB: $M=3.55$, $SE=.35$; $p>.05$). Additionally, a high internal consistency (Cronbach $\alpha =.85$)

was observed between each individual child's behaviour when playing with the human agent or the robot. Table 1 reports the children's proposed divisions to HA and RB.

Table 1: Statistics of children's offers when playing as PROPOSERS; ns = not significant; na = not applicable.

	HA – RB	HA – RB	HA vs. RB
Proposed Division	N	%	Sign (<i>p</i>)*
1-9	0 – 0	0 – 0	na
2-8	0 – 0	0 – 0	na
3-7	0 – 1	0 – 3	na
4-6	5 – 5	16 – 16	ns
5-5	7 – 4	23 – 13	ns
6-4	9 – 7	29 – 23	ns
7-3	3 – 5	10 – 16	ns
8-2	2 – 3	7 – 10	ns
9-1	5 – 6	16 – 19	ns
tot	31 – 31	100 – 100	

**Wilcoxon rank test*

These results are in line with the literature [e.g., 28] showing that pre-schoolers tend to make offers that favour their own gain, although the frequency of children that made offers towards fairness (i.e., ranging between 4-6 and 6-4) was quite substantial (68% towards HA; 55% towards RB). Additionally, these results extend previous findings showing that five-year-old children's behaviour and game strategy is consistent independently of whether the child plays with another child or with a robot, in line with the large body of existing literature on adults, as fully introduced above.

Receiver

Within this analysis, we summed up all acceptances when the child played as receiver, therefore calculating the total amount gained by each child. A t-test comparing the total acceptances from the other child and the robot showed no differences in the total amount accepted as a function of *agency* ($t=.75$, $p>.05$), indicating that the children accepted similar amounts when playing with HA ($M=10.97$, $SE=.77$) and with RB ($M=10.45$, $SE=.95$). This result is congruent with the data above described, showing children's tendency to adopt a similar game strategy when playing with the other child or with the robot.

Specifically comparing the children's acceptances of each proposed division from HA and RB, our results confirmed no differences in the frequency of acceptances as a function of agency within division (for statistics, see Table 2). Additionally, comparing the frequency of acceptances between successive divisions for both HA and RB, the Wilcoxon test showed not significant differences for the child (i.e., 5-5 vs. 6-4; 6-4 vs. 7-3; etc.; $p > .05$), whereas we observed significant differences for the robot. More specifically, acceptances of the 6-4 division were significantly lower than acceptances of the 5-5 division (71% vs. 90%, $p < .01$), as well as acceptances of the 7-3 compared to the 6-4 divisions (52% vs. 71%, $p < .01$). This latter result shows a significant, although minor, tendency of children to accept slight unfair offers more from another child than from the robot.

Table 2: Comparison of refusals and acceptances of proposed divisions during the UG when the child played as receiver with another child (HA) and with the robot (RB) (N=31). *P-values* were non-significant (ns) at a value of .05.

		HA	RB	<i>HA vs RB</i>
Division		N (%)	N (%)	Sign (<i>p</i>)*
5-5	Refuse	3 (10)	3 (10)	ns
	Accept	28 (90)	28 (90)	
6-4	Refuse	7 (23)	9 (29)	ns
	Accept	24 (77)	22 (71)	
7-3	Refuse	12 (39)	15 (48)	ns
	Accept	19 (61)	16 (52)	
8-2	Refuse	16 (52)	13 (42)	ns
	Accept	15 (48)	18 (58)	
9-1	Refuse	14 (45)	15 (48)	ns
	Accept	17 (55)	16 (52)	

*McNemar's Test

Correlations

Pearson's correlations were carried out between the total scores at the ultimatum game when the child played with the other child and the robot, as both proposer and receiver. The results showed, as expected, a substantial correlation between the total amount proposed to the other child and the robot ($r^2 = .56$, $p < .01$), as well as a strong correlation between the total amount accepted by the other child and the robot ($r^2 = .49$, $p < .01$). Additionally, the scores obtained at the UG were further correlated with demographic, cognitive, and socio-economic variables: age (months); the child's gender; working memory scores; the ability to inhibit behaviour scores; the intentionality test scores; and the Family

Affluence Scale scores. These correlations are summarized in Table 3. In general, no significant correlations were observed between the scores obtained at the UG and any of these variables ($p > .05$).

Table 3: Correlation analysis between the total scores at the Ultimatum Game when the child played as proposer with a robot (1) and the child (2) and when the child played as receiver with the robot (3) and the child (4). These scores at the UG were correlated with demographic, cognitive, and socio-economic variables: Age (months); child's Gender; working memory (WM) scores; ability to inhibit behaviour (INHI) scores; Intentionality Test scores (IT); and Family Affluence Scale (FAS) scores.

Pearson Correlations

		1	2	3	4	Age	Gender	WM	INHI	IT	FAS
1)	Total Offer to the Child	1	,746**	0,298	0,179	0,218	-0,085	0,186	0,01	0,146	0,213
2)	Total Offer to the Robot		1	0,191	-0,015	0,224	-0,004	0,202	0,024	0,233	0,237
3)	Total Acceptance from the Child			1	,700**	0,069	0,285	0,151	0,293	0,354	0,165
4)	Total Acceptance from the Robot				1	0,047	0,329	0,251	-0,1	0,255	0,195

** Correlation is significant at the 0.01 level (2-tailed).

Analysis of the children's justifications at the UG

After the child played the UG in both the proposer and receiver roles, the experimenter asked him or her to explain the reasons for his or her division. The children's answers were classified as "outcome", "equity", or "mentalistic" (for details, see methods). Two independent judges evaluated the children's justifications.

Proposer

The inter-rater reliability scores were substantial both when assessing the child's justifications when playing with the other child (Cronbach's Alpha = .88) and when playing with the robot (Cronbach's Alpha = .91).

Analysing the frequencies of children who gave a specific justification to their behaviour for each division when making an offer, the results showed an even distribution of justification type (amount, equity) when the children offered a precise fair amount (division 5-5), whereas a skewed distribution of justification type toward "amount" when the children started placing offers that privileged their

own gain. This was independent of whether the child played with the HA or the RB. A summary of the frequency distribution of justification types for each proposed division is presented in Table 4A.

Receiver

The inter-rater reliability scores were calculated for each proposed division (5-5; 6-4; 7-3; 8-2; 9-1). The results showed substantial agreements both when assessing the child's acceptance/refusals justifications interacting with the other child (mean Cronbach's Alpha = .83; min=.82, max=.84) and with the robot (mean Cronbach's Alpha = .83; min=.80, max=.84).

With this analysis, we compared the frequency of children that provided a justification when accepting or refusing each proposed division. Justification types were different when the child received a 5-5 or a 6-4 division, independently of *agency* (HA, RB). When receiving a 5-5 division, the justifications were either based on "outcome" (HA: N=13; RB: N=14) or on "equity" (HA: N=18; RB: N =16); only one child presented a mentalization-based justification when interacting with the robot. When faced with a 6-4 division, the majority of children (HA: N=26; RB: N =28) presented a justification for their acceptance or refusal based on "outcome"; five children presented a justification based on "equity" and none based on "mentalization" when interacting with the other child; only one child presented a justification based on "equity" and two children a justification based on "mentalization" when interacting with the robot. A summary of the frequency distribution and statistics of acceptances and refusals of each proposed division and type of justification is presented in Table 4B. In general, these results suggest that, when children received a division proposal skewing towards unfairness, the equity and mentalization-based justifications decreased substantially ($\chi^2_{(4)}=16.47, p<.001$), in favour of the outcome-based justification.

The analysis of the children's justification for their behaviour - both when playing as proponents and when playing as receivers - indicates that children tend to regard fair (and hyperfair) divisions either in terms of outcome or in terms of equity-based reasoning, with an approximately equal split. When the division starts skewing, even slightly (i.e., 6-4 division), towards unfairness, the types of justifications offered remarkably bias towards an outcome-based reasoning. It is noteworthy observing that mentalistic-based justifications were very poor, if not even inexistent, in all proposed scenarios. This general behaviour was observed both when the child played with the other child and with the robot, indicating no differences in the type of reasoning underlying specific choices as a function of agency.

On the whole, the results on the UG suggest that children aged five years behave quite fairly, though showing a tendency towards favouring their own gain placing and accepting unfair – and even *very* unfair – divisions, in line with current literature describing pre-schoolers' behaviour during the UG (see, for example, Lombardi et al., 2017). Lack of behavioural differences as a function of agency (HA vs. RB) further appears to indicate that the children at this age tend to disregard to other's mind when making choices, following a very consistent strategy throughout the game on the basis of other criteria (e.g., tendency to maximise gains) or personal traits (e.g., disposition to fairness). This is particularly true if considering the fact that the robot was indeed considered an entity different from the human agent (the child), so as observed from the analysis of the states attribution described above. This idea of a much ego-centred behaviour is further supported by the analysis of the children's justifications for their decisions when placing specific offers (proposers) and when accepting or refusing certain offers (receivers). In fact, analysing the frequencies of children who gave a specific justification for their behaviour, the results showed an even distribution of justification type (amount, equity) when the children offered or accepted a fair amount both to/from another child and to/from the robot; whereas we observed a remarkably skewed outcome-based justification when the children offered or accepted/refused unfair divisions. These latter results are further discussed below.

General Discussion

This study investigated 5 year-olds' behaviour at the ultimatum game. The aim of this study was to compare young children's game strategy when they played with another child (human agent) and with a robot. The results showed that children's game strategy was very similar when playing with the other child and with the robot, independently of the role played (proposer or receiver). The children were quite conservative both when offering and accepting proposals, that is, the children generally tended to offer and to accept fair divisions (5-5), although almost half of children proposed and accepted also unfair divisions, ranging from 6-4 to 9-1. These results are in line with the developmental literature on UG. For example, Benenson and colleagues (2007) observed that children aged 4 years donated less than 6 and 9-years-old, showing that sensitivity to fairness increases with age. Furthermore, a recent research by Lombardi and colleagues (Lombardi et al., 2017) showed that, at 6 years, children displayed a more selfish behaviour than children aged 8 and 10 years, highlighting that younger children tend to maximize their gain accepting also unfair offers.

Importantly for the present purpose, no significant differences were observed between offers and

acceptances made to or received from the other child or the robot. In this respect, children's behaviour observed in this study when interacting with the robot is comparable to the adults' behaviour reported in several studies. Terada and Takeuchi (2017) for example, showed that, when playing the UG, adult participants took approximately the same time to decide how to distribute goods between a human and a robot. In the study by Kahn and colleagues Kahn et al., (2012), the frequency of acceptances and refusals became closer to that toward a human when the robot had more human-like features. Similar results were also found by Rosenthal-von der Pütten and Krämer (2014). On the whole, these results suggest that, when bargaining, the other player is regarded independently of agency: the other player's mind appears to be a reflection of our own mind and strategic thinking, whether or not the other has a mind at all, such as in the case of a robot.

With respect to the acceptance of offers made when the child played as receiver in the present study, although behaviour was comparable when the child played with another child or with the robot, it is worth noting that the results showed a significant, although minor, tendency of children to accept slight unfair offers more from another child than from the robot. In this respect, one may suggest that children's expectancy from a robot is to be a totally fair player – since it does not have a mind of its own that can work strategically. In this light, divergence from this initial expectation is less accepted compared to situations in which children play with a human peer. In this latter case, in fact, the other player (the human) - having a mind - is supposed to be able to apply a game strategy and, eventually, to be also unfair. Alternatively, but not mutually exclusive, one may suggest that the child believes to have a distinctive status compared to the robot that, as assessed through the test of attribution of states, is perceived as a different entity with respect to a child at all levels: epistemic, emotional, imaginative, and physical. Also in this light, unfair offers would be less accepted when made by a robot than by a peer.

Finally, with respect to the results from the analysis of the children's justifications at the UG, it is interesting to observe that the reasons provided by the children for their behavior, both when playing as proposers and responders, suggest that children aged 5 years tend to consider fair only a division that is exactly fair (5-5). A slight skewed division towards unfairness (i.e., 6-4) already falls within the range of categorization that characterizes very unfair proposals, regardless of whether the proposals are made or received. Additionally, it is noteworthy to observe that fair or slightly hyperfair divisions are typically justified in either outcome or equity terms, whereas unfair offers are mostly justified in terms of quantity. Mentalization-based justifications are poorly made for all divisions, although – in these cases – it is curious to observe that, when playing as proposer, mentalization–

based justifications are uniquely confined to the most fair divisions (4-5; 5-5; 6-4). In general, these observations may suggest that children, particularly in the case of unfair offers, tend to not use mentalization-based explanations in order to reduce the distress stemming from the discrepancy between a “socially-expected” equal behaviour and the actual “selfish” behaviour. This interpretation can be further extended to the outcome-based justifications predominantly used to explain unfair offers that, in a certain sense, may serve to resolve a social cognitive conflict [e.g., 3], ultimately reducing the distress caused by the experimenter’s explicit enquiry.

Concluding remarks and limitations of the study

This study showed for the first time that young children's fairness is not affected by whether the child plays with another child or with a robot. In particular, it appears that children's decisions during social interactions are self-centred and poorly oriented towards the other's mind. Future studies could address the same issue focussing on different ages so to highlight the development of behavior in late childhood, when higher mentalistic abilities are maturing and eventually acquired. Additionally, we showed that the analysis of the justifications of children's behavior may be enlightening with respect to the child's actual psychological understanding of constructs, such as that of fairness.

It is important to stress that the present results, and in particular those referring to the behavioural differences here reported when the child played as receiver with the other child and with the robot, need to be confirmed with a more ample sample. Confirmation of these results could highlight a distinctive attitude towards a non-human interactive partner that emerges quite early in childhood and that may change during adulthood.

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Chapter 4

Object Use in children with autism: Building with Blocks from a Piagetian Perspective

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Abstract

Aim: This study focused on the manipulation of objects by children with suspected autism spectrum disorder. The aim was to demonstrate how objects can be seen as active agents of interpersonal exchange in face-to-face interactions.

Participants: Three children with suspected autism spectrum disorder (aged 18, 20, and 24 months) were selected as representative of the sensorimotor stage of development.

Methods: Starting from Piaget's classical approach to the sensorimotor and symbolic developmental stages, the study moved toward a socio-material interpretation in which some patterns of interaction involving object manipulation seem to create a space that supports adult-child communication. In videotaped observations of verbal and non-verbal signs during an (organized) free play session, each child manipulated seven small blocks of colored plastic in the presence of an adult. The observations were informed by a checklist of 14 items, including eye contact and building a tower of toy blocks from section B of the CHAT (*CHecklist for Autism in Toddlers*) instrument.

results: Based on a broad Piagetian perspective and recent work in the field of socio-materiality, key observations included the following: (1) sensorimotor and realistic play was observed in all three children; (2) there were some intriguing indications that objects serve as concrete mediators in the intersubjective space between adult and child; (3) some of the children's attention patterns were visibly mediated by the object.

Discussion and conclusion: All three children exhibited a particular sequence of actions. First, they manipulated the blocks through active experimentation; second, there was an apparent pause, during which, the children were in fact examining the blocks to determine how best to continue the interaction; and finally, the children monitored adult attention by means of eye contact or by restarting manipulation of the blocks. As this last step in the sequence indicated that the object became a mediator of reciprocal attention, this interpersonal process was labeled "attention mediated by object."

Introduction

According to Piaget (1928, 1952, 1954), children with autism achieve object conceptualization skills by the fifth stage of sensorimotor development. As several studies advise caution in using the *stage* concept to describe typical and atypical psychological development, it seems useful to characterize these psychological processes in terms of specific activities that the child can plan and implement when acting on their physical and social environment. For example, as a predictive index, the number and type of different actions produced by children with autism during a recreational activity may not always follow the same stages as in typical development, and this can also be correlated with the severity of autistic functioning (McDuffie et al., 2015). In fact, while imitation difficulties may reflect a possible delay in psychological development, not all pre-scholars with autism have problems with imitation or symbolic play (Vanvuchelen et al., 2011). Within the broad line of research that raises questions concerning object canonicity, we identified some interesting elements related to the socio-material function of mediation during communication.

It is known that canonical functions of objects are introduced by other people present in the child's world (Leontiev, 1981; Costall, 1997; Rodríguez and Moro, 2008; Barthélémy-Musso et al., 2013). Indeed, Sinha (2009) suggests that the canonical functions of the object are acquired as a normative phenomenon during social interactions, although cognitive understanding of that status is a prerequisite. Additionally, Sinha (2015) (p. 12) points out that “the materiality of meaning and meaningfulness of materiality is central to approaches in cognitive science emphasizing the importance of objects in extended cognitive embodiment.” In particular, there is evidence that canonical functions are acquired during child–adult interactions (Rodríguez and Moro, 1998; Sinha and Rodríguez, 2008; Moro, 2011, 2014). Several studies have reported how, under certain conditions (for example, impaired interpersonal relations or attentional focus), objects become mediators of social interaction (Williams et al., 1999; Dimitrova, 2014; Moro, 2014). Cárdenas et al. (2014) highlighted the importance of the reciprocal nature of these interactions by showing how they emerge from communicative and triadic contexts (adult–child–object). The crucial role of the adult in the acquisition of object use is observable from early infancy (Moreno-Núñez et al., 2017). Moreover, during child–object–adult interaction, the child's visual attention is more focused when interacting with an experienced caregiver than with an unfamiliar adult (Miller et al., 2009; Miller and Gros-Louis, 2013). Miller and Gros-Louis (2017) also showed that the child's attention is influenced by partner social style. Tomasello et al. (1993) and Tomasello (2016) highlighted different kinds of learning, such as imitative, instructed, and collaborative. For instance, imitation is important for

learning that involves others and objects, as it facilitates understanding of the normative expectations of a given cultural group (Tomasello, 2016). Sinha (2009) suggested that children apprehend canonical functions primarily by cognitive means, thereby accessing the normative identity of the cultural group. Bruckner and Yoder (2007) reported that, even among children with autism, object use can be linked to emergent functions in the preoperational stage, such as imitation and attention to the other person.

Most of the existing research suggests that imitation is impaired in children with autism (Charman and Baron-Cohen, 1994; Rogers, 1999; Rogers et al., 2003; Williams et al., 2004). Indeed, Smith and Bryson (2007) noted that children with autism exhibit difficulty in imitating any unconventional use of objects but are able to imitate canonical object use. By imitating this canonical use, children with autism access part of the cultural group's heritage. With respect to manipulative play activities, Kanner (1943) was among the first to note that, despite differences and limitations, children with autism exhibit a number of functions related to the use of canonical and non-canonical objects. Trevarthen and Hubley (1978) described the dynamics informing subject–subject–object triangulation (the theory of “secondary intersubjective tuning”). Typical children alternate their eye gaze between the object being viewed and the other person, so engendering joint attention. However, in atypical development, and especially for those on the autistic spectrum, an abnormality has been observed in the development of behaviors related to joint attention. Palacios and Rodríguez (2015) showed that in typical children aged 9–15 months, the symbolic use of an object develops within a triadic context. Ungerer and Sigman (1981) assessed the use of everyday objects in a group of children with autism ranging in age from 39 to 74 months in a structured and free play session and found that most were unable to use an object according to its designated function. Williams et al. (2005) interviewed parents of 10 children with autism (MA = 62.2 months; SD = 19.9) who reported problems relating to the use of an object, such as an interest in some unusual aspect of the object, an unusual way of using the object, or difficulty in generalizing object use. Custance et al. (2014) suggested that imitative deficits in children with autism can be reduced by means of object-related activities, especially if there are no time limits on use of the object. Object-related activities promote joint attention, motor imitation, and intentional communication with a social partner (Bruckner and Yoder, 2007), and there is evidence that interventions focused on play involving different objects can promote social and imitative behaviors (Brown and Murray, 2001; Stahmer et al., 2003; Lee et al., 2017). Swettenham et al. (1998) observed three types of attentional behavior: (1) between an object and another object, (2) between an object and a person, and (3) between one person and another. Children with autism showed relatively more attention to interactions between an object and another

object. In our recent studies, we have observed the important role of the object in activating attention in the child with autism, and we describe the phenomenon as “attention mediated by the object,” which may be a precursor of joint attention (Iannaccone et al., 2016; Manzi and Savarese, 2017; Savarese et al., 2017).

The observational study reported here incorporates a sociomaterial perspective, referring in particular to the mediating role that objects seem to assume in the interaction between children and adults, which has to date been neglected in the scientific literature. Using a selected set of objects, the study analyzed the child with autism’s ability to manipulate those objects and to evaluate their symbolic use. Starting from presentation of the object, a further objective was to identify the type of game engaged in by the child. During interaction with an adult, we observed first whether there was eye contact; second, whether this changed how the child used the object; and third, whether the canonical use of the object was an important element in the child–adult interaction.

Material and Methods

Participants

We used the tower building item from section B of the “CHecklist for Autism in Toddlers instrument” (*CHAT*; Baron-Cohen et al., 1992). It was developed to help identify children who are at risk of developing social-communication disorders (scoring “high risk of autism”). It was administered to filter participants and one child aged 22 months did not pass this item. Children aged 18 months are capable of tertiary circular reactions and can stop and restart a sequence of actions at any intermediate step, which is crucial in building a tower of blocks. Children older than 18 months can use symbolic mental representations. The selected age range, therefore, allowed us to observe the early development of symbolic functions.

The study’s participants were three non-verbal male children with suspected autism spectrum disorder. The suspected diagnosis of autism was identified through the use of the CHAT instrument.

Their different ages encompassed the transition from sensorimotor to preoperational stage; participant 1 was aged 18 months, participant 2 was aged 20 months, and participant 3 was aged 24 months.

Methods

The study employed videotaped observations (with one camera) of verbal and non-verbal signs during an organized free play session, in which each child played with seven small blocks of colored plastic in the presence of an adult (a different experimenter was used for each observation). The observations were conducted on the basis of a checklist consisting of 14 items (see Appendix A), including eye contact and the building of a tower of toy blocks from section B of the CHAT procedure.

The blocks were selected not only because of their use in the CHAT procedure but also in accordance with the empirical tradition of Piaget (1962) and Reifel (1984), who have shown the importance of toy blocks in the child's cognitive development. The interaction sequences from the video recordings were transcribed in full for microgenetic and semiotic analysis, primarily examining the children's non-verbal signs (gestures and posture) during interactions with the objects. Adult intervention was also analyzed in terms of non-verbal signs (gestures and posture), again focusing on sequences of microgenetic and semiotic actions. Sequences were selected using the following criteria: the presence of gestures, actions, or both, where (1) the adult intervened and the object became a mediator of the interaction, and (2) the object mediated the attention between child and adult. The observations of child and adult occurred simultaneously.

Ethical issues

This study was carried out in accordance with the recommendations of AIP (Associazione Italiana di Psicologia), and all of the children's parents gave written informed consent in accordance with the Declaration of Helsinki. As there is as yet no psychological ethics committee at the University of Salerno, the protocol was approved by the external experts group from the University's "Centro di Counseling Psicologico" (Counseling Center). While the Center is not specifically responsible for ethical approval, the external experts group supervises research carried out by psychological researchers at the University. In Italy, few universities have a psychological ethics committee, and these generally offer degree courses in psychology or have a psychology department or institute. The University of Salerno has not activated degree courses in psychology and has no such department. We would like to thank the external experts, Dr Oreste Fasano (Psychologist), Dr Nadia Pecoraro (Psychologist), and Dr Monica Mollo (Lecturer in Psychology).

Results

The interactions with the blocks helped to observe behaviors that related to the blocks' physical attributes and the child's competence to establish relations with them. This playful manipulation of

objects probably helps planning and coordinated action, stimulating and strengthening the child's ability to interact with the outside world. At the same time, these activities allow children to imagine new construction scenarios (Harris, 2000). In the presence of potential partners or competitors (children or adults), the child's management of play activities and their implementation of communication strategies can also be observed. For example, the 18-month-old touched and handled all seven blocks, the 21-month-old touched and handled six blocks, and the 24-month-old touched and mechanically stacked all seven blocks.

Based on their independent observations, the two researchers agreed that the three children's symbolic use of objects (see **Table 1**) could be assigned to the first level of symbolic play as proposed by McCune-Nicolich (1981), based on Piaget's sequence (1972), because the children played using sensorimotor schemes. In addition, unlike the 24-month-old, the 18- and 20-month-old played a realistic game. Pretend and symbolic play was not observed in any of the three children's behaviors.

Table 1. *Use of Objects*

	Child 1: 18 months	Child 2: 20 months	Child 3: 24 months
Realistic play	Yes	Yes	No
Pretend play	No	No	No
Symbolic play	No	No	No

Based on observations of the "Can the child build a tower of blocks?" item in section B of the CHAT instrument (see **Table 2**), it was established that all three children used the objects in a manner similar to that described by Piaget as part of the manipulative activities of sensorimotor functioning. The children showed active exploratory behaviors as the toy blocks were manipulated, sorted, and stacked.

Table 2. *CHAT Section B: non-key items.*

	Child 1: 18 months	Child 2: 20 months	Child 3: 24 months
Tower of Blocks	Yes	Yes	Yes
Eye-Contact	Yes	Yes	No

In observations of the Eye Contact item of CHAT section B, the 18- and 20-month-old made visual contact with the adult, but the 24-month-old showed no eye contact. In the child-object- adult or

simple child–object interactions excerpted below, a set of seven colored plastic blocks was placed in front of the child. Transcription commenced when the child began to manipulate the blocks.

Observational results

In this section, we describe the observations we made of children with autism in relation to the types of object use (see **Table 1**). Crucial episodes were selected to illustrate the characteristics of the interactions between the children and the adults.

Generally, adults help children to interact with objects. In the observation of Child 1, the child was able to perform a complex series of actions on the object during the interaction. The child grabbed the object, manipulated it to orient it, dropped it, balanced it, and connected the different objects by stacking them. Here, the adult's help was crucial, as the elements of the child's interaction with the object were changed; at the same time, the object became a mediator in transforming the interactive arrangement between the child and the adult. The adult's hand in direct contact with the object became a source of interest to the child, who focused on this subject–object hybrid.

Observation 1. Child 1. Difficulties in the use of the material features of the object induced the intervention of the adult.

The child cries because the blocks he had begun to stack fall; while he cries, he holds two blocks in his hands and tries to put them on a block on the table. The adult comes over and gets behind the child. The child tries to lay block 1 but fails because he is shaken by tears. The adult places the existing block in a better way. The child looks attentively at the adult's hand and places block 1. The adult takes block 1 with the child and helps to place it in the right position in balancing it.

(...) With his hand, the adult moves block 4 (stacked by the child) to achieve better balance. The child observes the adult's hand. The child leaves block in his left hand alone and, continuing to watch the stacked blocks, extends his right arm to grab block 6. He places block 5 onto block 4 and, without looking, tries to grab block 6.

The child's initial frustration on being unable to stack the blocks led to an intervention by the adult, who was seated on the ground behind the child. The adult intervened when the child played with the blocks, and the object became a mediator of interactions and interpersonal activity.

Observation 2. Child 1. The previous help of the adult activated the attention of the child.

Once block 4 is in his left hand, he stretches his right arm and grabs block 5 before positioning block 4. While watching block 5, the child places block 4 and leaves it on block 3a; in the meantime, he brings block 5 closer to his body. After leaving block 4, the child takes a step back to turn to the adult, and they look at each other.

(...) He places block 6 onto block 5 and leaves it. Having left block 6, he turns to the adult, and they look at each other.

The child continued to play with the blocks, which became a mediator of attention between the child and the adult. After his intervention, the adult facilitated the stronger relational attractiveness of the object, as it became a transformative element in the initial environmental arrangement.

Observation 3. Child 1. The child used the material features of the object correctly after the intervention of the adult.

The child stretches his right hand and grabs block 4. The child then passes block 4 to his left hand, no longer looking at block 4 and directing his gaze to block 5. Meanwhile, the child keeps block 5 in his right hand. Holding the new block, the child turns to the stacked blocks and simultaneously raises his right hand (with block 5). He raises both arms above his head and grabs block 5 with both hands.

The child combined the object's socio-material properties by combining the material properties of the object with the social structures inherent in the object itself.

Furthermore, a series of interesting gestures was observed in the child-object interaction. When the child took the block and raised it over his head, even though the blocks on which the held block was to be placed were much lower in height, the child may have been planning to build a much higher structure with different characteristics to the existing one. One may take these behaviors as possible evidence of an imaginative process. This can also be seen as an explanation of the socio-material link, as imagining a structure beyond what is immediately present may indicate the child's ability to combine the material properties of objects. As the adult intervened, he became an example for the activity of the child. In the child-adult interaction, the object became a mediator of attention.

In the observation of Child 2, the child's manipulative skill was organized in a complex series of actions. He eyed the objects, planned to grab and stack them, rotated the objects in both hands, left, and again grabbed the objects. The material characteristics of the objects were explored. The adult intervened when the child played with the blocks, and the clock (the object) became the mediator for the joint attention of the child and the adult.

Observation 4. Child 2. The child began to actively explore the objects.

The child moves the blocks in front of him (almost shuffling them), watching them carefully. Still looking at the five blocks in front of him, he moves his right hand and touches block 1, which is not present in his visual field.

The child explored the material features of the blocks, and through these actions, which blended complex activities, the child seemed to experience the object adapting and being adapted by its constituent elements. In building a tower of blocks, the child's aims and imaginative action planning appeared to converge. Thus, even though a symbolic game could not be identified, it seems that sensorimotor play and realistic play were present.

Observation 5. Child 2. The child used the material features of the object.

He raises block 1, keeping his eyes on it while grabbing block 2 with his left hand. He turns block 2 around, changing the side that rests on the ground; in the meantime, his right hand brings block 1, moves it in the air, and passes it over block 2. He is about to place block 1 but brings it back close to himself, touching it with his left hand and resting it on block 2.

Here, the child experienced the features of the object. The adult intervened several times during these child-object interactions. The subject-object hybrid identified during the observation of Child 1 is also present here. During the first stage, the child's attention was focused on the transformative mediation of the subject-object hybrid, highlighting how this inextricable relationship drives the modification of the initial environmental arrangement. The child's actions can be seen to occur in a synchronic and harmonic circle of the imitation of the adult's actions.

Observation 6. Child 2. The socio-material features emerged during the child-adult interaction.

The adult places his hand in the child's visual field by moving a block over to him; putting it onto the floor, the adult begins to stack the block. Throughout the sequence, the child is

attracted by the adult's hand manipulating the block. He directs his gaze to block 1 and grabs it; continuing to watch it, he takes it with both hands. The adult begins to stack the blocks. The child manipulates block 1, which he holds in his two hands. He rests block 1 and leaves it. Directing his gaze to the blocks in front of him, he watches the adult, who stacks blocks.

(...) The adult takes the blocks that the child had put in rows and stacks them on top of each other. The child again takes block 4 with both hands. The child carefully observes the adult's movements while stacking. Still with block 4 in his right hand, crawling and with momentum, the child approaches the blocks stacked by the adult. The child grabs block with both hands, looks at it, and manipulates it. He turns block 4 in the direction that seems to enable stacking. He watches the blocks being stacked by the adult and, with his right hand, places block 4 onto the stack of blocks.

The subject/adult-object hybrid appeared to represent the transformation of the subject/adult-object-subject/child relationship, leading to revised planning of the action and thereby structuring of general aims. As well as becoming a mediator of the child's exploration of the surrounding environment, the object also rewrote the relational terms. This last step seems to follow the socio-material perspective, as the social structure of the object was intertwined with its material characteristics.

In observation of Child 3's sequence of actions, the attractiveness of the object overrode the ability to create a contact area with the adult who remained peripheral, or as a mere spectator of the child's construction. Actions have a regularity of performance: blocks are looked at, the hand gets ready to grab, the arm is stretched out to get to the object, the object is grabbed, the child identifies where to put the object, and eventually rests it in balance for stacking.

Observation 7. Child 3. The child used only the material features of the objects.

The child grasps block 1 with his right hand and rests it on a raised board, which has a width equal to the side of the block. He looks closely at block 1 and grabs it with both hands as if to be sure it is in balance. He pulls his right hand away from block 1 and, holding himself with his left hand, leans over the board to see what is there. He directs his eyes to where the blocks are located. He lowers himself, leaning with his left hand on the board and gripping block 2 with his right hand. He gets up and, watching block 1, rests block 2 onto block 1. He removes his right hand from block 2, lowers his body to take block 3, and grabs it with his right hand. He gets up and places it onto block 2, leaving block 3.

Following this regularity of actions, which converged in a purposeful activity, we can assume that the child has completed the main stages of sensory–motor skill development and understood the object’s material characteristics. Additionally, the social function inherent to the object appears to be linked to its use.

In fact, the building of the tower was achieved through structured planning and with a constant imaginative tendency. What is lacking seems to be an understanding of the possibility to use the object as a social agent, because the adult was present only as a spectator.

Based on the regularity of actions that converged in purposeful activity, we can assume that Child 3 had completed the main stages of sensorimotor skill development and was able to understand the object’s material characteristics. Further, the objects’ inherent social functions appeared to be linked to their use. In fact, the building of the tower was achieved through structured planning and with a constant imaginative tendency. The adult did not intervene when the child played. In the child–adult interaction, what seemed to be lacking is an understanding of the possibility of using objects as social agents, as the adult was present only as a spectator.

Searching for constants in analyzing the filmed sequences of the three children, their successive actions were identified; initially, each actively manipulated all the blocks. This activity preceded an apparent break, but during that phase, the child observed the objects to determine how to continue. Immediately thereafter, the child either sought the adult’s attention through eye contact or resumed the interrupted object manipulation.

At the beginning of the game, the children moved, shook, and turned the items several times, and this correlated with activation of their hand movements. Here, we probably witnessed the typical secondary circular reactions of the sensorimotor stage. After the break and the search for mutual attention and/or eye contact with the adult, the children then proceeded (by trial and error) to build the tower of blocks, modifying their existing schemes in so doing. This was indicative of tertiary circular reactions.

Discussion and Conclusions

Consistent with a theoretical perspective emphasizing the role of social and material dimensions in psychological development and activities (Iannaccone, 2015), our analysis highlights two important implications in our observations of object manipulation. First, consistent with the Piagetian

perspective, the observations highlighted object manipulation and action planning identifying the presence of secondary and tertiary circular reactions (Piaget, 1972). In relation to the game, invoking the McCune-Nicolich model (1981), all the children exhibited sensorimotor play, in which the object was manipulated and understood in terms of its material characteristics.

The second implication relates to how, in some action sequences, the material and social characteristics of the objects contributed to shaping partner interactions between child and adult. This aligns with several empirical studies of the social uses of objects (conventional, canonical, and symbolic) (John-Steiner and Mahn, 1996; Moro, 2011). In such interpersonal situations, the activities of participants (child and adult) are clearly affected by the setting's physical and social affordances. In particular, during child–parent interactions (Moro, 2014), triadic child– object–adult interactions (Moro, 2011) seem to create relevant socio-material scenarios that frame communicational activities. In our observations, two of the three children in fact exhibited a kind of object management mode that seemed to replace eye contact with the adult. In some sequences of actions, child and adult managed to coordinate action planning through object manipulation, child exploratory activity, and adult scaffolding. For example, the child observed and touched the objects to encourage play activities; the adult touched the object with his hand, and this action frequently became a source of interest for the child. The child looked for the adult's attention through eye contact, and the child began to manipulate the object. In activities of these kinds, it seems evident that the objects can serve as mediators in communicative interactions with the adult. As well as taking into account the social function of objects, the observed children were already considering the socio-material characteristics of the play situation, as adults and children engaged in managing a kind of “socio-material space” as proposed by Rodríguez et al. (2015). In fact, from the first year of life, adults produce a shared space with objects that serve as effective tools of communication with children. Our findings in relation to the object as a tool for adult–child interaction align with Moreno-Núñez et al. (2017), confirming that the first shared understandings between adult and child take place around the object and its uses. Finally, in considering these first results, we can imagine relevant challenges for a new developmental psychology based on further related research.

Our observations of these interactions do not focus on direct joint attention but identify a kind of psychological process that we call “activity mediated by the object.” Unlike Tomasello (1995), we consider the object itself as mediator, not only of the mutual attention between adult and child but of the dynamic relational exchange between partners.

In conclusion, our study reported the preliminary results of a larger analysis. In considering these first results, we can imagine relevant challenges for the developmental psychology of children with autism. Consistent with the results of studies on children with typical development, our study on children with autism shows that the socio-material features of objects represent factors that mediate the construction of child–adult interactions. Starting from the first intervention of an adult, an object becomes a mediator and promoter of interpersonal activities and space.

Ethic Statement

This study was carried out in accordance with the recommendations of AIP (Associazione Italiana di Psicologia), and all of the children’s parents gave written informed consent in accordance with the Declaration of Helsinki. As there is as yet no psychological ethics committee at the University of Salerno, the protocol was approved by the external experts group from the University’s “Centro di Counseling Psicologico” (Counselling Centre). While the Centre is not specifically responsible for ethics approval, the external experts group supervise research carried out by psychological researchers at the University. In Italy, few universities have a psychological ethics committee, and these generally offer degree courses in psychology or have a psychology department or institute. The University of Salerno has not activated degree courses in psychology and has no such department. We would like to thank the external experts, Dr Oreste Fasano (Psychologist), Dr Nadia Pecoraro (Psychologist), and Dr Monica Mollo (Lecturer in Psychology).

Author Contributions

The introduction was written by AI. The observational analysis was written by FM. The discussion of the results and the conclusions were written by GS.

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Chapter 5

Social Functions in Autistic Children and Interaction with/through Object: A Brief Report

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Abstract

The aim is to analyse the social functions of pointing, of imitation and of joint attention in presence of the object for the autistic children. We have built an ad-hoc observation check-list and we have conducted 43 observations with verbal ASD-affected children aged between 2 years and 6 years. The results show that a better use of the object is correlated to the manifestation of social functions analysed.

Introduction

In a socio-material perspective (Iannaccone, 2015), the object is composed of material features and social components coexisting together. Considering that the social interaction is impaired in autistic children; consequently, the interaction with the “social world of objects” is impaired as well (Iannaccone, et al., 2016). Some autistic children show deficits in the use of objects: alterations in manipulation, exploration and describing. Thus, autistic children which do not present impairment in the use of the object show more social functions than impaired children (Trevvarthen & Hubley, 1978; Tomasello, 1995; 2016).

The three social functions, pointing, imitation and joint attention analysed in the study and they all have in common the presence of the object in their definition. Thus, our aim is to analyse these functions not only taking into account the development of these by the autistic child, but also what role plays the object specifically in social and relational terms.

Method

We have built an ad-hoc observation check-list inquiring on 9 areas (each of which has specifying under-questions), which refer to 9 psychological theory constructs developed by the literature on autism and object. The main objective of this check-list is that of describing characteristics and socio-material functions of the object with reference to autistic subjects. In this check-list, there are different psychological constructs, but here we have analysed in detail three constructs: declarative function, imitation and attention. As we can see the check-list was made of different constructs but we will analyse these other constructs in future.

During each observation, an educator following the child for rehabilitation was present and the educator completed the check-list. Each observation lasted 26 minutes on average and has been transcribed on an ad-hoc check-list.

Children have been observed while interacting with an object, a small-sized plastic toy, they had chosen from a set of objects, for instance, toy cars, trains, toy animals and others. When we refer to “acted and interacted with and through the object” we arranged different constructs of the check-list, such as: Understanding of the use of the object, interaction through the objects etc. Which are the constructs refer to the manipulation, exploration and describing.

We carried out 43 observations with verbal ASD-affected children aged between the end of the sensory-motor stage (24 months) and the start of the pre-operational stage (68 months, namely 6 years). Moreover, the literature shows some results showing a link between a better use of the object

and those functions that emerge during the pre-operating period, such as imitation and attention to the other (Bruckner & Yoder, 2007).

We were two samples. The first sample composed of 18 children who acted and interacted with and through the object while the second sample composed of 25 children who acted and interacted with and through the object.

Results

Regarding the association between the sample 1 and the declarative function (Figure 1) shows that the 66.7% of the sample present this association while the sample 2 shows that only the 24% present this association.

Indeed, it is possible also for autistic children to use the imperative function of pointing, as for typical development children, and pointing is often the ground- breaking of a full declarative function (Camaioni et al., 2003).

Regarding the association between the sample 1 and the imitation (Figure 2) shows that the 94.4% of the sample present this association while the sample 2 shows that only the 60% present this association.

Concerning imitation, it has been suggested that the specific imitation deficit of autism could be reduced or even eliminated with the use of activities linked to objects (Vanvuchelen et al., 2013; Custance et al., 2014), especially when no timelines in the use of objects are given.

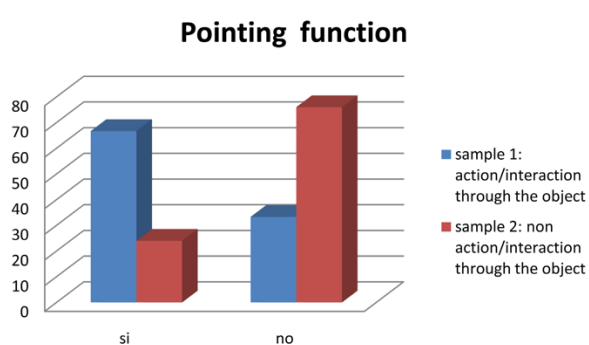


Figure 1. Pointing function

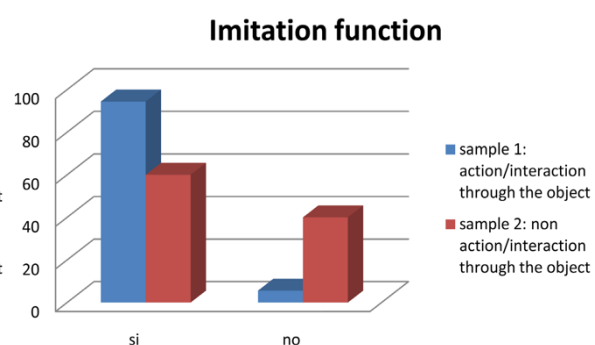


Figure 2. Imitation function

This would favour a higher joint attention, motor imitation and intentional communication with a social partner (Swettenham et al., 1998).

Regarding the association between the sample 1 and the Joint attention (Figure 3) shows that the 61.1% of the sample present this association while the sample 2 shows that only the 32% present this association.

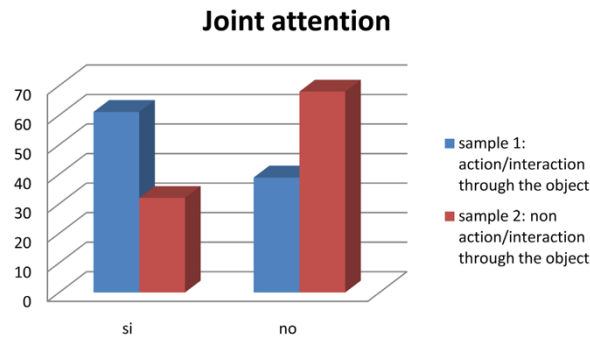


Figure 3. Attention to the adult function

Lastly, regarding joint attention it has been proved that manipulation of material objects can address the child's attention and favour the joint attention with both adults and peers (Korkiakangas & Rae, 2013).

Conclusion

The socio-material features of the object represent factors that mediate the construction of the interaction with the adult. Social functions contribute to this process are: the declarative function (relating to pointing), the imitative function, the function of joint attention.

In line with the literature (Bruckner & Yoder, 2007) on the child with typical development, our study with autistic children shows a link between a better use of the object and these functions that emerge during the pre-operating period, such as imitation and attention for interacting with people.

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Chapter 6

General Discussion

The aims of this thesis were: 1) to explore the intersubjectivity space that a child can establish with an object (the robot) that is also the interactive partner during the interactions; 2) to observe the role of the object as mediator of the child-adult interaction and as promoter of the construction of the intersubjectivity space. The first topic has been investigated in children with typical development while the second topic has been explored in children with atypical development, i.e. autistic children.

In this respect, there were designed two different interactional scenarios to evaluate the intersubjectivity: 1) concerning typical development it has been used an interactional situation involving humanoid robot in order to test the decision-making processes; 2) regarding autistic children the use of the object has been observed during an interaction with an adult mediated by an object, testing the role of the object as mediator and promoter of the interaction. The first situation, involving an innovative field of research, needed a review of the literature in order to understand which role can be assumed by the robot during the interactions with a human. Thus, it was important to analyse if human can ascribe a mind – mental states – to a robot, in particular in a life-span perspective in order to observe changes during the human development. The second scenarios used an original perspective to examine the interaction between autistic children and adults, showing that autistic children, despite their impairments in different areas of development, can create an intersubjective space with the adults. However, this is evident when child and adult use an object as mediator of this interaction.

The findings emerged from these scenarios arise two main questions:

Can a child treat a humanoid robot similarly to a human partner?

Futurologists hypothesised that in the next years robots will be introduced in different contexts of our everyday life such as household, elderly assistance, education etc, modifying the job market but also our social interactions. For instance, the use of robots in the educational context are inspiring new educational program. Moreover, children will be more conscious of the existence of the robots because robots become part of their everyday experience. Several studies underline the need to implement physical and behavioural features in order to make robots more sociable, promoting better

interactions. From Chapter 1 results that subjects ascribe mental states to a humanoid robot. However, the attribution of a mind is not similar at all ages, but it changes during the life-span. For instance, a recent study of Manzi and colleagues (2017) showed that children from 5 to 9 years of age distinguish a human from a robot as regards the attribution of mental states, in particular children ascribe different mental states to a robot at different age: younger children ascribe more emotional states compare to older children. However, several researches in the field of educational robotics show that children treat a robot as a companion and scaffolder in the educational contexts. These findings are evident in the study presented in Chapter 2. In fact, 5-years-old children ascribe less mental states to a robot compared to a human but despite these differences, they use similar strategy with human and robot when they play in an interactive game. This is a fundamental result because it means that children can treat a robot similarly to a human. Moreover, another innovative result of the study is the analyses of children justifications given to the Ultimatum Game. We observed that children tend to use justifications based on the outcome and not on the basis of mentalistic terms both for human and robot, showing how children behave like maximisers – according with the homo-oeconomicus theory – when they interact both with human and robot. In the human condition, children's justifications based on the 'outcome' given to the unfair divisions, both as a proponent and as a receiver, could be explained as the attempt to resolve a cognitive and social conflict (expected "social" fair behaviour VS real "selfish" behaviour). Moreover, in the robot condition, children's justifications based on mentalistic terms to unfair divisions, both as a proponent and as a receiver, can be explained as the social norms of equity might be less relevant (robot = "not perfectly like-me").

The literature review in Chapter 2 and the data of Chapter 3 represent an important finding for the HRI and cHRI because it is possible to infer that humans – from childhood to old age - tend to ascribe a mind to a robot and that besides 5-years-old children tend to treat a robot as social partner, using similar cognitive strategies both for human and for robot.

In conclusion, robots can be considered 'like-me' (Meltzoff, 2005, 2007a, 2007b, 2013) but it depends from: 1) the age of human partner interacting with a robot; 2) the methodological procedures, and particularly the nature offline (i.e., the AMS questionnaire used in Chapter 3) or online (i.e., the modified version of the Ultimatum Game used in Chapter 3) of the tasks employed; These final observations lead to reflect on the instruments used in research and this is even more important when the topic of research is new such as the HRI. In fact, it is essential to combine both offline and online measures, but also it is important use together ecological and laboratory tasks.

Can an object be a mediator and a promoter of the child-adult interaction also for autistic children?

We live in a social world composed by humans and objects. In the history of Psychology, the human-human interactions were largely investigated but few studies analysed the human-human interaction mediated by objects. In this regard, Piaget (1952, 1954) highlighted that children discover the world of the objects through a sensorimotor activity, which constitutes the basis of the cognitive development. Vygotskji (1962, 1978) showed that children with typical development use artefacts to interact with others, acquiring their knowledge about objects through the interaction with a scaffolder (peers or adults). Moreover, Moscovici (1976) examined the interpersonal relationships in a triadic perspective, highlighting that humans and objects are strictly connected. However, Linell (2009) proposed a dialogical interpretation of the objects, suggesting that it is important to understand the objects as external referent that can change human's perspective of the world. Several studies showed that an adult can be a scaffolder for the acquisition of the use of the objects in children with typical development (Moro, 2014). In Chapter 4 and 5 we demonstrated that also children with atypical development, in particular autistic children, can use the object to construct an intersubjectivity space during the interaction with the adult. The objects in these interactions acts as mediators of the child-adult interaction, creating a specific intersubjective space in which autistic children, despite their social impairments, are able of some social performances (i.e., ocular contact).

In Chapter 4 the results seem to demonstrate that the socio-material features of objects represent a key-element that mediates the construction of child–adult interactions, becoming a mediator and promoter of interpersonal activities and space. Chapter 5 shows a link between a better use of the object and the presence of social behaviors that emerge during the pre-operational stage, such as imitation and attention. However, it is important to highlight that the use of the object and the presence of social abilities largely vary in each autistic child because autism is a spectrum disorder that implies a wide range of phenotypes. Thus, the construction of intersubjectivity space has to consider the specific subjects of the interaction and their interpretation of the objects.

These findings lead to the conclusion that to understand how children with typical development interpret the use of the objects it is important that adults ‘share’ the child’s perspective in order to create an intersubjective space. If it is crucial in typical development, then it becomes even more essential in atypical development, in particular in autism that is a spectrum of disorders that imply a different kind of impairments in several areas of development. In fact, the adult has to consider that each autistic child constructs the intersubjectivity space in a subjective way, using all her/his skills.

In general, both as regards typical and atypical development, the adult should accept that each artefact is always reinterpreted by the child in a triadic relationship through a continuous and dynamic construction of the intersubjectivity.

Conclusion

The majority of the psychological research is inspired by everyday experiences and so I will try to give some examples of the key points of this thesis, starting from my life.

I am writing my thesis using my computer right now and its battery is almost discharged. I am saying “Why you do this to me?”. Despite my prayers, my computer will switch off if I will not put it in charge. What does this situation mean? I am ascribing intentions to my computer, in particular the intentions to turn off itself.

I remind that in UK when I was learning how to use a robot, I was staying in the Lab hours and hours without talk to anybody and so I was starting to talk to the robot, ‘praying’ it to work in the right way. It obviously continued to not work and to not reply to my questions and prayers (fortunately!).

I bought a toy for a son of two friends of mine when he was 6-moths-old. Then these friends moved to USA and sometimes we Skyped, but I did not see them for a long time. This summer when I came back to my hometown, I saw them after three years and the child still had the toy and when the mother said him that I bought it for him he smiled and give me the toy to play together.

The above examples highlight the two main points of this thesis: 1) we can ascribe mental qualities also to objects that have not ‘really’ a mind because we tend to project our internal states onto the external world; 2) we are fully immerse in a world of objects that give us the opportunity to create an interaction with another person beyond the time.

To attempt a tentative conclusion, the purpose of this thesis was to show that when humans build objects - from the classic ones to the more technological ones - they also achieve two further important objectives: to facilitate social interactions and to create an intersubjectivity space that includes both human and non-human partners. I sincerely hope my efforts have at least partially succeeded.

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Materiality and the construction of Intersubjectivity: human-robot interaction In typical development and the use of the Objects in ASD children

Federico Manzi

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Chapter 1

General Introduction

*Una mente tutta logica è come un coltello tutto lama.
Fa sanguinare la mano che lo usa.*
(Rabindranath Tagore)

The aims of the present dissertation are to analyse, in children with typical and atypical development, the construction of the intersubjectivity through the use of objects in atypical development (ASD) and through the interaction with a humanoid robot in typical development. About the humanoid robots, the issue is to observe the possible attribution of human-like features to a robot that can make the human-robot interaction similar to the human-human interaction that is a classic intersubjective interaction because of the presence of two human subjects. This purpose is investigated considering two theoretical frameworks: 1) Theory of Mind that explain the construction of the intersubjectivity through the attribution of mental states to others; 2) Socio-material perspective which postulates that the construction of the intersubjectivity is mediated by objects in many cases. Thus, the question arises in this dissertation about the humanoid robot is: what happen when the mediator object (the robot) is also the interactive partner.

To achieve this purposes, the present thesis studies two main topics: 1) the interactional patterns with and the attribution of a mind to a robot by typically developing children; 2) the interactional patterns in atypical development - autistic children - in a child-adult interaction mediated by objects. The first topic is analysed in an innovative theoretical perspective and a through novel methodological approach, leading to an innovative understanding of the child-robot interaction. The theoretical perspective connects the role of Theory of Mind in HRI; the methodological approach observes children's decision-making strategies in the HRI, comparing these behavioural patterns when children interact with a human and with a robot. The second issue of the thesis is about the role of the object as mediator of the relationship between autistic children and adults. This is studied through the Socio-material perspective that hypothesised that material features of the objects and their intrinsic social qualities are strictly connected.

A useful psychological paradigm to investigate the construction of intersubjectivity is the Theory of Mind construct that will be briefly introduced; subsequently I will give an overview on Human-Robot

Interaction and, finally, I will conclude with some observations concerning the role of the objects in autism.

Theory of Mind or how understand the social world

Theory of Mind (ToM) represent one of the most important psychological constructs used in the last decades to interpret social interactions. ToM is the ability to understand one's own and other people's mental states (intentions, emotions, desires, beliefs), and to predict and interpret one's own and others' behaviours on the basis of such meta-representations (Premack and Woodruff, 1978; Wimmer and Perner, 1983; Perner and Wimmer, 1985). This definition highlights how the presence of the other is crucial for the comprehension of ourselves and for the interpretation of the relational world. The history of the ToM begins with the pioneering study of Premack and Woodruff (1978), titled "Does the Chimpanzee Have a Theory of Mind?". This study paved the way to study the ToM also in different agents, not only in humans but also in primates. They found that also the primates can use ToM ability to understand and predict the conspecific's and human's behaviours. These results allowed to study the ToM in an evolutionary perspective. In fact, Adolphs (2009) theorised about the phylogeny of social abilities, showing that our brain is a social brain that evolved from primates to humans.

Furthermore, developmental psychology study the changes that occur during children's development, showing the ontogenesis of this ability. ToM is not a monolithic construct, but it is a complex and multimodal ability that involved both cognitive and affective processes (Shamay-Tsoory & Aharon-Peretz, 2007; Kalbe et al., 2010).

Wellman (1991) hypothesised a ToM development from 3 to 7 years of age considering the understanding of mental states in the childhood. The author drawn a line of development: children in the early stage of development understand the non-epistemic states (desires, emotions and intentions) – between 3 and 4 years – and only late – between 4 and 7 years – the epistemic states. The epistemic states are the bases for the true and false belief understanding: this allows children to construct a meta-representation of their own and other's mind. Thus, considering the important of belief, in particular false belief, a pioneering study of Wimmer and Perner (1983) used for the first time the paradigm of the false belief task to study the ToM development. In this study the authors used the Unexpected Transfer Task in which a character has to ascribe a false belief of another character. The results showed that 4 - to 5 - year-old children can predict the actions of someone with a first order false beliefs referred to the first level of recursive thinking (i.e. "I think that you think"). These findings are supported by a meta-analytic study by Wellman, Cross and Watson (2001) that confirmed

that children begin to attribute a false belief starting from 4 years of age. In a second study Perner and Wimmer (1985) used a different task, the Ice-Cream Van, in order to analyse the second level of the recursive thinking (i.e. ‘I think that you think that she/he thinks’), that is the *second order false belief*. They found that 6- to 7- years-old children can understand this second level of representation. These findings show that the ‘sensible period’ for the emergence of the ToM is from 3 to 7 years of age and that it is acquired in a hierarchical way (Wellman, Cross and Watson, 2001). However, several studies show that the ToM is an ability that gradually develop from childhood to adulthood (Sommerville et al., 2013; Dumontheil et al., 2010; Apperly et al., 2012) and in the last years several studies investigate the modification of the ToM ability during the old age (Happé et al., 1998; Castelli et al., 2011; Saltzman et al., 2000).

Human-Robot Interaction: an interdisciplinary approach to investigate socio-cognitive abilities

“Human–Robot Interaction (HRI) is a field of study dedicated to understand, design, and evaluate robotic systems for use by or with humans” (Goodrich and Schultz, 2008, pp.1). The HRI derived from the Human-Computer Interaction (HCI) studies. The differences between HRI and HCI is that HRI uses robots that have physical human-like features (along a gradient from completely non-human like to a complete similarity with humans) and they can behave as humans (i.e., a robot can recognize and follow the eyes of a human or it can reply semi-autonomously to a human question). Thus, HRI not only implement behavioural patterns into robots but also design robots that can be perceived more human-like (Minato et al., 2004). In the last two decades HRI received more visibility especially related to the development of new theoretical approaches and technical skills in the robotics’ domain. For instance, in 2004 the Ishiguro’s Geminoid Project¹, in Japan, built androids which very closely resemble specific human “models” as a platform for research aimed at understanding humans, applying methods from engineering, cognitive science and neuroscience. Indeed, the robots can be used as a research tool in two different ways: 1) to use a robot in order to test human cognitive models, implementing algorithms that can simulate the human cognitive processes (Di Nuovo et al., 2013; De La Cruz et al., 2014; Whitaker, Colombo and Rand, 2018; Scassellati, 2003, 2005); 2) to use the robot as a possible partner in scenarios that implies the interaction with a human in order to observe social interactional patterns (Manzi, et al., 2018; Breazel et al., 2016; Moriguchi et al. 2011; Nishio et al., 2018; Sandoval et al., 2016). There are different theoretical approaches in HRI and in robotics; the

¹ For more information on the Geminoid Project: <http://www.geminoid.jp/en/index.html>

most interesting are: Developmental Robotics (Cangelosi and Schlesinger, 2015; Lungarella et al., 2003) and Developmental Cybernetics (Itakura 2008; Itakura, Okanda and Moriguchi, 2008).

Developmental Robotics is an emerging field of research that connects robotics, cognitive science and developmental sciences – in particular developmental psychology and developmental neuroscience (Di Nuovo et al., 2014; Di Nuovo et al., 2017). This field is focused on the implementation of robots that should be more autonomous, adaptable and sociable– the cognitive developmental studies are crucial in this respect – but to achieve this goal it is fundamental to employ models of human development in order to embed these models into robots. Thus, it is important the collaboration between engineers and developmental psychologists in order to design the models mentioned above (Asada et al., 2001; Lungarella et al., 2003). Developmental Robotics represents an innovative approach to the development of HRI: its statement is that robots can learn as children (Cangelosi and Schlesinger, 2015). Roboticians use algorithms, deriving from the Machine Learning field, to build cognitive models of psychological processes (Cangelosi and Riga, 2006; Cangelosi, 2010; Cangelosi et al., 2010). However, these models derive from the research in developmental psychology because it is fundamental to understand the trajectory of development of the psychological processes (i.e., ToM or linguistic development). Since robots should be social partners, Scassellati (1999, 2001, 2002) assumes that they have to possess a ToM. This is only a theoretical assumption because today technical innovation does not permit an implementation of a ToM into robots despite our knowledge about ToM development: an explanation is that ToM ability is a complex process that involves several cognitive and affective components.

Developmental Cybernetics connects Developmental Psychology and robotics, using the human development models in order to identify the most important behaviours that can promote HRI. This is the other side of the coin because, while the Developmental Robotics uses the models to make robots behave socially, Developmental Cybernetics studies which kind of behaviours should be implemented into robots in order to promote HRI. In particular, Developmental Cybernetics studies the development of social behaviour in infants in order to implement specific behaviours so that the robots can be treated as a companion. In the case of interactions between children and robots, we shift in the field of Child-Robot Interaction (often abbreviated as cHRI), which differs from HRI because the partner of the interaction, the child, presents an immature cognitive development (Belpame et al., 2013 a, b). cHRI is crucial for Developmental Cybernetics because of its futuristic hypotheses: in the next decades the robots can be introduced into human societies in different contexts among which the educational ones. In this case, the robots should be attractive for children: to reach this goal,

physical and behavioural characteristics should be more human-like. In 2018 one of the biggest Japanese educational projects introduces 500 humanoid robots (NAO robot, created by Aldebaran Robotics) in the Primary School in order to teach English to Japanese children². Moreover, several research programs use humanoid robots in different educational contexts (Chang et al., 2010; Belapme et al., 2016; Gordon et al., 2016; Kanda et al., 2007), highlighting, in a vygotskian approach, how robot can be use as scaffold. Developmental Cybernetics postulates that to build a social robot is important to study and to develop research knowledge about three main domains connected to the robot: Theory of Body (ToB), Theory of Communication (ToC) and Theory of Mind (ToM). The ToB hypothesises that a robot should move its arms, legs and head in a conventional mode. For instance, Morita and colleagues (2012) test children's and adults' reaction to conventional and unconventional movements of the body of a human and of a humanoid robot, showing that children extend their reaction to the unconventional movements both of human and humanoid robot respect to adults that are more activated when the unconventional movements are made by a humanoid robot. With regard to the domain of Theory of Communication, several studies show that an effective robot is a robot that can communicate in verbal and non-verbal way (Breazel at al., 2005; Brooks and Arkin, 2007; Mavridis, 2015). These researches generally highlight that a robot that can use non-verbal signals (i.e., facial expressions or gestures) to promote the human involvement in the interaction is perceived more as a companion than a robot that not communicate in such ways. For instance, Aaron and Mataric (2015) use a robot that communicate with a worker to achieve a goal, finding that the robot was perceived as a teammate more than a robot without communicative behaviours. The last, but not the least, domain of the Developmental Cybernetics is Theory of Mind: this is a crucial objective of Developmental Cybernetics because it hopes that in the future robots can interact in a way that can be perceived as having a mind. Nevertheless, as above mentioned, the implementation of ToM into robot is more a futuristic dream, while has been demonstrated that humans use their ToM ability to understand robots' behaviours. This a fundamental assumption that connects the different sections of this thesis. In fact, already Piaget (1929) uses the concept of animism suggesting that the human ability to ascribe intentionality to an object is an early infant's disposition. However, when we talk about robots, we refer to an animate object that appears and behaves in a human-like way. Thus, the ToM ability is a very useful psychological construct that can help to better to understand the human's tendency to ascribe mental states to a robot. In Chapter 1 it will be shown as humans, in a

² For more information is possible to access to the article by the following link:
https://rep.repubblica.it/pwa/generale/2018/09/24/news/giappone_robot_insegnano_inglese-207218720/?ref=RHRS-BH-I0-C6-P21-S1.6-T1

life-span perspective, tend to attribute minds to robots. Some research points out, in particular as regards childhood and adolescence, that the ascription of mental states changes with age (Manzi et al., 2017; Kahn et al., 2012). Chapter 2 shows that younger children tend to ascribe to robots more intentions and desires and less epistemic states than older children, in line with the ToM literature (Wellman, 2001). These findings highlight an important point for Developmental Cybernetics, and in general for developmental psychology, because they demonstrate that children perceive a robot as a partner that appear and behave like a human when they interact with it. Additionally, the children's ascription of a mind to a robot is the prerequisite for the establishment of the intersubjectivity. The concept of intersubjectivity captures the way a person understands and relates to another people and implies that exist a bridge between the knowledge of oneself and the one's own knowledge of others (Rochat, Passos-Ferreira and Salem, 2009). In the light of above, this is a crucial theoretical mark for the HRI because, if the intersubjectivity is the assumption of the interpersonal relationship in humans, the presence of this dimension in the human-robot interactions allows to interpret these interactions not only in a mere behavioural way but also in a relational way.

The use of the object in children's development: an overview on autism

The Autistic Spectrum Disorder (ASD) is a syndrome that can be characterized by an intellectual disability (DSM-5, 2013). The main symptoms of the ASD are: impairments in the social interaction (Baron-Cohen, 1997; Frith, 2003); impairments in the verbal and non-verbal communication (Mundy et al., 1987; Happé, 1995); stereotypical and repetitive behaviours, interests and activities (Bodfish et al., 2000; Boyd et al., 2010). Since ASD is a syndrome that affects all the psychological development, social and cognitive deficits are very heterogenous both for the complexity and severity of disease. These symptoms can emerge and change in different moment of development (Frith, 2003; Yirmiya and Charman, 2010). The repetitive behaviours and activities affect also the use of objects: some researchers report that this impairment can be detected already at 12 months of age (Ozonoff et al., 2008; McCleery et al., 2009). Ozonoff and colleagues (2008) found that 12-months-old children tend to use the object in a repetitive way. The use of the object needs to be studied from the sensorimotor development point of view because the object is present since the early stage of the children's development. More recently, several researches show that autistic children present atypical sensorimotor development and sensory perception that predicts the severity of symptoms especially in the area of communication at 24 months of age (Estes et al., 2015; Robertson and Baron-Cohen, 2017).

In the history of psychology, several psychologists studied the role of the object in the human development, such as Piaget, Vygotskji and Moscovici. Within his work, Piaget (1956; 1958; 1977) describes two different types of knowledge. The first type of knowledge origins through physical experience; such experience produces the knowledge of the properties of objects that are used. The second type of knowledge is gained through the logical-mathematical experience, which does not produce knowledge about the objects but about actions and their results. Thus, micro-genetic analysis, which aims to observe the temporal and qualitative aspects of the interactions, is a basic methodological condition for understanding the development of materiality. Despite this embryonic change of course the epistemological approach of Piaget remains anchored to the dualism of subject and reality.

Nevertheless Vygotskji (1962) uses another theoretical perspective: he considered the objects, named artefacts, as a fundamental component of human life. He suggests that humans use both material (i.e., a computer) and psychological (i.e., language) artefacts to interact. Adults use in a better way these artefacts and through their scaffolding 'teach' to children how to appropriately use them. In this respect, the artefacts represent human 'instruments' essential for the communication and interaction.

In these terms, the behaviour and the understanding of the processes of consciousness are closely dependent on the nature of the interaction of human and non-human components of this dialectic dyad. In the history of psychology, some the psychologists abandoned a dyadic approach in favour of a triadic perspective. The key aspect is no longer just the dyadic relationship, but what Moscovici (1976) defines triadic relationship. Moscovici proposes a ternary reading of facts and relations, and in fact replaces the two- term view, subject and object, with a three-term one: individual subject, social subject, and object. In other words, the Ego, the Other and the Object. This aspect assumes a constant exchange between the three elements of the triadic relationship. Such relationship may be conceived as static or dynamic, implying a simple "co-presence" or an "interaction" that can result in changes in thought and behaviour.

However, the theories presented above about the objects are based on a non-dialogical conception of the artefacts. In fact, Linell (2009) considers artefacts as external objects, according to a dialogical theory of the artefacts. The objects serve as anchoring points for intersubjectivity. Moreover, the author suggests that exist an interplay between the human ability of using artefacts and the external objects which possess a wide range of uses for humans. Thus, the objects are used by humans but also can change the humans perspective of the interactional world.

The objects are involved in several psychological mechanisms, such as joint attention and imitation that are largely studied in autism. The joint attention implicates at least the presence of two

partners and of an object that plays the role of the mediator of their interaction (Tomasello, 1995; Mundy and Gomes, 1998; Moore, Dunham and Dunham, 2014). Thus, the object is a protagonist of this human phenomenon, acquiring a crucial role in the interaction. Moreover, the studies on imitation distinguish between body gestures imitation and object actions imitation (Masur & Ritz, 1984; Snow, 1989), showing that the object is involved in the human development as a fundamental ‘non-living partner’ that has a role in a lot of psychological processes.

In the light of above, about children with typical development, the use of the object is a crucial element for the interactions (Rodriguez and Moreno, 2008; Barthélémy-Musso et al., 2013). In fact, Rodriguez and Moreno (2008) hypothesizes that children with typical development use the object in order to interact with adults: the adult has the role to teach to the child different uses of the object which, derive from the human society, Thus, the adult acquires the role of a scaffolder for the conventional use of the object (Moro, 2011, 2014). This approach is particularly interesting because the children and adult create an intersubjective space in which they can interact with each other through an object. Thus, the object is a mediator of the child-adult interaction. Moreover, as already highlighted in the previous paragraphs, the establishment of an intersubjectivity space is the basis of the of human interpersonal relationships.

In the view of the above, it is important to analyse the role of the object also in children with atypical development, in particular in autistic children because they present a distinctive pattern of interaction with the object (i.e., repetitive actions on the object) and are also characterized by social impairments which represent an obstacle for the establishment of interpersonal relationships. In fact, being social interaction impaired in autistic children is consequently impaired the interaction with the “social world of objects”. In the socio-material perspective (Iannaccone, 2015) the object is composed of material features and social components which coexisting the same object. Some autistic children show deficit in the use of the object: alterations in manipulation, observation, understanding and denomination. The object is a significant communicative mediator in social interaction between adults and children (Iannaccone, Savarese and Manzi, 2016). Thus, autistic children which do not present impairment in the use of the object show more social behaviours as pointing (Bernabei, Camaioni and Levi, 1998), imitation (Vanvuchelen et al., 2013) and joint attention (Mundy, 2016). For instance, joint attention is typified by subject-subject-object triangulation in which children alternate their eye gaze between the object and the other person (Trevarthen and Hubley, 1978). In this respect, Chapter 3 and 4 deal with the role of the object as promoter of the child-adult interactions. Despite the identification of deficits in the expression of the most important early precursors for the social interaction, it has been observed that autistic children can use in specific ways the object that promote the intersubjectivity space. In Chapter 4 autistic children from 20 to 24

months of age exhibit specific sensorimotor patterns of use of objects (manipulation and exploration) that tend to involve the other partner – adults – to interact with the objects. Thus, also in the case of autistic children the object is a mediator of the relation with the adult. Moreover, Chapter 4 points out that autistic children that present a more complex and rhythmic patterns of interaction with the object present more social behaviours (i.e., joint attention and imitative actions).

These findings reveal the ability of autistic children to establish an intersubjectivity space, using the object as mediator of interactions with adults despite the evident social impairments that characterize this syndrome.

This Thesis

Chapter 1 is a review of the literature about the role of the Theory of Mind (ToM) in the Human-Robot Interaction (HRI) in a life-span perspective, showing that from the childhood to the adulthood humans can ascribe a mind to a robot, in particular to a humanoid robot. The HRI is analysed in two main domains: 1) mental states and actions; 2) physical human-like features. The first area highlights that a robot which behave like a human and use human-like cognitive processes promotes the attribution of a mind to a robot. Already in infancy some behaviours (i.e., eye-contact and goal directed actions) promote a better children's social involvement during the interaction with a robot. The robot human-likeness is effective in a life-span perspective. Moreover, the implementation of robots' human-like physical features (i.e. eyes, hands, legs etc) is a crucial goal for the promotion of a more complex human-robot interaction. However, it is also important for a robot to not be completely similar to a human since the risk of a perfect human-like appearance is the Uncanny Valley effect (Mori, 1970), in which the excessive similarity of a robot with humans can reduce the interaction. The main hypothesis is that through these technical innovations, concerning physical and behavioural features of a robot, humans construct an intersubjectivity space with a robot. This is possible because the recognition of a mind in a robot is the prerequisite because humans perceived it as social partner.

Chapter 2 is focuses on pre-schoolers' behaviour during the Ultimatum Game when they play with a human and a robot. In particular the study aims at analysing: the mental characteristics ascribed to the robot with respect to the human; children's behaviour at the UG when playing with the human and with the robot as proposers and receivers; children's justifications for their behaviour during the UG. To my knowledge, this is the first study which analyses children's behaviour during the UG, comparing human-human and human-robot interaction. In this respect, several tasks and tests were created *ad hoc*: 1) the Attribution of Mental State Scale (AMS) is a measure of mental states attribution that the child has to perform looking at pictures depicting a character; 2) to assess children's understanding of the first-order false belief, we introduced a new instrument, constituted by eight videos representing the classical story, introducing also the Robovie as a new character - we used a story similar to the classical *Unexpected Transfer* task as the script of the videos. The AMS results show that 5-year-old children recognize the robot as a different entity from the human. In fact, children ascribe mental states also to the robot, but they are different compared to the mental states attribute to the human. Nevertheless, children behaved similarly during the UG when playing with the human and with the robot, confirming a tendency to maximize gain. Additionally, children's

justifications at the UG showed that, independently on the interactive agent and on the role played (Proposer/Receiver), children tend to use ‘outcome’-based justifications to explain their behaviour for all divisions. This is the first qualitative evidence supporting the idea that, at the age considered, children mostly reason in economic/quantitative, homo-oeconomicus-like, terms. The almost total lack of equity and mentalization-based justifications of human unfair divisions further suggests an attempt of children to resolve a social cognitive conflict emerging from the discrepancy between a “socially-expected” fair behaviour and the actual “selfish” behaviour.

Chapter 3 presents an explorative study aimed at observing the quality of interactional patterns in child-adult interaction, using objects as key elements for the construction of intersubjectivity. This qualitative research is based on two theoretical perspectives: 1) Piaget's studies (1952, 1954), according to which children reach the conceptualization skills of objects in the fifth phase of the sensory-motor development; 2) studies that concern the canonical use of the objects, according to which the canonical functions of the objects are acquired as a normative phenomenon during social interactions (Tomasello, 2016), even if the cognitive understanding of these functions is a prerequisite. Several other studies show that canonical functions of the objects are acquired during child-adult interactions (Leontiev, 1981; Costall, 1997; Moro, 2011, 2014; Rodríguez & Moro, 1998; Sinha & Rodríguez, 2008). In this Chapter it will be analysed the manipulation of objects by children with autism spectrum disorder with the aim of showing how objects can be considered as active agents of interpersonal exchange between children and adults. The study adopts a socio-material interpretation, assuming that some interactional patterns, involving the manipulation of objects, can create a space that supports the child-adult relationship. The observations highlight that children present sensorial and realistic play and there are some children's behaviours (i.e., eye-contact) that show that the objects are concrete mediators for the construction of the intersubjective space in the interactions between children and adults. It has been observed in this study that children monitor adults' attention through eye contact or object manipulation. These actions are signs that the object becomes a mediator of mutual attention between the adult and the child: we called this kind of attention, “attention mediated by the object”.

Chapter 4 presents a brief report that investigates the role of the object as a factor that mediates the interaction between children and adults. We observed a group of autistic children in order to analyse if an object can be a promoter of social interactional functions: imitation, joint attention and pointing. The main focus of the study is to analyze in verbal ASD the understanding of social function intrinsic in the object through the use of material features of the object. In particular, the study evaluates the

relationship between the “interaction with/through object” (material features of the object) and three social functions classically impaired in ASD: pointing, imitation and joint attention. We observed a group of ASD children aged between the ending of the sensory-motor stage (24 months) and the beginning of the concrete operational stage (68 months). The group has been split in two sub-groups: group1 is composed of 18 children that act and interact through objects (for examples, balls, cars etc.). Indeed, children manipulate, observe, understand and sometimes give a definition of the object; group2 is composed of 25 children that do not act and interact through and with object. Group 1 shows more social functions (pointing, imitation and joint attention) than group 2 Autistic children which show a more complex use of the material features of the object and act and interact with and through object present more social functions. On the other hand, children which have alteration in the use of the object show fewer social functions. These differences depend on the children’s characteristics. In this study, the role of the object is a crucial element for the creation of the intersubjective space.

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Chapter 2

Theory of Mind and Humanoid Robots From a Lifespan Perspective

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Abstract

This mini-review focuses on some relevant issues concerning the relationship between Theory of Mind and humanoid robots. Humanoid robots are employed in different everyday-life contexts, so it seems relevant to question whether the relationships between human beings and humanoids can be characterized by a mode of interaction typical of the relationships between human beings, i.e., the attribution of mental states. Since Theory of Mind development continuously undergoes changes, from early childhood to late adulthood, a lifespan perspective was adopted. Contributions from the literature were analyzed by organizing them around the partition between ‘mental states and actions’ and ‘human-like features’. Finally, we considered the contribution that studying the human-robot interaction, within the paradigm of Theory of Mind, can give to the understanding of the intersubjective nature of this interaction.

Introduction

This contribution progresses from Turkle's (2004) opinion, which, reflecting on Steven Spielberg's movie, *AI*, exemplifies the most exquisite socio-relational issues of human–robot interaction:

. . .[S]cientists build a humanoid robot, David, who is programmed to love. David expresses this love to a woman who has adopted him as her child. In the discussion that followed the release of the film, emphasis usually fell on the question of whether such a robot could really be developed. People thereby passed over a deeper question. ... That question concerns...[w]hat kinds of people are we becoming as we develop more and more intimate relationships with machines? Today, we are faced with relational artifacts to which people respond in ways that have much in common with the mother in *A.I.* (p. 25).

For hundreds of years, the interest in human–robot interaction has occupied a space in the cultural productions of humankind. Today, we are witnessing a renewed interest in the human creation of a nonhuman alter ego. In particular, researchers are focusing their interest on social interactions with robots. Many scholars believe that a fundamental component of social interaction is the Theory of Mind (ToM; Wimmer & Perner, 1983). ToM is the ability to predict and interpret our own, and others', behavior on the basis of mental states. Herein we offer an overview of work that has focused on the study of human–robot interaction, in the context of ToM. In particular, we review studies investigating the attribution of mental states to robots in a lifespan perspective.

Without the claim of being chronologically exhaustive, we provide some examples of the pervasive interest in artificial partners in the history of humanity. Homer (2003), in the *Iliad* (XVIII, 573–579), told how Hephaestus, the god of fire, who needed help in his forges, built aides, similar to young men, who had hearts, voices, and life. Discussion of the more-or-less human characteristics of intelligent manmade machines has its most famous philosophical roots in the 17th and 18th centuries, in the debate around the works of Descartes and La Mettrie (Gunderson, 1964). Descartes equates animals with machines, but ascribes uniqueness to humans via the term, *cogito* (I think). On the contrary, La Mettrie extends the animal-machine analogy to humans, radicalizing the materialistic and mechanistic perspective.

The mechanical automaton was an attempt to build a human-like artifact, capable of replicating and repeating human activity. In the 13th century, Al-Jazari, an Arabic mechanical engineer, built a programmable device capable of playing sounds autonomously (Nadarajan, 2007). In the 15th

century, Leonardo da Vinci not only theorized on the possible robotic reproduction of an animal, but also advanced a project that attempted to mechanize the human being, with the mechanical knight of 1495 (Rosheim, 2006; Taddei, 2007).

A crucial qualitative leap into the anthropomorphization of machines is to ask whether robots can think, overcoming Cartesian dualism: the philosophical concept that asserts the existence of a separation between *res cogitans* and *res extensa* (i.e., respectively the mind and the body). From a psychological, and more intersubjective³, point of view, and for the purpose of this review, we can rephrase the question as: when will robots be able to make humans believe that they are human? In 1950, Turing published a seminal paper in which he imagined an imitation game with three participants. An interrogator asked questions of the other two participants and, based on the answers, had to guess who was a man and who was a woman. Then, without warning the interrogator, a computer would replace one of the participants. How long would it take to understand that the answers came from a machine, and not from a human being? According to Turing, during the imitation game, it would become increasingly difficult to distinguish the responses of a machine from those of a human (Turing, 1950).

Artistic creativity often anticipates scientific topics on the history of thought. There are many examples in literature and cinema about our subject. Let us remember Shelley (1830/1994), proposing the literary character of Frankenstein, or The Modern Prometheus⁴, destined for a much greater degree of notoriety thanks to the story's many cinematic adaptations. It is also worth mentioning Asimov (1983), who revisited the futuristic concept of a robot by conceiving it as a potential partner for supporting/replacing human activities.

³ The concept of intersubjectivity has various definitions, each of them highlighting different aspects: cognitive, affective, socio-cognitive. The various definitions have in common the idea that the meaning of the tasks and events that the person builds during development is not an operation in solitude but is the result of interaction with real or symbolic partners.

⁴ The story shows the human desire to create an immortal alter ego. The created alter ego turns out to be a monster. Dramatic events lead to the death of the monster's creator and then the monster itself. The monster suicides, explaining the evil deeds it has done while living with the contempt and rejection by humans. The fascination of this story consists in shaping the fears of both partners in this relationship.

Cinema has also represented – now as utopia, now as dystopia – the complexity of the robot’s relationship with humanoids. Fritz Lang’s *Metropolis* (1927) was the first movie to foreshadow the possibility that a robot could substitute for man in the hardest jobs, and that it could begin to interact with man in ways that went beyond any designed intentionality.

The iconic film *Blade Runner* (1982), drawing inspiration from Philip K. Dick’s *Do androids dream of electric sheep?* (1968), highlighted the risk of indistinguishability between

the creator of humanoids and his “children.” Freud (1919/1955) described the characteristics of a particular psychic experience with the experience of the “Perturbant” (Unheimlich-unfamiliar vs. Heimlich-familiar). Jentsch (1906, 1997) had already described this experience in relation to, for example, puppets and automatons. The latter consist of the uncertainty that a seemingly inanimate being is alive and, in a complementary way, that a living subject has the chance to be inanimate.

This phenomenon reappears in more recent literature as the “Uncanny Valley” experience. Mori (1970) described the sense of repulsion that can accompany interaction with humanoids whose appearance resembles, without being overly superimposed, that of a human (see also Mori, MacDorman, & Kageki, 2012). Another facet of the possible human–robot relationship worth mentioning is the one proposed by Spike Jonze’s *Her* (2013). The protagonist lives a true love story with an almost completely disincarnated artificial intelligence that manifests itself through a very sensual voice. Alongside this experience, the growing presence of anthropomorphic robots in everyday life, in educational, production, and welfare settings, raises several new issues – philosophical, ethical, political, economic, legal, and insurance⁵. While the anxiety about replacing men with robots in production situations, with the associated risk of unemployment and impoverishment, is not new, more recent discussions are about the status of robots, with respect to the new aforementioned issues (Floridi, 2017; Floridi & Sanders, 2004; see also the European Parliament Resolution of 16 February 2017).

In the case of robot-building for social purposes⁶, the extraordinary human capacity to invent and realize tools that integrate and expand the biologically-based abilities of our species (from work tools

⁵ To give just a few examples, think of the use of robots for assistance and companionship to the elderly, the educational and didactic use with children with typical and atypical development, and the execution of various activities in shopping centers, airports, and so forth.

⁶ The military is another area that makes extensive use of robotic engineering (just think of the recent massive use of drones in war). Although the psychological implications are multiple (attribution of responsibility, reliability of information, trust, etc.), we do not consider this field because there is no possibility of attributing mental states to the robot.

to sensory aids to external memory of electronic devices) has been driven in two directions. The first direction – developmental cybernetics (Itakura, 2008; Itakura, Okanda, & Moriguchi, 2008) – consists of creating a human-like system, with cognitive function (simulating psychological processes in the robot) and prosthetic functions (enhancing the function and life-style of persons). The second direction – developmental robotics – consists of the idea that robots can autonomously gain sensorimotor and mental capabilities with growing complexity, starting from intricate evolutionary principles (Cangelosi & Schlesinger, 2015). To date, developmental cybernetics aims to build robots that behave in a human-like way, while developmental robotics aims to build robots that develop in a human-like way. Based on these features, the two approaches are located at different points on a continuum that links interaction and relationship. Developmental cybernetics is closer to the relational dimension; in fact, it studies those human–robot exchanges in which the assumption of some form of subjectivity of the partners is involved. Let us think, for example, about the educational and welfare uses of intelligent machines, in which the dynamics associated with the use of prosthetic tools that improve quality of life are placed on the level of *hic et nunc* (here and now) interaction, without aiming at the construction of a relational story. Conversely, socio-relational dynamics value the level of the relationship (Gross et al., 2012; Tanaka, Cicourel, & Movellan, 2007). Developmental robotics is closer to the interactive dimension; it uses the interaction to study how a robot can develop new abilities, in a child-like fashion. For instance, consider the attempts at robotics modeling of the stages of language acquisition (Morse & Cangelosi, 2017), and the use of mutual imitation between humans and robots to promote the robot’s subsequent recognition of an interactive agent (Boucenna, Cohen, Meltzoff, Gaussier, & Chetouani, 2016).

We are interested in understanding how the attribution of mental states to robots evolves through the lifespan; therefore, we primarily analyze the studies conducted in the field of developmental cybernetics.

Why Robots Could Be Intended as Social Partners

From a psychological point of view, from the earliest moments and throughout one’s entire life, the possibility of establishing social exchanges involves the ability to recognize the other as being “like me” (Meltzoff, 2005; Meltzoff, 2007a, 2007b; Meltzoff, 2013; Meltzoff & Brooks, 2001). Infants can imitate facial movements, such as mouth opening and tongue protrusion (Meltzoff & Moore, 1977, 1983, 1989), and have visual acuity for human faces and stimuli, with characteristics similar to themselves (Johnson, Dziurawiec, Ellis, & Morton, 1991). Proto-conversations with the caregiver

root in these innate imitative mechanisms and, overall, the analysis of traits and characteristics of the relational partner contribute to building the intersubjective dimension underlying so many developmental acquisitions (Meltzoff, 2005; Meltzoff, 2007a, 2007b; Meltzoff, 2013). For this purpose, Trevarthen (1998) spoke of an innate specific human endowment that would guide us to the search for companionship, and put us in the condition of “understanding and using the intentions of other people in conversational talks of intentions, emotions, experiences, and meaning” (p. 16). According to Tronick, Als, Adamson, Wise, and Brazelton (1978), human beings experience the world in intersubjective terms. This trend is related to the tendency of children to first experience the world as if it were animated, and to make a distinction between animate and inanimate only later. This tendency is operationalized by the “still face” paradigm: the motionless face of the caregiver generates in the child a series of emotions from perplexity to anxiety, showing the infant’s expectation to interact with a human partner with an expressive, and therefore animated, face.

A fundamental question, therefore, is: what can the developmental research on human–robot interaction teach us about aspects, features, and cues that a robotic interactive partner must have to be recognized as “like-me?” This question has an epistemological basis. In fact, human–robot interaction represents a “technological gym” that specifies the social cues that must be implemented in a humanoid robot so that children of different ages recognize it and treat it as a social partner.

Below, we analyze contributions from the literature to the lifespan perspective in this regard, by organizing them around “mental states and actions” and “human-like features.” This division arises from the consideration that a representational ToM derives from the infants’ early understanding of the bodily cues of the mental states. In other words, the bodily roots of ToM remain through the lifespan, as the basis of more advanced representational mentalistic skills.

Mental States and Actions

Regarding the first element of the division that we set as the basis of robot attributions of features “like-me,” the research examines aspects of robotic actions that lead participants to believe that the actions imply mental states.

In this sense, a seminal study by Meltzoff (1995) investigated the reenactment of intended acts, performed by human beings versus robot-like devices, in a group of 18-month-old infants. An emerging sense of the person is revealed by the fact that infants did not reenact the action performed by the robot-like device, probably because they did not recognize its intentions and goals.

Itakura, Ishida, et al. (2008) studied this topic further, in children aged 24–35 months, and showed that the children were inclined to imitate goal-directed actions where the goal is not achieved; these failed actions implemented by a robot were imitated only when the robot's action was preceded by eye contact between the robot and an adult present at the scene. When the robot's eye contact with the adult was missing, the child did not mimic the robot's behavior. According to the authors, this evidence shows that it is not human-like morphology, but rather human-like behavior, through eye contact, that plays an important role in inducing children to imitate the goal-directed behavior of a nonhuman agent.

The theme of imitation of goal-directed actions relates to research on mirror neurons⁷, which seem to play an important role in understanding others' actions and, more generally, in social competence. On this basis, Moriguchi, Matsunaka, Itakura, and Hiraki (2012) initially elaborated that the actions are somehow related to perception, and that many human brain areas devoted to the execution of actions also function by observing other human actions, rather than robotic actions. The authors then built on this evidence through a research paradigm verifying whether, and how, actions taken by a human arm or a mechanical arm may somehow interfere with the child's search for an object. A human arm and a mechanical arm sought and found an object in position A. The object was then moved to position B. The child who was asked to look for the object attributed a kind of "retrospective trust" to the human arm, compared to the mechanical arm; in fact, the number of errors committed in the search for the object was higher when the human action preceded the search. The same result had already been obtained in a group of 3-year-olds (Moriguchi, Kanda, Ishiguro, & Itakura, 2010), suggesting that the presence of a mental simulation mechanism would only be activated when the children imitated human actions.

Okumura, Kanakogi, Kanda, Ishiguro, and Itakura (2013a) confirmed this in a paradigm that verified the ability to anticipate the appearance of an object, using the information from a human gaze, rather than a robotic gaze. Through the use of an eye tracker, gaze-following and object anticipation were measured in two groups of 10- and 12-month-old children. Both groups let themselves be guided by

⁷ The mirror neurons are a subset of neurons in the human brain that respond when an individual performs certain actions, and also when the same individual observes others performing the same movements. In other words, actions performed by one person can activate motor pathways in another's brain responsible for performing the same action. Mirror neurons, or mirror mechanism, provide a direct internal experience, and therefore understanding, of another person's act, intention, or emotion. Mirror neurons may also underlie the ability to imitate another's action, and thereby learn, making the mirror mechanism a bridge between individual brains for communication and connection on multiple levels (Rizzolatti, Fogassi, & Gallese 2006).

the human gaze and the robotic gaze; however, only the human gaze had an anticipation effect, and only for the 12-month-old children.

In the context of studies that analyze the importance of the perception of biological motion as the precursor of ToM (Frith & Frith, 1999), Breazeal et al. (2016) considered a group of 3- and 5-year-old children. Note that the ability to use a robotic informant with epistemic aims (name exotic, non-familiar animals for children) is strongly influenced by the nonverbal contingency of the informant (head movements, gaze shifts, arm movements, and facial movements) typical of human face-to-face interactions. From this perspective, Carter and Pelphrey (2006) explored, with functional Magnetic Resonance Imaging (fMRI), neural activations, corresponding to the perception of the movement of four different agents – human, robot, mechanical assembly, and grandfather clock – in 7- to 10-year-old children. The results showed different activations, according to the human-like nature of the perceived biological movement, that is, a motion made by a human or a robot. This brain network also included some components of the mirror neuron system. Replicating the evidence obtained on adults, these findings show that some portions of the neural circuit involved in the embodied simulation are recruited in the perception of the biological movement also enacted by a robot.

We now shift from studies that analyze indirect indicators of the attribution of human-like features to studies that explicitly analyze this attribution. Kahn et al. (2012) interviewed children aged 9, 12, and 15 years, and evaluated the attribution of social, mental, and moral features to robots previously observed in nine different interactive situations with the subject and the experimenter. The authors found an interesting developmental trend: 9- and 12-year-olds perceived the robotic partner as a more mental, social, and partially moral entity than did the 15-year-olds. Therefore, in the construction of robotic partners suitable for participants of preadolescent age, with different purposes (from play to education), it is important to analyze, in detail, what interactive features are strengthened, so that the robot is perceived as the holder of mental, social, and moral characteristics, even by teenagers. Similar results regarding the attribution of mentalistic features to robots, following the observation of goal-directed actions, were obtained using a semi-structured interview of participants aged between 5 and 16 years (Beran, Ramirez-Serrano, Kuzyk, Fior, & Nugent, 2011). The participants tended to attribute behavioral, cognitive, and affective features to robots observed in the execution of a block-stacking task, a construction game in which the robot stacked blocks of wood to form two towers. In carrying out these activities, the robot manifested autonomy through a series of behaviors, such as looking at the child's face, performing accidental actions, and so on. Reminiscent of Piagetian animism, there was also an effect of age such that younger children (under 12 years of age), more

than the older children, believed that robots possess a large number of human attributes (Piaget, 1954).

Chaminade et al. (2010) used behavioral and fMRI methods to explore emotion depiction (anger, joy, and disgust) in gestures acted by human beings and humanoid robots in a sample of young adults. Results showed higher emotion ratings for anger and disgust expressed by the human; no differences were found for joy. Neural evidence suggested less empathy from viewing the humanoid robot: in fact, the activation of the left anterior insula (perception of disgust) and the orbitofrontal cortex (perception of anger) was lower for robot stimuli than for human stimuli. Finally, the higher activation in the occipital and posterior temporal cortices with robot versus human stimuli probably arose from the additional visual processing linked to the perception of a behavior acted by the humanoid robot.

An ingenious way to look directly at the interaction between human and robot is to use economic interactive games. One of the most used interactive games is the Ultimatum Game: one player (responder) receives a monetary offer from another player (proposer), who has to divide the amount. The responder has the option of accepting or rejecting the offer. If the responder accepts the offer, the two participants split the sum of money; however, if the responder rejects the offer, both players receive nothing (Güth, Schmittberger, & Schwarze, 1982). Nishio, Ogawa, Kanakogi, Itakura, and Ishiguro (2012) had young adults play the Ultimatum Game with a robotic partner. Results showed that fairness-oriented behavior increased when “mentalizing stimuli” accompanied cues from the physical appearance of the robotic partner, such as the expression of utterances between experimental sessions (see also Castelli, Massaro, Sanfey, & Marchetti, 2010, for results in a sample of children with a human and a nonhuman partner).

Ultimately, the works presented in this section show that children and adults perceive an experience with an artificial partner as social when the artificial partner can express intentions and goals through behavioral cues that are typical of interactions among humans.

Human-Like Features

With regard to “human-like features,” the research focuses on the configuration of body features being indispensable to humanoid anthropomorphization. It seems that, very soon, human beings will be able to relate to robots according to a principle of similarity to themselves. A first question is

whether biological and psychological characteristics are attributed to robots similarly or differently from other living organisms, and other material entities. Kamewari, Kato, Kanda, Ishiguro, and Hiraki, (2005) showed that 6.5-month-old infants exhibited the ability to attribute agency to human and humanoid-robot motions, but not to a robot without a human-like appearance. A sophisticated teleological representation is assumed in interpreting actions during the early stages of an infant's life, insofar as the agents are human-like. This first result is strengthened by two studies that take into account two human features considered crucial in characterizing one's social nature – eyes and voice.

The first study by Okumura et al. (2013a) showed that the presence of eyes in a robot is crucial for 12-month-old children to have their attention directed by the movement of a robot. In fact, when a robot without eyes was set in motion, this movement was not as informative to the child. The authors interpreted this result by assuming that the presence of eyes was a crucial indicator for the attribution of a mind at this age. The second study by Okumura, Kanakogi, Kanda, Ishiguro, and Itakura (2013b) showed that, for children aged 12 months, the gaze of a robot can be effectively used to learn an object if it is accompanied by a verbalization (not a simple nonverbal sound).

Moving from the preverbal to the verbal age, results obtained by directly questioning the participants about the characteristics of the robots are consistent with the early propensity to attribute human-like characteristics to humanoids. With development, other elements, in addition to the look, become important in deciding whether a partner has human-like characteristics. Katayama, Katayama, Kitazaki, and Itakura (2010) compared humans, robots, animals, and cultural artifacts to study the possible recognition of biological and psychological features in robots by children aged 5 and 6 years, and by adults. While the adults' attributions were quite heterogeneous, both 5- and 6 year-olds attributed a variety of biological but not mentalistic features to robots. Somanader, Saylor, and Levin (2011) asked a sample of 4- and 5-year-olds about the presence of representational, biological and mechanical characteristics in a human being, and in cultural artifacts (i.e., a robot and a TV). They found that the children attributed more representational and biological features to the human being than to the cultural artifacts, and to the robot more than to the TV. They also found that such attributions were more likely to be given to the robot if they did not see that the robot was controlled by a remote. These data reverse the trend found in a previous study, by Saylor, Somanader, Levin, and Kawamura (2010), in which robots and other familiar artifacts, including a TV, were classified as the same thing in terms of biological and representational properties. The authors assumed that the difference between the results of the two studies was due to their efforts to formally anthropomorphize the robots.

Manzi et al. (2017) explored the mentalistic value of faces in anthropomorphic agents compared to human faces through a dichotomous morphing, or gradient, of progressive anthropomorphism. The authors showed that 7- and 9-year-old children ascribed more mental state (e.g., sensory, perceptive, emotive, will, imaginative, and epistemic attributes) to the human face than to a robotic face.

Fiore et al. (2013) explored which elements contributed to creating an impression of the social presence of an agent in a group of late teenagers. To this end, they analyzed the way human beings interpret social cues exhibited by robots, in terms of proxemic behavior (the distance that the robot travels within the human's space). This was investigated by placing the robot and the participant in a hallway-crossing scenario. In this scenario, the authors varied the level of proximity the robot would permit the human in establishing whether to cross paths, and if the robot waited until the participant had passed. The authors also measured the role of the gaze, performed at three levels of direction (congruent with the robot's movement, human-oriented, and variable). The results showed that the robot that waited until the participant passed was evaluated as an agent more socially present than the robot that crossed the path without waiting. Furthermore, gaze did not play a significant role as a social cue in this situation.

Krach et al. (2008) explored human-robot interaction with a group of young adults, using the interactive game the Prisoner's Dilemma and fMRI. In the game, two players must decide whether to cooperate with each other or defect. They may gain a defined sum of points, depending on their own, and their counterpart's decision. A unilateral win is maximized by defection, if the counterpart cooperates, but both players are punished if they defect. Relying on mutual cooperation involves the risk of being deceived. In this study, the game included four different partners, each with an increasing level of anthropomorphization (computer, functional robot, anthropomorphic robot, human). Anthropomorphization was operationalized by following Epley, Waytz, and Cacioppo (2007), who included cues relating explicitly to physical aspects and mental states (elicited agent knowledge, effectiveness motivation). Participants were asked to evaluate the game partner for fun, intelligence, competitiveness, and sympathy. Results showed a linearly increasing attribution of fun and intelligence as the partner appeared more human-like. Interestingly, the anthropomorphic robot and the human were perceived as equally competitive, and more competitive than the computer and the functional robot. Moreover, the authors of the study pointed out that higher levels of human-likeness

were positively correlated with a greater activation of the ToM network, that is, the brain areas⁸ that the literature has shown to be specifically recruited when people interact with a social partner.

Takahashi et al. (2014) focused on the neural bases of human–robot interaction when participants were involved in an economic interactive game (Matching Pennies) with several partners: human, human-like android, mechanical robot, interactive robot, and a computer. The game was played between two players: a participant and an opponent. They had to press a button corresponding to the left or the right side of their bodies. The win situation was reached only when the same side was selected by both participant and opponent. The partners were evaluated concerning two dimensions: mind-holderness (having mental functions) and mind-readerness (being intelligent). As predicted by game theory, the more robotic partners were thought to be mind-readers the more the human opponents changed their play strategies, increasing the level of entropy of exchanges through random choices. fMRI data showed the involvement of different subsets of the social brain, according to the attribution of mind-holderness (dorsal aspect of the temporoparietal junction, medial prefrontal and posterior paracingulate cortices) or mind-readerness (ventral temporoparietal junction and the temporal pole).

Broadbent et al. (2013) studied how the facial characteristics of a robot may influence recognition of the robot's qualities, such as mind, personality, and eeriness, using a sample of young adults involved in a simulated healthcare environment. They employed three robots, respectively showing lack of face, silver face, and human face. The results showed a clear preference for the robot with the human-like face, which was rated as having the most mind and personality, and the lowest eeriness. This specific result relates to the uncanny valley, demonstrating just how subtle the boundary is between a pleasant likeness to the human and a disquieting one.

Similarly, Martini, Gonzalez, and Wiese (2016) studied whether specific degrees of humanness were needed to attribute different typologies of internal states to non–human agents. Interestingly, they found that the threshold “having a mind” must be reached, before being able to ascribe any other kind of internal state. The more the non–human face resembled that of a human, the more this threshold was overcome.

⁸ The ToM network includes the medial prefrontal cortex (mPFC), parts of precuneus and posterior cingulate cortex, the temporoparietal junction (TPJ), the posterior superior temporal sulcus (pSTS) bilaterally; some studies also include the bilateral anterior temporal lobes and areas in the amygdala (Schurz, Radua, Aichhorn, Richlan, & Perner, 2014).

Considering the studies reviewed so far, it is useful to emphasize the great importance given to the face and eyes when considering the physical features capable of representing an agent in anthropomorphic terms. This evidence confirms the great amount of data from ethology, evolutionary psychology, and even studies of aesthetic perception, in support of the great power of the human face in creating a sense of social interaction (Brooks & Meltzoff, 2005; Call & Carpenter, 2001; Emery, 2000; Itakura, Agnetta, Hare, & Tomasello, 1999; Massaro et al., 2012; Moore & Corkum, 1998; Morales, Mundy, & Rojas, 1998; Savazzi et al., 2014; Slaughter & McConnell, 2003; Tomasello, Hare, & Fogleman, 2001; Tomasello, Hare, Lehmann, & Call, 2007).

In conclusion, the information presented in this section shows that interaction with artificial agents is more preferred, and perceived as human-like, when the artificial agent presents aesthetic features that reproduce those of humans, with particular relevance to face and gaze.

Human Beings and Robots: Preliminary Steps Toward Intersubjectivity

The studies reviewed identify features pertaining to mentalizing cues and physical appearance as important bases of the “like me” experience with humanoids. Recent research also suggests that Meltzoff’s (2007a, 2013) “like me” framework can be extended to encompass other dimensions on which human perceivers make “like me” attributions. These dimensions pertain to the nature of the interaction, and other, deeper factors that are just beginning to be explored. A minority of studies delineates an emerging trend of research in this field. These are investigations across the lifespan that consider the role of attitudes and expectations of the human partner, involved in different interactive contexts, in determining preferences and acceptance of the humanoid partner.

Meltzoff, Brooks, Shon, and Rao (2010) explored the hypothesis that 18-month-old infants may use information gained from observing human–robot interactions as evidence about whether the robot is a perceiver. The results showed that the infants attributed mind to the robot, based on the socially-communicative interactions the robot engaged in. This study also demonstrated that the nature of the interaction, and not only the robot’s behavior, mattered.

Tanaka et al. (2007) studied the relationship between 18- to 24-month-old children and a robot, through a long-life immersion technique (45 sessions of approximately 50 min each, spanning 5 months, in the children’s play area). One of the great problems of human–robot interaction is the

duration; long-term study is difficult. Children tire, even though they initially have great interest. The experiment aimed to verify relationship tenure for a time longer than the 10-hr barrier, comparing the employment of a robot able to manifest an entire repertoire of behavior (walking, head- moving, dancing, sitting down, standing up, lying down, hand gesturing, and giggling) to a robot able to manifest only predictable behavior. The relationship improved when the robot was programmed to manifest the entire repertoire of behaviors (27 sessions), worsened when the robot exhibited predictable behavior (15 sessions), and improved again when the robot began to manifest its entire repertoire. The development of socialization strategies correlated positively with frequency of contact with the robot.

Contextualizing the relationship in an educational setting, Movellan, Eckhardt, Virnes, and Rodriguez (2009) showed that interaction between 18- to 24-month-old toddlers and a low-cost sociable robot in an Early Childhood Education Center can significantly enhance word-learning. This evidence is promising, in view of the use of these humanoids with educational and didactic purposes, based on the intersubjective sharing of significant goal-oriented activities. Similarly, Tanaka and Matsuzoe (2012) employed a care-receiving robot to support foreign language learning in 3- to 6-year-old children. These authors showed that the care-receiving role, and not only the teaching role, could be successful in a teaching context. In fact, the condition in which a robot gave wrong answers improved the children's English verb acquisition more than the condition without the robot. Taking into account the relationship between peers, Westlund and Breazeal (2015) introduced a robot, programmed to behave as a peer, to a group of 4- to 6-year-old preschoolers in a storytelling context. The robot was able to lower its linguistic competence in order to match the child's current ability. The evidence showed that a storytelling robot capable of adapting to its partner in terms of language competence, was effective in supporting the oral language development of the child. Robots would seem to have educational skills not only as storytellers, but also as sympathetic listeners. Conti, Di Nuovo, Cirasa, and Di Nuovo (2017) compared a humanoid robot story- teller to a human teacher storyteller in a group of preschoolers. The authors evaluated how the storytellers' social behaviors influenced the children's memorization of the story. Results showed a similar performance in memorizing the details of the story when the storyteller was a robot or a human with an expressive behavior (expression of appropriate emotions with the body and with the voice). The expressive robot was even more efficient than a static inexpressive human storyteller (fixed gaze, motionless body, monotonous voice).

Park, Gelsomini, Lee, and Breazeal (2017) investigated the adaptive capacities of robots as listeners in: giving feedback that informed children about the presence of an active listener, given the abilities

of gazing, leaning forward, nodding, smiling, eye-widening to emulate eyebrow movement, and short utterances. The authors tested two robotic relational styles: a contingent style of the robot capable of reflecting the nonverbal behavior of the child; and a non- contingent style of the robot that emitted random, nonverbal behaviors. Based on children's gaze patterns, the results showed that the contingent robot most relationally engaged the children.

Human-robot interaction research ranges from ToM pre- cursors to social skills of the elderly. Iwamura, Shiomi, Kanda, Ishiguro, and Hagita (2011) focused on the use of a robot by a group of elderly shoppers in a supermarket. They found that an assistive robot that also engaged in non-shopping-oriented conversation was preferred to a robot capable only of functionally oriented conversation. Sabelli, Kanda, and Hagita (2011) introduced a conversational robot into an elderly care setting for 3.5 months, and analyzed its main interactive exchanges with the elderly and the staff using an ethnographic methodology. Three of the six identified trends (basic social interaction, telling robot information, and emotional elements) pertained to the socio-relational/mentalistic dimension.

Again working on the relationship between robots and the elderly in a retirement village, Stafford, MacDonald, Jayawardena, Wegner, and Broadbent (2014) analyzed the attitudes to use mind agency, and attribute mind agency to the robots. The evidence showed that older people preferred to interact with robots to which they attributed less mind agency. These findings were rather counterintuitive because they question the presumed importance of mental state attribution in effective social exchanges. It is likely that the elderly were frightened by the robots because of an overestimation of their cognitive capacities which decreased with actual use.

Gross et al. (2012) presented preliminary results of the implementation of a companion robot for elderly people with Mild Cognitive Impairment (MCI). The evidence emphasized how satisfied the elderly were when interacting with a robot that could support them in executing daily tasks. This work opens up the use of robots in the context of caring for people with neurodegenerative diseases. It also places the importance of assessing the effectiveness of such long-term interventions (weeks or months), and fostering relationships with a truly autonomous robotic partner (hypothetically endowed with a wide behavioral repertoire), as the first point in the agenda for future research.

The studies presented in this section, many of which were conducted in extra-experimental settings, show the importance of a detailed analysis of the contexts in which human-robot interactions take place to fully understand the intersubjective nature of the human-robot interaction.

Conclusions

This review aimed to analyze human–robot interaction from two vantage points: (1) the human attribution of mental states to the robot and (2) the human recognition of the robot as “like-me.” The experience that the robot is “like me” is based mainly on the physical appearance of the robot, and its behavior; however, another aspect emerges that pertains neither to humans, nor to humanoids, but which is a characteristic of their encounters. This aspect is the intersubjective level of the exchange. This dimension contributes some design features of the humanoids, which cannot be conceived as simple artificial instruments for the extension of human abilities. The more a humanoid partner/companion can go beyond a functionally and mechanistically perfect performance, the more it seems “like me.” In other words, an exchange is especially meaningful if it happens with a partner with a human-like capacity to be engaged in somewhat unpredictable, intersubjective exchanges. From our point of view, this unpredictability depends on the subjective nature of the human knowledge and representations of the world. During social exchanges, partners share mental states and representations of the world. The construction of intersubjectivity is based on mutual recognition of the subjective nature of such states and of such representations.

In light of these considerations, this somewhat unpredictable meeting of minds can take different directions, and can be conceptualized in different ways. For example, it can be seen as the optimal level of frustration (Kohut, 1977). All human exchanges with significant partners are characterized by an alternation of gratification and frustration. However, this fact does not compromise human exchanges, provided that the frustration is remediable. A second possible way to conceive the somewhat unpredictable meeting of minds is that of the imperfect contingency (Bigelow, 1998). There is no optimum level of contingent responsiveness in early relationships with caregivers; rather each of us experiences an imperfect contingent responsiveness through parental interactions (i.e., the partners occasionally find the level of relational contingency adequate to the ongoing interaction). This responsiveness influences future exchanges with nonfamily partners. A further possible conceptualization is marked mirroring (Gergely, 2007; Gergely & Watson, 1996), which happens during a child’s affect-regulative interactions. The adult offers the child a reflection of an experience of the world, and of the emotional states of the child itself, and at the same time, the adult informs the child that this reflection is not expressing her/his own feelings. A final interesting conceptualization is offered by the work of Tronick and Beeghly (2011). They stated that interactions consist of a flow of matching and mismatching of meaning, and the reparation of mismatches to

matches. Intersubjective attunement would emerge from the experience of reparation, which in turn would create the experience of connection and shared states.

In the Vygotskian theoretical framework, the unpredictability and possibility of relational mismatching takes on a particularly interesting form in the Zone of Proximal Development (“the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers”: Vygotsky, 1978, p. 86). In fact, cognitive discrepancy, if salient in intersubjective exchange, can become a powerful engine of learning and development. From this point of view, one of the most intriguing challenges for future humanoids is the possibility that they provide the partner stimuli, inputs, and interpretations that moderately surpass the present partner’s abilities, constructing bridges toward more advanced forms of understanding and capabilities. Looking at the future, our reflections allow us to glimpse the theme of technological singularity. It consists of the invention of a super-artificial intelligence that would result in a sudden “evolutionary” change, able in principle to overcome human intelligence (Eden, Moor, Soraker, & Steinhart, 2012). All this is possible if we consider the intersubjective nature of developmental and educational interactions in which both partners contribute to change and learning. ToM – which has as its core concept the “meeting of minds” – seems to us a theoretical perspective that is particularly well suited to understanding intersubjective interactions.

The end of the Blade Runner movie sums up this possible scenario of potentially open, flexible, and plastic exchanges between human beings and humanoids metaphorically. In fact, it shows as plausible a future of love between Rick Deckard, the replicant hunter, and Rachael, the first replicant without an a priori expiration date. Ultimately, the beauty of uncertainty, more than any other quality, made Rachel special, and therefore very humanlike.

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Chapter 3

It does not matter who you are: fairness in pre-schoolers interacting with human and robotic partners

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Abstract

The relationship between humans and robots is increasingly becoming focus of interest in many fields of research. The studies addressing the various dynamics underpinning the human-robot interaction have, up to date, mainly investigated this relationship analysing adults' behaviour when interacting with different forms of robotic agents. With this study, we present results assessing the human-robot interaction, in which children are the interactive partners. The child-robot interaction was studied – for the first time – observing thirty-one children aged 5 to 6 years playing the Ultimatum Game (UG) with either another child or with a humanoid robot. First, we found that children did recognize the robot as a distinct entity, as assessed through the children's attribution of mentalistic, emotional and physical properties to the interactive agents. Nevertheless, consistently with literature on adults, the results on the UG revealed a very similar behavioural approach when the child played with the other child and with the robot. We finally analysed the children's justifications for their behaviour at the ultimatum game and found that very young children tend to consider “fair” only the divisions that are exactly equal (5-5 divisions) and to justify them either in mere mathematical terms (outcome) or in terms of equity. These results are discussed in terms of Theory of Mind, as well as in light of developmental theories underpinning children's behaviour at the ultimatum game.

Introduction

The introduction of social robots - defined as “autonomous or semi-autonomous robots that interact and communicate with humans by following the behavioural norms expected by the people with whom the robot is intended to interact” (Bartneck & Forlizzi, 2004) - is deeply affecting our society in different fields of the human life. The robots used in industrial processes, for instance, are modifying the job roles and rules [Argote et al., 1983; Kang et al., 2008; Lin et al., 2011; see also European Union, 2017). Prospectively, the introduction of robots in other contexts, such as households, education, care assistance, manufacturing, etc., will also presumably have an increasingly significant effect on human activities and roles. In this perspective, several researches are working towards the implementation of robots in the attempt to make them increasingly similar to the human being [Asada et al., 2001; Di Salvo et al., 2002; Hoffman & Ju, 2014; Robins et al., 2005). The humanoid robots – the ultimate realization of such attempts – are characterized by human-like physical features, behaviours and cognitive processes. The mode and quality of the interaction between humanoid robots and humans will thus possibly change because of the robots’ similarities with humans that call to mind the idea of “they are more like-me” (Meltzoff & Brooks, 2001). The underlying rationale for the implementation of this new generation of robots is to create social partners in everyday life (Kanda et al., 2012), although the other side of the coin that researchers have to deal with in the robot human-likeness is the Uncanny Valley effect (Mori, 1970; Mori et al., 2012). This means that the more a robot has human features and behaves like a human, the more its “eeriness” will induce negative feelings in the interlocutor (Burleigh et al., 2013; Fink, 2012; Gray & Wegner, 2012; MacDorman, 2006; Mori et al., 2012; Sandoval et al., 2016; Scassellati, 2005).

Besides the contexts above mentioned, the implementation of robots is also aimed at aiding different scientific fields, such as anthropology, psychology, ethics, sociology, engineering, informatics, mathematics, physics, etc. (Saygin, 2011; Scassellati, 2003), for example, suggests that the use of the human-like robot could be useful for the study of typical and atypical human social development, allowing to test cognitive, behavioural and development models. In this sense, and from a multidisciplinary perspective, knowledge from developmental psychology is crucial to the implementation of these models since it contributes to the understanding and identification of the precursors underlying human sociality and their ontogenesis. In this respect, Itakura (2008) proposed a new research domain that connects developmental psychology and the study of human-robot interaction. This new investigation field was named Developmental Cybernetics (DC; 2008): it explores the child-robot interactions through the construction of theoretical frameworks that

characterize the design of the robot with the aim to facilitate these interactions (Itakura, 2008; Itakura et al., 2008b). Several studies used the Advanced Telecommunications Research Institute International (ATR) humanoid robot Robovie that can generate human-like behaviours (Ishiguro et al., 2001; Ishiguro et al., 2003). This humanoid robot has been used to test interactions with children in different contexts (Kahn et al., 2012; Kanda et al., 2004). Kanda and colleagues (2012), for example, introduced Robovie to 6th-graders to teach them how to use a Lego Mindstorms. This research showed how Robovie's human-like behaviours contribute to build a human-robot relationship, which goes beyond the more simple human-robot interaction.

Developmental Cybernetics hypothesizes that children can understand the non-human agent through mentalization, and that the construction of social intelligent agents could shed some light on the development processes and mechanisms of the child's mind (2008). In this respect, within the DC approach, Itakura (2008) proposes three abilities, which are critical for making a robot a social agent: Theory of Communication (Itakura, 2012; Itakura, 2013; Nitsch & Glassen, 2015), Theory of Body (Minato et al., 2006; Morita et al., 2012) and Theory of Mind (Itakura, 2008; Itakura et al., 2008a,b). With respect to the Theory of Mind (ToM), it has been proposed that ToM represents an important psychological ability for the study of the human-robot interaction [for a review, see Marchetti et al., 2018). In fact, ToM is essential for the development of social competences, in that it represents the ability to understand one's own and other people's mental states (intentions, emotions, desires, beliefs), and to predict and interpret one's own and others' behaviours on the basis of such meta-representations (Park et al., 2017; Piaget, 1929; White et al., 2009). Several ToM studies show that there are many different behaviours and cognitive processes that are linked to this human skill: imitation, joint attention, pointing, and gaze-following, just to mention a few. (Bandura, 1991; Brooks & Meltzoff, 2002; Camaioni et al., 2004; Charman et al., 2000; Meltzoff, & Gopnik, 1993; Meltzoff & Brooks, 2001).

The researches in the field of child-robot interaction have been increasing in the last decades. Generally, these researches explore what features should be implemented in the robot in order to establish a better interaction between humans and robots. Several studies have been conducted to analyse the effect of different ToM precursors on the interaction between humans and different non-human agents, including humanoid robots [Boucenna et al., 2014; Boucenna et al., 2016; Breazel et al., 2016; Chaminade et al., 2010; Fogassi et al., 2005; Itakura et al., 2008a; Kanngiesser et al., 2015; Meltzoff et al., 2010; Moriguchi et al., 2012; Mutlu et al., 2012; Okanda et al., 2013; Okumura et al., 2013; Rizzolatti et al., 2001; Sloane et al., 2012; Wellman et al., 2001). Generally, the results of

these studies have shown that children tend to attribute mental states to a humanoid robot (Beran et al., 2007; Breazeal et al., 2016; Kahn et al., 2004; Manzi et al., 2017; Moriguchi et al., 2012; Nishio et al., 2012; Park et al., 2017). Already Piaget (1929) suggested that children younger than six-years-old tend to attribute consciousness to objects - namely the capability to feel and perceive - and that children consider “alive” also the things that are inanimate for the adult, *if* these objects serve a function or are used to reach a goal: a phenomenon called animism. In their study, Katayama and colleagues (Katayama et al., 2010) showed that when five and six-years-old children had to attribute biological and psychological proprieties to a human or a robot, children generally discriminated between the two agents, though ascribing some human traits also to the robot. Thus, in line with Torta and colleagues (Torta et al., 2013) idea, when young children interact with artefacts, these acquire the status of relational artefacts: children believe the artefacts – like the robots – to be “alive” and to have an “intention”.

Interaction skills in social contexts are typically studied through use of interactive games deriving from the Game Theory (Camerer, 2013; Villani et al., 2013). One of such games is the Ultimatum Game (Güth & Kocher, 2014; Güth et al., 1982). Used with children, the Ultimatum Game (UG) serves to delineate development in terms of equity and negotiation ability in decision-making, thus focusing on sensitivity to fairness and aversion to inequality (Fehr & Schmidt, 1999). The UG involves interacting with at least another agent, and it is related to the development of ToM in that it activates the ability of mental comprehension, detection and anticipation of the other’s behaviour (Catelli et al., 2014a,b; Castelli et al., 2017; Hoffman & Ju, 2014; Lombardi et al., 2017; Marchetti et al., 2011; Marchetti et al., 2008; Massaro et al., 2017; Srinivasan et al., 2013; Turkle, 2004). In the UG, the subject can play as either the proposer or the receiver. In the *proposer* situation, the subject decides how to allocate resources; in the *receiver* situation, the subject decides whether to accept or refuse a proposed division of goods. The general rule underlying the UG is that the proposer makes an offer, proposing a certain division of goods between him or her and the other player. If the receiver refuses the offer, neither players get anything, whereas if the offer is accepted, both players obtain the proposed division. Using the UG, it is then possible to study interactive behaviour in reciprocal situations from a developmental perspective, comparing behaviour at different ages. Starting from infancy, some studies suggest that infants are responsive to an unequal resource distribution already at 19-month-olds (e.g., Seyama & Nagayama, 2007). Fehr and colleagues (2008) showed that sensitivity to fairness increases from 3 to 8 years of age, and that selfish behaviour decreases from 3-4 years to 5-6 years, although most of 5-6 year olds still tend to not share (78% of the sample).

Additionally, school age children (>7 years) generally behave more fairly when distributing resources and share more than younger children (Fehr et al., 2008;House et al., 2013).

Only few studies have employed the UG paradigm with robots, and – even so – uniquely in interaction with adults. There is in fact not research specifically addressing the relation between robot and children in a UG game. Research on adults generally shows that participants are more likely to behave in a similar fashion when playing the UG with another human or a robotic agent, and this similarity increases the more the robotic agent presents human-like features. Terada and Takeuchi (2017), for example, reported that rejection scores in the ultimatum game were higher in the case of a computer opponent than in the case of a human or robotic opponent, suggesting that people might treat a robot as a reciprocal partner as when playing with another human. Nishio and colleagues (2012) also tested university students while playing the UG with four different artificial agents, which differed in the degree of similarity with humans. In their study, there were four conditions: computer terminal (Computer condition), humanoid robot (Humanoid condition), android robot (Android condition) and human (Human condition). They included a mentalizing stimulus for each agent, which consisted of four shorts interactional sentences pronounced by each agent when meeting the subject, e.g., “how are things going?”. Furthermore, the authors administered a post-experimental questionnaire in order to test how participants perceived the agents (i.e., human likeness, or machine likeness). The authors examined the number of rejections of the agent’s proposals and the number of the agents’ fair and unfair proposals, both measures used as indicators of recognition of the agents as social entities. The results showed that, when the agent looked like a human, the fairness of the proposals and the refusal rate were similar to when interacting with a human, and particularly, when introducing the artificial agent after the interactional sentences. Additionally, Nitsch and Glassen (2015) analysed a group of young adults, who played the UG with a human agent and with a humanoid robot behaving so as to be perceived animated or apathetic. The results showed that the participants that played in the animated robot condition perceived the interactions more positively and human-like than in the apathetic condition. Robins and colleagues (Robins et al., 2005) also studied reciprocity in the human-robot interaction in a sample of young adults through the UG and the Prisoner Dilemma. The results showed that the participants were equally reciprocal with the human and the robot, despite the fact that the robots collaborated more with humans in the Prisoner Dilemma task, indicating that the human-human interactions are nevertheless privileged with respect to the human-robot interactions. Finally, Takagishi and colleagues (2010) examined the effect of different robots’ facial expressions in the UG, and showed that emotional expressions had an effect on the offers made by the participant to the robot compared to offers made to a computer displaying a simple line drawings face.

Altogether, the results from the studies here described suggest - in adult subjects - a proclivity to interact with robotic agents in a very similar fashion as when interacting with other humans.

As far as children's behaviour is concerned, there are no studies so far addressing children's decision making during an interactive and reciprocal social situation with a robot. In the present study, we made an attempt to fill this developmental gap exploring interactive behaviour during the UG when a child played with either another child (human agent) or with a robot (humanoid robot). Our sample children were aged five-to-six years. At this age, children show to have an acquired ToM capability of – at least - first order (Wardle et al., 2002). First order ToM entails a recursive thinking, which implies the meta-representation or the representation of a mental representation, of a low level of complexity, of the kind of: “I think that you think...”. In this respect, we hypothesized that children aged 5-6 years were able to discriminate between *agency* (human agent and humanoid robot) on the basis of mental states attribution. However, we were not able to advance any predictions in terms of differences in children's decision-making strategies when playing with a human and a robot, since no such literature exists specifically referred to the UG.

In this study, the children played both as proposers and as receivers. Additionally, children's performance on the UG task as a function of *agency* was evaluated against several socio-demographic, as well as, cognitive factors. Finally, an analysis of the children's justifications for their behaviour, both when playing as proposers and receivers, was carried out, outlining – for the first time – some response patterns that characterize the rationale underlying these children's game strategy.

Method

Participant

Thirty-three (33) Italian kindergarten children participated in the experiment. Two children were excluded from the study: one failed the First-Order ToM task and the other one failed the Inhibition task (see below). Data analysis was therefore carried out on 31 children (males=18, females=13; mean age = 70.8 months, SD=2.99). The children attended three different schools of Milan and Turin areas. The children's parents received a written explanation of the procedure of the study, the measurement items, and the materials used and gave written consent. Children were neither referred to social services nor reported by teachers for leaning and/or socio-relational difficulties. The study was

approved by the Local Ethic Committee (Università Cattolica del Sacro Cuore, Milan).

General Procedure and measures

The children were tested individually in a quiet room in the kindergartens. Administrations were carried out by a single researcher both in the morning and afternoon during normal activity. The children were assessed in two experimental sessions in different days within two weeks timeframe. The administration of the tasks in two independent sessions was done not to overly tire the children with an excessively long procedure as well as not to significantly disrupt the child's normal school activity.

In the first session, the children were administered the following tests: the First-Order False-Belief task, and two First-Order False-Belief videos, assessing first-order Theory of Mind; two Strange Stories, assessing advanced Theory of Mind; and the Attribution of Mental States scale. In the second session, the children were administered the following tests: the Family Affluence Scale, assessing the socioeconomic status; two executive functions tests, assessing the ability to inhibit behaviour and working memory; further two First-Order False-Belief videos; further two Strange Stories; and the Ultimatum Game, assessing fairness.

The tests were so distributed within sessions to balance the total time required to complete the whole battery, which was of approximately 45-50 minutes. In fact, each session lasted about 25 minutes. Within each session, the administration of the tests was randomized across children.

Socioeconomic status

To assess the children's socio-economic status, we used the Italian translation of the Family Affluence Scale (FAS; Boyce et al., 2006). This test is composed of four items measuring family wealth, and more specifically: 1) family car ownership (score range = 0–2); 2) own bedroom (range = 0–1); number of computers at home (range = 0–3); how many times they went on holiday during the past year (range = 0–3). The FAS total score was obtained adding up the four-item scores (total range = 0-9).

Executive functions (Inhibition and Working Memory)

We tested the children's executive functions using the Inhibition "A Developmental NEuroPSYchological Assessment" subtest (NEPSY II; Korkman et al., 2007), testing the ability to inhibit automatic responses in favour of novel responses and the ability to switch between response types. The child looks at a series of black and white shapes or arrows and names either the shape or direction or an alternate response, depending on the colour of the shape or arrow. In the present study, we used the combined scores of the Inhibition NEPSY-II subtest, which associates accuracy and speed of response.

Furthermore, we used the Backward Digit Span, testing working memory. Concerning the Backward Digit Span, the experimenter presented orally number sequences and the child was required to repeat them in reverse order. The test started with three sequences of two digits, gradually introducing triples of sequences of increasing length, to a maximum possible length of eight digits. The test stopped when the child failed all three sequences at the same length. The score was calculated as follows: children received 1 when they reversed at least two out of three sequences; if successful, the child passed to the next longer series, scoring 0.33 reserving at least one out of three sequences. The decimal scores were then summed to obtain the main score (e.g. $1+0.33 = 1.33$) until the children reached 1 (e.g. $1+0.33+0.33+0.33 = 2$), if necessary.

First-order false belief task

To assess first-order ToM, we used the story of the classical *Unexpected Transfer* task (Wimmer & Perner, 1983). The experimenter told the story using: two dolls (one male and one female), one ball, one box and one basket. The story is about two siblings playing with a ball in a room. One of the children puts the ball in a box and leaves the room. Meanwhile, the other child takes the ball out of the box, puts it in the basket and goes away. Finally, the first character comes back in the room and wants to play with the ball. At the end of the story the experimenter asks the child the following questions: "What is the first place where he will look for a teddy bear?" – referring to the first character (First-Order False Belief question); "Where did the child put the ball before going upstairs?" (control memory question); "Where is the ball really?" (Reality control question).

The answers to the two control questions (memory and reality) were used to filter the children's performance: children who did not pass them scored 0 and their performance on the First-Order False Belief question was not evaluated. If the children passed the control questions, the test question about the false belief scored 1 if correct and 0 if incorrect.

First-order false belief task: Video Stimuli

To assess children on the First-Order False Belief, we introduced – besides the commonly used task as described above – a new instrument, namely eight videos representing the classical story, this time introducing also the Robovie as a new character. More specifically, we used a story similar to the classical *Unexpected Transfer* task (Wimmer & Perner, 1983) as the script of the videos. The videos started presenting two characters (two children, two robots, or a child and a robot) in a room with two different boxes of a different colour (blue and pink) placed in front of them. Subsequently, one of the characters put a teddy bear under one box (the same for all videos) and then left the room. When the other character was alone in the room, he or she moved the teddy bear under the other box and left the room. Finally, the first character returned into the room to take the teddy bear. A voiceover narration described the story in each video.

The videos were recorded with five different actors: two children (C1 and C2) and three Robovies of different colours (White Robovie, WR; Green Robovie, GR; and Red Robovie, RR). Moreover, the five actors could play two different roles: the character who made the transfer (MtT) and the character who underwent the transfer (UtT). We used the WR for the human-robot videos and the other two Robovies (GR and RR) for the robot-robot videos. Thus, we videotaped eight different videos crossing the two children, the three Robovies, and the two roles. We created two different protocols, which were randomly assigned to the children. The first protocol was composed of four videos: 1) C1 playing the MtT role with C2; 2) C1 playing the MtT role with WR; 3) WR playing the MtT with C1; 4) GR playing the MtT with RR. The second protocol was composed of the following four videos: 1) C2 playing the MtT role with C1; 2) C2 playing the MtT role with WR; 3) WR playing the MtT with C2; 4) RR playing the MtT with GR. Within each protocol, the videos were presented randomly. We used the same scoring criteria as that used for the First-Order False Belief task (see above). The videos can be found in Electronic Supplementary Material.

At the end of the story, the experimenter asked to the child the following questions: “What is the first place where she will look for the teddy bear?” (First-Order False Belief question); two control questions (Memory and Reality as described above).

Strange Stories

We assessed the children's advanced ToM using the Strange Stories task (Happé, 1994; Westlund et al., 2017), whose Italian translation had been already used in other studies (Cattaneo et al., 2007; Lillard, 1994). This task evaluates the ability to make inferences about mental states by interpreting non-literal statements. We selected a subgroup of four mentalistic stories involving double bluffs, misunderstandings, white lies, and persuasion. After reading the stories, we asked the children to explain a character's behaviour without a time limit. The experimenter transcribed *ad verbatim* the child's answers. Scoring was based on the general guidelines (Westlund et al., 2017): 0 for incorrect answers, 1 for partially correct answers, and 2 for full and explicit answers. Two raters independently coded 30% of the responses. The inter-rater agreement was substantial (Cronbach's Alpha = .96). Disagreements were resolved through discussion between the raters. Total scores ranged from 0 to 8. The analysis of the children's performance on the strange stories showed a quite poor general performance. In fact, the children scored very low, ranging from 0 to 3 out of a total possible score of 8.

Attribution of States

The Attribution of States is a measure of states attribution that the child has to make looking at pictures depicting a character. The Attribution of States (AoF) is an *ad-hoc* questionnaire that was drawn from the questionnaire described in Martini and colleagues (Martini et al., 2016). This test was aimed at assessing what features the subject (the child) ascribed to the interactive agent (another child or the robot) in mental, emotional and physical terms. In this study, the experimenter first showed to the child two pictures depicting a child and a robot and then asked the child - as a control question - what was depicted in the picture (Reality question): if the child correctly recognized the child and the robot, the test went on; if the child responded incorrectly, the experimenter corrected the child making sure that he or she was fully aware of the agent's identity and then proceeded with the test. No children failed in the Reality question; that is, all of the children correctly recognized the child and the robot at first instance.

The presentation order of the two face pictures was randomized across children. After presenting the picture and asking the Reality question, the experimenter asked the child 25 questions referred to the agent's mental states. The child had to respond "Yes" or "No" to each question. The 25 questions were grouped in five different categories of mental states: Epistemic, Emotional, Desires and Intentions, Imaginative, and Perceptive. The total score was the sum of the "Yes" answers (score range = 0-25); the five partial scores were the sum of the "Yes" answer to each category (score range

= 0-5).

Ultimatum Game

A standard version of the Ultimatum Game (UG; Güth et al., 1982) was used to evaluate fairness. During the game, the child (playing as proponent) could decide how to distribute 10 stickers between him or her and a passive player, represented by a graphic representation of either a child – human agent (e.g., Castelli et al., 2010) or a robot. The graphic representation of the other child corresponded to a male figure when the child was a boy, whereas it represented a female when the child was a girl. The stickers depicted known animals by the children (e.g., dogs, cats, tigers, lions, birds, fishes, etc.). The minimum amount of stickers that could be offered during the game was 1, and the maximum amount was 9. After playing the UG, the child was actually given a final amount of stickers

During the UG, the children played one round as proposer and five rounds as responder, for a total of six rounds. Playing as proposer, the child could decide how to divide the stickers with the other child or the robot (graphic representation) and, playing as responder, the child could decide whether to accept or refuse the proposed division. In case of acceptance, both players received the respective proposed amounts; in case of refusal, neither player gained anything.

When playing as responder, each round (5 in total) corresponded to a specific type of proposal, ranging from a division of 5-5 (fair) to a division of 1-9 (highly unfair). The rounds were randomized across children. For each round, the child could accept or refuse the offered amount, receiving a score 1 in case of acceptance and 0 when refusing the offer. The total amount accepted was also calculated (range = 0-15) when the child played as receiver, which corresponded to the total gain for each child. Similarly, when playing as proposer, the total amount proposed was also calculated for each child (range= 0-9).

UG procedure

Before starting the game, the experimenter explained the game rules presenting four different examples in a graphic format: 1) an adult playing as proposer with a child, who accepted the offer; 2) an adult playing as proposer with a child, who refused the offer; 3) a robot playing as proposer with a child, who accepted the offer; 4) a robot playing as proposer with a child, who refused the offer.

During the game, the researcher played “the other child’s/robot’s” role, proposing, accepting, or refusing offers. The children’s performance at the Ultimatum Game was evaluated in a single session lasting approximately 10 minutes in total.

At the end of the game, the children were asked the reasons that they placed a certain offer (proposer) or accepted/refused a certain proposal (receiver). The children’s answers were classified according to three criteria: 1) outcome – the justification refers uniquely to the *amount offered or received* without commenting on or referring to the other player in mental terms (e.g., “because I like that he does not have anything and I have them all”; “because I wanted to win”); 2) equity – the justification includes terms that refer explicitly to the *construct* of equity, independently of whether the amount offered or received was equal or unequal (e.g., “because in this way we are even”; “because it was nicer to give him three and I like to share them”); 3) mentalistic – the justification includes terms that *refer to the other player in mental terms* (e.g., “because he would like me to receive more”; “he believed that I would win”)⁹.

Results and Discussion

All of the continuous variables were normally distributed with skewness between -1 and 1.

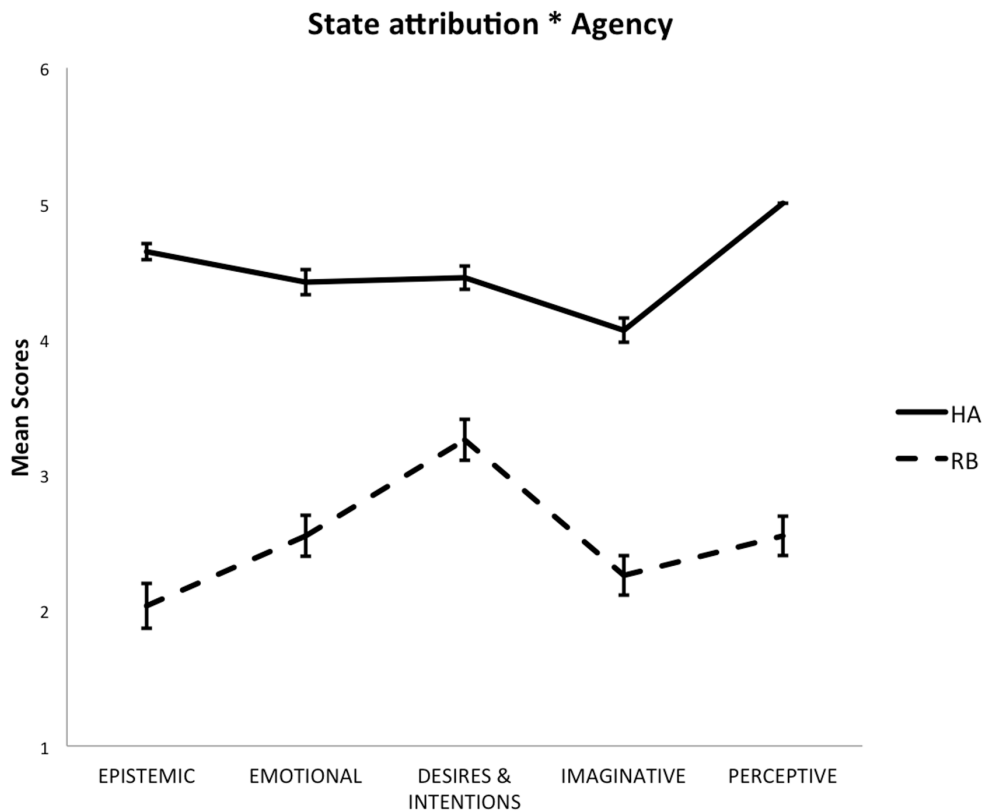
Attribution of States Scale

With this analysis, we compared the attribution of states - as described in the methods session - to the human agent (the other child) and to the robot. The inspection of the boxplots revealed a tendency towards maximum scores (5) in the case of state attribution to the human agent - particularly with respect to the perceptive state, where we observed a ceiling effect - and a normal distribution in the case of states attribution to the robot. A repeated measures general linear model (GLM) was carried out with five levels of *state* (epistemic, emotional, desires and intentions, imaginative, perceptive), and two levels of *agency* (human vs. robot) as the within groups factors. The results showed a main effect of *state* ($F_{4,120}=5.94$, $p<.0001$, $partial-\eta^2=.17$, $\delta=.98$), a main effect of *agency* (HA>RB; $F_{1,30}=53.82$, $p<.0001$, $partial-\eta^2=.64$, $\delta=.1$) and a significant interaction *state*agency* ($F_{4,120}=7.90$, $p<.0001$, $partial-\eta^2=.21$, $\delta=.1$). Post hoc analyses (Bonferroni corrected) showed that the states that scored higher were desires and intentions – which scored significantly higher than both epistemic

⁹ Ad verbatim translation from Italian.

($M_{diff}=.69, p<.01$) and imaginative ($M_{diff}=.52, p<.05$) – and perceptive state, that scored significantly higher than imaginative state ($M_{diff}=.61, p<.01$). Additionally, the analyses showed that the interaction effect stemmed primarily from differences between *states* within *agency* (HA, RB). More specifically, with respect to states attribution to HA, the epistemic state scored higher than imaginative state ($M_{diff}=.58, p<.01$); whereas the perceptive state scored higher than all the other states ($p<.05$) except for the epistemic state, which just failed to reach significance ($M_{diff}=.36, p=.055$). With respect to state attribution to RB, the results showed that desires and intentions received higher scores compared to the epistemic and imaginative states ($M_{diff}=1.23, M_{diff}=1.00$, respectively; $p<.001$). These results are summarized in Figure 1.

Figure 1: Mean scores obtained by the children during the attribution of states (epistemic, emotional, desires and intentions, imaginative, and perceptive) to the human agent (HA) and to the robot (RB). The bars represent the Standard Error of the mean.



The results on the attribution of states to HA and RB revealed that children clearly attributed different states on the basis of agency, with HA receiving higher scores on all states attribution compared to RB. This shows that children had a correct perception that the other child had epistemic and emotional

states, intentions and desires, an imagination and perceptive properties, which are different from that of a robot, therefore considering this latter as a distinct entity.

Within agency, children tended to ascribe poor imagination to both the child and the robot. This is in line with evidence showing that young children's imagination abilities mature gradually (Harris, 2000; Harris & Leivers, 2000; Lillard, 1994; Lillard, 2013). Interestingly, the differences observed within the attribution of states to the robot indicate that children tended to ascribe desires and intentions also to the robot, although to a significantly lesser extent than to the human agent. Desires and intentions attribution to the RB, in fact, received greater scores than all the other states, and substantially more than the epistemic and imaginative states. During video watching (see methods), the children observed the RB in action, and this may have led the children believe the robot as having intentions. In fact, also from a neurophysiological perspective, movement and intentions go hand in hand [see, for example, Gray & Wegnaer, 2012; Premack & Woodruff, 1978) as also suggested by psychophysiological evidence with children (Cavallini et al., 2013). All the same, in the present study, while attributing intentions to the robot, the children ascribed to the robot a low ability to think, understand, and decide (epistemic attribution). These results, apparently in contrast, are on the other hand much in line with the idea of animism introduced above, and namely with young children's tendency to attribute a living soul to plants, inanimate objects, and natural phenomena, while being aware that these entities are non-living. The fact that this idea applies to objects only *if* these objects serve a function or are used to reach a goal (see Katayama et al., 2010; Perner & wimmer, 1985; Turkle, 2004], further supports the movement and intention interpretation just described (Chaminade et al., 2010; Sandoval et al., 2016).

Ultimatum Game

The main aim of the present study was to assess whether the child behaves differently when acting with a human agent or with a robot during an interactive situation. We therefore had the child playing the UG with either another child or with the robot, as both proposer and receiver.

Proposer

A t-test comparing the total amount offered to the other child or to the robot when the participant played as proposer showed no significant difference in the total amount offered (HA: $M=3.71$, $SE=.31$; RB: $M=3.55$, $SE=.35$; $p>.05$). Additionally, a high internal consistency (Cronbach $\alpha =.85$)

was observed between each individual child's behaviour when playing with the human agent or the robot. Table 1 reports the children's proposed divisions to HA and RB.

Table 1: Statistics of children's offers when playing as PROPOSERS; ns = not significant; na = not applicable.

	HA – RB	HA – RB	HA vs. RB
Proposed Division	N	%	Sign (<i>p</i>)*
1-9	0 – 0	0 – 0	na
2-8	0 – 0	0 – 0	na
3-7	0 – 1	0 – 3	na
4-6	5 – 5	16 – 16	ns
5-5	7 – 4	23 – 13	ns
6-4	9 – 7	29 – 23	ns
7-3	3 – 5	10 – 16	ns
8-2	2 – 3	7 – 10	ns
9-1	5 – 6	16 – 19	ns
tot	31 – 31	100 – 100	

**Wilcoxon rank test*

These results are in line with the literature [e.g., 28] showing that pre-schoolers tend to make offers that favour their own gain, although the frequency of children that made offers towards fairness (i.e., ranging between 4-6 and 6-4) was quite substantial (68% towards HA; 55% towards RB). Additionally, these results extend previous findings showing that five-year-old children's behaviour and game strategy is consistent independently of whether the child plays with another child or with a robot, in line with the large body of existing literature on adults, as fully introduced above.

Receiver

Within this analysis, we summed up all acceptances when the child played as receiver, therefore calculating the total amount gained by each child. A t-test comparing the total acceptances from the other child and the robot showed no differences in the total amount accepted as a function of *agency* ($t=.75$, $p>.05$), indicating that the children accepted similar amounts when playing with HA ($M=10.97$, $SE=.77$) and with RB ($M=10.45$, $SE=.95$). This result is congruent with the data above described, showing children's tendency to adopt a similar game strategy when playing with the other child or with the robot.

Specifically comparing the children's acceptances of each proposed division from HA and RB, our results confirmed no differences in the frequency of acceptances as a function of agency within division (for statistics, see Table 2). Additionally, comparing the frequency of acceptances between successive divisions for both HA and RB, the Wilcoxon test showed not significant differences for the child (i.e., 5-5 vs. 6-4; 6-4 vs. 7-3; etc.; $p > .05$), whereas we observed significant differences for the robot. More specifically, acceptances of the 6-4 division were significantly lower than acceptances of the 5-5 division (71% vs. 90%, $p < .01$), as well as acceptances of the 7-3 compared to the 6-4 divisions (52% vs. 71%, $p < .01$). This latter result shows a significant, although minor, tendency of children to accept slight unfair offers more from another child than from the robot.

Table 2: Comparison of refusals and acceptances of proposed divisions during the UG when the child played as receiver with another child (HA) and with the robot (RB) (N=31). *P-values* were non-significant (ns) at a value of .05.

		HA	RB	<i>HA vs RB</i>
Division		N (%)	N (%)	Sign (<i>p</i>)*
5-5	Refuse	3 (10)	3 (10)	ns
	Accept	28 (90)	28 (90)	
6-4	Refuse	7 (23)	9 (29)	ns
	Accept	24 (77)	22 (71)	
7-3	Refuse	12 (39)	15 (48)	ns
	Accept	19 (61)	16 (52)	
8-2	Refuse	16 (52)	13 (42)	ns
	Accept	15 (48)	18 (58)	
9-1	Refuse	14 (45)	15 (48)	ns
	Accept	17 (55)	16 (52)	

*McNemar's Test

Correlations

Pearson's correlations were carried out between the total scores at the ultimatum game when the child played with the other child and the robot, as both proposer and receiver. The results showed, as expected, a substantial correlation between the total amount proposed to the other child and the robot ($r^2 = .56$, $p < .01$), as well as a strong correlation between the total amount accepted by the other child and the robot ($r^2 = .49$, $p < .01$). Additionally, the scores obtained at the UG were further correlated with demographic, cognitive, and socio-economic variables: age (months); the child's gender; working memory scores; the ability to inhibit behaviour scores; the intentionality test scores; and the Family

Affluence Scale scores. These correlations are summarized in Table 3. In general, no significant correlations were observed between the scores obtained at the UG and any of these variables ($p>.05$).

Table 3: Correlation analysis between the total scores at the Ultimatum Game when the child played as proposer with a robot (1) and the child (2) and when the child played as receiver with the robot (3) and the child (4). These scores at the UG were correlated with demographic, cognitive, and socio-economic variables: Age (months); child's Gender; working memory (WM) scores; ability to inhibit behaviour (INHI) scores; Intentionality Test scores (IT); and Family Affluence Scale (FAS) scores.

Pearson Correlations

		1	2	3	4	Age	Gender	WM	INHI	IT	FAS
1)	Total Offer to the Child	1	,746**	0,298	0,179	0,218	-0,085	0,186	0,01	0,146	0,213
2)	Total Offer to the Robot		1	0,191	-0,015	0,224	-0,004	0,202	0,024	0,233	0,237
3)	Total Acceptance from the Child			1	,700**	0,069	0,285	0,151	0,293	0,354	0,165
4)	Total Acceptance from the Robot				1	0,047	0,329	0,251	-0,1	0,255	0,195

** Correlation is significant at the 0.01 level (2-tailed).

Analysis of the children's justifications at the UG

After the child played the UG in both the proposer and receiver roles, the experimenter asked him or her to explain the reasons for his or her division. The children's answers were classified as "outcome", "equity", or "mentalistic" (for details, see methods). Two independent judges evaluated the children's justifications.

Proposer

The inter-rater reliability scores were substantial both when assessing the child's justifications when playing with the other child (Cronbach's Alpha = .88) and when playing with the robot (Cronbach's Alpha = .91).

Analysing the frequencies of children who gave a specific justification to their behaviour for each division when making an offer, the results showed an even distribution of justification type (amount, equity) when the children offered a precise fair amount (division 5-5), whereas a skewed distribution of justification type toward "amount" when the children started placing offers that privileged their

own gain. This was independent of whether the child played with the HA or the RB. A summary of the frequency distribution of justification types for each proposed division is presented in Table 4A.

Receiver

The inter-rater reliability scores were calculated for each proposed division (5-5; 6-4; 7-3; 8-2; 9-1). The results showed substantial agreements both when assessing the child's acceptance/refusals justifications interacting with the other child (mean Cronbach's Alpha = .83; min=.82, max=.84) and with the robot (mean Cronbach's Alpha = .83; min=.80, max=.84).

With this analysis, we compared the frequency of children that provided a justification when accepting or refusing each proposed division. Justification types were different when the child received a 5-5 or a 6-4 division, independently of *agency* (HA, RB). When receiving a 5-5 division, the justifications were either based on "outcome" (HA: N=13; RB: N=14) or on "equity" (HA: N=18; RB: N =16); only one child presented a mentalization-based justification when interacting with the robot. When faced with a 6-4 division, the majority of children (HA: N=26; RB: N =28) presented a justification for their acceptance or refusal based on "outcome"; five children presented a justification based on "equity" and none based on "mentalization" when interacting with the other child; only one child presented a justification based on "equity" and two children a justification based on "mentalization" when interacting with the robot. A summary of the frequency distribution and statistics of acceptances and refusals of each proposed division and type of justification is presented in Table 4B. In general, these results suggest that, when children received a division proposal skewing towards unfairness, the equity and mentalization-based justifications decreased substantially ($\chi^2_{(4)}=16.47, p<.001$), in favour of the outcome-based justification.

The analysis of the children's justification for their behaviour - both when playing as proponents and when playing as receivers - indicates that children tend to regard fair (and hyperfair) divisions either in terms of outcome or in terms of equity-based reasoning, with an approximately equal split. When the division starts skewing, even slightly (i.e., 6-4 division), towards unfairness, the types of justifications offered remarkably bias towards an outcome-based reasoning. It is noteworthy observing that mentalistic-based justifications were very poor, if not even inexistent, in all proposed scenarios. This general behaviour was observed both when the child played with the other child and with the robot, indicating no differences in the type of reasoning underlying specific choices as a function of agency.

On the whole, the results on the UG suggest that children aged five years behave quite fairly, though showing a tendency towards favouring their own gain placing and accepting unfair – and even *very* unfair – divisions, in line with current literature describing pre-schoolers' behaviour during the UG (see, for example, Lombardi et al., 2017). Lack of behavioural differences as a function of agency (HA vs. RB) further appears to indicate that the children at this age tend to disregard to other's mind when making choices, following a very consistent strategy throughout the game on the basis of other criteria (e.g., tendency to maximise gains) or personal traits (e.g., disposition to fairness). This is particularly true if considering the fact that the robot was indeed considered an entity different from the human agent (the child), so as observed from the analysis of the states attribution described above. This idea of a much ego-centred behaviour is further supported by the analysis of the children's justifications for their decisions when placing specific offers (proposers) and when accepting or refusing certain offers (receivers). In fact, analysing the frequencies of children who gave a specific justification for their behaviour, the results showed an even distribution of justification type (amount, equity) when the children offered or accepted a fair amount both to/from another child and to/from the robot; whereas we observed a remarkably skewed outcome-based justification when the children offered or accepted/refused unfair divisions. These latter results are further discussed below.

General Discussion

This study investigated 5 year-olds' behaviour at the ultimatum game. The aim of this study was to compare young children's game strategy when they played with another child (human agent) and with a robot. The results showed that children's game strategy was very similar when playing with the other child and with the robot, independently of the role played (proposer or receiver). The children were quite conservative both when offering and accepting proposals, that is, the children generally tended to offer and to accept fair divisions (5-5), although almost half of children proposed and accepted also unfair divisions, ranging from 6-4 to 9-1. These results are in line with the developmental literature on UG. For example, Benenson and colleagues (2007) observed that children aged 4 years donated less than 6 and 9-years-old, showing that sensitivity to fairness increases with age. Furthermore, a recent research by Lombardi and colleagues (Lombardi et al., 2017) showed that, at 6 years, children displayed a more selfish behaviour than children aged 8 and 10 years, highlighting that younger children tend to maximize their gain accepting also unfair offers.

Importantly for the present purpose, no significant differences were observed between offers and

acceptances made to or received from the other child or the robot. In this respect, children's behaviour observed in this study when interacting with the robot is comparable to the adults' behaviour reported in several studies. Terada and Takeuchi (2017) for example, showed that, when playing the UG, adult participants took approximately the same time to decide how to distribute goods between a human and a robot. In the study by Kahn and colleagues Kahn et al., (2012), the frequency of acceptances and refusals became closer to that toward a human when the robot had more human-like features. Similar results were also found by Rosenthal-von der Pütten and Krämer (2014). On the whole, these results suggest that, when bargaining, the other player is regarded independently of agency: the other player's mind appears to be a reflection of our own mind and strategic thinking, whether or not the other has a mind at all, such as in the case of a robot.

With respect to the acceptance of offers made when the child played as receiver in the present study, although behaviour was comparable when the child played with another child or with the robot, it is worth noting that the results showed a significant, although minor, tendency of children to accept slight unfair offers more from another child than from the robot. In this respect, one may suggest that children's expectancy from a robot is to be a totally fair player – since it does not have a mind of its own that can work strategically. In this light, divergence from this initial expectation is less accepted compared to situations in which children play with a human peer. In this latter case, in fact, the other player (the human) - having a mind - is supposed to be able to apply a game strategy and, eventually, to be also unfair. Alternatively, but not mutually exclusive, one may suggest that the child believes to have a distinctive status compared to the robot that, as assessed through the test of attribution of states, is perceived as a different entity with respect to a child at all levels: epistemic, emotional, imaginative, and physical. Also in this light, unfair offers would be less accepted when made by a robot than by a peer.

Finally, with respect to the results from the analysis of the children's justifications at the UG, it is interesting to observe that the reasons provided by the children for their behavior, both when playing as proposers and responders, suggest that children aged 5 years tend to consider fair only a division that is exactly fair (5-5). A slight skewed division towards unfairness (i.e., 6-4) already falls within the range of categorization that characterizes very unfair proposals, regardless of whether the proposals are made or received. Additionally, it is noteworthy to observe that fair or slightly hyperfair divisions are typically justified in either outcome or equity terms, whereas unfair offers are mostly justified in terms of quantity. Mentalization-based justifications are poorly made for all divisions, although – in these cases – it is curious to observe that, when playing as proposer, mentalization–

based justifications are uniquely confined to the most fair divisions (4-5; 5-5; 6-4). In general, these observations may suggest that children, particularly in the case of unfair offers, tend to not use mentalization-based explanations in order to reduce the distress stemming from the discrepancy between a “socially-expected” equal behaviour and the actual “selfish” behaviour. This interpretation can be further extended to the outcome-based justifications predominantly used to explain unfair offers that, in a certain sense, may serve to resolve a social cognitive conflict [e.g., 3], ultimately reducing the distress caused by the experimenter’s explicit enquiry.

Concluding remarks and limitations of the study

This study showed for the first time that young children's fairness is not affected by whether the child plays with another child or with a robot. In particular, it appears that children's decisions during social interactions are self-centred and poorly oriented towards the other's mind. Future studies could address the same issue focussing on different ages so to highlight the development of behavior in late childhood, when higher mentalistic abilities are maturing and eventually acquired. Additionally, we showed that the analysis of the justifications of children's behavior may be enlightening with respect to the child's actual psychological understanding of constructs, such as that of fairness.

It is important to stress that the present results, and in particular those referring to the behavioural differences here reported when the child played as receiver with the other child and with the robot, need to be confirmed with a more ample sample. Confirmation of these results could highlight a distinctive attitude towards a non-human interactive partner that emerges quite early in childhood and that may change during adulthood.

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Chapter 4

Object Use in children with autism: Building with Blocks from a Piagetian Perspective

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Abstract

Aim: This study focused on the manipulation of objects by children with suspected autism spectrum disorder. The aim was to demonstrate how objects can be seen as active agents of interpersonal exchange in face-to-face interactions.

Participants: Three children with suspected autism spectrum disorder (aged 18, 20, and 24 months) were selected as representative of the sensorimotor stage of development.

Methods: Starting from Piaget's classical approach to the sensorimotor and symbolic developmental stages, the study moved toward a socio-material interpretation in which some patterns of interaction involving object manipulation seem to create a space that supports adult-child communication. In videotaped observations of verbal and non-verbal signs during an (organized) free play session, each child manipulated seven small blocks of colored plastic in the presence of an adult. The observations were informed by a checklist of 14 items, including eye contact and building a tower of toy blocks from section B of the CHAT (*CHecklist for Autism in Toddlers*) instrument.

results: Based on a broad Piagetian perspective and recent work in the field of socio-materiality, key observations included the following: (1) sensorimotor and realistic play was observed in all three children; (2) there were some intriguing indications that objects serve as concrete mediators in the intersubjective space between adult and child; (3) some of the children's attention patterns were visibly mediated by the object.

Discussion and conclusion: All three children exhibited a particular sequence of actions. First, they manipulated the blocks through active experimentation; second, there was an apparent pause, during which, the children were in fact examining the blocks to determine how best to continue the interaction; and finally, the children monitored adult attention by means of eye contact or by restarting manipulation of the blocks. As this last step in the sequence indicated that the object became a mediator of reciprocal attention, this interpersonal process was labeled "attention mediated by object."

Introduction

According to Piaget (1928, 1952, 1954), children with autism achieve object conceptualization skills by the fifth stage of sensorimotor development. As several studies advise caution in using the *stage* concept to describe typical and atypical psychological development, it seems useful to characterize these psychological processes in terms of specific activities that the child can plan and implement when acting on their physical and social environment. For example, as a predictive index, the number and type of different actions produced by children with autism during a recreational activity may not always follow the same stages as in typical development, and this can also be correlated with the severity of autistic functioning (McDuffie et al., 2015). In fact, while imitation difficulties may reflect a possible delay in psychological development, not all pre-scholars with autism have problems with imitation or symbolic play (Vanvuchelen et al., 2011). Within the broad line of research that raises questions concerning object canonicity, we identified some interesting elements related to the socio-material function of mediation during communication.

It is known that canonical functions of objects are introduced by other people present in the child's world (Leontiev, 1981; Costall, 1997; Rodríguez and Moro, 2008; Barthélémy-Musso et al., 2013). Indeed, Sinha (2009) suggests that the canonical functions of the object are acquired as a normative phenomenon during social interactions, although cognitive understanding of that status is a prerequisite. Additionally, Sinha (2015) (p. 12) points out that “the materiality of meaning and meaningfulness of materiality is central to approaches in cognitive science emphasizing the importance of objects in extended cognitive embodiment.” In particular, there is evidence that canonical functions are acquired during child–adult interactions (Rodríguez and Moro, 1998; Sinha and Rodríguez, 2008; Moro, 2011, 2014). Several studies have reported how, under certain conditions (for example, impaired interpersonal relations or attentional focus), objects become mediators of social interaction (Williams et al., 1999; Dimitrova, 2014; Moro, 2014). Cárdenas et al. (2014) highlighted the importance of the reciprocal nature of these interactions by showing how they emerge from communicative and triadic contexts (adult–child–object). The crucial role of the adult in the acquisition of object use is observable from early infancy (Moreno-Núñez et al., 2017). Moreover, during child–object–adult interaction, the child's visual attention is more focused when interacting with an experienced caregiver than with an unfamiliar adult (Miller et al., 2009; Miller and Gros-Louis, 2013). Miller and Gros-Louis (2017) also showed that the child's attention is influenced by partner social style. Tomasello et al. (1993) and Tomasello (2016) highlighted different kinds of learning, such as imitative, instructed, and collaborative. For instance, imitation is important for

learning that involves others and objects, as it facilitates understanding of the normative expectations of a given cultural group (Tomasello, 2016). Sinha (2009) suggested that children apprehend canonical functions primarily by cognitive means, thereby accessing the normative identity of the cultural group. Bruckner and Yoder (2007) reported that, even among children with autism, object use can be linked to emergent functions in the preoperational stage, such as imitation and attention to the other person.

Most of the existing research suggests that imitation is impaired in children with autism (Charman and Baron-Cohen, 1994; Rogers, 1999; Rogers et al., 2003; Williams et al., 2004). Indeed, Smith and Bryson (2007) noted that children with autism exhibit difficulty in imitating any unconventional use of objects but are able to imitate canonical object use. By imitating this canonical use, children with autism access part of the cultural group's heritage. With respect to manipulative play activities, Kanner (1943) was among the first to note that, despite differences and limitations, children with autism exhibit a number of functions related to the use of canonical and non-canonical objects. Trevarthen and Hubley (1978) described the dynamics informing subject–subject–object triangulation (the theory of “secondary intersubjective tuning”). Typical children alternate their eye gaze between the object being viewed and the other person, so engendering joint attention. However, in atypical development, and especially for those on the autistic spectrum, an abnormality has been observed in the development of behaviors related to joint attention. Palacios and Rodríguez (2015) showed that in typical children aged 9–15 months, the symbolic use of an object develops within a triadic context. Ungerer and Sigman (1981) assessed the use of everyday objects in a group of children with autism ranging in age from 39 to 74 months in a structured and free play session and found that most were unable to use an object according to its designated function. Williams et al. (2005) interviewed parents of 10 children with autism (MA = 62.2 months; SD = 19.9) who reported problems relating to the use of an object, such as an interest in some unusual aspect of the object, an unusual way of using the object, or difficulty in generalizing object use. Custance et al. (2014) suggested that imitative deficits in children with autism can be reduced by means of object-related activities, especially if there are no time limits on use of the object. Object-related activities promote joint attention, motor imitation, and intentional communication with a social partner (Bruckner and Yoder, 2007), and there is evidence that interventions focused on play involving different objects can promote social and imitative behaviors (Brown and Murray, 2001; Stahmer et al., 2003; Lee et al., 2017). Swettenham et al. (1998) observed three types of attentional behavior: (1) between an object and another object, (2) between an object and a person, and (3) between one person and another. Children with autism showed relatively more attention to interactions between an object and another

object. In our recent studies, we have observed the important role of the object in activating attention in the child with autism, and we describe the phenomenon as “attention mediated by the object,” which may be a precursor of joint attention (Iannaccone et al., 2016; Manzi and Savarese, 2017; Savarese et al., 2017).

The observational study reported here incorporates a sociomaterial perspective, referring in particular to the mediating role that objects seem to assume in the interaction between children and adults, which has to date been neglected in the scientific literature. Using a selected set of objects, the study analyzed the child with autism’s ability to manipulate those objects and to evaluate their symbolic use. Starting from presentation of the object, a further objective was to identify the type of game engaged in by the child. During interaction with an adult, we observed first whether there was eye contact; second, whether this changed how the child used the object; and third, whether the canonical use of the object was an important element in the child–adult interaction.

Material and Methods

Participants

We used the tower building item from section B of the “CHecklist for Autism in Toddlers instrument” (*CHAT*; Baron-Cohen et al., 1992). It was developed to help identify children who are at risk of developing social-communication disorders (scoring “high risk of autism”). It was administered to filter participants and one child aged 22 months did not pass this item. Children aged 18 months are capable of tertiary circular reactions and can stop and restart a sequence of actions at any intermediate step, which is crucial in building a tower of blocks. Children older than 18 months can use symbolic mental representations. The selected age range, therefore, allowed us to observe the early development of symbolic functions.

The study’s participants were three non-verbal male children with suspected autism spectrum disorder. The suspected diagnosis of autism was identified through the use of the CHAT instrument.

Their different ages encompassed the transition from sensorimotor to preoperational stage; participant 1 was aged 18 months, participant 2 was aged 20 months, and participant 3 was aged 24 months.

Methods

The study employed videotaped observations (with one camera) of verbal and non-verbal signs during an organized free play session, in which each child played with seven small blocks of colored plastic in the presence of an adult (a different experimenter was used for each observation). The observations were conducted on the basis of a checklist consisting of 14 items (see Appendix A), including eye contact and the building of a tower of toy blocks from section B of the CHAT procedure.

The blocks were selected not only because of their use in the CHAT procedure but also in accordance with the empirical tradition of Piaget (1962) and Reifel (1984), who have shown the importance of toy blocks in the child's cognitive development. The interaction sequences from the video recordings were transcribed in full for microgenetic and semiotic analysis, primarily examining the children's non-verbal signs (gestures and posture) during interactions with the objects. Adult intervention was also analyzed in terms of non-verbal signs (gestures and posture), again focusing on sequences of microgenetic and semiotic actions. Sequences were selected using the following criteria: the presence of gestures, actions, or both, where (1) the adult intervened and the object became a mediator of the interaction, and (2) the object mediated the attention between child and adult. The observations of child and adult occurred simultaneously.

Ethical issues

This study was carried out in accordance with the recommendations of AIP (Associazione Italiana di Psicologia), and all of the children's parents gave written informed consent in accordance with the Declaration of Helsinki. As there is as yet no psychological ethics committee at the University of Salerno, the protocol was approved by the external experts group from the University's "Centro di Counseling Psicologico" (Counseling Center). While the Center is not specifically responsible for ethical approval, the external experts group supervises research carried out by psychological researchers at the University. In Italy, few universities have a psychological ethics committee, and these generally offer degree courses in psychology or have a psychology department or institute. The University of Salerno has not activated degree courses in psychology and has no such department. We would like to thank the external experts, Dr Oreste Fasano (Psychologist), Dr Nadia Pecoraro (Psychologist), and Dr Monica Mollo (Lecturer in Psychology).

Results

The interactions with the blocks helped to observe behaviors that related to the blocks' physical attributes and the child's competence to establish relations with them. This playful manipulation of

objects probably helps planning and coordinated action, stimulating and strengthening the child's ability to interact with the outside world. At the same time, these activities allow children to imagine new construction scenarios (Harris, 2000). In the presence of potential partners or competitors (children or adults), the child's management of play activities and their implementation of communication strategies can also be observed. For example, the 18-month-old touched and handled all seven blocks, the 21-month-old touched and handled six blocks, and the 24-month-old touched and mechanically stacked all seven blocks.

Based on their independent observations, the two researchers agreed that the three children's symbolic use of objects (see **Table 1**) could be assigned to the first level of symbolic play as proposed by McCune-Nicolich (1981), based on Piaget's sequence (1972), because the children played using sensorimotor schemes. In addition, unlike the 24-month-old, the 18- and 20-month-old played a realistic game. Pretend and symbolic play was not observed in any of the three children's behaviors.

Table 1. *Use of Objects*

	Child 1: 18 months	Child 2: 20 months	Child 3: 24 months
Realistic play	Yes	Yes	No
Pretend play	No	No	No
Symbolic play	No	No	No

Based on observations of the "Can the child build a tower of blocks?" item in section B of the CHAT instrument (see **Table 2**), it was established that all three children used the objects in a manner similar to that described by Piaget as part of the manipulative activities of sensorimotor functioning. The children showed active exploratory behaviors as the toy blocks were manipulated, sorted, and stacked.

Table 2. *CHAT Section B: non-key items.*

	Child 1: 18 months	Child 2: 20 months	Child 3: 24 months
Tower of Blocks	Yes	Yes	Yes
Eye-Contact	Yes	Yes	No

In observations of the Eye Contact item of CHAT section B, the 18- and 20-month-old made visual contact with the adult, but the 24-month-old showed no eye contact. In the child-object- adult or

simple child–object interactions excerpted below, a set of seven colored plastic blocks was placed in front of the child. Transcription commenced when the child began to manipulate the blocks.

Observational results

In this section, we describe the observations we made of children with autism in relation to the types of object use (see **Table 1**). Crucial episodes were selected to illustrate the characteristics of the interactions between the children and the adults.

Generally, adults help children to interact with objects. In the observation of Child 1, the child was able to perform a complex series of actions on the object during the interaction. The child grabbed the object, manipulated it to orient it, dropped it, balanced it, and connected the different objects by stacking them. Here, the adult's help was crucial, as the elements of the child's interaction with the object were changed; at the same time, the object became a mediator in transforming the interactive arrangement between the child and the adult. The adult's hand in direct contact with the object became a source of interest to the child, who focused on this subject–object hybrid.

Observation 1. Child 1. Difficulties in the use of the material features of the object induced the intervention of the adult.

The child cries because the blocks he had begun to stack fall; while he cries, he holds two blocks in his hands and tries to put them on a block on the table. The adult comes over and gets behind the child. The child tries to lay block 1 but fails because he is shaken by tears. The adult places the existing block in a better way. The child looks attentively at the adult's hand and places block 1. The adult takes block 1 with the child and helps to place it in the right position in balancing it.

(...) With his hand, the adult moves block 4 (stacked by the child) to achieve better balance. The child observes the adult's hand. The child leaves block in his left hand alone and, continuing to watch the stacked blocks, extends his right arm to grab block 6. He places block 5 onto block 4 and, without looking, tries to grab block 6.

The child's initial frustration on being unable to stack the blocks led to an intervention by the adult, who was seated on the ground behind the child. The adult intervened when the child played with the blocks, and the object became a mediator of interactions and interpersonal activity.

Observation 2. Child 1. The previous help of the adult activated the attention of the child.

Once block 4 is in his left hand, he stretches his right arm and grabs block 5 before positioning block 4. While watching block 5, the child places block 4 and leaves it on block 3a; in the meantime, he brings block 5 closer to his body. After leaving block 4, the child takes a step back to turn to the adult, and they look at each other.

(...) He places block 6 onto block 5 and leaves it. Having left block 6, he turns to the adult, and they look at each other.

The child continued to play with the blocks, which became a mediator of attention between the child and the adult. After his intervention, the adult facilitated the stronger relational attractiveness of the object, as it became a transformative element in the initial environmental arrangement.

Observation 3. Child 1. The child used the material features of the object correctly after the intervention of the adult.

The child stretches his right hand and grabs block 4. The child then passes block 4 to his left hand, no longer looking at block 4 and directing his gaze to block 5. Meanwhile, the child keeps block 5 in his right hand. Holding the new block, the child turns to the stacked blocks and simultaneously raises his right hand (with block 5). He raises both arms above his head and grabs block 5 with both hands.

The child combined the object's socio-material properties by combining the material properties of the object with the social structures inherent in the object itself.

Furthermore, a series of interesting gestures was observed in the child-object interaction. When the child took the block and raised it over his head, even though the blocks on which the held block was to be placed were much lower in height, the child may have been planning to build a much higher structure with different characteristics to the existing one. One may take these behaviors as possible evidence of an imaginative process. This can also be seen as an explanation of the socio-material link, as imagining a structure beyond what is immediately present may indicate the child's ability to combine the material properties of objects. As the adult intervened, he became an example for the activity of the child. In the child-adult interaction, the object became a mediator of attention.

In the observation of Child 2, the child's manipulative skill was organized in a complex series of actions. He eyed the objects, planned to grab and stack them, rotated the objects in both hands, left, and again grabbed the objects. The material characteristics of the objects were explored. The adult intervened when the child played with the blocks, and the clock (the object) became the mediator for the joint attention of the child and the adult.

Observation 4. Child 2. The child began to actively explore the objects.

The child moves the blocks in front of him (almost shuffling them), watching them carefully. Still looking at the five blocks in front of him, he moves his right hand and touches block 1, which is not present in his visual field.

The child explored the material features of the blocks, and through these actions, which blended complex activities, the child seemed to experience the object adapting and being adapted by its constituent elements. In building a tower of blocks, the child's aims and imaginative action planning appeared to converge. Thus, even though a symbolic game could not be identified, it seems that sensorimotor play and realistic play were present.

Observation 5. Child 2. The child used the material features of the object.

He raises block 1, keeping his eyes on it while grabbing block 2 with his left hand. He turns block 2 around, changing the side that rests on the ground; in the meantime, his right hand brings block 1, moves it in the air, and passes it over block 2. He is about to place block 1 but brings it back close to himself, touching it with his left hand and resting it on block 2.

Here, the child experienced the features of the object. The adult intervened several times during these child-object interactions. The subject-object hybrid identified during the observation of Child 1 is also present here. During the first stage, the child's attention was focused on the transformative mediation of the subject-object hybrid, highlighting how this inextricable relationship drives the modification of the initial environmental arrangement. The child's actions can be seen to occur in a synchronic and harmonic circle of the imitation of the adult's actions.

Observation 6. Child 2. The socio-material features emerged during the child-adult interaction.

The adult places his hand in the child's visual field by moving a block over to him; putting it onto the floor, the adult begins to stack the block. Throughout the sequence, the child is

attracted by the adult's hand manipulating the block. He directs his gaze to block 1 and grabs it; continuing to watch it, he takes it with both hands. The adult begins to stack the blocks. The child manipulates block 1, which he holds in his two hands. He rests block 1 and leaves it. Directing his gaze to the blocks in front of him, he watches the adult, who stacks blocks.

(...) The adult takes the blocks that the child had put in rows and stacks them on top of each other. The child again takes block 4 with both hands. The child carefully observes the adult's movements while stacking. Still with block 4 in his right hand, crawling and with momentum, the child approaches the blocks stacked by the adult. The child grabs block with both hands, looks at it, and manipulates it. He turns block 4 in the direction that seems to enable stacking. He watches the blocks being stacked by the adult and, with his right hand, places block 4 onto the stack of blocks.

The subject/adult-object hybrid appeared to represent the transformation of the subject/adult-object-subject/child relationship, leading to revised planning of the action and thereby structuring of general aims. As well as becoming a mediator of the child's exploration of the surrounding environment, the object also rewrote the relational terms. This last step seems to follow the socio-material perspective, as the social structure of the object was intertwined with its material characteristics.

In observation of Child 3's sequence of actions, the attractiveness of the object overrode the ability to create a contact area with the adult who remained peripheral, or as a mere spectator of the child's construction. Actions have a regularity of performance: blocks are looked at, the hand gets ready to grab, the arm is stretched out to get to the object, the object is grabbed, the child identifies where to put the object, and eventually rests it in balance for stacking.

Observation 7. Child 3. The child used only the material features of the objects.

The child grasps block 1 with his right hand and rests it on a raised board, which has a width equal to the side of the block. He looks closely at block 1 and grabs it with both hands as if to be sure it is in balance. He pulls his right hand away from block 1 and, holding himself with his left hand, leans over the board to see what is there. He directs his eyes to where the blocks are located. He lowers himself, leaning with his left hand on the board and gripping block 2 with his right hand. He gets up and, watching block 1, rests block 2 onto block 1. He removes his right hand from block 2, lowers his body to take block 3, and grabs it with his right hand. He gets up and places it onto block 2, leaving block 3.

Following this regularity of actions, which converged in a purposeful activity, we can assume that the child has completed the main stages of sensory–motor skill development and understood the object’s material characteristics. Additionally, the social function inherent to the object appears to be linked to its use.

In fact, the building of the tower was achieved through structured planning and with a constant imaginative tendency. What is lacking seems to be an understanding of the possibility to use the object as a social agent, because the adult was present only as a spectator.

Based on the regularity of actions that converged in purposeful activity, we can assume that Child 3 had completed the main stages of sensorimotor skill development and was able to understand the object’s material characteristics. Further, the objects’ inherent social functions appeared to be linked to their use. In fact, the building of the tower was achieved through structured planning and with a constant imaginative tendency. The adult did not intervene when the child played. In the child–adult interaction, what seemed to be lacking is an understanding of the possibility of using objects as social agents, as the adult was present only as a spectator.

Searching for constants in analyzing the filmed sequences of the three children, their successive actions were identified; initially, each actively manipulated all the blocks. This activity preceded an apparent break, but during that phase, the child observed the objects to determine how to continue. Immediately thereafter, the child either sought the adult’s attention through eye contact or resumed the interrupted object manipulation.

At the beginning of the game, the children moved, shook, and turned the items several times, and this correlated with activation of their hand movements. Here, we probably witnessed the typical secondary circular reactions of the sensorimotor stage. After the break and the search for mutual attention and/or eye contact with the adult, the children then proceeded (by trial and error) to build the tower of blocks, modifying their existing schemes in so doing. This was indicative of tertiary circular reactions.

Discussion and Conclusions

Consistent with a theoretical perspective emphasizing the role of social and material dimensions in psychological development and activities (Iannaccone, 2015), our analysis highlights two important implications in our observations of object manipulation. First, consistent with the Piagetian

perspective, the observations highlighted object manipulation and action planning identifying the presence of secondary and tertiary circular reactions (Piaget, 1972). In relation to the game, invoking the McCune-Nicolich model (1981), all the children exhibited sensorimotor play, in which the object was manipulated and understood in terms of its material characteristics.

The second implication relates to how, in some action sequences, the material and social characteristics of the objects contributed to shaping partner interactions between child and adult. This aligns with several empirical studies of the social uses of objects (conventional, canonical, and symbolic) (John-Steiner and Mahn, 1996; Moro, 2011). In such interpersonal situations, the activities of participants (child and adult) are clearly affected by the setting's physical and social affordances. In particular, during child–parent interactions (Moro, 2014), triadic child– object–adult interactions (Moro, 2011) seem to create relevant socio-material scenarios that frame communicational activities. In our observations, two of the three children in fact exhibited a kind of object management mode that seemed to replace eye contact with the adult. In some sequences of actions, child and adult managed to coordinate action planning through object manipulation, child exploratory activity, and adult scaffolding. For example, the child observed and touched the objects to encourage play activities; the adult touched the object with his hand, and this action frequently became a source of interest for the child. The child looked for the adult's attention through eye contact, and the child began to manipulate the object. In activities of these kinds, it seems evident that the objects can serve as mediators in communicative interactions with the adult. As well as taking into account the social function of objects, the observed children were already considering the socio-material characteristics of the play situation, as adults and children engaged in managing a kind of “socio-material space” as proposed by Rodríguez et al. (2015). In fact, from the first year of life, adults produce a shared space with objects that serve as effective tools of communication with children. Our findings in relation to the object as a tool for adult–child interaction align with Moreno-Núñez et al. (2017), confirming that the first shared understandings between adult and child take place around the object and its uses. Finally, in considering these first results, we can imagine relevant challenges for a new developmental psychology based on further related research.

Our observations of these interactions do not focus on direct joint attention but identify a kind of psychological process that we call “activity mediated by the object.” Unlike Tomasello (1995), we consider the object itself as mediator, not only of the mutual attention between adult and child but of the dynamic relational exchange between partners.

In conclusion, our study reported the preliminary results of a larger analysis. In considering these first results, we can imagine relevant challenges for the developmental psychology of children with autism. Consistent with the results of studies on children with typical development, our study on children with autism shows that the socio-material features of objects represent factors that mediate the construction of child–adult interactions. Starting from the first intervention of an adult, an object becomes a mediator and promoter of interpersonal activities and space.

Ethic Statement

This study was carried out in accordance with the recommendations of AIP (Associazione Italiana di Psicologia), and all of the children’s parents gave written informed consent in accordance with the Declaration of Helsinki. As there is as yet no psychological ethics committee at the University of Salerno, the protocol was approved by the external experts group from the University’s “Centro di Counseling Psicologico” (Counselling Centre). While the Centre is not specifically responsible for ethics approval, the external experts group supervise research carried out by psychological researchers at the University. In Italy, few universities have a psychological ethics committee, and these generally offer degree courses in psychology or have a psychology department or institute. The University of Salerno has not activated degree courses in psychology and has no such department. We would like to thank the external experts, Dr Oreste Fasano (Psychologist), Dr Nadia Pecoraro (Psychologist), and Dr Monica Mollo (Lecturer in Psychology).

Author Contributions

The introduction was written by AI. The observational analysis was written by FM. The discussion of the results and the conclusions were written by GS.

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Chapter 5

Social Functions in Autistic Children and Interaction with/through Object: A Brief Report

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Abstract

The aim is to analyse the social functions of pointing, of imitation and of joint attention in presence of the object for the autistic children. We have built an ad-hoc observation check-list and we have conducted 43 observations with verbal ASD-affected children aged between 2 years and 6 years. The results show that a better use of the object is correlated to the manifestation of social functions analysed.

Introduction

In a socio-material perspective (Iannaccone, 2015), the object is composed of material features and social components coexisting together. Considering that the social interaction is impaired in autistic children; consequently, the interaction with the “social world of objects” is impaired as well (Iannaccone, et al., 2016). Some autistic children show deficits in the use of objects: alterations in manipulation, exploration and describing. Thus, autistic children which do not present impairment in the use of the object show more social functions than impaired children (Trevvarthen & Hubley, 1978; Tomasello, 1995; 2016).

The three social functions, pointing, imitation and joint attention analysed in the study and they all have in common the presence of the object in their definition. Thus, our aim is to analyse these functions not only taking into account the development of these by the autistic child, but also what role plays the object specifically in social and relational terms.

Method

We have built an ad-hoc observation check-list inquiring on 9 areas (each of which has specifying under-questions), which refer to 9 psychological theory constructs developed by the literature on autism and object. The main objective of this check-list is that of describing characteristics and socio-material functions of the object with reference to autistic subjects. In this check-list, there are different psychological constructs, but here we have analysed in detail three constructs: declarative function, imitation and attention. As we can see the check-list was made of different constructs but we will analyse these other constructs in future.

During each observation, an educator following the child for rehabilitation was present and the educator completed the check-list. Each observation lasted 26 minutes on average and has been transcribed on an ad-hoc check-list.

Children have been observed while interacting with an object, a small-sized plastic toy, they had chosen from a set of objects, for instance, toy cars, trains, toy animals and others. When we refer to “acted and interacted with and through the object” we arranged different constructs of the check-list, such as: Understanding of the use of the object, interaction through the objects etc. Which are the constructs refer to the manipulation, exploration and describing.

We carried out 43 observations with verbal ASD-affected children aged between the end of the sensory-motor stage (24 months) and the start of the pre-operational stage (68 months, namely 6 years). Moreover, the literature shows some results showing a link between a better use of the object

and those functions that emerge during the pre-operating period, such as imitation and attention to the other (Bruckner & Yoder, 2007).

We were two samples. The first sample composed of 18 children who acted and interacted with and through the object while the second sample composed of 25 children who acted and interacted with and through the object.

Results

Regarding the association between the sample 1 and the declarative function (Figure 1) shows that the 66.7% of the sample present this association while the sample 2 shows that only the 24% present this association.

Indeed, it is possible also for autistic children to use the imperative function of pointing, as for typical development children, and pointing is often the ground- breaking of a full declarative function (Camaioni et al., 2003).

Regarding the association between the sample 1 and the imitation (Figure 2) shows that the 94.4% of the sample present this association while the sample 2 shows that only the 60% present this association.

Concerning imitation, it has been suggested that the specific imitation deficit of autism could be reduced or even eliminated with the use of activities linked to objects (Vanvuchelen et al., 2013; Custance et al., 2014), especially when no timelines in the use of objects are given.

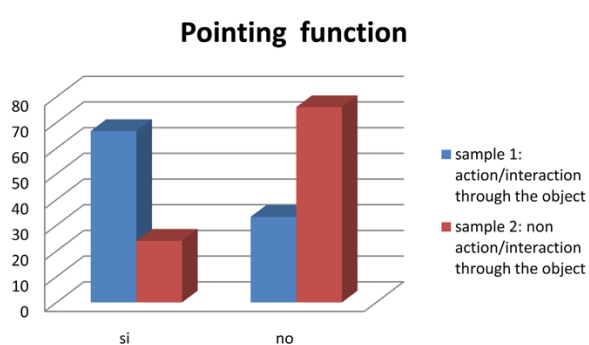


Figure 1. Pointing function

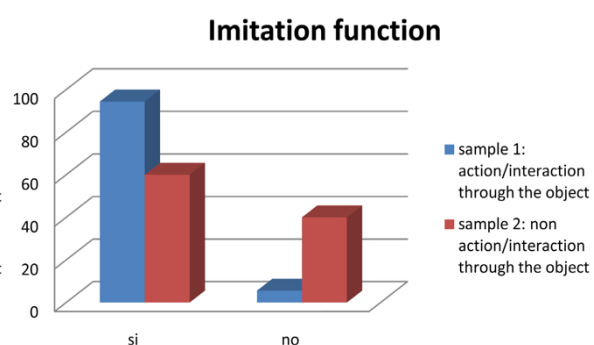


Figure 2. Imitation function

This would favour a higher joint attention, motor imitation and intentional communication with a social partner (Swettenham et al., 1998).

Regarding the association between the sample 1 and the Joint attention (Figure 3) shows that the 61.1% of the sample present this association while the sample 2 shows that only the 32% present this association.

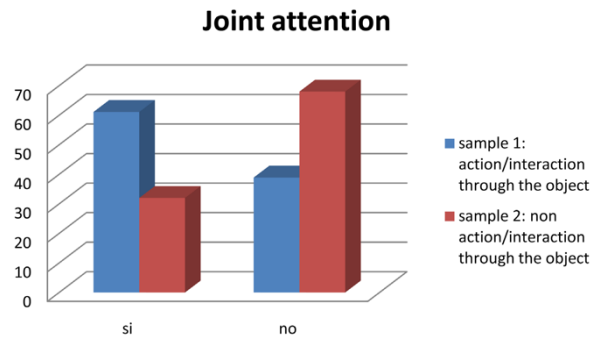


Figure 3. Attention to the adult function

Lastly, regarding joint attention it has been proved that manipulation of material objects can address the child's attention and favour the joint attention with both adults and peers (Korkiakangas & Rae, 2013).

Conclusion

The socio-material features of the object represent factors that mediate the construction of the interaction with the adult. Social functions contribute to this process are: the declarative function (relating to pointing), the imitative function, the function of joint attention.

In line with the literature (Bruckner & Yoder, 2007) on the child with typical development, our study with autistic children shows a link between a better use of the object and these functions that emerge during the pre-operating period, such as imitation and attention for interacting with people.

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Chapter 6

General Discussion

The aims of this thesis were: 1) to explore the intersubjectivity space that a child can establish with an object (the robot) that is also the interactive partner during the interactions; 2) to observe the role of the object as mediator of the child-adult interaction and as promoter of the construction of the intersubjectivity space. The first topic has been investigated in children with typical development while the second topic has been explored in children with atypical development, i.e. autistic children.

In this respect, there were designed two different interactional scenarios to evaluate the intersubjectivity: 1) concerning typical development it has been used an interactional situation involving humanoid robot in order to test the decision-making processes; 2) regarding autistic children the use of the object has been observed during an interaction with an adult mediated by an object, testing the role of the object as mediator and promoter of the interaction. The first situation, involving an innovative field of research, needed a review of the literature in order to understand which role can be assumed by the robot during the interactions with a human. Thus, it was important to analyse if human can ascribe a mind – mental states – to a robot, in particular in a life-span perspective in order to observe changes during the human development. The second scenarios used an original perspective to examine the interaction between autistic children and adults, showing that autistic children, despite their impairments in different areas of development, can create an intersubjective space with the adults. However, this is evident when child and adult use an object as mediator of this interaction.

The findings emerged from these scenarios arise two main questions:

Can a child treat a humanoid robot similarly to a human partner?

Futurologists hypothesised that in the next years robots will be introduced in different contexts of our everyday life such as household, elderly assistance, education etc, modifying the job market but also our social interactions. For instance, the use of robots in the educational context are inspiring new educational program. Moreover, children will be more conscious of the existence of the robots because robots become part of their everyday experience. Several studies underline the need to implement physical and behavioural features in order to make robots more sociable, promoting better

interactions. From Chapter 1 results that subjects ascribe mental states to a humanoid robot. However, the attribution of a mind is not similar at all ages, but it changes during the life-span. For instance, a recent study of Manzi and colleagues (2017) showed that children from 5 to 9 years of age distinguish a human from a robot as regards the attribution of mental states, in particular children ascribe different mental states to a robot at different age: younger children ascribe more emotional states compare to older children. However, several researches in the field of educational robotics show that children treat a robot as a companion and scaffolder in the educational contexts. These findings are evident in the study presented in Chapter 2. In fact, 5-years-old children ascribe less mental states to a robot compared to a human but despite these differences, they use similar strategy with human and robot when they play in an interactive game. This is a fundamental result because it means that children can treat a robot similarly to a human. Moreover, another innovative result of the study is the analyses of children justifications given to the Ultimatum Game. We observed that children tend to use justifications based on the outcome and not on the basis of mentalistic terms both for human and robot, showing how children behave like maximisers – according with the homo-oeconomicus theory – when they interact both with human and robot. In the human condition, children's justifications based on the 'outcome' given to the unfair divisions, both as a proponent and as a receiver, could be explained as the attempt to resolve a cognitive and social conflict (expected "social" fair behaviour VS real "selfish" behaviour). Moreover, in the robot condition, children's justifications based on mentalistic terms to unfair divisions, both as a proponent and as a receiver, can be explained as the social norms of equity might be less relevant (robot = "not perfectly like-me").

The literature review in Chapter 2 and the data of Chapter 3 represent an important finding for the HRI and cHRI because it is possible to infer that humans – from childhood to old age - tend to ascribe a mind to a robot and that besides 5-years-old children tend to treat a robot as social partner, using similar cognitive strategies both for human and for robot.

In conclusion, robots can be considered 'like-me' (Meltzoff, 2005, 2007a, 2007b, 2013) but it depends from: 1) the age of human partner interacting with a robot; 2) the methodological procedures, and particularly the nature offline (i.e., the AMS questionnaire used in Chapter 3) or online (i.e., the modified version of the Ultimatum Game used in Chapter 3) of the tasks employed; These final observations lead to reflect on the instruments used in research and this is even more important when the topic of research is new such as the HRI. In fact, it is essential to combine both offline and online measures, but also it is important use together ecological and laboratory tasks.

Can an object be a mediator and a promoter of the child-adult interaction also for autistic children?

We live in a social world composed by humans and objects. In the history of Psychology, the human-human interactions were largely investigated but few studies analysed the human-human interaction mediated by objects. In this regard, Piaget (1952, 1954) highlighted that children discover the world of the objects through a sensorimotor activity, which constitutes the basis of the cognitive development. Vygotskji (1962, 1978) showed that children with typical development use artefacts to interact with others, acquiring their knowledge about objects through the interaction with a scaffolder (peers or adults). Moreover, Moscovici (1976) examined the interpersonal relationships in a triadic perspective, highlighting that humans and objects are strictly connected. However, Linell (2009) proposed a dialogical interpretation of the objects, suggesting that it is important to understand the objects as external referent that can change human's perspective of the world. Several studies showed that an adult can be a scaffolder for the acquisition of the use of the objects in children with typical development (Moro, 2014). In Chapter 4 and 5 we demonstrated that also children with atypical development, in particular autistic children, can use the object to construct an intersubjectivity space during the interaction with the adult. The objects in these interactions acts as mediators of the child-adult interaction, creating a specific intersubjective space in which autistic children, despite their social impairments, are able of some social performances (i.e., ocular contact).

In Chapter 4 the results seem to demonstrate that the socio-material features of objects represent a key-element that mediates the construction of child–adult interactions, becoming a mediator and promoter of interpersonal activities and space. Chapter 5 shows a link between a better use of the object and the presence of social behaviors that emerge during the pre-operational stage, such as imitation and attention. However, it is important to highlight that the use of the object and the presence of social abilities largely vary in each autistic child because autism is a spectrum disorder that implies a wide range of phenotypes. Thus, the construction of intersubjectivity space has to consider the specific subjects of the interaction and their interpretation of the objects.

These findings lead to the conclusion that to understand how children with typical development interpret the use of the objects it is important that adults ‘share’ the child’s perspective in order to create an intersubjective space. If it is crucial in typical development, then it becomes even more essential in atypical development, in particular in autism that is a spectrum of disorders that imply a different kind of impairments in several areas of development. In fact, the adult has to consider that each autistic child constructs the intersubjectivity space in a subjective way, using all her/his skills.

In general, both as regards typical and atypical development, the adult should accept that each artefact is always reinterpreted by the child in a triadic relationship through a continuous and dynamic construction of the intersubjectivity.

Conclusion

The majority of the psychological research is inspired by everyday experiences and so I will try to give some examples of the key points of this thesis, starting from my life.

I am writing my thesis using my computer right now and its battery is almost discharged. I am saying “Why you do this to me?”. Despite my prayers, my computer will switch off if I will not put it in charge. What does this situation mean? I am ascribing intentions to my computer, in particular the intentions to turn off itself.

I remind that in UK when I was learning how to use a robot, I was staying in the Lab hours and hours without talk to anybody and so I was starting to talk to the robot, ‘praying’ it to work in the right way. It obviously continued to not work and to not reply to my questions and prayers (fortunately!).

I bought a toy for a son of two friends of mine when he was 6-moths-old. Then these friends moved to USA and sometimes we Skyped, but I did not see them for a long time. This summer when I came back to my hometown, I saw them after three years and the child still had the toy and when the mother said him that I bought it for him he smiled and give me the toy to play together.

The above examples highlight the two main points of this thesis: 1) we can ascribe mental qualities also to objects that have not ‘really’ a mind because we tend to project our internal states onto the external world; 2) we are fully immerse in a world of objects that give us the opportunity to create an interaction with another person beyond the time.

To attempt a tentative conclusion, the purpose of this thesis was to show that when humans build objects - from the classic ones to the more technological ones - they also achieve two further important objectives: to facilitate social interactions and to create an intersubjectivity space that includes both human and non-human partners. I sincerely hope my efforts have at least partially succeeded.

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Materiality and the construction of Intersubjectivity: human-robot interaction In typical development and the use of the Objects in ASD children

Federico Manzi

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Chapter 1

General Introduction

*Una mente tutta logica è come un coltello tutto lama.
Fa sanguinare la mano che lo usa.*
(Rabindranath Tagore)

The aims of the present dissertation are to analyse, in children with typical and atypical development, the construction of the intersubjectivity through the use of objects in atypical development (ASD) and through the interaction with a humanoid robot in typical development. About the humanoid robots, the issue is to observe the possible attribution of human-like features to a robot that can make the human-robot interaction similar to the human-human interaction that is a classic intersubjective interaction because of the presence of two human subjects. This purpose is investigated considering two theoretical frameworks: 1) Theory of Mind that explain the construction of the intersubjectivity through the attribution of mental states to others; 2) Socio-material perspective which postulates that the construction of the intersubjectivity is mediated by objects in many cases. Thus, the question arises in this dissertation about the humanoid robot is: what happen when the mediator object (the robot) is also the interactive partner.

To achieve this purposes, the present thesis studies two main topics: 1) the interactional patterns with and the attribution of a mind to a robot by typically developing children; 2) the interactional patterns in atypical development - autistic children - in a child-adult interaction mediated by objects. The first topic is analysed in an innovative theoretical perspective and a through novel methodological approach, leading to an innovative understanding of the child-robot interaction. The theoretical perspective connects the role of Theory of Mind in HRI; the methodological approach observes children's decision-making strategies in the HRI, comparing these behavioural patterns when children interact with a human and with a robot. The second issue of the thesis is about the role of the object as mediator of the relationship between autistic children and adults. This is studied through the Socio-material perspective that hypothesised that material features of the objects and their intrinsic social qualities are strictly connected.

A useful psychological paradigm to investigate the construction of intersubjectivity is the Theory of Mind construct that will be briefly introduced; subsequently I will give an overview on Human-Robot

Interaction and, finally, I will conclude with some observations concerning the role of the objects in autism.

Theory of Mind or how understand the social world

Theory of Mind (ToM) represent one of the most important psychological constructs used in the last decades to interpret social interactions. ToM is the ability to understand one's own and other people's mental states (intentions, emotions, desires, beliefs), and to predict and interpret one's own and others' behaviours on the basis of such meta-representations (Premack and Woodruff, 1978; Wimmer and Perner, 1983; Perner and Wimmer, 1985). This definition highlights how the presence of the other is crucial for the comprehension of ourselves and for the interpretation of the relational world. The history of the ToM begins with the pioneering study of Premack and Woodruff (1978), titled "Does the Chimpanzee Have a Theory of Mind?". This study paved the way to study the ToM also in different agents, not only in humans but also in primates. They found that also the primates can use ToM ability to understand and predict the conspecific's and human's behaviours. These results allowed to study the ToM in an evolutionary perspective. In fact, Adolphs (2009) theorised about the phylogeny of social abilities, showing that our brain is a social brain that evolved from primates to humans.

Furthermore, developmental psychology study the changes that occur during children's development, showing the ontogenesis of this ability. ToM is not a monolithic construct, but it is a complex and multimodal ability that involved both cognitive and affective processes (Shamay-Tsoory & Aharon-Peretz, 2007; Kalbe et al., 2010).

Wellman (1991) hypothesised a ToM development from 3 to 7 years of age considering the understanding of mental states in the childhood. The author drawn a line of development: children in the early stage of development understand the non-epistemic states (desires, emotions and intentions) – between 3 and 4 years – and only late – between 4 and 7 years – the epistemic states. The epistemic states are the bases for the true and false belief understanding: this allows children to construct a meta-representation of their own and other's mind. Thus, considering the important of belief, in particular false belief, a pioneering study of Wimmer and Perner (1983) used for the first time the paradigm of the false belief task to study the ToM development. In this study the authors used the Unexpected Transfer Task in which a character has to ascribe a false belief of another character. The results showed that 4 - to 5 - year-old children can predict the actions of someone with a first order false beliefs referred to the first level of recursive thinking (i.e. "I think that you think"). These findings are supported by a meta-analytic study by Wellman, Cross and Watson (2001) that confirmed

that children begin to attribute a false belief starting from 4 years of age. In a second study Perner and Wimmer (1985) used a different task, the Ice-Cream Van, in order to analyse the second level of the recursive thinking (i.e. ‘I think that you think that she/he thinks’), that is the *second order false belief*. They found that 6- to 7- years-old children can understand this second level of representation. These findings show that the ‘sensible period’ for the emergence of the ToM is from 3 to 7 years of age and that it is acquired in a hierarchical way (Wellman, Cross and Watson, 2001). However, several studies show that the ToM is an ability that gradually develop from childhood to adulthood (Sommerville et al., 2013; Dumontheil et al., 2010; Apperly et al., 2012) and in the last years several studies investigate the modification of the ToM ability during the old age (Happé et al., 1998; Castelli et al., 2011; Saltzman et al., 2000).

Human-Robot Interaction: an interdisciplinary approach to investigate socio-cognitive abilities

“Human–Robot Interaction (HRI) is a field of study dedicated to understand, design, and evaluate robotic systems for use by or with humans” (Goodrich and Schultz, 2008, pp.1). The HRI derived from the Human-Computer Interaction (HCI) studies. The differences between HRI and HCI is that HRI uses robots that have physical human-like features (along a gradient from completely non-human like to a complete similarity with humans) and they can behave as humans (i.e., a robot can recognize and follow the eyes of a human or it can reply semi-autonomously to a human question). Thus, HRI not only implement behavioural patterns into robots but also design robots that can be perceived more human-like (Minato et al., 2004). In the last two decades HRI received more visibility especially related to the development of new theoretical approaches and technical skills in the robotics’ domain. For instance, in 2004 the Ishiguro’s Geminoid Project¹, in Japan, built androids which very closely resemble specific human “models” as a platform for research aimed at understanding humans, applying methods from engineering, cognitive science and neuroscience. Indeed, the robots can be used as a research tool in two different ways: 1) to use a robot in order to test human cognitive models, implementing algorithms that can simulate the human cognitive processes (Di Nuovo et al., 2013; De La Cruz et al., 2014; Whitaker, Colombo and Rand, 2018; Scassellati, 2003, 2005); 2) to use the robot as a possible partner in scenarios that implies the interaction with a human in order to observe social interactional patterns (Manzi, et al., 2018; Breazel et al., 2016; Moriguchi et al. 2011; Nishio et al., 2018; Sandoval et al., 2016). There are different theoretical approaches in HRI and in robotics; the

¹ For more information on the Geminoid Project: <http://www.geminoid.jp/en/index.html>

most interesting are: Developmental Robotics (Cangelosi and Schlesinger, 2015; Lungarella et al., 2003) and Developmental Cybernetics (Itakura 2008; Itakura, Okanda and Moriguchi, 2008).

Developmental Robotics is an emerging field of research that connects robotics, cognitive science and developmental sciences – in particular developmental psychology and developmental neuroscience (Di Nuovo et al., 2014; Di Nuovo et al., 2017). This field is focused on the implementation of robots that should be more autonomous, adaptable and sociable– the cognitive developmental studies are crucial in this respect – but to achieve this goal it is fundamental to employ models of human development in order to embed these models into robots. Thus, it is important the collaboration between engineers and developmental psychologists in order to design the models mentioned above (Asada et al., 2001; Lungarella et al., 2003). Developmental Robotics represents an innovative approach to the development of HRI: its statement is that robots can learn as children (Cangelosi and Schlesinger, 2015). Roboticians use algorithms, deriving from the Machine Learning field, to build cognitive models of psychological processes (Cangelosi and Riga, 2006; Cangelosi, 2010; Cangelosi et al., 2010). However, these models derive from the research in developmental psychology because it is fundamental to understand the trajectory of development of the psychological processes (i.e., ToM or linguistic development). Since robots should be social partners, Scassellati (1999, 2001, 2002) assumes that they have to possess a ToM. This is only a theoretical assumption because today technical innovation does not permit an implementation of a ToM into robots despite our knowledge about ToM development: an explanation is that ToM ability is a complex process that involves several cognitive and affective components.

Developmental Cybernetics connects Developmental Psychology and robotics, using the human development models in order to identify the most important behaviours that can promote HRI. This is the other side of the coin because, while the Developmental Robotics uses the models to make robots behave socially, Developmental Cybernetics studies which kind of behaviours should be implemented into robots in order to promote HRI. In particular, Developmental Cybernetics studies the development of social behaviour in infants in order to implement specific behaviours so that the robots can be treated as a companion. In the case of interactions between children and robots, we shift in the field of Child-Robot Interaction (often abbreviated as cHRI), which differs from HRI because the partner of the interaction, the child, presents an immature cognitive development (Belpame et al., 2013 a, b). cHRI is crucial for Developmental Cybernetics because of its futuristic hypotheses: in the next decades the robots can be introduced into human societies in different contexts among which the educational ones. In this case, the robots should be attractive for children: to reach this goal,

physical and behavioural characteristics should be more human-like. In 2018 one of the biggest Japanese educational projects introduces 500 humanoid robots (NAO robot, created by Aldebaran Robotics) in the Primary School in order to teach English to Japanese children². Moreover, several research programs use humanoid robots in different educational contexts (Chang et al., 2010; Belapme et al., 2016; Gordon et al., 2016; Kanda et al., 2007), highlighting, in a vygotskian approach, how robot can be use as scaffold. Developmental Cybernetics postulates that to build a social robot is important to study and to develop research knowledge about three main domains connected to the robot: Theory of Body (ToB), Theory of Communication (ToC) and Theory of Mind (ToM). The ToB hypothesises that a robot should move its arms, legs and head in a conventional mode. For instance, Morita and colleagues (2012) test children's and adults' reaction to conventional and unconventional movements of the body of a human and of a humanoid robot, showing that children extend their reaction to the unconventional movements both of human and humanoid robot respect to adults that are more activated when the unconventional movements are made by a humanoid robot. With regard to the domain of Theory of Communication, several studies show that an effective robot is a robot that can communicate in verbal and non-verbal way (Breazel at al., 2005; Brooks and Arkin, 2007; Mavridis, 2015). These researches generally highlight that a robot that can use non-verbal signals (i.e., facial expressions or gestures) to promote the human involvement in the interaction is perceived more as a companion than a robot that not communicate in such ways. For instance, Aaron and Mataric (2015) use a robot that communicate with a worker to achieve a goal, finding that the robot was perceived as a teammate more than a robot without communicative behaviours. The last, but not the least, domain of the Developmental Cybernetics is Theory of Mind: this is a crucial objective of Developmental Cybernetics because it hopes that in the future robots can interact in a way that can be perceived as having a mind. Nevertheless, as above mentioned, the implementation of ToM into robot is more a futuristic dream, while has been demonstrated that humans use their ToM ability to understand robots' behaviours. This a fundamental assumption that connects the different sections of this thesis. In fact, already Piaget (1929) uses the concept of animism suggesting that the human ability to ascribe intentionality to an object is an early infant's disposition. However, when we talk about robots, we refer to an animate object that appears and behaves in a human-like way. Thus, the ToM ability is a very useful psychological construct that can help to better to understand the human's tendency to ascribe mental states to a robot. In Chapter 1 it will be shown as humans, in a

² For more information is possible to access to the article by the following link:
https://rep.repubblica.it/pwa/generale/2018/09/24/news/giappone_robot_insegnano_inglese-207218720/?ref=RHRS-BH-I0-C6-P21-S1.6-T1

life-span perspective, tend to attribute minds to robots. Some research points out, in particular as regards childhood and adolescence, that the ascription of mental states changes with age (Manzi et al., 2017; Kahn et al., 2012). Chapter 2 shows that younger children tend to ascribe to robots more intentions and desires and less epistemic states than older children, in line with the ToM literature (Wellman, 2001). These findings highlight an important point for Developmental Cybernetics, and in general for developmental psychology, because they demonstrate that children perceive a robot as a partner that appear and behave like a human when they interact with it. Additionally, the children's ascription of a mind to a robot is the prerequisite for the establishment of the intersubjectivity. The concept of intersubjectivity captures the way a person understands and relates to another people and implies that exist a bridge between the knowledge of oneself and the one's own knowledge of others (Rochat, Passos-Ferreira and Salem, 2009). In the light of above, this is a crucial theoretical mark for the HRI because, if the intersubjectivity is the assumption of the interpersonal relationship in humans, the presence of this dimension in the human-robot interactions allows to interpret these interactions not only in a mere behavioural way but also in a relational way.

The use of the object in children's development: an overview on autism

The Autistic Spectrum Disorder (ASD) is a syndrome that can be characterized by an intellectual disability (DSM-5, 2013). The main symptoms of the ASD are: impairments in the social interaction (Baron-Cohen, 1997; Frith, 2003); impairments in the verbal and non-verbal communication (Mundy et al., 1987; Happé, 1995); stereotypical and repetitive behaviours, interests and activities (Bodfish et al., 2000; Boyd et al., 2010). Since ASD is a syndrome that affects all the psychological development, social and cognitive deficits are very heterogenous both for the complexity and severity of disease. These symptoms can emerge and change in different moment of development (Frith, 2003; Yirmiya and Charman, 2010). The repetitive behaviours and activities affect also the use of objects: some researchers report that this impairment can be detected already at 12 months of age (Ozonoff et al., 2008; McCleery et al., 2009). Ozonoff and colleagues (2008) found that 12-months-old children tend to use the object in a repetitive way. The use of the object needs to be studied from the sensorimotor development point of view because the object is present since the early stage of the children's development. More recently, several researches show that autistic children present atypical sensorimotor development and sensory perception that predicts the severity of symptoms especially in the area of communication at 24 months of age (Estes et al., 2015; Robertson and Baron-Cohen, 2017).

In the history of psychology, several psychologists studied the role of the object in the human development, such as Piaget, Vygotskji and Moscovici. Within his work, Piaget (1956; 1958; 1977) describes two different types of knowledge. The first type of knowledge origins through physical experience; such experience produces the knowledge of the properties of objects that are used. The second type of knowledge is gained through the logical-mathematical experience, which does not produce knowledge about the objects but about actions and their results. Thus, micro-genetic analysis, which aims to observe the temporal and qualitative aspects of the interactions, is a basic methodological condition for understanding the development of materiality. Despite this embryonic change of course the epistemological approach of Piaget remains anchored to the dualism of subject and reality.

Nevertheless Vygotskji (1962) uses another theoretical perspective: he considered the objects, named artefacts, as a fundamental component of human life. He suggests that humans use both material (i.e., a computer) and psychological (i.e., language) artefacts to interact. Adults use in a better way these artefacts and through their scaffolding 'teach' to children how to appropriately use them. In this respect, the artefacts represent human 'instruments' essential for the communication and interaction.

In these terms, the behaviour and the understanding of the processes of consciousness are closely dependent on the nature of the interaction of human and non-human components of this dialectic dyad. In the history of psychology, some the psychologists abandoned a dyadic approach in favour of a triadic perspective. The key aspect is no longer just the dyadic relationship, but what Moscovici (1976) defines triadic relationship. Moscovici proposes a ternary reading of facts and relations, and in fact replaces the two- term view, subject and object, with a three-term one: individual subject, social subject, and object. In other words, the Ego, the Other and the Object. This aspect assumes a constant exchange between the three elements of the triadic relationship. Such relationship may be conceived as static or dynamic, implying a simple "co-presence" or an "interaction" that can result in changes in thought and behaviour.

However, the theories presented above about the objects are based on a non-dialogical conception of the artefacts. In fact, Linell (2009) considers artefacts as external objects, according to a dialogical theory of the artefacts. The objects serve as anchoring points for intersubjectivity. Moreover, the author suggests that exist an interplay between the human ability of using artefacts and the external objects which possess a wide range of uses for humans. Thus, the objects are used by humans but also can change the humans perspective of the interactional world.

The objects are involved in several psychological mechanisms, such as joint attention and imitation that are largely studied in autism. The joint attention implicates at least the presence of two

partners and of an object that plays the role of the mediator of their interaction (Tomasello, 1995; Mundy and Gomes, 1998; Moore, Dunham and Dunham, 2014). Thus, the object is a protagonist of this human phenomenon, acquiring a crucial role in the interaction. Moreover, the studies on imitation distinguish between body gestures imitation and object actions imitation (Masur & Ritz, 1984; Snow, 1989), showing that the object is involved in the human development as a fundamental ‘non-living partner’ that has a role in a lot of psychological processes.

In the light of above, about children with typical development, the use of the object is a crucial element for the interactions (Rodriguez and Moreno, 2008; Barthélémy-Musso et al., 2013). In fact, Rodriguez and Moreno (2008) hypothesizes that children with typical development use the object in order to interact with adults: the adult has the role to teach to the child different uses of the object which, derive from the human society, Thus, the adult acquires the role of a scaffolder for the conventional use of the object (Moro, 2011, 2014). This approach is particularly interesting because the children and adult create an intersubjective space in which they can interact with each other through an object. Thus, the object is a mediator of the child-adult interaction. Moreover, as already highlighted in the previous paragraphs, the establishment of an intersubjectivity space is the basis of the of human interpersonal relationships.

In the view of the above, it is important to analyse the role of the object also in children with atypical development, in particular in autistic children because they present a distinctive pattern of interaction with the object (i.e., repetitive actions on the object) and are also characterized by social impairments which represent an obstacle for the establishment of interpersonal relationships. In fact, being social interaction impaired in autistic children is consequently impaired the interaction with the “social world of objects”. In the socio-material perspective (Iannaccone, 2015) the object is composed of material features and social components which coexisting the same object. Some autistic children show deficit in the use of the object: alterations in manipulation, observation, understanding and denomination. The object is a significant communicative mediator in social interaction between adults and children (Iannaccone, Savarese and Manzi, 2016). Thus, autistic children which do not present impairment in the use of the object show more social behaviours as pointing (Bernabei, Camaioni and Levi, 1998), imitation (Vanvuchelen et al., 2013) and joint attention (Mundy, 2016). For instance, joint attention is typified by subject-subject-object triangulation in which children alternate their eye gaze between the object and the other person (Trevvarthen and Hubley, 1978). In this respect, Chapter 3 and 4 deal with the role of the object as promoter of the child-adult interactions. Despite the identification of deficits in the expression of the most important early precursors for the social interaction, it has been observed that autistic children can use in specific ways the object that promote the intersubjectivity space. In Chapter 4 autistic children from 20 to 24

months of age exhibit specific sensorimotor patterns of use of objects (manipulation and exploration) that tend to involve the other partner – adults – to interact with the objects. Thus, also in the case of autistic children the object is a mediator of the relation with the adult. Moreover, Chapter 4 points out that autistic children that present a more complex and rhythmic patterns of interaction with the object present more social behaviours (i.e., joint attention and imitative actions).

These findings reveal the ability of autistic children to establish an intersubjectivity space, using the object as mediator of interactions with adults despite the evident social impairments that characterize this syndrome.

This Thesis

Chapter 1 is a review of the literature about the role of the Theory of Mind (ToM) in the Human-Robot Interaction (HRI) in a life-span perspective, showing that from the childhood to the adulthood humans can ascribe a mind to a robot, in particular to a humanoid robot. The HRI is analysed in two main domains: 1) mental states and actions; 2) physical human-like features. The first area highlights that a robot which behave like a human and use human-like cognitive processes promotes the attribution of a mind to a robot. Already in infancy some behaviours (i.e., eye-contact and goal directed actions) promote a better children's social involvement during the interaction with a robot. The robot human-likeness is effective in a life-span perspective. Moreover, the implementation of robots' human-like physical features (i.e. eyes, hands, legs etc) is a crucial goal for the promotion of a more complex human-robot interaction. However, it is also important for a robot to not be completely similar to a human since the risk of a perfect human-like appearance is the Uncanny Valley effect (Mori, 1970), in which the excessive similarity of a robot with humans can reduce the interaction. The main hypothesis is that through these technical innovations, concerning physical and behavioural features of a robot, humans construct an intersubjectivity space with a robot. This is possible because the recognition of a mind in a robot is the prerequisite because humans perceived it as social partner.

Chapter 2 is focuses on pre-schoolers' behaviour during the Ultimatum Game when they play with a human and a robot. In particular the study aims at analysing: the mental characteristics ascribed to the robot with respect to the human; children's behaviour at the UG when playing with the human and with the robot as proposers and receivers; children's justifications for their behaviour during the UG. To my knowledge, this is the first study which analyses children's behaviour during the UG, comparing human-human and human-robot interaction. In this respect, several tasks and tests were created *ad hoc*: 1) the Attribution of Mental State Scale (AMS) is a measure of mental states attribution that the child has to perform looking at pictures depicting a character; 2) to assess children's understanding of the first-order false belief, we introduced a new instrument, constituted by eight videos representing the classical story, introducing also the Robovie as a new character - we used a story similar to the classical *Unexpected Transfer* task as the script of the videos. The AMS results show that 5-year-old children recognize the robot as a different entity from the human. In fact, children ascribe mental states also to the robot, but they are different compared to the mental states attribute to the human. Nevertheless, children behaved similarly during the UG when playing with the human and with the robot, confirming a tendency to maximize gain. Additionally, children's

justifications at the UG showed that, independently on the interactive agent and on the role played (Proposer/Receiver), children tend to use ‘outcome’-based justifications to explain their behaviour for all divisions. This is the first qualitative evidence supporting the idea that, at the age considered, children mostly reason in economic/quantitative, homo-oeconomicus-like, terms. The almost total lack of equity and mentalization-based justifications of human unfair divisions further suggests an attempt of children to resolve a social cognitive conflict emerging from the discrepancy between a “socially-expected” fair behaviour and the actual “selfish” behaviour.

Chapter 3 presents an explorative study aimed at observing the quality of interactional patterns in child-adult interaction, using objects as key elements for the construction of intersubjectivity. This qualitative research is based on two theoretical perspectives: 1) Piaget's studies (1952, 1954), according to which children reach the conceptualization skills of objects in the fifth phase of the sensory-motor development; 2) studies that concern the canonical use of the objects, according to which the canonical functions of the objects are acquired as a normative phenomenon during social interactions (Tomasello, 2016), even if the cognitive understanding of these functions is a prerequisite. Several other studies show that canonical functions of the objects are acquired during child-adult interactions (Leontiev, 1981; Costall, 1997; Moro, 2011, 2014; Rodríguez & Moro, 1998; Sinha & Rodríguez, 2008). In this Chapter it will be analysed the manipulation of objects by children with autism spectrum disorder with the aim of showing how objects can be considered as active agents of interpersonal exchange between children and adults. The study adopts a socio-material interpretation, assuming that some interactional patterns, involving the manipulation of objects, can create a space that supports the child-adult relationship. The observations highlight that children present sensorial and realistic play and there are some children's behaviours (i.e., eye-contact) that show that the objects are concrete mediators for the construction of the intersubjective space in the interactions between children and adults. It has been observed in this study that children monitor adults' attention through eye contact or object manipulation. These actions are signs that the object becomes a mediator of mutual attention between the adult and the child: we called this kind of attention, “attention mediated by the object”.

Chapter 4 presents a brief report that investigates the role of the object as a factor that mediates the interaction between children and adults. We observed a group of autistic children in order to analyse if an object can be a promoter of social interactional functions: imitation, joint attention and pointing. The main focus of the study is to analyze in verbal ASD the understanding of social function intrinsic in the object through the use of material features of the object. In particular, the study evaluates the

relationship between the “interaction with/through object” (material features of the object) and three social functions classically impaired in ASD: pointing, imitation and joint attention. We observed a group of ASD children aged between the ending of the sensory-motor stage (24 months) and the beginning of the concrete operational stage (68 months). The group has been split in two sub-groups: group1 is composed of 18 children that act and interact through objects (for examples, balls, cars etc.). Indeed, children manipulate, observe, understand and sometimes give a definition of the object; group2 is composed of 25 children that do not act and interact through and with object. Group 1 shows more social functions (pointing, imitation and joint attention) than group 2 Autistic children which show a more complex use of the material features of the object and act and interact with and through object present more social functions. On the other hand, children which have alteration in the use of the object show fewer social functions. These differences depend on the children’s characteristics. In this study, the role of the object is a crucial element for the creation of the intersubjective space.

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Chapter 2

Theory of Mind and Humanoid Robots From a Lifespan Perspective

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Abstract

This mini-review focuses on some relevant issues concerning the relationship between Theory of Mind and humanoid robots. Humanoid robots are employed in different everyday-life contexts, so it seems relevant to question whether the relationships between human beings and humanoids can be characterized by a mode of interaction typical of the relationships between human beings, i.e., the attribution of mental states. Since Theory of Mind development continuously undergoes changes, from early childhood to late adulthood, a lifespan perspective was adopted. Contributions from the literature were analyzed by organizing them around the partition between ‘mental states and actions’ and ‘human-like features’. Finally, we considered the contribution that studying the human-robot interaction, within the paradigm of Theory of Mind, can give to the understanding of the intersubjective nature of this interaction.

Introduction

This contribution progresses from Turkle's (2004) opinion, which, reflecting on Steven Spielberg's movie, *AI*, exemplifies the most exquisite socio-relational issues of human–robot interaction:

. . .[S]cientists build a humanoid robot, David, who is programmed to love. David expresses this love to a woman who has adopted him as her child. In the discussion that followed the release of the film, emphasis usually fell on the question of whether such a robot could really be developed. People thereby passed over a deeper question. ... That question concerns...[w]hat kinds of people are we becoming as we develop more and more intimate relationships with machines? Today, we are faced with relational artifacts to which people respond in ways that have much in common with the mother in *A.I.* (p. 25).

For hundreds of years, the interest in human–robot interaction has occupied a space in the cultural productions of humankind. Today, we are witnessing a renewed interest in the human creation of a nonhuman alter ego. In particular, researchers are focusing their interest on social interactions with robots. Many scholars believe that a fundamental component of social interaction is the Theory of Mind (ToM; Wimmer & Perner, 1983). ToM is the ability to predict and interpret our own, and others', behavior on the basis of mental states. Herein we offer an overview of work that has focused on the study of human–robot interaction, in the context of ToM. In particular, we review studies investigating the attribution of mental states to robots in a lifespan perspective.

Without the claim of being chronologically exhaustive, we provide some examples of the pervasive interest in artificial partners in the history of humanity. Homer (2003), in the *Iliad* (XVIII, 573–579), told how Hephaestus, the god of fire, who needed help in his forges, built aides, similar to young men, who had hearts, voices, and life. Discussion of the more-or-less human characteristics of intelligent manmade machines has its most famous philosophical roots in the 17th and 18th centuries, in the debate around the works of Descartes and La Mettrie (Gunderson, 1964). Descartes equates animals with machines, but ascribes uniqueness to humans via the term, *cogito* (I think). On the contrary, La Mettrie extends the animal-machine analogy to humans, radicalizing the materialistic and mechanistic perspective.

The mechanical automaton was an attempt to build a human-like artifact, capable of replicating and repeating human activity. In the 13th century, Al-Jazari, an Arabic mechanical engineer, built a programmable device capable of playing sounds autonomously (Nadarajan, 2007). In the 15th

century, Leonardo da Vinci not only theorized on the possible robotic reproduction of an animal, but also advanced a project that attempted to mechanize the human being, with the mechanical knight of 1495 (Rosheim, 2006; Taddei, 2007).

A crucial qualitative leap into the anthropomorphization of machines is to ask whether robots can think, overcoming Cartesian dualism: the philosophical concept that asserts the existence of a separation between *res cogitans* and *res extensa* (i.e., respectively the mind and the body). From a psychological, and more intersubjective³, point of view, and for the purpose of this review, we can rephrase the question as: when will robots be able to make humans believe that they are human? In 1950, Turing published a seminal paper in which he imagined an imitation game with three participants. An interrogator asked questions of the other two participants and, based on the answers, had to guess who was a man and who was a woman. Then, without warning the interrogator, a computer would replace one of the participants. How long would it take to understand that the answers came from a machine, and not from a human being? According to Turing, during the imitation game, it would become increasingly difficult to distinguish the responses of a machine from those of a human (Turing, 1950).

Artistic creativity often anticipates scientific topics on the history of thought. There are many examples in literature and cinema about our subject. Let us remember Shelley (1830/1994), proposing the literary character of Frankenstein, or The Modern Prometheus⁴, destined for a much greater degree of notoriety thanks to the story's many cinematic adaptations. It is also worth mentioning Asimov (1983), who revisited the futuristic concept of a robot by conceiving it as a potential partner for supporting/replacing human activities.

³ The concept of intersubjectivity has various definitions, each of them highlighting different aspects: cognitive, affective, socio-cognitive. The various definitions have in common the idea that the meaning of the tasks and events that the person builds during development is not an operation in solitude but is the result of interaction with real or symbolic partners.

⁴ The story shows the human desire to create an immortal alter ego. The created alter ego turns out to be a monster. Dramatic events lead to the death of the monster's creator and then the monster itself. The monster suicides, explaining the evil deeds it has done while living with the contempt and rejection by humans. The fascination of this story consists in shaping the fears of both partners in this relationship.

Cinema has also represented – now as utopia, now as dystopia – the complexity of the robot’s relationship with humanoids. Fritz Lang’s *Metropolis* (1927) was the first movie to foreshadow the possibility that a robot could substitute for man in the hardest jobs, and that it could begin to interact with man in ways that went beyond any designed intentionality.

The iconic film *Blade Runner* (1982), drawing inspiration from Philip K. Dick’s *Do androids dream of electric sheep?* (1968), highlighted the risk of indistinguishability between

the creator of humanoids and his “children.” Freud (1919/1955) described the characteristics of a particular psychic experience with the experience of the “Perturbant” (Unheimlich-unfamiliar vs. Heimlich-familiar). Jentsch (1906, 1997) had already described this experience in relation to, for example, puppets and automatons. The latter consist of the uncertainty that a seemingly inanimate being is alive and, in a complementary way, that a living subject has the chance to be inanimate.

This phenomenon reappears in more recent literature as the “Uncanny Valley” experience. Mori (1970) described the sense of repulsion that can accompany interaction with humanoids whose appearance resembles, without being overly superimposed, that of a human (see also Mori, MacDorman, & Kageki, 2012). Another facet of the possible human–robot relationship worth mentioning is the one proposed by Spike Jonze’s *Her* (2013). The protagonist lives a true love story with an almost completely disincarnated artificial intelligence that manifests itself through a very sensual voice. Alongside this experience, the growing presence of anthropomorphic robots in everyday life, in educational, production, and welfare settings, raises several new issues – philosophical, ethical, political, economic, legal, and insurance⁵. While the anxiety about replacing men with robots in production situations, with the associated risk of unemployment and impoverishment, is not new, more recent discussions are about the status of robots, with respect to the new aforementioned issues (Floridi, 2017; Floridi & Sanders, 2004; see also the European Parliament Resolution of 16 February 2017).

In the case of robot-building for social purposes⁶, the extraordinary human capacity to invent and realize tools that integrate and expand the biologically-based abilities of our species (from work tools

⁵ To give just a few examples, think of the use of robots for assistance and companionship to the elderly, the educational and didactic use with children with typical and atypical development, and the execution of various activities in shopping centers, airports, and so forth.

⁶ The military is another area that makes extensive use of robotic engineering (just think of the recent massive use of drones in war). Although the psychological implications are multiple (attribution of responsibility, reliability of information, trust, etc.), we do not consider this field because there is no possibility of attributing mental states to the robot.

to sensory aids to external memory of electronic devices) has been driven in two directions. The first direction – developmental cybernetics (Itakura, 2008; Itakura, Okanda, & Moriguchi, 2008) – consists of creating a human-like system, with cognitive function (simulating psychological processes in the robot) and prosthetic functions (enhancing the function and life-style of persons). The second direction – developmental robotics – consists of the idea that robots can autonomously gain sensorimotor and mental capabilities with growing complexity, starting from intricate evolutionary principles (Cangelosi & Schlesinger, 2015). To date, developmental cybernetics aims to build robots that behave in a human-like way, while developmental robotics aims to build robots that develop in a human-like way. Based on these features, the two approaches are located at different points on a continuum that links interaction and relationship. Developmental cybernetics is closer to the relational dimension; in fact, it studies those human–robot exchanges in which the assumption of some form of subjectivity of the partners is involved. Let us think, for example, about the educational and welfare uses of intelligent machines, in which the dynamics associated with the use of prosthetic tools that improve quality of life are placed on the level of *hic et nunc* (here and now) interaction, without aiming at the construction of a relational story. Conversely, socio-relational dynamics value the level of the relationship (Gross et al., 2012; Tanaka, Cicourel, & Movellan, 2007). Developmental robotics is closer to the interactive dimension; it uses the interaction to study how a robot can develop new abilities, in a child-like fashion. For instance, consider the attempts at robotics modeling of the stages of language acquisition (Morse & Cangelosi, 2017), and the use of mutual imitation between humans and robots to promote the robot’s subsequent recognition of an interactive agent (Boucenna, Cohen, Meltzoff, Gaussier, & Chetouani, 2016).

We are interested in understanding how the attribution of mental states to robots evolves through the lifespan; therefore, we primarily analyze the studies conducted in the field of developmental cybernetics.

Why Robots Could Be Intended as Social Partners

From a psychological point of view, from the earliest moments and throughout one’s entire life, the possibility of establishing social exchanges involves the ability to recognize the other as being “like me” (Meltzoff, 2005; Meltzoff, 2007a, 2007b; Meltzoff, 2013; Meltzoff & Brooks, 2001). Infants can imitate facial movements, such as mouth opening and tongue protrusion (Meltzoff & Moore, 1977, 1983, 1989), and have visual acuity for human faces and stimuli, with characteristics similar to themselves (Johnson, Dziurawiec, Ellis, & Morton, 1991). Proto-conversations with the caregiver

root in these innate imitative mechanisms and, overall, the analysis of traits and characteristics of the relational partner contribute to building the intersubjective dimension underlying so many developmental acquisitions (Meltzoff, 2005; Meltzoff, 2007a, 2007b; Meltzoff, 2013). For this purpose, Trevarthen (1998) spoke of an innate specific human endowment that would guide us to the search for companionship, and put us in the condition of “understanding and using the intentions of other people in conversational talks of intentions, emotions, experiences, and meaning” (p. 16). According to Tronick, Als, Adamson, Wise, and Brazelton (1978), human beings experience the world in intersubjective terms. This trend is related to the tendency of children to first experience the world as if it were animated, and to make a distinction between animate and inanimate only later. This tendency is operationalized by the “still face” paradigm: the motionless face of the caregiver generates in the child a series of emotions from perplexity to anxiety, showing the infant’s expectation to interact with a human partner with an expressive, and therefore animated, face.

A fundamental question, therefore, is: what can the developmental research on human–robot interaction teach us about aspects, features, and cues that a robotic interactive partner must have to be recognized as “like-me?” This question has an epistemological basis. In fact, human–robot interaction represents a “technological gym” that specifies the social cues that must be implemented in a humanoid robot so that children of different ages recognize it and treat it as a social partner.

Below, we analyze contributions from the literature to the lifespan perspective in this regard, by organizing them around “mental states and actions” and “human-like features.” This division arises from the consideration that a representational ToM derives from the infants’ early understanding of the bodily cues of the mental states. In other words, the bodily roots of ToM remain through the lifespan, as the basis of more advanced representational mentalistic skills.

Mental States and Actions

Regarding the first element of the division that we set as the basis of robot attributions of features “like-me,” the research examines aspects of robotic actions that lead participants to believe that the actions imply mental states.

In this sense, a seminal study by Meltzoff (1995) investigated the reenactment of intended acts, performed by human beings versus robot-like devices, in a group of 18-month-old infants. An emerging sense of the person is revealed by the fact that infants did not reenact the action performed by the robot-like device, probably because they did not recognize its intentions and goals.

Itakura, Ishida, et al. (2008) studied this topic further, in children aged 24–35 months, and showed that the children were inclined to imitate goal-directed actions where the goal is not achieved; these failed actions implemented by a robot were imitated only when the robot's action was preceded by eye contact between the robot and an adult present at the scene. When the robot's eye contact with the adult was missing, the child did not mimic the robot's behavior. According to the authors, this evidence shows that it is not human-like morphology, but rather human-like behavior, through eye contact, that plays an important role in inducing children to imitate the goal-directed behavior of a nonhuman agent.

The theme of imitation of goal-directed actions relates to research on mirror neurons⁷, which seem to play an important role in understanding others' actions and, more generally, in social competence. On this basis, Moriguchi, Matsunaka, Itakura, and Hiraki (2012) initially elaborated that the actions are somehow related to perception, and that many human brain areas devoted to the execution of actions also function by observing other human actions, rather than robotic actions. The authors then built on this evidence through a research paradigm verifying whether, and how, actions taken by a human arm or a mechanical arm may somehow interfere with the child's search for an object. A human arm and a mechanical arm sought and found an object in position A. The object was then moved to position B. The child who was asked to look for the object attributed a kind of "retrospective trust" to the human arm, compared to the mechanical arm; in fact, the number of errors committed in the search for the object was higher when the human action preceded the search. The same result had already been obtained in a group of 3-year-olds (Moriguchi, Kanda, Ishiguro, & Itakura, 2010), suggesting that the presence of a mental simulation mechanism would only be activated when the children imitated human actions.

Okumura, Kanakogi, Kanda, Ishiguro, and Itakura (2013a) confirmed this in a paradigm that verified the ability to anticipate the appearance of an object, using the information from a human gaze, rather than a robotic gaze. Through the use of an eye tracker, gaze-following and object anticipation were measured in two groups of 10- and 12-month-old children. Both groups let themselves be guided by

⁷ The mirror neurons are a subset of neurons in the human brain that respond when an individual performs certain actions, and also when the same individual observes others performing the same movements. In other words, actions performed by one person can activate motor pathways in another's brain responsible for performing the same action. Mirror neurons, or mirror mechanism, provide a direct internal experience, and therefore understanding, of another person's act, intention, or emotion. Mirror neurons may also underlie the ability to imitate another's action, and thereby learn, making the mirror mechanism a bridge between individual brains for communication and connection on multiple levels (Rizzolatti, Fogassi, & Gallese 2006).

the human gaze and the robotic gaze; however, only the human gaze had an anticipation effect, and only for the 12-month-old children.

In the context of studies that analyze the importance of the perception of biological motion as the precursor of ToM (Frith & Frith, 1999), Breazeal et al. (2016) considered a group of 3- and 5-year-old children. Note that the ability to use a robotic informant with epistemic aims (name exotic, non-familiar animals for children) is strongly influenced by the nonverbal contingency of the informant (head movements, gaze shifts, arm movements, and facial movements) typical of human face-to-face interactions. From this perspective, Carter and Pelphrey (2006) explored, with functional Magnetic Resonance Imaging (fMRI), neural activations, corresponding to the perception of the movement of four different agents – human, robot, mechanical assembly, and grandfather clock – in 7- to 10-year-old children. The results showed different activations, according to the human-like nature of the perceived biological movement, that is, a motion made by a human or a robot. This brain network also included some components of the mirror neuron system. Replicating the evidence obtained on adults, these findings show that some portions of the neural circuit involved in the embodied simulation are recruited in the perception of the biological movement also enacted by a robot.

We now shift from studies that analyze indirect indicators of the attribution of human-like features to studies that explicitly analyze this attribution. Kahn et al. (2012) interviewed children aged 9, 12, and 15 years, and evaluated the attribution of social, mental, and moral features to robots previously observed in nine different interactive situations with the subject and the experimenter. The authors found an interesting developmental trend: 9- and 12-year-olds perceived the robotic partner as a more mental, social, and partially moral entity than did the 15-year-olds. Therefore, in the construction of robotic partners suitable for participants of preadolescent age, with different purposes (from play to education), it is important to analyze, in detail, what interactive features are strengthened, so that the robot is perceived as the holder of mental, social, and moral characteristics, even by teenagers. Similar results regarding the attribution of mentalistic features to robots, following the observation of goal-directed actions, were obtained using a semi-structured interview of participants aged between 5 and 16 years (Beran, Ramirez-Serrano, Kuzyk, Fior, & Nugent, 2011). The participants tended to attribute behavioral, cognitive, and affective features to robots observed in the execution of a block-stacking task, a construction game in which the robot stacked blocks of wood to form two towers. In carrying out these activities, the robot manifested autonomy through a series of behaviors, such as looking at the child's face, performing accidental actions, and so on. Reminiscent of Piagetian animism, there was also an effect of age such that younger children (under 12 years of age), more

than the older children, believed that robots possess a large number of human attributes (Piaget, 1954).

Chaminade et al. (2010) used behavioral and fMRI methods to explore emotion depiction (anger, joy, and disgust) in gestures acted by human beings and humanoid robots in a sample of young adults. Results showed higher emotion ratings for anger and disgust expressed by the human; no differences were found for joy. Neural evidence suggested less empathy from viewing the humanoid robot: in fact, the activation of the left anterior insula (perception of disgust) and the orbitofrontal cortex (perception of anger) was lower for robot stimuli than for human stimuli. Finally, the higher activation in the occipital and posterior temporal cortices with robot versus human stimuli probably arose from the additional visual processing linked to the perception of a behavior acted by the humanoid robot.

An ingenious way to look directly at the interaction between human and robot is to use economic interactive games. One of the most used interactive games is the Ultimatum Game: one player (responder) receives a monetary offer from another player (proposer), who has to divide the amount. The responder has the option of accepting or rejecting the offer. If the responder accepts the offer, the two participants split the sum of money; however, if the responder rejects the offer, both players receive nothing (Güth, Schmittberger, & Schwarze, 1982). Nishio, Ogawa, Kanakogi, Itakura, and Ishiguro (2012) had young adults play the Ultimatum Game with a robotic partner. Results showed that fairness-oriented behavior increased when “mentalizing stimuli” accompanied cues from the physical appearance of the robotic partner, such as the expression of utterances between experimental sessions (see also Castelli, Massaro, Sanfey, & Marchetti, 2010, for results in a sample of children with a human and a nonhuman partner).

Ultimately, the works presented in this section show that children and adults perceive an experience with an artificial partner as social when the artificial partner can express intentions and goals through behavioral cues that are typical of interactions among humans.

Human-Like Features

With regard to “human-like features,” the research focuses on the configuration of body features being indispensable to humanoid anthropomorphization. It seems that, very soon, human beings will be able to relate to robots according to a principle of similarity to themselves. A first question is

whether biological and psychological characteristics are attributed to robots similarly or differently from other living organisms, and other material entities. Kamewari, Kato, Kanda, Ishiguro, and Hiraki, (2005) showed that 6.5-month-old infants exhibited the ability to attribute agency to human and humanoid-robot motions, but not to a robot without a human-like appearance. A sophisticated teleological representation is assumed in interpreting actions during the early stages of an infant's life, insofar as the agents are human-like. This first result is strengthened by two studies that take into account two human features considered crucial in characterizing one's social nature – eyes and voice.

The first study by Okumura et al. (2013a) showed that the presence of eyes in a robot is crucial for 12-month-old children to have their attention directed by the movement of a robot. In fact, when a robot without eyes was set in motion, this movement was not as informative to the child. The authors interpreted this result by assuming that the presence of eyes was a crucial indicator for the attribution of a mind at this age. The second study by Okumura, Kanakogi, Kanda, Ishiguro, and Itakura (2013b) showed that, for children aged 12 months, the gaze of a robot can be effectively used to learn an object if it is accompanied by a verbalization (not a simple nonverbal sound).

Moving from the preverbal to the verbal age, results obtained by directly questioning the participants about the characteristics of the robots are consistent with the early propensity to attribute human-like characteristics to humanoids. With development, other elements, in addition to the look, become important in deciding whether a partner has human-like characteristics. Katayama, Katayama, Kitazaki, and Itakura (2010) compared humans, robots, animals, and cultural artifacts to study the possible recognition of biological and psychological features in robots by children aged 5 and 6 years, and by adults. While the adults' attributions were quite heterogeneous, both 5- and 6 year-olds attributed a variety of biological but not mentalistic features to robots. Somanader, Saylor, and Levin (2011) asked a sample of 4- and 5-year-olds about the presence of representational, biological and mechanical characteristics in a human being, and in cultural artifacts (i.e., a robot and a TV). They found that the children attributed more representational and biological features to the human being than to the cultural artifacts, and to the robot more than to the TV. They also found that such attributions were more likely to be given to the robot if they did not see that the robot was controlled by a remote. These data reverse the trend found in a previous study, by Saylor, Somanader, Levin, and Kawamura (2010), in which robots and other familiar artifacts, including a TV, were classified as the same thing in terms of biological and representational properties. The authors assumed that the difference between the results of the two studies was due to their efforts to formally anthropomorphize the robots.

Manzi et al. (2017) explored the mentalistic value of faces in anthropomorphic agents compared to human faces through a dichotomous morphing, or gradient, of progressive anthropomorphism. The authors showed that 7- and 9-year-old children ascribed more mental state (e.g., sensory, perceptive, emotive, will, imaginative, and epistemic attributes) to the human face than to a robotic face.

Fiore et al. (2013) explored which elements contributed to creating an impression of the social presence of an agent in a group of late teenagers. To this end, they analyzed the way human beings interpret social cues exhibited by robots, in terms of proxemic behavior (the distance that the robot travels within the human's space). This was investigated by placing the robot and the participant in a hallway-crossing scenario. In this scenario, the authors varied the level of proximity the robot would permit the human in establishing whether to cross paths, and if the robot waited until the participant had passed. The authors also measured the role of the gaze, performed at three levels of direction (congruent with the robot's movement, human-oriented, and variable). The results showed that the robot that waited until the participant passed was evaluated as an agent more socially present than the robot that crossed the path without waiting. Furthermore, gaze did not play a significant role as a social cue in this situation.

Krach et al. (2008) explored human-robot interaction with a group of young adults, using the interactive game the Prisoner's Dilemma and fMRI. In the game, two players must decide whether to cooperate with each other or defect. They may gain a defined sum of points, depending on their own, and their counterpart's decision. A unilateral win is maximized by defection, if the counterpart cooperates, but both players are punished if they defect. Relying on mutual cooperation involves the risk of being deceived. In this study, the game included four different partners, each with an increasing level of anthropomorphization (computer, functional robot, anthropomorphic robot, human). Anthropomorphization was operationalized by following Epley, Waytz, and Cacioppo (2007), who included cues relating explicitly to physical aspects and mental states (elicited agent knowledge, effectiveness motivation). Participants were asked to evaluate the game partner for fun, intelligence, competitiveness, and sympathy. Results showed a linearly increasing attribution of fun and intelligence as the partner appeared more human-like. Interestingly, the anthropomorphic robot and the human were perceived as equally competitive, and more competitive than the computer and the functional robot. Moreover, the authors of the study pointed out that higher levels of human-likeness

were positively correlated with a greater activation of the ToM network, that is, the brain areas⁸ that the literature has shown to be specifically recruited when people interact with a social partner.

Takahashi et al. (2014) focused on the neural bases of human–robot interaction when participants were involved in an economic interactive game (Matching Pennies) with several partners: human, human-like android, mechanical robot, interactive robot, and a computer. The game was played between two players: a participant and an opponent. They had to press a button corresponding to the left or the right side of their bodies. The win situation was reached only when the same side was selected by both participant and opponent. The partners were evaluated concerning two dimensions: mind-holderness (having mental functions) and mind-readerness (being intelligent). As predicted by game theory, the more robotic partners were thought to be mind-readers the more the human opponents changed their play strategies, increasing the level of entropy of exchanges through random choices. fMRI data showed the involvement of different subsets of the social brain, according to the attribution of mind-holderness (dorsal aspect of the temporoparietal junction, medial prefrontal and posterior paracingulate cortices) or mind-readerness (ventral temporoparietal junction and the temporal pole).

Broadbent et al. (2013) studied how the facial characteristics of a robot may influence recognition of the robot's qualities, such as mind, personality, and eeriness, using a sample of young adults involved in a simulated healthcare environment. They employed three robots, respectively showing lack of face, silver face, and human face. The results showed a clear preference for the robot with the human-like face, which was rated as having the most mind and personality, and the lowest eeriness. This specific result relates to the uncanny valley, demonstrating just how subtle the boundary is between a pleasant likeness to the human and a disquieting one.

Similarly, Martini, Gonzalez, and Wiese (2016) studied whether specific degrees of humanness were needed to attribute different typologies of internal states to non–human agents. Interestingly, they found that the threshold “having a mind” must be reached, before being able to ascribe any other kind of internal state. The more the non–human face resembled that of a human, the more this threshold was overcome.

⁸ The ToM network includes the medial prefrontal cortex (mPFC), parts of precuneus and posterior cingulate cortex, the temporoparietal junction (TPJ), the posterior superior temporal sulcus (pSTS) bilaterally; some studies also include the bilateral anterior temporal lobes and areas in the amygdala (Schurz, Radua, Aichhorn, Richlan, & Perner, 2014).

Considering the studies reviewed so far, it is useful to emphasize the great importance given to the face and eyes when considering the physical features capable of representing an agent in anthropomorphic terms. This evidence confirms the great amount of data from ethology, evolutionary psychology, and even studies of aesthetic perception, in support of the great power of the human face in creating a sense of social interaction (Brooks & Meltzoff, 2005; Call & Carpenter, 2001; Emery, 2000; Itakura, Agnetta, Hare, & Tomasello, 1999; Massaro et al., 2012; Moore & Corkum, 1998; Morales, Mundy, & Rojas, 1998; Savazzi et al., 2014; Slaughter & McConnell, 2003; Tomasello, Hare, & Fogleman, 2001; Tomasello, Hare, Lehmann, & Call, 2007).

In conclusion, the information presented in this section shows that interaction with artificial agents is more preferred, and perceived as human-like, when the artificial agent presents aesthetic features that reproduce those of humans, with particular relevance to face and gaze.

Human Beings and Robots: Preliminary Steps Toward Intersubjectivity

The studies reviewed identify features pertaining to mentalizing cues and physical appearance as important bases of the “like me” experience with humanoids. Recent research also suggests that Meltzoff’s (2007a, 2013) “like me” framework can be extended to encompass other dimensions on which human perceivers make “like me” attributions. These dimensions pertain to the nature of the interaction, and other, deeper factors that are just beginning to be explored. A minority of studies delineates an emerging trend of research in this field. These are investigations across the lifespan that consider the role of attitudes and expectations of the human partner, involved in different interactive contexts, in determining preferences and acceptance of the humanoid partner.

Meltzoff, Brooks, Shon, and Rao (2010) explored the hypothesis that 18-month-old infants may use information gained from observing human–robot interactions as evidence about whether the robot is a perceiver. The results showed that the infants attributed mind to the robot, based on the socially-communicative interactions the robot engaged in. This study also demonstrated that the nature of the interaction, and not only the robot’s behavior, mattered.

Tanaka et al. (2007) studied the relationship between 18- to 24-month-old children and a robot, through a long-life immersion technique (45 sessions of approximately 50 min each, spanning 5 months, in the children’s play area). One of the great problems of human–robot interaction is the

duration; long-term study is difficult. Children tire, even though they initially have great interest. The experiment aimed to verify relationship tenure for a time longer than the 10-hr barrier, comparing the employment of a robot able to manifest an entire repertoire of behavior (walking, head- moving, dancing, sitting down, standing up, lying down, hand gesturing, and giggling) to a robot able to manifest only predictable behavior. The relationship improved when the robot was programmed to manifest the entire repertoire of behaviors (27 sessions), worsened when the robot exhibited predictable behavior (15 sessions), and improved again when the robot began to manifest its entire repertoire. The development of socialization strategies correlated positively with frequency of contact with the robot.

Contextualizing the relationship in an educational setting, Movellan, Eckhardt, Virnes, and Rodriguez (2009) showed that interaction between 18- to 24-month-old toddlers and a low-cost sociable robot in an Early Childhood Education Center can significantly enhance word-learning. This evidence is promising, in view of the use of these humanoids with educational and didactic purposes, based on the intersubjective sharing of significant goal-oriented activities. Similarly, Tanaka and Matsuzoe (2012) employed a care-receiving robot to support foreign language learning in 3- to 6-year-old children. These authors showed that the care-receiving role, and not only the teaching role, could be successful in a teaching context. In fact, the condition in which a robot gave wrong answers improved the children's English verb acquisition more than the condition without the robot. Taking into account the relationship between peers, Westlund and Breazeal (2015) introduced a robot, programmed to behave as a peer, to a group of 4- to 6-year-old preschoolers in a storytelling context. The robot was able to lower its linguistic competence in order to match the child's current ability. The evidence showed that a storytelling robot capable of adapting to its partner in terms of language competence, was effective in supporting the oral language development of the child. Robots would seem to have educational skills not only as storytellers, but also as sympathetic listeners. Conti, Di Nuovo, Cirasa, and Di Nuovo (2017) compared a humanoid robot story- teller to a human teacher storyteller in a group of preschoolers. The authors evaluated how the storytellers' social behaviors influenced the children's memorization of the story. Results showed a similar performance in memorizing the details of the story when the storyteller was a robot or a human with an expressive behavior (expression of appropriate emotions with the body and with the voice). The expressive robot was even more efficient than a static inexpressive human storyteller (fixed gaze, motionless body, monotonous voice).

Park, Gelsomini, Lee, and Breazeal (2017) investigated the adaptive capacities of robots as listeners in: giving feedback that informed children about the presence of an active listener, given the abilities

of gazing, leaning forward, nodding, smiling, eye-widening to emulate eyebrow movement, and short utterances. The authors tested two robotic relational styles: a contingent style of the robot capable of reflecting the nonverbal behavior of the child; and a non- contingent style of the robot that emitted random, nonverbal behaviors. Based on children's gaze patterns, the results showed that the contingent robot most relationally engaged the children.

Human-robot interaction research ranges from ToM pre- cursors to social skills of the elderly. Iwamura, Shiomi, Kanda, Ishiguro, and Hagita (2011) focused on the use of a robot by a group of elderly shoppers in a supermarket. They found that an assistive robot that also engaged in non-shopping-oriented conversation was preferred to a robot capable only of functionally oriented conversation. Sabelli, Kanda, and Hagita (2011) introduced a conversational robot into an elderly care setting for 3.5 months, and analyzed its main interactive exchanges with the elderly and the staff using an ethnographic methodology. Three of the six identified trends (basic social interaction, telling robot information, and emotional elements) pertained to the socio-relational/mentalistic dimension.

Again working on the relationship between robots and the elderly in a retirement village, Stafford, MacDonald, Jayawardena, Wegner, and Broadbent (2014) analyzed the attitudes to use mind agency, and attribute mind agency to the robots. The evidence showed that older people preferred to interact with robots to which they attributed less mind agency. These findings were rather counterintuitive because they question the presumed importance of mental state attribution in effective social exchanges. It is likely that the elderly were frightened by the robots because of an overestimation of their cognitive capacities which decreased with actual use.

Gross et al. (2012) presented preliminary results of the implementation of a companion robot for elderly people with Mild Cognitive Impairment (MCI). The evidence emphasized how satisfied the elderly were when interacting with a robot that could support them in executing daily tasks. This work opens up the use of robots in the context of caring for people with neurodegenerative diseases. It also places the importance of assessing the effectiveness of such long-term interventions (weeks or months), and fostering relationships with a truly autonomous robotic partner (hypothetically endowed with a wide behavioral repertoire), as the first point in the agenda for future research.

The studies presented in this section, many of which were conducted in extra-experimental settings, show the importance of a detailed analysis of the contexts in which human-robot interactions take place to fully understand the intersubjective nature of the human-robot interaction.

Conclusions

This review aimed to analyze human–robot interaction from two vantage points: (1) the human attribution of mental states to the robot and (2) the human recognition of the robot as “like-me.” The experience that the robot is “like me” is based mainly on the physical appearance of the robot, and its behavior; however, another aspect emerges that pertains neither to humans, nor to humanoids, but which is a characteristic of their encounters. This aspect is the intersubjective level of the exchange. This dimension contributes some design features of the humanoids, which cannot be conceived as simple artificial instruments for the extension of human abilities. The more a humanoid partner/companion can go beyond a functionally and mechanistically perfect performance, the more it seems “like me.” In other words, an exchange is especially meaningful if it happens with a partner with a human-like capacity to be engaged in somewhat unpredictable, intersubjective exchanges. From our point of view, this unpredictability depends on the subjective nature of the human knowledge and representations of the world. During social exchanges, partners share mental states and representations of the world. The construction of intersubjectivity is based on mutual recognition of the subjective nature of such states and of such representations.

In light of these considerations, this somewhat unpredictable meeting of minds can take different directions, and can be conceptualized in different ways. For example, it can be seen as the optimal level of frustration (Kohut, 1977). All human exchanges with significant partners are characterized by an alternation of gratification and frustration. However, this fact does not compromise human exchanges, provided that the frustration is remediable. A second possible way to conceive the somewhat unpredictable meeting of minds is that of the imperfect contingency (Bigelow, 1998). There is no optimum level of contingent responsiveness in early relationships with caregivers; rather each of us experiences an imperfect contingent responsiveness through parental interactions (i.e., the partners occasionally find the level of relational contingency adequate to the ongoing interaction). This responsiveness influences future exchanges with nonfamily partners. A further possible conceptualization is marked mirroring (Gergely, 2007; Gergely & Watson, 1996), which happens during a child’s affect-regulative interactions. The adult offers the child a reflection of an experience of the world, and of the emotional states of the child itself, and at the same time, the adult informs the child that this reflection is not expressing her/his own feelings. A final interesting conceptualization is offered by the work of Tronick and Beeghly (2011). They stated that interactions consist of a flow of matching and mismatching of meaning, and the reparation of mismatches to

matches. Intersubjective attunement would emerge from the experience of reparation, which in turn would create the experience of connection and shared states.

In the Vygotskian theoretical framework, the unpredictability and possibility of relational mismatching takes on a particularly interesting form in the Zone of Proximal Development (“the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers”: Vygotsky, 1978, p. 86). In fact, cognitive discrepancy, if salient in intersubjective exchange, can become a powerful engine of learning and development. From this point of view, one of the most intriguing challenges for future humanoids is the possibility that they provide the partner stimuli, inputs, and interpretations that moderately surpass the present partner’s abilities, constructing bridges toward more advanced forms of understanding and capabilities. Looking at the future, our reflections allow us to glimpse the theme of technological singularity. It consists of the invention of a super-artificial intelligence that would result in a sudden “evolutionary” change, able in principle to overcome human intelligence (Eden, Moor, Soraker, & Steinhart, 2012). All this is possible if we consider the intersubjective nature of developmental and educational interactions in which both partners contribute to change and learning. ToM – which has as its core concept the “meeting of minds” – seems to us a theoretical perspective that is particularly well suited to understanding intersubjective interactions.

The end of the Blade Runner movie sums up this possible scenario of potentially open, flexible, and plastic exchanges between human beings and humanoids metaphorically. In fact, it shows as plausible a future of love between Rick Deckard, the replicant hunter, and Rachael, the first replicant without an a priori expiration date. Ultimately, the beauty of uncertainty, more than any other quality, made Rachel special, and therefore very humanlike.

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Chapter 3

It does not matter who you are: fairness in pre-schoolers interacting with human and robotic partners

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Abstract

The relationship between humans and robots is increasingly becoming focus of interest in many fields of research. The studies addressing the various dynamics underpinning the human-robot interaction have, up to date, mainly investigated this relationship analysing adults' behaviour when interacting with different forms of robotic agents. With this study, we present results assessing the human-robot interaction, in which children are the interactive partners. The child-robot interaction was studied – for the first time – observing thirty-one children aged 5 to 6 years playing the Ultimatum Game (UG) with either another child or with a humanoid robot. First, we found that children did recognize the robot as a distinct entity, as assessed through the children's attribution of mentalistic, emotional and physical properties to the interactive agents. Nevertheless, consistently with literature on adults, the results on the UG revealed a very similar behavioural approach when the child played with the other child and with the robot. We finally analysed the children's justifications for their behaviour at the ultimatum game and found that very young children tend to consider “fair” only the divisions that are exactly equal (5-5 divisions) and to justify them either in mere mathematical terms (outcome) or in terms of equity. These results are discussed in terms of Theory of Mind, as well as in light of developmental theories underpinning children's behaviour at the ultimatum game.

Introduction

The introduction of social robots - defined as “autonomous or semi-autonomous robots that interact and communicate with humans by following the behavioural norms expected by the people with whom the robot is intended to interact” (Bartneck & Forlizzi, 2004) - is deeply affecting our society in different fields of the human life. The robots used in industrial processes, for instance, are modifying the job roles and rules [Argote et al., 1983; Kang et al., 2008; Lin et al., 2011; see also European Union, 2017). Prospectively, the introduction of robots in other contexts, such as households, education, care assistance, manufacturing, etc., will also presumably have an increasingly significant effect on human activities and roles. In this perspective, several researches are working towards the implementation of robots in the attempt to make them increasingly similar to the human being [Asada et al., 2001; Di Salvo et al., 2002; Hoffman & Ju, 2014; Robins et al., 2005). The humanoid robots – the ultimate realization of such attempts – are characterized by human-like physical features, behaviours and cognitive processes. The mode and quality of the interaction between humanoid robots and humans will thus possibly change because of the robots’ similarities with humans that call to mind the idea of “they are more like-me” (Meltzoff & Brooks, 2001). The underlying rationale for the implementation of this new generation of robots is to create social partners in everyday life (Kanda et al., 2012), although the other side of the coin that researchers have to deal with in the robot human-likeness is the Uncanny Valley effect (Mori, 1970; Mori et al., 2012). This means that the more a robot has human features and behaves like a human, the more its “eeriness” will induce negative feelings in the interlocutor (Burleigh et al., 2013; Fink, 2012; Gray & Wegner, 2012; MacDorman, 2006; Mori et al., 2012; Sandoval et al., 2016; Scassellati, 2005).

Besides the contexts above mentioned, the implementation of robots is also aimed at aiding different scientific fields, such as anthropology, psychology, ethics, sociology, engineering, informatics, mathematics, physics, etc. (Saygin, 2011; Scassellati, 2003), for example, suggests that the use of the human-like robot could be useful for the study of typical and atypical human social development, allowing to test cognitive, behavioural and development models. In this sense, and from a multidisciplinary perspective, knowledge from developmental psychology is crucial to the implementation of these models since it contributes to the understanding and identification of the precursors underlying human sociality and their ontogenesis. In this respect, Itakura (2008) proposed a new research domain that connects developmental psychology and the study of human-robot interaction. This new investigation field was named Developmental Cybernetics (DC; 2008): it explores the child-robot interactions through the construction of theoretical frameworks that

characterize the design of the robot with the aim to facilitate these interactions (Itakura, 2008; Itakura et al., 2008b). Several studies used the Advanced Telecommunications Research Institute International (ATR) humanoid robot Robovie that can generate human-like behaviours (Ishiguro et al., 2001; Ishiguro et al., 2003). This humanoid robot has been used to test interactions with children in different contexts (Kahn et al., 2012; Kanda et al., 2004). Kanda and colleagues (2012), for example, introduced Robovie to 6th-graders to teach them how to use a Lego Mindstorms. This research showed how Robovie's human-like behaviours contribute to build a human-robot relationship, which goes beyond the more simple human-robot interaction.

Developmental Cybernetics hypothesizes that children can understand the non-human agent through mentalization, and that the construction of social intelligent agents could shed some light on the development processes and mechanisms of the child's mind (2008). In this respect, within the DC approach, Itakura (2008) proposes three abilities, which are critical for making a robot a social agent: Theory of Communication (Itakura, 2012; Itakura, 2013; Nitsch & Glassen, 2015), Theory of Body (Minato et al., 2006; Morita et al., 2012) and Theory of Mind (Itakura, 2008; Itakura et al., 2008a,b). With respect to the Theory of Mind (ToM), it has been proposed that ToM represents an important psychological ability for the study of the human-robot interaction [for a review, see Marchetti et al., 2018). In fact, ToM is essential for the development of social competences, in that it represents the ability to understand one's own and other people's mental states (intentions, emotions, desires, beliefs), and to predict and interpret one's own and others' behaviours on the basis of such meta-representations (Park et al., 2017; Piaget, 1929; White et al., 2009). Several ToM studies show that there are many different behaviours and cognitive processes that are linked to this human skill: imitation, joint attention, pointing, and gaze-following, just to mention a few. (Bandura, 1991; Brooks & Meltzoff, 2002; Camaioni et al., 2004; Charman et al., 2000; Meltzoff, & Gopnik, 1993; Meltzoff & Brooks, 2001).

The researches in the field of child-robot interaction have been increasing in the last decades. Generally, these researches explore what features should be implemented in the robot in order to establish a better interaction between humans and robots. Several studies have been conducted to analyse the effect of different ToM precursors on the interaction between humans and different non-human agents, including humanoid robots [Boucenna et al., 2014; Boucenna et al., 2016; Breazel et al., 2016; Chaminade et al., 2010; Fogassi et al., 2005; Itakura et al., 2008a; Kanngiesser et al., 2015; Meltzoff et al., 2010; Moriguchi et al., 2012; Mutlu et al., 2012; Okanda et al., 2013; Okumura et al., 2013; Rizzolatti et al., 2001; Sloane et al., 2012; Wellman et al., 2001). Generally, the results of

these studies have shown that children tend to attribute mental states to a humanoid robot (Beran et al., 2007; Breazeal et al., 2016; Kahn et al., 2004; Manzi et al., 2017; Moriguchi et al., 2012; Nishio et al., 2012; Park et al., 2017). Already Piaget (1929) suggested that children younger than six-years-old tend to attribute consciousness to objects - namely the capability to feel and perceive - and that children consider “alive” also the things that are inanimate for the adult, *if* these objects serve a function or are used to reach a goal: a phenomenon called animism. In their study, Katayama and colleagues (Katayama et al., 2010) showed that when five and six-years-old children had to attribute biological and psychological proprieties to a human or a robot, children generally discriminated between the two agents, though ascribing some human traits also to the robot. Thus, in line with Torta and colleagues (Torta et al., 2013) idea, when young children interact with artefacts, these acquire the status of relational artefacts: children believe the artefacts – like the robots – to be “alive” and to have an “intention”.

Interaction skills in social contexts are typically studied through use of interactive games deriving from the Game Theory (Camerer, 2013; Villani et al., 2013). One of such games is the Ultimatum Game (Güth & Kocher, 2014; Güth et al., 1982). Used with children, the Ultimatum Game (UG) serves to delineate development in terms of equity and negotiation ability in decision-making, thus focusing on sensitivity to fairness and aversion to inequality (Fehr & Schmidt, 1999). The UG involves interacting with at least another agent, and it is related to the development of ToM in that it activates the ability of mental comprehension, detection and anticipation of the other’s behaviour (Catelli et al., 2014a,b; Castelli et al., 2017; Hoffman & Ju, 2014; Lombardi et al., 2017; Marchetti et al., 2011; Marchetti et al., 2008; Massaro et al., 2017; Srinivasan et al., 2013; Turkle, 2004). In the UG, the subject can play as either the proposer or the receiver. In the *proposer* situation, the subject decides how to allocate resources; in the *receiver* situation, the subject decides whether to accept or refuse a proposed division of goods. The general rule underlying the UG is that the proposer makes an offer, proposing a certain division of goods between him or her and the other player. If the receiver refuses the offer, neither players get anything, whereas if the offer is accepted, both players obtain the proposed division. Using the UG, it is then possible to study interactive behaviour in reciprocal situations from a developmental perspective, comparing behaviour at different ages. Starting from infancy, some studies suggest that infants are responsive to an unequal resource distribution already at 19-month-olds (e.g., Seyama & Nagayama, 2007). Fehr and colleagues (2008) showed that sensitivity to fairness increases from 3 to 8 years of age, and that selfish behaviour decreases from 3-4 years to 5-6 years, although most of 5-6 year olds still tend to not share (78% of the sample).

Additionally, school age children (>7 years) generally behave more fairly when distributing resources and share more than younger children (Fehr et al., 2008;House et al., 2013).

Only few studies have employed the UG paradigm with robots, and – even so – uniquely in interaction with adults. There is in fact not research specifically addressing the relation between robot and children in a UG game. Research on adults generally shows that participants are more likely to behave in a similar fashion when playing the UG with another human or a robotic agent, and this similarity increases the more the robotic agent presents human-like features. Terada and Takeuchi (2017), for example, reported that rejection scores in the ultimatum game were higher in the case of a computer opponent than in the case of a human or robotic opponent, suggesting that people might treat a robot as a reciprocal partner as when playing with another human. Nishio and colleagues (2012) also tested university students while playing the UG with four different artificial agents, which differed in the degree of similarity with humans. In their study, there were four conditions: computer terminal (Computer condition), humanoid robot (Humanoid condition), android robot (Android condition) and human (Human condition). They included a mentalizing stimulus for each agent, which consisted of four shorts interactional sentences pronounced by each agent when meeting the subject, e.g., “how are things going?”. Furthermore, the authors administered a post-experimental questionnaire in order to test how participants perceived the agents (i.e., human likeness, or machine likeness). The authors examined the number of rejections of the agent’s proposals and the number of the agents’ fair and unfair proposals, both measures used as indicators of recognition of the agents as social entities. The results showed that, when the agent looked like a human, the fairness of the proposals and the refusal rate were similar to when interacting with a human, and particularly, when introducing the artificial agent after the interactional sentences. Additionally, Nitsch and Glassen (2015) analysed a group of young adults, who played the UG with a human agent and with a humanoid robot behaving so as to be perceived animated or apathetic. The results showed that the participants that played in the animated robot condition perceived the interactions more positively and human-like than in the apathetic condition. Robins and colleagues (Robins et al., 2005) also studied reciprocity in the human-robot interaction in a sample of young adults through the UG and the Prisoner Dilemma. The results showed that the participants were equally reciprocal with the human and the robot, despite the fact that the robots collaborated more with humans in the Prisoner Dilemma task, indicating that the human-human interactions are nevertheless privileged with respect to the human-robot interactions. Finally, Takagishi and colleagues (2010) examined the effect of different robots’ facial expressions in the UG, and showed that emotional expressions had an effect on the offers made by the participant to the robot compared to offers made to a computer displaying a simple line drawings face.

Altogether, the results from the studies here described suggest - in adult subjects - a proclivity to interact with robotic agents in a very similar fashion as when interacting with other humans.

As far as children's behaviour is concerned, there are no studies so far addressing children's decision making during an interactive and reciprocal social situation with a robot. In the present study, we made an attempt to fill this developmental gap exploring interactive behaviour during the UG when a child played with either another child (human agent) or with a robot (humanoid robot). Our sample children were aged five-to-six years. At this age, children show to have an acquired ToM capability of – at least - first order (Wardle et al., 2002). First order ToM entails a recursive thinking, which implies the meta-representation or the representation of a mental representation, of a low level of complexity, of the kind of: “I think that you think...”. In this respect, we hypothesized that children aged 5-6 years were able to discriminate between *agency* (human agent and humanoid robot) on the basis of mental states attribution. However, we were not able to advance any predictions in terms of differences in children's decision-making strategies when playing with a human and a robot, since no such literature exists specifically referred to the UG.

In this study, the children played both as proposers and as receivers. Additionally, children's performance on the UG task as a function of *agency* was evaluated against several socio-demographic, as well as, cognitive factors. Finally, an analysis of the children's justifications for their behaviour, both when playing as proposers and receivers, was carried out, outlining – for the first time – some response patterns that characterize the rationale underlying these children's game strategy.

Method

Participant

Thirty-three (33) Italian kindergarten children participated in the experiment. Two children were excluded from the study: one failed the First-Order ToM task and the other one failed the Inhibition task (see below). Data analysis was therefore carried out on 31 children (males=18, females=13; mean age = 70.8 months, SD=2.99). The children attended three different schools of Milan and Turin areas. The children's parents received a written explanation of the procedure of the study, the measurement items, and the materials used and gave written consent. Children were neither referred to social services nor reported by teachers for leaning and/or socio-relational difficulties. The study was

approved by the Local Ethic Committee (Università Cattolica del Sacro Cuore, Milan).

General Procedure and measures

The children were tested individually in a quiet room in the kindergartens. Administrations were carried out by a single researcher both in the morning and afternoon during normal activity. The children were assessed in two experimental sessions in different days within two weeks timeframe. The administration of the tasks in two independent sessions was done not to overly tire the children with an excessively long procedure as well as not to significantly disrupt the child's normal school activity.

In the first session, the children were administered the following tests: the First-Order False-Belief task, and two First-Order False-Belief videos, assessing first-order Theory of Mind; two Strange Stories, assessing advanced Theory of Mind; and the Attribution of Mental States scale. In the second session, the children were administered the following tests: the Family Affluence Scale, assessing the socioeconomic status; two executive functions tests, assessing the ability to inhibit behaviour and working memory; further two First-Order False-Belief videos; further two Strange Stories; and the Ultimatum Game, assessing fairness.

The tests were so distributed within sessions to balance the total time required to complete the whole battery, which was of approximately 45-50 minutes. In fact, each session lasted about 25 minutes. Within each session, the administration of the tests was randomized across children.

Socioeconomic status

To assess the children's socio-economic status, we used the Italian translation of the Family Affluence Scale (FAS; Boyce et al., 2006). This test is composed of four items measuring family wealth, and more specifically: 1) family car ownership (score range = 0–2); 2) own bedroom (range = 0–1); number of computers at home (range = 0–3); how many times they went on holiday during the past year (range = 0–3). The FAS total score was obtained adding up the four-item scores (total range = 0-9).

Executive functions (Inhibition and Working Memory)

We tested the children's executive functions using the Inhibition "A Developmental NEuroPSYchological Assessment" subtest (NEPSY II; Korkman et al., 2007), testing the ability to inhibit automatic responses in favour of novel responses and the ability to switch between response types. The child looks at a series of black and white shapes or arrows and names either the shape or direction or an alternate response, depending on the colour of the shape or arrow. In the present study, we used the combined scores of the Inhibition NEPSY-II subtest, which associates accuracy and speed of response.

Furthermore, we used the Backward Digit Span, testing working memory. Concerning the Backward Digit Span, the experimenter presented orally number sequences and the child was required to repeat them in reverse order. The test started with three sequences of two digits, gradually introducing triples of sequences of increasing length, to a maximum possible length of eight digits. The test stopped when the child failed all three sequences at the same length. The score was calculated as follows: children received 1 when they reversed at least two out of three sequences; if successful, the child passed to the next longer series, scoring 0.33 reserving at least one out of three sequences. The decimal scores were then summed to obtain the main score (e.g. $1+0.33 = 1.33$) until the children reached 1 (e.g. $1+0.33+0.33+0.33 = 2$), if necessary.

First-order false belief task

To assess first-order ToM, we used the story of the classical *Unexpected Transfer* task (Wimmer & Perner, 1983). The experimenter told the story using: two dolls (one male and one female), one ball, one box and one basket. The story is about two siblings playing with a ball in a room. One of the children puts the ball in a box and leaves the room. Meanwhile, the other child takes the ball out of the box, puts it in the basket and goes away. Finally, the first character comes back in the room and wants to play with the ball. At the end of the story the experimenter asks the child the following questions: "What is the first place where he will look for a teddy bear?" – referring to the first character (First-Order False Belief question); "Where did the child put the ball before going upstairs?" (control memory question); "Where is the ball really?" (Reality control question).

The answers to the two control questions (memory and reality) were used to filter the children's performance: children who did not pass them scored 0 and their performance on the First-Order False Belief question was not evaluated. If the children passed the control questions, the test question about the false belief scored 1 if correct and 0 if incorrect.

First-order false belief task: Video Stimuli

To assess children on the First-Order False Belief, we introduced – besides the commonly used task as described above – a new instrument, namely eight videos representing the classical story, this time introducing also the Robovie as a new character. More specifically, we used a story similar to the classical *Unexpected Transfer* task (Wimmer & Perner, 1983) as the script of the videos. The videos started presenting two characters (two children, two robots, or a child and a robot) in a room with two different boxes of a different colour (blue and pink) placed in front of them. Subsequently, one of the characters put a teddy bear under one box (the same for all videos) and then left the room. When the other character was alone in the room, he or she moved the teddy bear under the other box and left the room. Finally, the first character returned into the room to take the teddy bear. A voiceover narration described the story in each video.

The videos were recorded with five different actors: two children (C1 and C2) and three Robovies of different colours (White Robovie, WR; Green Robovie, GR; and Red Robovie, RR). Moreover, the five actors could play two different roles: the character who made the transfer (MtT) and the character who underwent the transfer (UtT). We used the WR for the human-robot videos and the other two Robovies (GR and RR) for the robot-robot videos. Thus, we videotaped eight different videos crossing the two children, the three Robovies, and the two roles. We created two different protocols, which were randomly assigned to the children. The first protocol was composed of four videos: 1) C1 playing the MtT role with C2; 2) C1 playing the MtT role with WR; 3) WR playing the MtT with C1; 4) GR playing the MtT with RR. The second protocol was composed of the following four videos: 1) C2 playing the MtT role with C1; 2) C2 playing the MtT role with WR; 3) WR playing the MtT with C2; 4) RR playing the MtT with GR. Within each protocol, the videos were presented randomly. We used the same scoring criteria as that used for the First-Order False Belief task (see above). The videos can be found in Electronic Supplementary Material.

At the end of the story, the experimenter asked to the child the following questions: “What is the first place where she will look for the teddy bear?” (First-Order False Belief question); two control questions (Memory and Reality as described above).

Strange Stories

We assessed the children's advanced ToM using the Strange Stories task (Happé, 1994; Westlund et al., 2017), whose Italian translation had been already used in other studies (Cattaneo et al., 2007; Lillard, 1994). This task evaluates the ability to make inferences about mental states by interpreting non-literal statements. We selected a subgroup of four mentalistic stories involving double bluffs, misunderstandings, white lies, and persuasion. After reading the stories, we asked the children to explain a character's behaviour without a time limit. The experimenter transcribed *ad verbatim* the child's answers. Scoring was based on the general guidelines (Westlund et al., 2017): 0 for incorrect answers, 1 for partially correct answers, and 2 for full and explicit answers. Two raters independently coded 30% of the responses. The inter-rater agreement was substantial (Cronbach's Alpha = .96). Disagreements were resolved through discussion between the raters. Total scores ranged from 0 to 8. The analysis of the children's performance on the strange stories showed a quite poor general performance. In fact, the children scored very low, ranging from 0 to 3 out of a total possible score of 8.

Attribution of States

The Attribution of States is a measure of states attribution that the child has to make looking at pictures depicting a character. The Attribution of States (AoF) is an *ad-hoc* questionnaire that was drawn from the questionnaire described in Martini and colleagues (Martini et al., 2016). This test was aimed at assessing what features the subject (the child) ascribed to the interactive agent (another child or the robot) in mental, emotional and physical terms. In this study, the experimenter first showed to the child two pictures depicting a child and a robot and then asked the child - as a control question - what was depicted in the picture (Reality question): if the child correctly recognized the child and the robot, the test went on; if the child responded incorrectly, the experimenter corrected the child making sure that he or she was fully aware of the agent's identity and then proceeded with the test. No children failed in the Reality question; that is, all of the children correctly recognized the child and the robot at first instance.

The presentation order of the two face pictures was randomized across children. After presenting the picture and asking the Reality question, the experimenter asked the child 25 questions referred to the agent's mental states. The child had to respond "Yes" or "No" to each question. The 25 questions were grouped in five different categories of mental states: Epistemic, Emotional, Desires and Intentions, Imaginative, and Perceptive. The total score was the sum of the "Yes" answers (score range = 0-25); the five partial scores were the sum of the "Yes" answer to each category (score range

= 0-5).

Ultimatum Game

A standard version of the Ultimatum Game (UG; Güth et al., 1982) was used to evaluate fairness. During the game, the child (playing as proponent) could decide how to distribute 10 stickers between him or her and a passive player, represented by a graphic representation of either a child – human agent (e.g., Castelli et al., 2010) or a robot. The graphic representation of the other child corresponded to a male figure when the child was a boy, whereas it represented a female when the child was a girl. The stickers depicted known animals by the children (e.g., dogs, cats, tigers, lions, birds, fishes, etc.). The minimum amount of stickers that could be offered during the game was 1, and the maximum amount was 9. After playing the UG, the child was actually given a final amount of stickers

During the UG, the children played one round as proposer and five rounds as responder, for a total of six rounds. Playing as proposer, the child could decide how to divide the stickers with the other child or the robot (graphic representation) and, playing as responder, the child could decide whether to accept or refuse the proposed division. In case of acceptance, both players received the respective proposed amounts; in case of refusal, neither player gained anything.

When playing as responder, each round (5 in total) corresponded to a specific type of proposal, ranging from a division of 5-5 (fair) to a division of 1-9 (highly unfair). The rounds were randomized across children. For each round, the child could accept or refuse the offered amount, receiving a score 1 in case of acceptance and 0 when refusing the offer. The total amount accepted was also calculated (range = 0-15) when the child played as receiver, which corresponded to the total gain for each child. Similarly, when playing as proposer, the total amount proposed was also calculated for each child (range= 0-9).

UG procedure

Before starting the game, the experimenter explained the game rules presenting four different examples in a graphic format: 1) an adult playing as proposer with a child, who accepted the offer; 2) an adult playing as proposer with a child, who refused the offer; 3) a robot playing as proposer with a child, who accepted the offer; 4) a robot playing as proposer with a child, who refused the offer.

During the game, the researcher played “the other child’s/robot’s” role, proposing, accepting, or refusing offers. The children’s performance at the Ultimatum Game was evaluated in a single session lasting approximately 10 minutes in total.

At the end of the game, the children were asked the reasons that they placed a certain offer (proposer) or accepted/refused a certain proposal (receiver). The children’s answers were classified according to three criteria: 1) outcome – the justification refers uniquely to the *amount offered or received* without commenting on or referring to the other player in mental terms (e.g., “because I like that he does not have anything and I have them all”; “because I wanted to win”); 2) equity – the justification includes terms that refer explicitly to the *construct* of equity, independently of whether the amount offered or received was equal or unequal (e.g., “because in this way we are even”; “because it was nicer to give him three and I like to share them”); 3) mentalistic – the justification includes terms that *refer to the other player in mental terms* (e.g., “because he would like me to receive more”; “he believed that I would win”)⁹.

Results and Discussion

All of the continuous variables were normally distributed with skewness between -1 and 1.

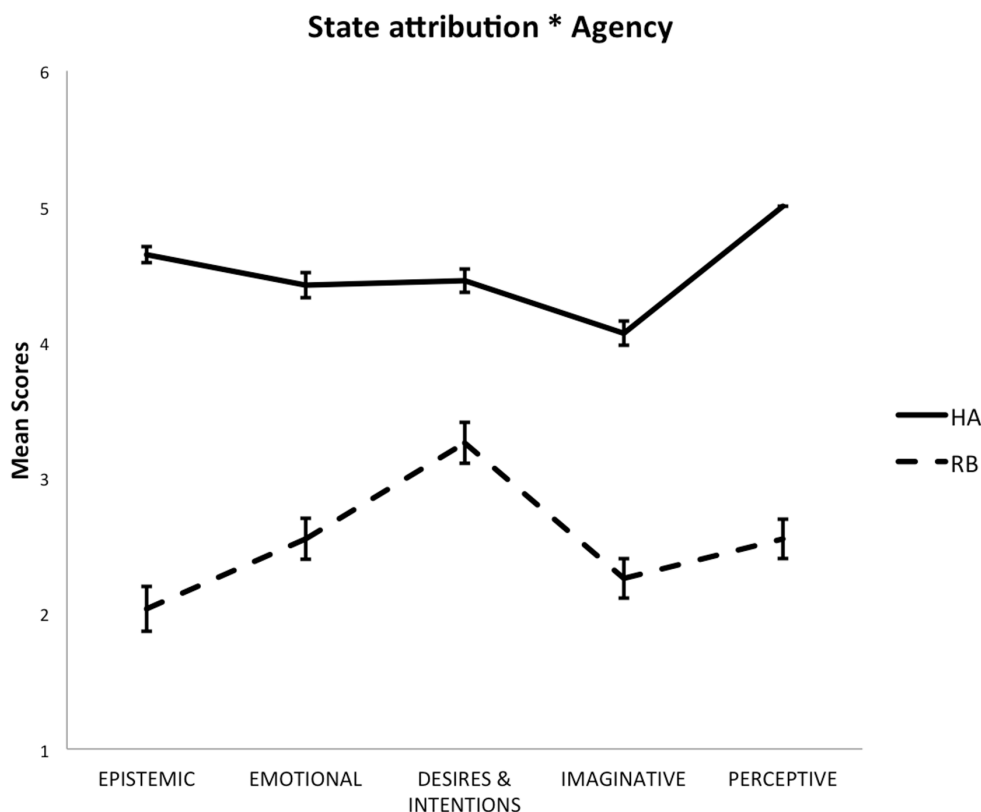
Attribution of States Scale

With this analysis, we compared the attribution of states - as described in the methods session - to the human agent (the other child) and to the robot. The inspection of the boxplots revealed a tendency towards maximum scores (5) in the case of state attribution to the human agent - particularly with respect to the perceptive state, where we observed a ceiling effect - and a normal distribution in the case of states attribution to the robot. A repeated measures general linear model (GLM) was carried out with five levels of *state* (epistemic, emotional, desires and intentions, imaginative, perceptive), and two levels of *agency* (human vs. robot) as the within groups factors. The results showed a main effect of *state* ($F_{4,120}=5.94$, $p<.0001$, $partial-\eta^2=.17$, $\delta=.98$), a main effect of *agency* (HA>RB; $F_{1,30}=53.82$, $p<.0001$, $partial-\eta^2=.64$, $\delta=.1$) and a significant interaction *state*agency* ($F_{4,120}=7.90$, $p<.0001$, $partial-\eta^2=.21$, $\delta=.1$). Post hoc analyses (Bonferroni corrected) showed that the states that scored higher were desires and intentions – which scored significantly higher than both epistemic

⁹ Ad verbatim translation from Italian.

($M_{diff}=.69, p<.01$) and imaginative ($M_{diff}=.52, p<.05$) – and perceptive state, that scored significantly higher than imaginative state ($M_{diff}=.61, p<.01$). Additionally, the analyses showed that the interaction effect stemmed primarily from differences between *states* within *agency* (HA, RB). More specifically, with respect to states attribution to HA, the epistemic state scored higher than imaginative state ($M_{diff}=.58, p<.01$); whereas the perceptive state scored higher than all the other states ($p<.05$) except for the epistemic state, which just failed to reach significance ($M_{diff}=.36, p=.055$). With respect to state attribution to RB, the results showed that desires and intentions received higher scores compared to the epistemic and imaginative states ($M_{diff}=1.23, M_{diff}=1.00$, respectively; $p<.001$). These results are summarized in Figure 1.

Figure 1: Mean scores obtained by the children during the attribution of states (epistemic, emotional, desires and intentions, imaginative, and perceptive) to the human agent (HA) and to the robot (RB). The bars represent the Standard Error of the mean.



The results on the attribution of states to HA and RB revealed that children clearly attributed different states on the basis of agency, with HA receiving higher scores on all states attribution compared to RB. This shows that children had a correct perception that the other child had epistemic and emotional

states, intentions and desires, an imagination and perceptive properties, which are different from that of a robot, therefore considering this latter as a distinct entity.

Within agency, children tended to ascribe poor imagination to both the child and the robot. This is in line with evidence showing that young children's imagination abilities mature gradually (Harris, 2000; Harris & Leivers, 2000; Lillard, 1994; Lillard, 2013). Interestingly, the differences observed within the attribution of states to the robot indicate that children tended to ascribe desires and intentions also to the robot, although to a significantly lesser extent than to the human agent. Desires and intentions attribution to the RB, in fact, received greater scores than all the other states, and substantially more than the epistemic and imaginative states. During video watching (see methods), the children observed the RB in action, and this may have led the children believe the robot as having intentions. In fact, also from a neurophysiological perspective, movement and intentions go hand in hand [see, for example, Gray & Wegnaer, 2012; Premack & Woodrouff, 1978) as also suggested by psychophysiological evidence with children (Cavallini et al., 2013). All the same, in the present study, while attributing intentions to the robot, the children ascribed to the robot a low ability to think, understand, and decide (epistemic attribution). These results, apparently in contrast, are on the other hand much in line with the idea of animism introduced above, and namely with young children's tendency to attribute a living soul to plants, inanimate objects, and natural phenomena, while being aware that these entities are non-living. The fact that this idea applies to objects only *if* these objects serve a function or are used to reach a goal (see Katayama et al., 2010; Perner & wimmer, 1985; Turkle, 2004], further supports the movement and intention interpretation just described (Chaminade et al., 2010; Sandoval et al., 2016).

Ultimatum Game

The main aim of the present study was to assess whether the child behaves differently when acting with a human agent or with a robot during an interactive situation. We therefore had the child playing the UG with either another child or with the robot, as both proposer and receiver.

Proposer

A t-test comparing the total amount offered to the other child or to the robot when the participant played as proposer showed no significant difference in the total amount offered (HA: $M=3.71$, $SE=.31$; RB: $M=3.55$, $SE=.35$; $p>.05$). Additionally, a high internal consistency (Cronbach $\alpha =.85$)

was observed between each individual child's behaviour when playing with the human agent or the robot. Table 1 reports the children's proposed divisions to HA and RB.

Table 1: Statistics of children's offers when playing as PROPOSERS; ns = not significant; na = not applicable.

	HA – RB	HA – RB	HA vs. RB
Proposed Division	N	%	Sign (<i>p</i>)*
1-9	0 – 0	0 – 0	na
2-8	0 – 0	0 – 0	na
3-7	0 – 1	0 – 3	na
4-6	5 – 5	16 – 16	ns
5-5	7 – 4	23 – 13	ns
6-4	9 – 7	29 – 23	ns
7-3	3 – 5	10 – 16	ns
8-2	2 – 3	7 – 10	ns
9-1	5 – 6	16 – 19	ns
tot	31 – 31	100 – 100	

**Wilcoxon rank test*

These results are in line with the literature [e.g., 28] showing that pre-schoolers tend to make offers that favour their own gain, although the frequency of children that made offers towards fairness (i.e., ranging between 4-6 and 6-4) was quite substantial (68% towards HA; 55% towards RB). Additionally, these results extend previous findings showing that five-year-old children's behaviour and game strategy is consistent independently of whether the child plays with another child or with a robot, in line with the large body of existing literature on adults, as fully introduced above.

Receiver

Within this analysis, we summed up all acceptances when the child played as receiver, therefore calculating the total amount gained by each child. A t-test comparing the total acceptances from the other child and the robot showed no differences in the total amount accepted as a function of *agency* ($t=.75$, $p>.05$), indicating that the children accepted similar amounts when playing with HA ($M=10.97$, $SE=.77$) and with RB ($M=10.45$, $SE=.95$). This result is congruent with the data above described, showing children's tendency to adopt a similar game strategy when playing with the other child or with the robot.

Specifically comparing the children's acceptances of each proposed division from HA and RB, our results confirmed no differences in the frequency of acceptances as a function of agency within division (for statistics, see Table 2). Additionally, comparing the frequency of acceptances between successive divisions for both HA and RB, the Wilcoxon test showed not significant differences for the child (i.e., 5-5 vs. 6-4; 6-4 vs. 7-3; etc.; $p > .05$), whereas we observed significant differences for the robot. More specifically, acceptances of the 6-4 division were significantly lower than acceptances of the 5-5 division (71% vs. 90%, $p < .01$), as well as acceptances of the 7-3 compared to the 6-4 divisions (52% vs. 71%, $p < .01$). This latter result shows a significant, although minor, tendency of children to accept slight unfair offers more from another child than from the robot.

Table 2: Comparison of refusals and acceptances of proposed divisions during the UG when the child played as receiver with another child (HA) and with the robot (RB) (N=31). *P-values* were non-significant (ns) at a value of .05.

		HA	RB	<i>HA vs RB</i>
Division		N (%)	N (%)	Sign (<i>p</i>)*
5-5	Refuse	3 (10)	3 (10)	ns
	Accept	28 (90)	28 (90)	
6-4	Refuse	7 (23)	9 (29)	ns
	Accept	24 (77)	22 (71)	
7-3	Refuse	12 (39)	15 (48)	ns
	Accept	19 (61)	16 (52)	
8-2	Refuse	16 (52)	13 (42)	ns
	Accept	15 (48)	18 (58)	
9-1	Refuse	14 (45)	15 (48)	ns
	Accept	17 (55)	16 (52)	

*McNemar's Test

Correlations

Pearson's correlations were carried out between the total scores at the ultimatum game when the child played with the other child and the robot, as both proposer and receiver. The results showed, as expected, a substantial correlation between the total amount proposed to the other child and the robot ($r^2 = .56$, $p < .01$), as well as a strong correlation between the total amount accepted by the other child and the robot ($r^2 = .49$, $p < .01$). Additionally, the scores obtained at the UG were further correlated with demographic, cognitive, and socio-economic variables: age (months); the child's gender; working memory scores; the ability to inhibit behaviour scores; the intentionality test scores; and the Family

Affluence Scale scores. These correlations are summarized in Table 3. In general, no significant correlations were observed between the scores obtained at the UG and any of these variables ($p > .05$).

Table 3: Correlation analysis between the total scores at the Ultimatum Game when the child played as proposer with a robot (1) and the child (2) and when the child played as receiver with the robot (3) and the child (4). These scores at the UG were correlated with demographic, cognitive, and socio-economic variables: Age (months); child's Gender; working memory (WM) scores; ability to inhibit behaviour (INHI) scores; Intentionality Test scores (IT); and Family Affluence Scale (FAS) scores.

Pearson Correlations

		1	2	3	4	Age	Gender	WM	INHI	IT	FAS
1)	Total Offer to the Child	1	,746**	0,298	0,179	0,218	-0,085	0,186	0,01	0,146	0,213
2)	Total Offer to the Robot		1	0,191	-0,015	0,224	-0,004	0,202	0,024	0,233	0,237
3)	Total Acceptance from the Child			1	,700**	0,069	0,285	0,151	0,293	0,354	0,165
4)	Total Acceptance from the Robot				1	0,047	0,329	0,251	-0,1	0,255	0,195

** Correlation is significant at the 0.01 level (2-tailed).

Analysis of the children's justifications at the UG

After the child played the UG in both the proposer and receiver roles, the experimenter asked him or her to explain the reasons for his or her division. The children's answers were classified as "outcome", "equity", or "mentalistic" (for details, see methods). Two independent judges evaluated the children's justifications.

Proposer

The inter-rater reliability scores were substantial both when assessing the child's justifications when playing with the other child (Cronbach's Alpha = .88) and when playing with the robot (Cronbach's Alpha = .91).

Analysing the frequencies of children who gave a specific justification to their behaviour for each division when making an offer, the results showed an even distribution of justification type (amount, equity) when the children offered a precise fair amount (division 5-5), whereas a skewed distribution of justification type toward "amount" when the children started placing offers that privileged their

own gain. This was independent of whether the child played with the HA or the RB. A summary of the frequency distribution of justification types for each proposed division is presented in Table 4A.

Receiver

The inter-rater reliability scores were calculated for each proposed division (5-5; 6-4; 7-3; 8-2; 9-1). The results showed substantial agreements both when assessing the child's acceptance/refusals justifications interacting with the other child (mean Cronbach's Alpha = .83; min=.82, max=.84) and with the robot (mean Cronbach's Alpha = .83; min=.80, max=.84).

With this analysis, we compared the frequency of children that provided a justification when accepting or refusing each proposed division. Justification types were different when the child received a 5-5 or a 6-4 division, independently of *agency* (HA, RB). When receiving a 5-5 division, the justifications were either based on "outcome" (HA: N=13; RB: N=14) or on "equity" (HA: N=18; RB: N =16); only one child presented a mentalization-based justification when interacting with the robot. When faced with a 6-4 division, the majority of children (HA: N=26; RB: N =28) presented a justification for their acceptance or refusal based on "outcome"; five children presented a justification based on "equity" and none based on "mentalization" when interacting with the other child; only one child presented a justification based on "equity" and two children a justification based on "mentalization" when interacting with the robot. A summary of the frequency distribution and statistics of acceptances and refusals of each proposed division and type of justification is presented in Table 4B. In general, these results suggest that, when children received a division proposal skewing towards unfairness, the equity and mentalization-based justifications decreased substantially ($\chi^2_{(4)}=16.47, p<.001$), in favour of the outcome-based justification.

The analysis of the children's justification for their behaviour - both when playing as proponents and when playing as receivers - indicates that children tend to regard fair (and hyperfair) divisions either in terms of outcome or in terms of equity-based reasoning, with an approximately equal split. When the division starts skewing, even slightly (i.e., 6-4 division), towards unfairness, the types of justifications offered remarkably bias towards an outcome-based reasoning. It is noteworthy observing that mentalistic-based justifications were very poor, if not even inexistent, in all proposed scenarios. This general behaviour was observed both when the child played with the other child and with the robot, indicating no differences in the type of reasoning underlying specific choices as a function of agency.

On the whole, the results on the UG suggest that children aged five years behave quite fairly, though showing a tendency towards favouring their own gain placing and accepting unfair – and even *very* unfair – divisions, in line with current literature describing pre-schoolers' behaviour during the UG (see, for example, Lombardi et al., 2017). Lack of behavioural differences as a function of agency (HA vs. RB) further appears to indicate that the children at this age tend to disregard to other's mind when making choices, following a very consistent strategy throughout the game on the basis of other criteria (e.g., tendency to maximise gains) or personal traits (e.g., disposition to fairness). This is particularly true if considering the fact that the robot was indeed considered an entity different from the human agent (the child), so as observed from the analysis of the states attribution described above. This idea of a much ego-centred behaviour is further supported by the analysis of the children's justifications for their decisions when placing specific offers (proposers) and when accepting or refusing certain offers (receivers). In fact, analysing the frequencies of children who gave a specific justification for their behaviour, the results showed an even distribution of justification type (amount, equity) when the children offered or accepted a fair amount both to/from another child and to/from the robot; whereas we observed a remarkably skewed outcome-based justification when the children offered or accepted/refused unfair divisions. These latter results are further discussed below.

General Discussion

This study investigated 5 year-olds' behaviour at the ultimatum game. The aim of this study was to compare young children's game strategy when they played with another child (human agent) and with a robot. The results showed that children's game strategy was very similar when playing with the other child and with the robot, independently of the role played (proposer or receiver). The children were quite conservative both when offering and accepting proposals, that is, the children generally tended to offer and to accept fair divisions (5-5), although almost half of children proposed and accepted also unfair divisions, ranging from 6-4 to 9-1. These results are in line with the developmental literature on UG. For example, Benenson and colleagues (2007) observed that children aged 4 years donated less than 6 and 9-years-old, showing that sensitivity to fairness increases with age. Furthermore, a recent research by Lombardi and colleagues (Lombardi et al., 2017) showed that, at 6 years, children displayed a more selfish behaviour than children aged 8 and 10 years, highlighting that younger children tend to maximize their gain accepting also unfair offers.

Importantly for the present purpose, no significant differences were observed between offers and

acceptances made to or received from the other child or the robot. In this respect, children's behaviour observed in this study when interacting with the robot is comparable to the adults' behaviour reported in several studies. Terada and Takeuchi (2017) for example, showed that, when playing the UG, adult participants took approximately the same time to decide how to distribute goods between a human and a robot. In the study by Kahn and colleagues Kahn et al., (2012), the frequency of acceptances and refusals became closer to that toward a human when the robot had more human-like features. Similar results were also found by Rosenthal-von der Pütten and Krämer (2014). On the whole, these results suggest that, when bargaining, the other player is regarded independently of agency: the other player's mind appears to be a reflection of our own mind and strategic thinking, whether or not the other has a mind at all, such as in the case of a robot.

With respect to the acceptance of offers made when the child played as receiver in the present study, although behaviour was comparable when the child played with another child or with the robot, it is worth noting that the results showed a significant, although minor, tendency of children to accept slight unfair offers more from another child than from the robot. In this respect, one may suggest that children's expectancy from a robot is to be a totally fair player – since it does not have a mind of its own that can work strategically. In this light, divergence from this initial expectation is less accepted compared to situations in which children play with a human peer. In this latter case, in fact, the other player (the human) - having a mind - is supposed to be able to apply a game strategy and, eventually, to be also unfair. Alternatively, but not mutually exclusive, one may suggest that the child believes to have a distinctive status compared to the robot that, as assessed through the test of attribution of states, is perceived as a different entity with respect to a child at all levels: epistemic, emotional, imaginative, and physical. Also in this light, unfair offers would be less accepted when made by a robot than by a peer.

Finally, with respect to the results from the analysis of the children's justifications at the UG, it is interesting to observe that the reasons provided by the children for their behavior, both when playing as proposers and responders, suggest that children aged 5 years tend to consider fair only a division that is exactly fair (5-5). A slight skewed division towards unfairness (i.e., 6-4) already falls within the range of categorization that characterizes very unfair proposals, regardless of whether the proposals are made or received. Additionally, it is noteworthy to observe that fair or slightly hyperfair divisions are typically justified in either outcome or equity terms, whereas unfair offers are mostly justified in terms of quantity. Mentalization-based justifications are poorly made for all divisions, although – in these cases – it is curious to observe that, when playing as proposer, mentalization–

based justifications are uniquely confined to the most fair divisions (4-5; 5-5; 6-4). In general, these observations may suggest that children, particularly in the case of unfair offers, tend to not use mentalization-based explanations in order to reduce the distress stemming from the discrepancy between a “socially-expected” equal behaviour and the actual “selfish” behaviour. This interpretation can be further extended to the outcome-based justifications predominantly used to explain unfair offers that, in a certain sense, may serve to resolve a social cognitive conflict [e.g., 3], ultimately reducing the distress caused by the experimenter’s explicit enquiry.

Concluding remarks and limitations of the study

This study showed for the first time that young children's fairness is not affected by whether the child plays with another child or with a robot. In particular, it appears that children's decisions during social interactions are self-centred and poorly oriented towards the other's mind. Future studies could address the same issue focussing on different ages so to highlight the development of behavior in late childhood, when higher mentalistic abilities are maturing and eventually acquired. Additionally, we showed that the analysis of the justifications of children's behavior may be enlightening with respect to the child's actual psychological understanding of constructs, such as that of fairness.

It is important to stress that the present results, and in particular those referring to the behavioural differences here reported when the child played as receiver with the other child and with the robot, need to be confirmed with a more ample sample. Confirmation of these results could highlight a distinctive attitude towards a non-human interactive partner that emerges quite early in childhood and that may change during adulthood.

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Chapter 4

Object Use in children with autism: Building with Blocks from a Piagetian Perspective

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Abstract

Aim: This study focused on the manipulation of objects by children with suspected autism spectrum disorder. The aim was to demonstrate how objects can be seen as active agents of interpersonal exchange in face-to-face interactions.

Participants: Three children with suspected autism spectrum disorder (aged 18, 20, and 24 months) were selected as representative of the sensorimotor stage of development.

Methods: Starting from Piaget's classical approach to the sensorimotor and symbolic developmental stages, the study moved toward a socio-material interpretation in which some patterns of interaction involving object manipulation seem to create a space that supports adult-child communication. In videotaped observations of verbal and non-verbal signs during an (organized) free play session, each child manipulated seven small blocks of colored plastic in the presence of an adult. The observations were informed by a checklist of 14 items, including eye contact and building a tower of toy blocks from section B of the CHAT (*CHecklist for Autism in Toddlers*) instrument.

results: Based on a broad Piagetian perspective and recent work in the field of socio-materiality, key observations included the following: (1) sensorimotor and realistic play was observed in all three children; (2) there were some intriguing indications that objects serve as concrete mediators in the intersubjective space between adult and child; (3) some of the children's attention patterns were visibly mediated by the object.

Discussion and conclusion: All three children exhibited a particular sequence of actions. First, they manipulated the blocks through active experimentation; second, there was an apparent pause, during which, the children were in fact examining the blocks to determine how best to continue the interaction; and finally, the children monitored adult attention by means of eye contact or by restarting manipulation of the blocks. As this last step in the sequence indicated that the object became a mediator of reciprocal attention, this interpersonal process was labeled "attention mediated by object."

Introduction

According to Piaget (1928, 1952, 1954), children with autism achieve object conceptualization skills by the fifth stage of sensorimotor development. As several studies advise caution in using the *stage* concept to describe typical and atypical psychological development, it seems useful to characterize these psychological processes in terms of specific activities that the child can plan and implement when acting on their physical and social environment. For example, as a predictive index, the number and type of different actions produced by children with autism during a recreational activity may not always follow the same stages as in typical development, and this can also be correlated with the severity of autistic functioning (McDuffie et al., 2015). In fact, while imitation difficulties may reflect a possible delay in psychological development, not all pre-scholars with autism have problems with imitation or symbolic play (Vanvuchelen et al., 2011). Within the broad line of research that raises questions concerning object canonicity, we identified some interesting elements related to the socio-material function of mediation during communication.

It is known that canonical functions of objects are introduced by other people present in the child's world (Leontiev, 1981; Costall, 1997; Rodríguez and Moro, 2008; Barthélémy-Musso et al., 2013). Indeed, Sinha (2009) suggests that the canonical functions of the object are acquired as a normative phenomenon during social interactions, although cognitive understanding of that status is a prerequisite. Additionally, Sinha (2015) (p. 12) points out that “the materiality of meaning and meaningfulness of materiality is central to approaches in cognitive science emphasizing the importance of objects in extended cognitive embodiment.” In particular, there is evidence that canonical functions are acquired during child–adult interactions (Rodríguez and Moro, 1998; Sinha and Rodríguez, 2008; Moro, 2011, 2014). Several studies have reported how, under certain conditions (for example, impaired interpersonal relations or attentional focus), objects become mediators of social interaction (Williams et al., 1999; Dimitrova, 2014; Moro, 2014). Cárdenas et al. (2014) highlighted the importance of the reciprocal nature of these interactions by showing how they emerge from communicative and triadic contexts (adult–child–object). The crucial role of the adult in the acquisition of object use is observable from early infancy (Moreno-Núñez et al., 2017). Moreover, during child–object–adult interaction, the child's visual attention is more focused when interacting with an experienced caregiver than with an unfamiliar adult (Miller et al., 2009; Miller and Gros-Louis, 2013). Miller and Gros-Louis (2017) also showed that the child's attention is influenced by partner social style. Tomasello et al. (1993) and Tomasello (2016) highlighted different kinds of learning, such as imitative, instructed, and collaborative. For instance, imitation is important for

learning that involves others and objects, as it facilitates understanding of the normative expectations of a given cultural group (Tomasello, 2016). Sinha (2009) suggested that children apprehend canonical functions primarily by cognitive means, thereby accessing the normative identity of the cultural group. Bruckner and Yoder (2007) reported that, even among children with autism, object use can be linked to emergent functions in the preoperational stage, such as imitation and attention to the other person.

Most of the existing research suggests that imitation is impaired in children with autism (Charman and Baron-Cohen, 1994; Rogers, 1999; Rogers et al., 2003; Williams et al., 2004). Indeed, Smith and Bryson (2007) noted that children with autism exhibit difficulty in imitating any unconventional use of objects but are able to imitate canonical object use. By imitating this canonical use, children with autism access part of the cultural group's heritage. With respect to manipulative play activities, Kanner (1943) was among the first to note that, despite differences and limitations, children with autism exhibit a number of functions related to the use of canonical and non-canonical objects. Trevarthen and Hubley (1978) described the dynamics informing subject–subject–object triangulation (the theory of “secondary intersubjective tuning”). Typical children alternate their eye gaze between the object being viewed and the other person, so engendering joint attention. However, in atypical development, and especially for those on the autistic spectrum, an abnormality has been observed in the development of behaviors related to joint attention. Palacios and Rodríguez (2015) showed that in typical children aged 9–15 months, the symbolic use of an object develops within a triadic context. Ungerer and Sigman (1981) assessed the use of everyday objects in a group of children with autism ranging in age from 39 to 74 months in a structured and free play session and found that most were unable to use an object according to its designated function. Williams et al. (2005) interviewed parents of 10 children with autism (MA = 62.2 months; SD = 19.9) who reported problems relating to the use of an object, such as an interest in some unusual aspect of the object, an unusual way of using the object, or difficulty in generalizing object use. Custance et al. (2014) suggested that imitative deficits in children with autism can be reduced by means of object-related activities, especially if there are no time limits on use of the object. Object-related activities promote joint attention, motor imitation, and intentional communication with a social partner (Bruckner and Yoder, 2007), and there is evidence that interventions focused on play involving different objects can promote social and imitative behaviors (Brown and Murray, 2001; Stahmer et al., 2003; Lee et al., 2017). Swettenham et al. (1998) observed three types of attentional behavior: (1) between an object and another object, (2) between an object and a person, and (3) between one person and another. Children with autism showed relatively more attention to interactions between an object and another

object. In our recent studies, we have observed the important role of the object in activating attention in the child with autism, and we describe the phenomenon as “attention mediated by the object,” which may be a precursor of joint attention (Iannaccone et al., 2016; Manzi and Savarese, 2017; Savarese et al., 2017).

The observational study reported here incorporates a sociomaterial perspective, referring in particular to the mediating role that objects seem to assume in the interaction between children and adults, which has to date been neglected in the scientific literature. Using a selected set of objects, the study analyzed the child with autism’s ability to manipulate those objects and to evaluate their symbolic use. Starting from presentation of the object, a further objective was to identify the type of game engaged in by the child. During interaction with an adult, we observed first whether there was eye contact; second, whether this changed how the child used the object; and third, whether the canonical use of the object was an important element in the child–adult interaction.

Material and Methods

Participants

We used the tower building item from section B of the “CHecklist for Autism in Toddlers instrument” (*CHAT*; Baron-Cohen et al., 1992). It was developed to help identify children who are at risk of developing social-communication disorders (scoring “high risk of autism”). It was administered to filter participants and one child aged 22 months did not pass this item. Children aged 18 months are capable of tertiary circular reactions and can stop and restart a sequence of actions at any intermediate step, which is crucial in building a tower of blocks. Children older than 18 months can use symbolic mental representations. The selected age range, therefore, allowed us to observe the early development of symbolic functions.

The study’s participants were three non-verbal male children with suspected autism spectrum disorder. The suspected diagnosis of autism was identified through the use of the CHAT instrument.

Their different ages encompassed the transition from sensorimotor to preoperational stage; participant 1 was aged 18 months, participant 2 was aged 20 months, and participant 3 was aged 24 months.

Methods

The study employed videotaped observations (with one camera) of verbal and non-verbal signs during an organized free play session, in which each child played with seven small blocks of colored plastic in the presence of an adult (a different experimenter was used for each observation). The observations were conducted on the basis of a checklist consisting of 14 items (see Appendix A), including eye contact and the building of a tower of toy blocks from section B of the CHAT procedure.

The blocks were selected not only because of their use in the CHAT procedure but also in accordance with the empirical tradition of Piaget (1962) and Reifel (1984), who have shown the importance of toy blocks in the child's cognitive development. The interaction sequences from the video recordings were transcribed in full for microgenetic and semiotic analysis, primarily examining the children's non-verbal signs (gestures and posture) during interactions with the objects. Adult intervention was also analyzed in terms of non-verbal signs (gestures and posture), again focusing on sequences of microgenetic and semiotic actions. Sequences were selected using the following criteria: the presence of gestures, actions, or both, where (1) the adult intervened and the object became a mediator of the interaction, and (2) the object mediated the attention between child and adult. The observations of child and adult occurred simultaneously.

Ethical issues

This study was carried out in accordance with the recommendations of AIP (Associazione Italiana di Psicologia), and all of the children's parents gave written informed consent in accordance with the Declaration of Helsinki. As there is as yet no psychological ethics committee at the University of Salerno, the protocol was approved by the external experts group from the University's "Centro di Counseling Psicologico" (Counseling Center). While the Center is not specifically responsible for ethical approval, the external experts group supervises research carried out by psychological researchers at the University. In Italy, few universities have a psychological ethics committee, and these generally offer degree courses in psychology or have a psychology department or institute. The University of Salerno has not activated degree courses in psychology and has no such department. We would like to thank the external experts, Dr Oreste Fasano (Psychologist), Dr Nadia Pecoraro (Psychologist), and Dr Monica Mollo (Lecturer in Psychology).

Results

The interactions with the blocks helped to observe behaviors that related to the blocks' physical attributes and the child's competence to establish relations with them. This playful manipulation of

objects probably helps planning and coordinated action, stimulating and strengthening the child's ability to interact with the outside world. At the same time, these activities allow children to imagine new construction scenarios (Harris, 2000). In the presence of potential partners or competitors (children or adults), the child's management of play activities and their implementation of communication strategies can also be observed. For example, the 18-month-old touched and handled all seven blocks, the 21-month-old touched and handled six blocks, and the 24-month-old touched and mechanically stacked all seven blocks.

Based on their independent observations, the two researchers agreed that the three children's symbolic use of objects (see **Table 1**) could be assigned to the first level of symbolic play as proposed by McCune-Nicolich (1981), based on Piaget's sequence (1972), because the children played using sensorimotor schemes. In addition, unlike the 24-month-old, the 18- and 20-month-old played a realistic game. Pretend and symbolic play was not observed in any of the three children's behaviors.

Table 1. *Use of Objects*

	Child 1: 18 months	Child 2: 20 months	Child 3: 24 months
Realistic play	Yes	Yes	No
Pretend play	No	No	No
Symbolic play	No	No	No

Based on observations of the "Can the child build a tower of blocks?" item in section B of the CHAT instrument (see **Table 2**), it was established that all three children used the objects in a manner similar to that described by Piaget as part of the manipulative activities of sensorimotor functioning. The children showed active exploratory behaviors as the toy blocks were manipulated, sorted, and stacked.

Table 2. *CHAT Section B: non-key items.*

	Child 1: 18 months	Child 2: 20 months	Child 3: 24 months
Tower of Blocks	Yes	Yes	Yes
Eye-Contact	Yes	Yes	No

In observations of the Eye Contact item of CHAT section B, the 18- and 20-month-old made visual contact with the adult, but the 24-month-old showed no eye contact. In the child-object- adult or

simple child–object interactions excerpted below, a set of seven colored plastic blocks was placed in front of the child. Transcription commenced when the child began to manipulate the blocks.

Observational results

In this section, we describe the observations we made of children with autism in relation to the types of object use (see **Table 1**). Crucial episodes were selected to illustrate the characteristics of the interactions between the children and the adults.

Generally, adults help children to interact with objects. In the observation of Child 1, the child was able to perform a complex series of actions on the object during the interaction. The child grabbed the object, manipulated it to orient it, dropped it, balanced it, and connected the different objects by stacking them. Here, the adult's help was crucial, as the elements of the child's interaction with the object were changed; at the same time, the object became a mediator in transforming the interactive arrangement between the child and the adult. The adult's hand in direct contact with the object became a source of interest to the child, who focused on this subject–object hybrid.

Observation 1. Child 1. Difficulties in the use of the material features of the object induced the intervention of the adult.

The child cries because the blocks he had begun to stack fall; while he cries, he holds two blocks in his hands and tries to put them on a block on the table. The adult comes over and gets behind the child. The child tries to lay block 1 but fails because he is shaken by tears. The adult places the existing block in a better way. The child looks attentively at the adult's hand and places block 1. The adult takes block 1 with the child and helps to place it in the right position in balancing it.

(...) With his hand, the adult moves block 4 (stacked by the child) to achieve better balance. The child observes the adult's hand. The child leaves block in his left hand alone and, continuing to watch the stacked blocks, extends his right arm to grab block 6. He places block 5 onto block 4 and, without looking, tries to grab block 6.

The child's initial frustration on being unable to stack the blocks led to an intervention by the adult, who was seated on the ground behind the child. The adult intervened when the child played with the blocks, and the object became a mediator of interactions and interpersonal activity.

Observation 2. Child 1. The previous help of the adult activated the attention of the child.

Once block 4 is in his left hand, he stretches his right arm and grabs block 5 before positioning block 4. While watching block 5, the child places block 4 and leaves it on block 3a; in the meantime, he brings block 5 closer to his body. After leaving block 4, the child takes a step back to turn to the adult, and they look at each other.

(...) He places block 6 onto block 5 and leaves it. Having left block 6, he turns to the adult, and they look at each other.

The child continued to play with the blocks, which became a mediator of attention between the child and the adult. After his intervention, the adult facilitated the stronger relational attractiveness of the object, as it became a transformative element in the initial environmental arrangement.

Observation 3. Child 1. The child used the material features of the object correctly after the intervention of the adult.

The child stretches his right hand and grabs block 4. The child then passes block 4 to his left hand, no longer looking at block 4 and directing his gaze to block 5. Meanwhile, the child keeps block 5 in his right hand. Holding the new block, the child turns to the stacked blocks and simultaneously raises his right hand (with block 5). He raises both arms above his head and grabs block 5 with both hands.

The child combined the object's socio-material properties by combining the material properties of the object with the social structures inherent in the object itself.

Furthermore, a series of interesting gestures was observed in the child-object interaction. When the child took the block and raised it over his head, even though the blocks on which the held block was to be placed were much lower in height, the child may have been planning to build a much higher structure with different characteristics to the existing one. One may take these behaviors as possible evidence of an imaginative process. This can also be seen as an explanation of the socio-material link, as imagining a structure beyond what is immediately present may indicate the child's ability to combine the material properties of objects. As the adult intervened, he became an example for the activity of the child. In the child-adult interaction, the object became a mediator of attention.

In the observation of Child 2, the child's manipulative skill was organized in a complex series of actions. He eyed the objects, planned to grab and stack them, rotated the objects in both hands, left, and again grabbed the objects. The material characteristics of the objects were explored. The adult intervened when the child played with the blocks, and the clock (the object) became the mediator for the joint attention of the child and the adult.

Observation 4. Child 2. The child began to actively explore the objects.

The child moves the blocks in front of him (almost shuffling them), watching them carefully. Still looking at the five blocks in front of him, he moves his right hand and touches block 1, which is not present in his visual field.

The child explored the material features of the blocks, and through these actions, which blended complex activities, the child seemed to experience the object adapting and being adapted by its constituent elements. In building a tower of blocks, the child's aims and imaginative action planning appeared to converge. Thus, even though a symbolic game could not be identified, it seems that sensorimotor play and realistic play were present.

Observation 5. Child 2. The child used the material features of the object.

He raises block 1, keeping his eyes on it while grabbing block 2 with his left hand. He turns block 2 around, changing the side that rests on the ground; in the meantime, his right hand brings block 1, moves it in the air, and passes it over block 2. He is about to place block 1 but brings it back close to himself, touching it with his left hand and resting it on block 2.

Here, the child experienced the features of the object. The adult intervened several times during these child-object interactions. The subject-object hybrid identified during the observation of Child 1 is also present here. During the first stage, the child's attention was focused on the transformative mediation of the subject-object hybrid, highlighting how this inextricable relationship drives the modification of the initial environmental arrangement. The child's actions can be seen to occur in a synchronic and harmonic circle of the imitation of the adult's actions.

Observation 6. Child 2. The socio-material features emerged during the child-adult interaction.

The adult places his hand in the child's visual field by moving a block over to him; putting it onto the floor, the adult begins to stack the block. Throughout the sequence, the child is

attracted by the adult's hand manipulating the block. He directs his gaze to block 1 and grabs it; continuing to watch it, he takes it with both hands. The adult begins to stack the blocks. The child manipulates block 1, which he holds in his two hands. He rests block 1 and leaves it. Directing his gaze to the blocks in front of him, he watches the adult, who stacks blocks.

(...) The adult takes the blocks that the child had put in rows and stacks them on top of each other. The child again takes block 4 with both hands. The child carefully observes the adult's movements while stacking. Still with block 4 in his right hand, crawling and with momentum, the child approaches the blocks stacked by the adult. The child grabs block with both hands, looks at it, and manipulates it. He turns block 4 in the direction that seems to enable stacking. He watches the blocks being stacked by the adult and, with his right hand, places block 4 onto the stack of blocks.

The subject/adult-object hybrid appeared to represent the transformation of the subject/adult-object-subject/child relationship, leading to revised planning of the action and thereby structuring of general aims. As well as becoming a mediator of the child's exploration of the surrounding environment, the object also rewrote the relational terms. This last step seems to follow the socio-material perspective, as the social structure of the object was intertwined with its material characteristics.

In observation of Child 3's sequence of actions, the attractiveness of the object overrode the ability to create a contact area with the adult who remained peripheral, or as a mere spectator of the child's construction. Actions have a regularity of performance: blocks are looked at, the hand gets ready to grab, the arm is stretched out to get to the object, the object is grabbed, the child identifies where to put the object, and eventually rests it in balance for stacking.

Observation 7. Child 3. The child used only the material features of the objects.

The child grasps block 1 with his right hand and rests it on a raised board, which has a width equal to the side of the block. He looks closely at block 1 and grabs it with both hands as if to be sure it is in balance. He pulls his right hand away from block 1 and, holding himself with his left hand, leans over the board to see what is there. He directs his eyes to where the blocks are located. He lowers himself, leaning with his left hand on the board and gripping block 2 with his right hand. He gets up and, watching block 1, rests block 2 onto block 1. He removes his right hand from block 2, lowers his body to take block 3, and grabs it with his right hand. He gets up and places it onto block 2, leaving block 3.

Following this regularity of actions, which converged in a purposeful activity, we can assume that the child has completed the main stages of sensory–motor skill development and understood the object’s material characteristics. Additionally, the social function inherent to the object appears to be linked to its use.

In fact, the building of the tower was achieved through structured planning and with a constant imaginative tendency. What is lacking seems to be an understanding of the possibility to use the object as a social agent, because the adult was present only as a spectator.

Based on the regularity of actions that converged in purposeful activity, we can assume that Child 3 had completed the main stages of sensorimotor skill development and was able to understand the object’s material characteristics. Further, the objects’ inherent social functions appeared to be linked to their use. In fact, the building of the tower was achieved through structured planning and with a constant imaginative tendency. The adult did not intervene when the child played. In the child–adult interaction, what seemed to be lacking is an understanding of the possibility of using objects as social agents, as the adult was present only as a spectator.

Searching for constants in analyzing the filmed sequences of the three children, their successive actions were identified; initially, each actively manipulated all the blocks. This activity preceded an apparent break, but during that phase, the child observed the objects to determine how to continue. Immediately thereafter, the child either sought the adult’s attention through eye contact or resumed the interrupted object manipulation.

At the beginning of the game, the children moved, shook, and turned the items several times, and this correlated with activation of their hand movements. Here, we probably witnessed the typical secondary circular reactions of the sensorimotor stage. After the break and the search for mutual attention and/or eye contact with the adult, the children then proceeded (by trial and error) to build the tower of blocks, modifying their existing schemes in so doing. This was indicative of tertiary circular reactions.

Discussion and Conclusions

Consistent with a theoretical perspective emphasizing the role of social and material dimensions in psychological development and activities (Iannaccone, 2015), our analysis highlights two important implications in our observations of object manipulation. First, consistent with the Piagetian

perspective, the observations highlighted object manipulation and action planning identifying the presence of secondary and tertiary circular reactions (Piaget, 1972). In relation to the game, invoking the McCune-Nicolich model (1981), all the children exhibited sensorimotor play, in which the object was manipulated and understood in terms of its material characteristics.

The second implication relates to how, in some action sequences, the material and social characteristics of the objects contributed to shaping partner interactions between child and adult. This aligns with several empirical studies of the social uses of objects (conventional, canonical, and symbolic) (John-Steiner and Mahn, 1996; Moro, 2011). In such interpersonal situations, the activities of participants (child and adult) are clearly affected by the setting's physical and social affordances. In particular, during child–parent interactions (Moro, 2014), triadic child– object–adult interactions (Moro, 2011) seem to create relevant socio-material scenarios that frame communicational activities. In our observations, two of the three children in fact exhibited a kind of object management mode that seemed to replace eye contact with the adult. In some sequences of actions, child and adult managed to coordinate action planning through object manipulation, child exploratory activity, and adult scaffolding. For example, the child observed and touched the objects to encourage play activities; the adult touched the object with his hand, and this action frequently became a source of interest for the child. The child looked for the adult's attention through eye contact, and the child began to manipulate the object. In activities of these kinds, it seems evident that the objects can serve as mediators in communicative interactions with the adult. As well as taking into account the social function of objects, the observed children were already considering the socio-material characteristics of the play situation, as adults and children engaged in managing a kind of “socio-material space” as proposed by Rodríguez et al. (2015). In fact, from the first year of life, adults produce a shared space with objects that serve as effective tools of communication with children. Our findings in relation to the object as a tool for adult–child interaction align with Moreno-Núñez et al. (2017), confirming that the first shared understandings between adult and child take place around the object and its uses. Finally, in considering these first results, we can imagine relevant challenges for a new developmental psychology based on further related research.

Our observations of these interactions do not focus on direct joint attention but identify a kind of psychological process that we call “activity mediated by the object.” Unlike Tomasello (1995), we consider the object itself as mediator, not only of the mutual attention between adult and child but of the dynamic relational exchange between partners.

In conclusion, our study reported the preliminary results of a larger analysis. In considering these first results, we can imagine relevant challenges for the developmental psychology of children with autism. Consistent with the results of studies on children with typical development, our study on children with autism shows that the socio-material features of objects represent factors that mediate the construction of child–adult interactions. Starting from the first intervention of an adult, an object becomes a mediator and promoter of interpersonal activities and space.

Ethic Statement

This study was carried out in accordance with the recommendations of AIP (Associazione Italiana di Psicologia), and all of the children’s parents gave written informed consent in accordance with the Declaration of Helsinki. As there is as yet no psychological ethics committee at the University of Salerno, the protocol was approved by the external experts group from the University’s “Centro di Counseling Psicologico” (Counselling Centre). While the Centre is not specifically responsible for ethics approval, the external experts group supervise research carried out by psychological researchers at the University. In Italy, few universities have a psychological ethics committee, and these generally offer degree courses in psychology or have a psychology department or institute. The University of Salerno has not activated degree courses in psychology and has no such department. We would like to thank the external experts, Dr Oreste Fasano (Psychologist), Dr Nadia Pecoraro (Psychologist), and Dr Monica Mollo (Lecturer in Psychology).

Author Contributions

The introduction was written by AI. The observational analysis was written by FM. The discussion of the results and the conclusions were written by GS.

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Chapter 5

Social Functions in Autistic Children and Interaction with/through Object: A Brief Report

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Abstract

The aim is to analyse the social functions of pointing, of imitation and of joint attention in presence of the object for the autistic children. We have built an ad-hoc observation check-list and we have conducted 43 observations with verbal ASD-affected children aged between 2 years and 6 years. The results show that a better use of the object is correlated to the manifestation of social functions analysed.

Introduction

In a socio-material perspective (Iannaccone, 2015), the object is composed of material features and social components coexisting together. Considering that the social interaction is impaired in autistic children; consequently, the interaction with the “social world of objects” is impaired as well (Iannaccone, et al., 2016). Some autistic children show deficits in the use of objects: alterations in manipulation, exploration and describing. Thus, autistic children which do not present impairment in the use of the object show more social functions than impaired children (Trevvarthen & Hubley, 1978; Tomasello, 1995; 2016).

The three social functions, pointing, imitation and joint attention analysed in the study and they all have in common the presence of the object in their definition. Thus, our aim is to analyse these functions not only taking into account the development of these by the autistic child, but also what role plays the object specifically in social and relational terms.

Method

We have built an ad-hoc observation check-list inquiring on 9 areas (each of which has specifying under-questions), which refer to 9 psychological theory constructs developed by the literature on autism and object. The main objective of this check-list is that of describing characteristics and socio-material functions of the object with reference to autistic subjects. In this check-list, there are different psychological constructs, but here we have analysed in detail three constructs: declarative function, imitation and attention. As we can see the check-list was made of different constructs but we will analyse these other constructs in future.

During each observation, an educator following the child for rehabilitation was present and the educator completed the check-list. Each observation lasted 26 minutes on average and has been transcribed on an ad-hoc check-list.

Children have been observed while interacting with an object, a small-sized plastic toy, they had chosen from a set of objects, for instance, toy cars, trains, toy animals and others. When we refer to “acted and interacted with and through the object” we arranged different constructs of the check-list, such as: Understanding of the use of the object, interaction through the objects etc. Which are the constructs refer to the manipulation, exploration and describing.

We carried out 43 observations with verbal ASD-affected children aged between the end of the sensory-motor stage (24 months) and the start of the pre- operational stage (68 months, namely 6 years). Moreover, the literature shows some results showing a link between a better use of the object

and those functions that emerge during the pre-operating period, such as imitation and attention to the other (Bruckner & Yoder, 2007).

We were two samples. The first sample composed of 18 children who acted and interacted with and through the object while the second sample composed of 25 children who acted and interacted with and through the object.

Results

Regarding the association between the sample 1 and the declarative function (Figure 1) shows that the 66.7% of the sample present this association while the sample 2 shows that only the 24% present this association.

Indeed, it is possible also for autistic children to use the imperative function of pointing, as for typical development children, and pointing is often the ground- breaking of a full declarative function (Camaioni et al., 2003).

Regarding the association between the sample 1 and the imitation (Figure 2) shows that the 94.4% of the sample present this association while the sample 2 shows that only the 60% present this association.

Concerning imitation, it has been suggested that the specific imitation deficit of autism could be reduced or even eliminated with the use of activities linked to objects (Vanvuchelen et al., 2013; Custance et al., 2014), especially when no timelines in the use of objects are given.

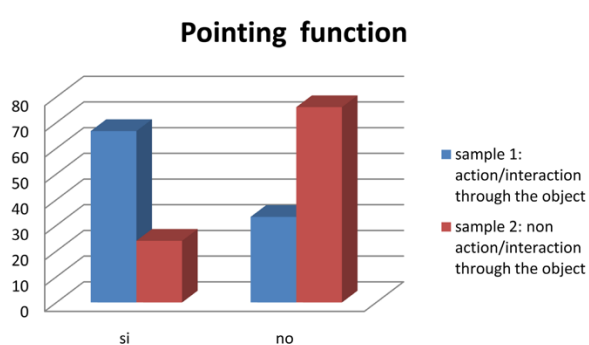


Figure 1. Pointing function

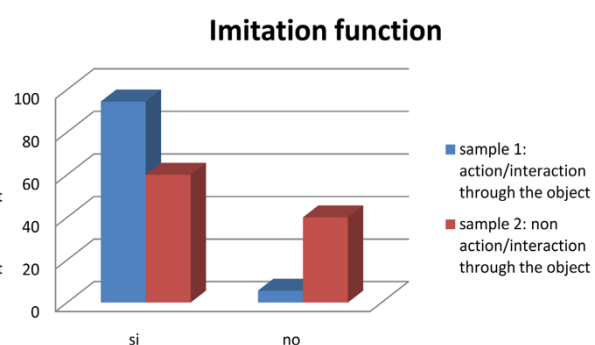


Figure 2. Imitation function

This would favour a higher joint attention, motor imitation and intentional communication with a social partner (Swettenham et al., 1998).

Regarding the association between the sample 1 and the Joint attention (Figure 3) shows that the 61.1% of the sample present this association while the sample 2 shows that only the 32% present this association.

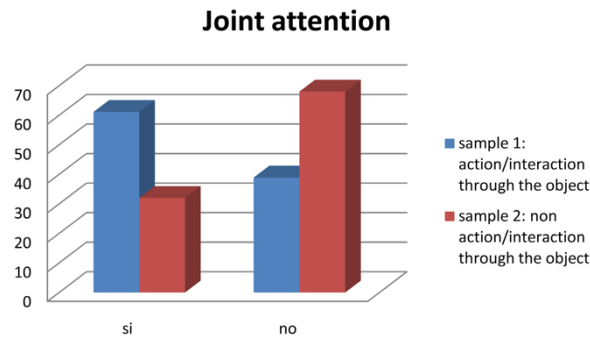


Figure 3. Attention to the adult function

Lastly, regarding joint attention it has been proved that manipulation of material objects can address the child's attention and favour the joint attention with both adults and peers (Korkiakangas & Rae, 2013).

Conclusion

The socio-material features of the object represent factors that mediate the construction of the interaction with the adult. Social functions contribute to this process are: the declarative function (relating to pointing), the imitative function, the function of joint attention.

In line with the literature (Bruckner & Yoder, 2007) on the child with typical development, our study with autistic children shows a link between a better use of the object and these functions that emerge during the pre-operating period, such as imitation and attention for interacting with people.

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Chapter 6

General Discussion

The aims of this thesis were: 1) to explore the intersubjectivity space that a child can establish with an object (the robot) that is also the interactive partner during the interactions; 2) to observe the role of the object as mediator of the child-adult interaction and as promoter of the construction of the intersubjectivity space. The first topic has been investigated in children with typical development while the second topic has been explored in children with atypical development, i.e. autistic children.

In this respect, there were designed two different interactional scenarios to evaluate the intersubjectivity: 1) concerning typical development it has been used an interactional situation involving humanoid robot in order to test the decision-making processes; 2) regarding autistic children the use of the object has been observed during an interaction with an adult mediated by an object, testing the role of the object as mediator and promoter of the interaction. The first situation, involving an innovative field of research, needed a review of the literature in order to understand which role can be assumed by the robot during the interactions with a human. Thus, it was important to analyse if human can ascribe a mind – mental states – to a robot, in particular in a life-span perspective in order to observe changes during the human development. The second scenarios used an original perspective to examine the interaction between autistic children and adults, showing that autistic children, despite their impairments in different areas of development, can create an intersubjective space with the adults. However, this is evident when child and adult use an object as mediator of this interaction.

The findings emerged from these scenarios arise two main questions:

Can a child treat a humanoid robot similarly to a human partner?

Futurologists hypothesised that in the next years robots will be introduced in different contexts of our everyday life such as household, elderly assistance, education etc, modifying the job market but also our social interactions. For instance, the use of robots in the educational context are inspiring new educational program. Moreover, children will be more conscious of the existence of the robots because robots become part of their everyday experience. Several studies underline the need to implement physical and behavioural features in order to make robots more sociable, promoting better

interactions. From Chapter 1 results that subjects ascribe mental states to a humanoid robot. However, the attribution of a mind is not similar at all ages, but it changes during the life-span. For instance, a recent study of Manzi and colleagues (2017) showed that children from 5 to 9 years of age distinguish a human from a robot as regards the attribution of mental states, in particular children ascribe different mental states to a robot at different age: younger children ascribe more emotional states compare to older children. However, several researches in the field of educational robotics show that children treat a robot as a companion and scaffolder in the educational contexts. These findings are evident in the study presented in Chapter 2. In fact, 5-years-old children ascribe less mental states to a robot compared to a human but despite these differences, they use similar strategy with human and robot when they play in an interactive game. This is a fundamental result because it means that children can treat a robot similarly to a human. Moreover, another innovative result of the study is the analyses of children justifications given to the Ultimatum Game. We observed that children tend to use justifications based on the outcome and not on the basis of mentalistic terms both for human and robot, showing how children behave like maximisers – according with the homo-oeconomicus theory – when they interact both with human and robot. In the human condition, children's justifications based on the 'outcome' given to the unfair divisions, both as a proponent and as a receiver, could be explained as the attempt to resolve a cognitive and social conflict (expected "social" fair behaviour VS real "selfish" behaviour). Moreover, in the robot condition, children's justifications based on mentalistic terms to unfair divisions, both as a proponent and as a receiver, can be explained as the social norms of equity might be less relevant (robot = "not perfectly like-me").

The literature review in Chapter 2 and the data of Chapter 3 represent an important finding for the HRI and cHRI because it is possible to infer that humans – from childhood to old age - tend to ascribe a mind to a robot and that besides 5-years-old children tend to treat a robot as social partner, using similar cognitive strategies both for human and for robot.

In conclusion, robots can be considered 'like-me' (Meltzoff, 2005, 2007a, 2007b, 2013) but it depends from: 1) the age of human partner interacting with a robot; 2) the methodological procedures, and particularly the nature offline (i.e., the AMS questionnaire used in Chapter 3) or online (i.e., the modified version of the Ultimatum Game used in Chapter 3) of the tasks employed; These final observations lead to reflect on the instruments used in research and this is even more important when the topic of research is new such as the HRI. In fact, it is essential to combine both offline and online measures, but also it is important use together ecological and laboratory tasks.

Can an object be a mediator and a promoter of the child-adult interaction also for autistic children?

We live in a social world composed by humans and objects. In the history of Psychology, the human-human interactions were largely investigated but few studies analysed the human-human interaction mediated by objects. In this regard, Piaget (1952, 1954) highlighted that children discover the world of the objects through a sensorimotor activity, which constitutes the basis of the cognitive development. Vygotskji (1962, 1978) showed that children with typical development use artefacts to interact with others, acquiring their knowledge about objects through the interaction with a scaffolder (peers or adults). Moreover, Moscovici (1976) examined the interpersonal relationships in a triadic perspective, highlighting that humans and objects are strictly connected. However, Linell (2009) proposed a dialogical interpretation of the objects, suggesting that it is important to understand the objects as external referent that can change human's perspective of the world. Several studies showed that an adult can be a scaffolder for the acquisition of the use of the objects in children with typical development (Moro, 2014). In Chapter 4 and 5 we demonstrated that also children with atypical development, in particular autistic children, can use the object to construct an intersubjectivity space during the interaction with the adult. The objects in these interactions acts as mediators of the child-adult interaction, creating a specific intersubjective space in which autistic children, despite their social impairments, are able of some social performances (i.e., ocular contact).

In Chapter 4 the results seem to demonstrate that the socio-material features of objects represent a key-element that mediates the construction of child-adult interactions, becoming a mediator and promoter of interpersonal activities and space. Chapter 5 shows a link between a better use of the object and the presence of social behaviors that emerge during the pre-operational stage, such as imitation and attention. However, it is important to highlight that the use of the object and the presence of social abilities largely vary in each autistic child because autism is a spectrum disorder that implies a wide range of phenotypes. Thus, the construction of intersubjectivity space has to consider the specific subjects of the interaction and their interpretation of the objects.

These findings lead to the conclusion that to understand how children with typical development interpret the use of the objects it is important that adults 'share' the child's perspective in order to create an intersubjective space. If it is crucial in typical development, then it becomes even more essential in atypical development, in particular in autism that is a spectrum of disorders that imply a different kind of impairments in several areas of development. In fact, the adult has to consider that each autistic child constructs the intersubjectivity space in a subjective way, using all her/his skills.

In general, both as regards typical and atypical development, the adult should accept that each artefact is always reinterpreted by the child in a triadic relationship through a continuous and dynamic construction of the intersubjectivity.

Conclusion

The majority of the psychological research is inspired by everyday experiences and so I will try to give some examples of the key points of this thesis, starting from my life.

I am writing my thesis using my computer right now and its battery is almost discharged. I am saying “Why you do this to me?”. Despite my prayers, my computer will switch off if I will not put it in charge. What does this situation mean? I am ascribing intentions to my computer, in particular the intentions to turn off itself.

I remind that in UK when I was learning how to use a robot, I was staying in the Lab hours and hours without talk to anybody and so I was starting to talk to the robot, ‘praying’ it to work in the right way. It obviously continued to not work and to not reply to my questions and prayers (fortunately!).

I bought a toy for a son of two friends of mine when he was 6-moths-old. Then these friends moved to USA and sometimes we Skyped, but I did not see them for a long time. This summer when I came back to my hometown, I saw them after three years and the child still had the toy and when the mother said him that I bought it for him he smiled and give me the toy to play together.

The above examples highlight the two main points of this thesis: 1) we can ascribe mental qualities also to objects that have not ‘really’ a mind because we tend to project our internal states onto the external world; 2) we are fully immerse in a world of objects that give us the opportunity to create an interaction with another person beyond the time.

To attempt a tentative conclusion, the purpose of this thesis was to show that when humans build objects - from the classic ones to the more technological ones - they also achieve two further important objectives: to facilitate social interactions and to create an intersubjectivity space that includes both human and non-human partners. I sincerely hope my efforts have at least partially succeeded.

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Materiality and the construction of Intersubjectivity: human-robot interaction In typical development and the use of the Objects in ASD children

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Chapter 1

General Introduction

*Una mente tutta logica è come un coltello tutto lama.
Fa sanguinare la mano che lo usa.*
(Rabindranath Tagore)

The aims of the present dissertation are to analyse, in children with typical and atypical development, the construction of the intersubjectivity through the use of objects in atypical development (ASD) and through the interaction with a humanoid robot in typical development. About the humanoid robots, the issue is to observe the possible attribution of human-like features to a robot that can make the human-robot interaction similar to the human-human interaction that is a classic intersubjective interaction because of the presence of two human subjects. This purpose is investigated considering two theoretical frameworks: 1) Theory of Mind that explain the construction of the intersubjectivity through the attribution of mental states to others; 2) Socio-material perspective which postulates that the construction of the intersubjectivity is mediated by objects in many cases. Thus, the question arises in this dissertation about the humanoid robot is: what happen when the mediator object (the robot) is also the interactive partner.

To achieve this purposes, the present thesis studies two main topics: 1) the interactional patterns with and the attribution of a mind to a robot by typically developing children; 2) the interactional patterns in atypical development - autistic children - in a child-adult interaction mediated by objects. The first topic is analysed in an innovative theoretical perspective and a through novel methodological approach, leading to an innovative understanding of the child-robot interaction. The theoretical perspective connects the role of Theory of Mind in HRI; the methodological approach observes children's decision-making strategies in the HRI, comparing these behavioural patterns when children interact with a human and with a robot. The second issue of the thesis is about the role of the object as mediator of the relationship between autistic children and adults. This is studied through the Socio-material perspective that hypothesised that material features of the objects and their intrinsic social qualities are strictly connected.

A useful psychological paradigm to investigate the construction of intersubjectivity is the Theory of Mind construct that will be briefly introduced; subsequently I will give an overview on Human-Robot

Interaction and, finally, I will conclude with some observations concerning the role of the objects in autism.

Theory of Mind or how understand the social world

Theory of Mind (ToM) represent one of the most important psychological constructs used in the last decades to interpret social interactions. ToM is the ability to understand one's own and other people's mental states (intentions, emotions, desires, beliefs), and to predict and interpret one's own and others' behaviours on the basis of such meta-representations (Premack and Woodruff, 1978; Wimmer and Perner, 1983; Perner and Wimmer, 1985). This definition highlights how the presence of the other is crucial for the comprehension of ourselves and for the interpretation of the relational world. The history of the ToM begins with the pioneering study of Premack and Woodruff (1978), titled "Does the Chimpanzee Have a Theory of Mind?". This study paved the way to study the ToM also in different agents, not only in humans but also in primates. They found that also the primates can use ToM ability to understand and predict the conspecific's and human's behaviours. These results allowed to study the ToM in an evolutionary perspective. In fact, Adolphs (2009) theorised about the phylogeny of social abilities, showing that our brain is a social brain that evolved from primates to humans.

Furthermore, developmental psychology study the changes that occur during children's development, showing the ontogenesis of this ability. ToM is not a monolithic construct, but it is a complex and multimodal ability that involved both cognitive and affective processes (Shamay-Tsoory & Aharon-Peretz, 2007; Kalbe et al., 2010).

Wellman (1991) hypothesised a ToM development from 3 to 7 years of age considering the understanding of mental states in the childhood. The author drawn a line of development: children in the early stage of development understand the non-epistemic states (desires, emotions and intentions) – between 3 and 4 years – and only late – between 4 and 7 years – the epistemic states. The epistemic states are the bases for the true and false belief understanding: this allows children to construct a meta-representation of their own and other's mind. Thus, considering the important of belief, in particular false belief, a pioneering study of Wimmer and Perner (1983) used for the first time the paradigm of the false belief task to study the ToM development. In this study the authors used the Unexpected Transfer Task in which a character has to ascribe a false belief of another character. The results showed that 4 - to 5 - year-old children can predict the actions of someone with a first order false beliefs referred to the first level of recursive thinking (i.e. "I think that you think"). These findings are supported by a meta-analytic study by Wellman, Cross and Watson (2001) that confirmed

that children begin to attribute a false belief starting from 4 years of age. In a second study Perner and Wimmer (1985) used a different task, the Ice-Cream Van, in order to analyse the second level of the recursive thinking (i.e. ‘I think that you think that she/he thinks’), that is the *second order false belief*. They found that 6- to 7- years-old children can understand this second level of representation. These findings show that the ‘sensible period’ for the emergence of the ToM is from 3 to 7 years of age and that it is acquired in a hierarchical way (Wellman, Cross and Watson, 2001). However, several studies show that the ToM is an ability that gradually develop from childhood to adulthood (Sommerville et al., 2013; Dumontheil et al., 2010; Apperly et al., 2012) and in the last years several studies investigate the modification of the ToM ability during the old age (Happé et al., 1998; Castelli et al., 2011; Saltzman et al., 2000).

Human-Robot Interaction: an interdisciplinary approach to investigate socio-cognitive abilities

“Human–Robot Interaction (HRI) is a field of study dedicated to understand, design, and evaluate robotic systems for use by or with humans” (Goodrich and Schultz, 2008, pp.1). The HRI derived from the Human-Computer Interaction (HCI) studies. The differences between HRI and HCI is that HRI uses robots that have physical human-like features (along a gradient from completely non-human like to a complete similarity with humans) and they can behave as humans (i.e., a robot can recognize and follow the eyes of a human or it can reply semi-autonomously to a human question). Thus, HRI not only implement behavioural patterns into robots but also design robots that can be perceived more human-like (Minato et al., 2004). In the last two decades HRI received more visibility especially related to the development of new theoretical approaches and technical skills in the robotics’ domain. For instance, in 2004 the Ishiguro’s Geminoid Project¹, in Japan, built androids which very closely resemble specific human “models” as a platform for research aimed at understanding humans, applying methods from engineering, cognitive science and neuroscience. Indeed, the robots can be used as a research tool in two different ways: 1) to use a robot in order to test human cognitive models, implementing algorithms that can simulate the human cognitive processes (Di Nuovo et al., 2013; De La Cruz et al., 2014; Whitaker, Colombo and Rand, 2018; Scassellati, 2003, 2005); 2) to use the robot as a possible partner in scenarios that implies the interaction with a human in order to observe social interactional patterns (Manzi, et al., 2018; Breazel et al., 2016; Moriguchi et al. 2011; Nishio et al., 2018; Sandoval et al., 2016). There are different theoretical approaches in HRI and in robotics; the

¹ For more information on the Geminoid Project: <http://www.geminoid.jp/en/index.html>

most interesting are: Developmental Robotics (Cangelosi and Schlesinger, 2015; Lungarella et al., 2003) and Developmental Cybernetics (Itakura 2008; Itakura, Okanda and Moriguchi, 2008).

Developmental Robotics is an emerging field of research that connects robotics, cognitive science and developmental sciences – in particular developmental psychology and developmental neuroscience (Di Nuovo et al., 2014; Di Nuovo et al., 2017). This field is focused on the implementation of robots that should be more autonomous, adaptable and sociable– the cognitive developmental studies are crucial in this respect – but to achieve this goal it is fundamental to employ models of human development in order to embed these models into robots. Thus, it is important the collaboration between engineers and developmental psychologists in order to design the models mentioned above (Asada et al., 2001; Lungarella et al., 2003). Developmental Robotics represents an innovative approach to the development of HRI: its statement is that robots can learn as children (Cangelosi and Schlesinger, 2015). Roboticians use algorithms, deriving from the Machine Learning field, to build cognitive models of psychological processes (Cangelosi and Riga, 2006; Cangelosi, 2010; Cangelosi et al., 2010). However, these models derive from the research in developmental psychology because it is fundamental to understand the trajectory of development of the psychological processes (i.e., ToM or linguistic development). Since robots should be social partners, Scassellati (1999, 2001, 2002) assumes that they have to possess a ToM. This is only a theoretical assumption because today technical innovation does not permit an implementation of a ToM into robots despite our knowledge about ToM development: an explanation is that ToM ability is a complex process that involves several cognitive and affective components.

Developmental Cybernetics connects Developmental Psychology and robotics, using the human development models in order to identify the most important behaviours that can promote HRI. This is the other side of the coin because, while the Developmental Robotics uses the models to make robots behave socially, Developmental Cybernetics studies which kind of behaviours should be implemented into robots in order to promote HRI. In particular, Developmental Cybernetics studies the development of social behaviour in infants in order to implement specific behaviours so that the robots can be treated as a companion. In the case of interactions between children and robots, we shift in the field of Child-Robot Interaction (often abbreviated as cHRI), which differs from HRI because the partner of the interaction, the child, presents an immature cognitive development (Belpame et al., 2013 a, b). cHRI is crucial for Developmental Cybernetics because of its futuristic hypotheses: in the next decades the robots can be introduced into human societies in different contexts among which the educational ones. In this case, the robots should be attractive for children: to reach this goal,

physical and behavioural characteristics should be more human-like. In 2018 one of the biggest Japanese educational projects introduces 500 humanoid robots (NAO robot, created by Aldebaran Robotics) in the Primary School in order to teach English to Japanese children². Moreover, several research programs use humanoid robots in different educational contexts (Chang et al., 2010; Belapme et al., 2016; Gordon et al., 2016; Kanda et al., 2007), highlighting, in a vygotskian approach, how robot can be use as scaffold. Developmental Cybernetics postulates that to build a social robot is important to study and to develop research knowledge about three main domains connected to the robot: Theory of Body (ToB), Theory of Communication (ToC) and Theory of Mind (ToM). The ToB hypothesises that a robot should move its arms, legs and head in a conventional mode. For instance, Morita and colleagues (2012) test children's and adults' reaction to conventional and unconventional movements of the body of a human and of a humanoid robot, showing that children extend their reaction to the unconventional movements both of human and humanoid robot respect to adults that are more activated when the unconventional movements are made by a humanoid robot. With regard to the domain of Theory of Communication, several studies show that an effective robot is a robot that can communicate in verbal and non-verbal way (Breazel at al., 2005; Brooks and Arkin, 2007; Mavridis, 2015). These researches generally highlight that a robot that can use non-verbal signals (i.e., facial expressions or gestures) to promote the human involvement in the interaction is perceived more as a companion than a robot that not communicate in such ways. For instance, Aaron and Mataric (2015) use a robot that communicate with a worker to achieve a goal, finding that the robot was perceived as a teammate more than a robot without communicative behaviours. The last, but not the least, domain of the Developmental Cybernetics is Theory of Mind: this is a crucial objective of Developmental Cybernetics because it hopes that in the future robots can interact in a way that can be perceived as having a mind. Nevertheless, as above mentioned, the implementation of ToM into robot is more a futuristic dream, while has been demonstrated that humans use their ToM ability to understand robots' behaviours. This a fundamental assumption that connects the different sections of this thesis. In fact, already Piaget (1929) uses the concept of animism suggesting that the human ability to ascribe intentionality to an object is an early infant's disposition. However, when we talk about robots, we refer to an animate object that appears and behaves in a human-like way. Thus, the ToM ability is a very useful psychological construct that can help to better to understand the human's tendency to ascribe mental states to a robot. In Chapter 1 it will be shown as humans, in a

² For more information is possible to access to the article by the following link:
https://rep.repubblica.it/pwa/generale/2018/09/24/news/giappone_robot_insegnano_inglese-207218720/?ref=RHRS-BH-I0-C6-P21-S1.6-T1

life-span perspective, tend to attribute minds to robots. Some research points out, in particular as regards childhood and adolescence, that the ascription of mental states changes with age (Manzi et al., 2017; Kahn et al., 2012). Chapter 2 shows that younger children tend to ascribe to robots more intentions and desires and less epistemic states than older children, in line with the ToM literature (Wellman, 2001). These findings highlight an important point for Developmental Cybernetics, and in general for developmental psychology, because they demonstrate that children perceive a robot as a partner that appear and behave like a human when they interact with it. Additionally, the children's ascription of a mind to a robot is the prerequisite for the establishment of the intersubjectivity. The concept of intersubjectivity captures the way a person understands and relates to another people and implies that exist a bridge between the knowledge of oneself and the one's own knowledge of others (Rochat, Passos-Ferreira and Salem, 2009). In the light of above, this is a crucial theoretical mark for the HRI because, if the intersubjectivity is the assumption of the interpersonal relationship in humans, the presence of this dimension in the human-robot interactions allows to interpret these interactions not only in a mere behavioural way but also in a relational way.

The use of the object in children's development: an overview on autism

The Autistic Spectrum Disorder (ASD) is a syndrome that can be characterized by an intellectual disability (DSM-5, 2013). The main symptoms of the ASD are: impairments in the social interaction (Baron-Cohen, 1997; Frith, 2003); impairments in the verbal and non-verbal communication (Mundy et al., 1987; Happé, 1995); stereotypical and repetitive behaviours, interests and activities (Bodfish et al., 2000; Boyd et al., 2010). Since ASD is a syndrome that affects all the psychological development, social and cognitive deficits are very heterogenous both for the complexity and severity of disease. These symptoms can emerge and change in different moment of development (Frith, 2003; Yirmiya and Charman, 2010). The repetitive behaviours and activities affect also the use of objects: some researchers report that this impairment can be detected already at 12 months of age (Ozonoff et al., 2008; McCleery et al., 2009). Ozonoff and colleagues (2008) found that 12-months-old children tend to use the object in a repetitive way. The use of the object needs to be studied from the sensorimotor development point of view because the object is present since the early stage of the children's development. More recently, several researches show that autistic children present atypical sensorimotor development and sensory perception that predicts the severity of symptoms especially in the area of communication at 24 months of age (Estes et al., 2015; Robertson and Baron-Cohen, 2017).

In the history of psychology, several psychologists studied the role of the object in the human development, such as Piaget, Vygotskji and Moscovici. Within his work, Piaget (1956; 1958; 1977) describes two different types of knowledge. The first type of knowledge origins through physical experience; such experience produces the knowledge of the properties of objects that are used. The second type of knowledge is gained through the logical-mathematical experience, which does not produce knowledge about the objects but about actions and their results. Thus, micro-genetic analysis, which aims to observe the temporal and qualitative aspects of the interactions, is a basic methodological condition for understanding the development of materiality. Despite this embryonic change of course the epistemological approach of Piaget remains anchored to the dualism of subject and reality.

Nevertheless Vygotskji (1962) uses another theoretical perspective: he considered the objects, named artefacts, as a fundamental component of human life. He suggests that humans use both material (i.e., a computer) and psychological (i.e., language) artefacts to interact. Adults use in a better way these artefacts and through their scaffolding 'teach' to children how to appropriately use them. In this respect, the artefacts represent human 'instruments' essential for the communication and interaction.

In these terms, the behaviour and the understanding of the processes of consciousness are closely dependent on the nature of the interaction of human and non-human components of this dialectic dyad. In the history of psychology, some the psychologists abandoned a dyadic approach in favour of a triadic perspective. The key aspect is no longer just the dyadic relationship, but what Moscovici (1976) defines triadic relationship. Moscovici proposes a ternary reading of facts and relations, and in fact replaces the two- term view, subject and object, with a three-term one: individual subject, social subject, and object. In other words, the Ego, the Other and the Object. This aspect assumes a constant exchange between the three elements of the triadic relationship. Such relationship may be conceived as static or dynamic, implying a simple "co-presence" or an "interaction" that can result in changes in thought and behaviour.

However, the theories presented above about the objects are based on a non-dialogical conception of the artefacts. In fact, Linell (2009) considers artefacts as external objects, according to a dialogical theory of the artefacts. The objects serve as anchoring points for intersubjectivity. Moreover, the author suggests that exist an interplay between the human ability of using artefacts and the external objects which possess a wide range of uses for humans. Thus, the objects are used by humans but also can change the humans perspective of the interactional world.

The objects are involved in several psychological mechanisms, such as joint attention and imitation that are largely studied in autism. The joint attention implicates at least the presence of two

partners and of an object that plays the role of the mediator of their interaction (Tomasello, 1995; Mundy and Gomes, 1998; Moore, Dunham and Dunham, 2014). Thus, the object is a protagonist of this human phenomenon, acquiring a crucial role in the interaction. Moreover, the studies on imitation distinguish between body gestures imitation and object actions imitation (Masur & Ritz, 1984; Snow, 1989), showing that the object is involved in the human development as a fundamental ‘non-living partner’ that has a role in a lot of psychological processes.

In the light of above, about children with typical development, the use of the object is a crucial element for the interactions (Rodriguez and Moreno, 2008; Barthélémy-Musso et al., 2013). In fact, Rodriguez and Moreno (2008) hypothesizes that children with typical development use the object in order to interact with adults: the adult has the role to teach to the child different uses of the object which, derive from the human society, Thus, the adult acquires the role of a scaffolder for the conventional use of the object (Moro, 2011, 2014). This approach is particularly interesting because the children and adult create an intersubjective space in which they can interact with each other through an object. Thus, the object is a mediator of the child-adult interaction. Moreover, as already highlighted in the previous paragraphs, the establishment of an intersubjectivity space is the basis of the of human interpersonal relationships.

In the view of the above, it is important to analyse the role of the object also in children with atypical development, in particular in autistic children because they present a distinctive pattern of interaction with the object (i.e., repetitive actions on the object) and are also characterized by social impairments which represent an obstacle for the establishment of interpersonal relationships. In fact, being social interaction impaired in autistic children is consequently impaired the interaction with the “social world of objects”. In the socio-material perspective (Iannaccone, 2015) the object is composed of material features and social components which coexisting the same object. Some autistic children show deficit in the use of the object: alterations in manipulation, observation, understanding and denomination. The object is a significant communicative mediator in social interaction between adults and children (Iannaccone, Savarese and Manzi, 2016). Thus, autistic children which do not present impairment in the use of the object show more social behaviours as pointing (Bernabei, Camaioni and Levi, 1998), imitation (Vanvuchelen et al., 2013) and joint attention (Mundy, 2016). For instance, joint attention is typified by subject-subject-object triangulation in which children alternate their eye gaze between the object and the other person (Trevvarthen and Hubley, 1978). In this respect, Chapter 3 and 4 deal with the role of the object as promoter of the child-adult interactions. Despite the identification of deficits in the expression of the most important early precursors for the social interaction, it has been observed that autistic children can use in specific ways the object that promote the intersubjectivity space. In Chapter 4 autistic children from 20 to 24

months of age exhibit specific sensorimotor patterns of use of objects (manipulation and exploration) that tend to involve the other partner – adults – to interact with the objects. Thus, also in the case of autistic children the object is a mediator of the relation with the adult. Moreover, Chapter 4 points out that autistic children that present a more complex and rhythmic patterns of interaction with the object present more social behaviours (i.e., joint attention and imitative actions).

These findings reveal the ability of autistic children to establish an intersubjectivity space, using the object as mediator of interactions with adults despite the evident social impairments that characterize this syndrome.

This Thesis

Chapter 1 is a review of the literature about the role of the Theory of Mind (ToM) in the Human-Robot Interaction (HRI) in a life-span perspective, showing that from the childhood to the adulthood humans can ascribe a mind to a robot, in particular to a humanoid robot. The HRI is analysed in two main domains: 1) mental states and actions; 2) physical human-like features. The first area highlights that a robot which behave like a human and use human-like cognitive processes promotes the attribution of a mind to a robot. Already in infancy some behaviours (i.e., eye-contact and goal directed actions) promote a better children's social involvement during the interaction with a robot. The robot human-likeness is effective in a life-span perspective. Moreover, the implementation of robots' human-like physical features (i.e. eyes, hands, legs etc) is a crucial goal for the promotion of a more complex human-robot interaction. However, it is also important for a robot to not be completely similar to a human since the risk of a perfect human-like appearance is the Uncanny Valley effect (Mori, 1970), in which the excessive similarity of a robot with humans can reduce the interaction. The main hypothesis is that through these technical innovations, concerning physical and behavioural features of a robot, humans construct an intersubjectivity space with a robot. This is possible because the recognition of a mind in a robot is the prerequisite because humans perceived it as social partner.

Chapter 2 is focuses on pre-schoolers' behaviour during the Ultimatum Game when they play with a human and a robot. In particular the study aims at analysing: the mental characteristics ascribed to the robot with respect to the human; children's behaviour at the UG when playing with the human and with the robot as proposers and receivers; children's justifications for their behaviour during the UG. To my knowledge, this is the first study which analyses children's behaviour during the UG, comparing human-human and human-robot interaction. In this respect, several tasks and tests were created *ad hoc*: 1) the Attribution of Mental State Scale (AMS) is a measure of mental states attribution that the child has to perform looking at pictures depicting a character; 2) to assess children's understanding of the first-order false belief, we introduced a new instrument, constituted by eight videos representing the classical story, introducing also the Robovie as a new character - we used a story similar to the classical *Unexpected Transfer* task as the script of the videos. The AMS results show that 5-year-old children recognize the robot as a different entity from the human. In fact, children ascribe mental states also to the robot, but they are different compared to the mental states attribute to the human. Nevertheless, children behaved similarly during the UG when playing with the human and with the robot, confirming a tendency to maximize gain. Additionally, children's

justifications at the UG showed that, independently on the interactive agent and on the role played (Proposer/Receiver), children tend to use ‘outcome’-based justifications to explain their behaviour for all divisions. This is the first qualitative evidence supporting the idea that, at the age considered, children mostly reason in economic/quantitative, homo-oeconomicus-like, terms. The almost total lack of equity and mentalization-based justifications of human unfair divisions further suggests an attempt of children to resolve a social cognitive conflict emerging from the discrepancy between a “socially-expected” fair behaviour and the actual “selfish” behaviour.

Chapter 3 presents an explorative study aimed at observing the quality of interactional patterns in child-adult interaction, using objects as key elements for the construction of intersubjectivity. This qualitative research is based on two theoretical perspectives: 1) Piaget's studies (1952, 1954), according to which children reach the conceptualization skills of objects in the fifth phase of the sensory-motor development; 2) studies that concern the canonical use of the objects, according to which the canonical functions of the objects are acquired as a normative phenomenon during social interactions (Tomasello, 2016), even if the cognitive understanding of these functions is a prerequisite. Several other studies show that canonical functions of the objects are acquired during child-adult interactions (Leontiev, 1981; Costall, 1997; Moro, 2011, 2014; Rodríguez & Moro, 1998; Sinha & Rodríguez, 2008). In this Chapter it will be analysed the manipulation of objects by children with autism spectrum disorder with the aim of showing how objects can be considered as active agents of interpersonal exchange between children and adults. The study adopts a socio-material interpretation, assuming that some interactional patterns, involving the manipulation of objects, can create a space that supports the child-adult relationship. The observations highlight that children present sensorial and realistic play and there are some children's behaviours (i.e., eye-contact) that show that the objects are concrete mediators for the construction of the intersubjective space in the interactions between children and adults. It has been observed in this study that children monitor adults' attention through eye contact or object manipulation. These actions are signs that the object becomes a mediator of mutual attention between the adult and the child: we called this kind of attention, “attention mediated by the object”.

Chapter 4 presents a brief report that investigates the role of the object as a factor that mediates the interaction between children and adults. We observed a group of autistic children in order to analyse if an object can be a promoter of social interactional functions: imitation, joint attention and pointing. The main focus of the study is to analyze in verbal ASD the understanding of social function intrinsic in the object through the use of material features of the object. In particular, the study evaluates the

relationship between the “interaction with/through object” (material features of the object) and three social functions classically impaired in ASD: pointing, imitation and joint attention. We observed a group of ASD children aged between the ending of the sensory-motor stage (24 months) and the beginning of the concrete operational stage (68 months). The group has been split in two sub-groups: group1 is composed of 18 children that act and interact through objects (for examples, balls, cars etc.). Indeed, children manipulate, observe, understand and sometimes give a definition of the object; group2 is composed of 25 children that do not act and interact through and with object. Group 1 shows more social functions (pointing, imitation and joint attention) than group 2 Autistic children which show a more complex use of the material features of the object and act and interact with and through object present more social functions. On the other hand, children which have alteration in the use of the object show fewer social functions. These differences depend on the children’s characteristics. In this study, the role of the object is a crucial element for the creation of the intersubjective space.

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Chapter 2

Theory of Mind and Humanoid Robots From a Lifespan Perspective

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Abstract

This mini-review focuses on some relevant issues concerning the relationship between Theory of Mind and humanoid robots. Humanoid robots are employed in different everyday-life contexts, so it seems relevant to question whether the relationships between human beings and humanoids can be characterized by a mode of interaction typical of the relationships between human beings, i.e., the attribution of mental states. Since Theory of Mind development continuously undergoes changes, from early childhood to late adulthood, a lifespan perspective was adopted. Contributions from the literature were analyzed by organizing them around the partition between ‘mental states and actions’ and ‘human-like features’. Finally, we considered the contribution that studying the human-robot interaction, within the paradigm of Theory of Mind, can give to the understanding of the intersubjective nature of this interaction.

Introduction

This contribution progresses from Turkle's (2004) opinion, which, reflecting on Steven Spielberg's movie, *AI*, exemplifies the most exquisite socio-relational issues of human–robot interaction:

. . .[S]cientists build a humanoid robot, David, who is programmed to love. David expresses this love to a woman who has adopted him as her child. In the discussion that followed the release of the film, emphasis usually fell on the question of whether such a robot could really be developed. People thereby passed over a deeper question. ... That question concerns...[w]hat kinds of people are we becoming as we develop more and more intimate relationships with machines? Today, we are faced with relational artifacts to which people respond in ways that have much in common with the mother in *A.I.* (p. 25).

For hundreds of years, the interest in human–robot interaction has occupied a space in the cultural productions of humankind. Today, we are witnessing a renewed interest in the human creation of a nonhuman alter ego. In particular, researchers are focusing their interest on social interactions with robots. Many scholars believe that a fundamental component of social interaction is the Theory of Mind (ToM; Wimmer & Perner, 1983). ToM is the ability to predict and interpret our own, and others', behavior on the basis of mental states. Herein we offer an overview of work that has focused on the study of human–robot interaction, in the context of ToM. In particular, we review studies investigating the attribution of mental states to robots in a lifespan perspective.

Without the claim of being chronologically exhaustive, we provide some examples of the pervasive interest in artificial partners in the history of humanity. Homer (2003), in the *Iliad* (XVIII, 573–579), told how Hephaestus, the god of fire, who needed help in his forges, built aides, similar to young men, who had hearts, voices, and life. Discussion of the more-or-less human characteristics of intelligent manmade machines has its most famous philosophical roots in the 17th and 18th centuries, in the debate around the works of Descartes and La Mettrie (Gunderson, 1964). Descartes equates animals with machines, but ascribes uniqueness to humans via the term, *cogito* (I think). On the contrary, La Mettrie extends the animal-machine analogy to humans, radicalizing the materialistic and mechanistic perspective.

The mechanical automaton was an attempt to build a human-like artifact, capable of replicating and repeating human activity. In the 13th century, Al-Jazari, an Arabic mechanical engineer, built a programmable device capable of playing sounds autonomously (Nadarajan, 2007). In the 15th

century, Leonardo da Vinci not only theorized on the possible robotic reproduction of an animal, but also advanced a project that attempted to mechanize the human being, with the mechanical knight of 1495 (Rosheim, 2006; Taddei, 2007).

A crucial qualitative leap into the anthropomorphization of machines is to ask whether robots can think, overcoming Cartesian dualism: the philosophical concept that asserts the existence of a separation between *res cogitans* and *res extensa* (i.e., respectively the mind and the body). From a psychological, and more intersubjective³, point of view, and for the purpose of this review, we can rephrase the question as: when will robots be able to make humans believe that they are human? In 1950, Turing published a seminal paper in which he imagined an imitation game with three participants. An interrogator asked questions of the other two participants and, based on the answers, had to guess who was a man and who was a woman. Then, without warning the interrogator, a computer would replace one of the participants. How long would it take to understand that the answers came from a machine, and not from a human being? According to Turing, during the imitation game, it would become increasingly difficult to distinguish the responses of a machine from those of a human (Turing, 1950).

Artistic creativity often anticipates scientific topics on the history of thought. There are many examples in literature and cinema about our subject. Let us remember Shelley (1830/1994), proposing the literary character of Frankenstein, or The Modern Prometheus⁴, destined for a much greater degree of notoriety thanks to the story's many cinematic adaptations. It is also worth mentioning Asimov (1983), who revisited the futuristic concept of a robot by conceiving it as a potential partner for supporting/replacing human activities.

³ The concept of intersubjectivity has various definitions, each of them highlighting different aspects: cognitive, affective, socio-cognitive. The various definitions have in common the idea that the meaning of the tasks and events that the person builds during development is not an operation in solitude but is the result of interaction with real or symbolic partners.

⁴ The story shows the human desire to create an immortal alter ego. The created alter ego turns out to be a monster. Dramatic events lead to the death of the monster's creator and then the monster itself. The monster suicides, explaining the evil deeds it has done while living with the contempt and rejection by humans. The fascination of this story consists in shaping the fears of both partners in this relationship.

Cinema has also represented – now as utopia, now as dystopia – the complexity of the robot’s relationship with humanoids. Fritz Lang’s *Metropolis* (1927) was the first movie to foreshadow the possibility that a robot could substitute for man in the hardest jobs, and that it could begin to interact with man in ways that went beyond any designed intentionality.

The iconic film *Blade Runner* (1982), drawing inspiration from Philip K. Dick’s *Do androids dream of electric sheep?* (1968), highlighted the risk of indistinguishability between

the creator of humanoids and his “children.” Freud (1919/1955) described the characteristics of a particular psychic experience with the experience of the “Perturbant” (*Unheimlich*-unfamiliar vs. *Heimlich*-familiar). Jentsch (1906, 1997) had already described this experience in relation to, for example, puppets and automatons. The latter consist of the uncertainty that a seemingly inanimate being is alive and, in a complementary way, that a living subject has the chance to be inanimate.

This phenomenon reappears in more recent literature as the “Uncanny Valley” experience. Mori (1970) described the sense of repulsion that can accompany interaction with humanoids whose appearance resembles, without being overly superimposed, that of a human (see also Mori, MacDorman, & Kageki, 2012). Another facet of the possible human–robot relationship worth mentioning is the one proposed by Spike Jonze’s *Her* (2013). The protagonist lives a true love story with an almost completely disincarnated artificial intelligence that manifests itself through a very sensual voice. Alongside this experience, the growing presence of anthropomorphic robots in everyday life, in educational, production, and welfare settings, raises several new issues – philosophical, ethical, political, economic, legal, and insurance⁵. While the anxiety about replacing men with robots in production situations, with the associated risk of unemployment and impoverishment, is not new, more recent discussions are about the status of robots, with respect to the new aforementioned issues (Floridi, 2017; Floridi & Sanders, 2004; see also the European Parliament Resolution of 16 February 2017).

In the case of robot-building for social purposes⁶, the extraordinary human capacity to invent and realize tools that integrate and expand the biologically-based abilities of our species (from work tools

⁵ To give just a few examples, think of the use of robots for assistance and companionship to the elderly, the educational and didactic use with children with typical and atypical development, and the execution of various activities in shopping centers, airports, and so forth.

⁶ The military is another area that makes extensive use of robotic engineering (just think of the recent massive use of drones in war). Although the psychological implications are multiple (attribution of responsibility, reliability of information, trust, etc.), we do not consider this field because there is no possibility of attributing mental states to the robot.

to sensory aids to external memory of electronic devices) has been driven in two directions. The first direction – developmental cybernetics (Itakura, 2008; Itakura, Okanda, & Moriguchi, 2008) – consists of creating a human-like system, with cognitive function (simulating psychological processes in the robot) and prosthetic functions (enhancing the function and life-style of persons). The second direction – developmental robotics – consists of the idea that robots can autonomously gain sensorimotor and mental capabilities with growing complexity, starting from intricate evolutionary principles (Cangelosi & Schlesinger, 2015). To date, developmental cybernetics aims to build robots that behave in a human-like way, while developmental robotics aims to build robots that develop in a human-like way. Based on these features, the two approaches are located at different points on a continuum that links interaction and relationship. Developmental cybernetics is closer to the relational dimension; in fact, it studies those human–robot exchanges in which the assumption of some form of subjectivity of the partners is involved. Let us think, for example, about the educational and welfare uses of intelligent machines, in which the dynamics associated with the use of prosthetic tools that improve quality of life are placed on the level of *hic et nunc* (here and now) interaction, without aiming at the construction of a relational story. Conversely, socio-relational dynamics value the level of the relationship (Gross et al., 2012; Tanaka, Cicourel, & Movellan, 2007). Developmental robotics is closer to the interactive dimension; it uses the interaction to study how a robot can develop new abilities, in a child-like fashion. For instance, consider the attempts at robotics modeling of the stages of language acquisition (Morse & Cangelosi, 2017), and the use of mutual imitation between humans and robots to promote the robot’s subsequent recognition of an interactive agent (Boucenna, Cohen, Meltzoff, Gaussier, & Chetouani, 2016).

We are interested in understanding how the attribution of mental states to robots evolves through the lifespan; therefore, we primarily analyze the studies conducted in the field of developmental cybernetics.

Why Robots Could Be Intended as Social Partners

From a psychological point of view, from the earliest moments and throughout one’s entire life, the possibility of establishing social exchanges involves the ability to recognize the other as being “like me” (Meltzoff, 2005; Meltzoff, 2007a, 2007b; Meltzoff, 2013; Meltzoff & Brooks, 2001). Infants can imitate facial movements, such as mouth opening and tongue protrusion (Meltzoff & Moore, 1977, 1983, 1989), and have visual acuity for human faces and stimuli, with characteristics similar to themselves (Johnson, Dziurawiec, Ellis, & Morton, 1991). Proto-conversations with the caregiver

root in these innate imitative mechanisms and, overall, the analysis of traits and characteristics of the relational partner contribute to building the intersubjective dimension underlying so many developmental acquisitions (Meltzoff, 2005; Meltzoff, 2007a, 2007b; Meltzoff, 2013). For this purpose, Trevarthen (1998) spoke of an innate specific human endowment that would guide us to the search for companionship, and put us in the condition of “understanding and using the intentions of other people in conversational talks of intentions, emotions, experiences, and meaning” (p. 16). According to Tronick, Als, Adamson, Wise, and Brazelton (1978), human beings experience the world in intersubjective terms. This trend is related to the tendency of children to first experience the world as if it were animated, and to make a distinction between animate and inanimate only later. This tendency is operationalized by the “still face” paradigm: the motionless face of the caregiver generates in the child a series of emotions from perplexity to anxiety, showing the infant’s expectation to interact with a human partner with an expressive, and therefore animated, face.

A fundamental question, therefore, is: what can the developmental research on human–robot interaction teach us about aspects, features, and cues that a robotic interactive partner must have to be recognized as “like-me?” This question has an epistemological basis. In fact, human–robot interaction represents a “technological gym” that specifies the social cues that must be implemented in a humanoid robot so that children of different ages recognize it and treat it as a social partner.

Below, we analyze contributions from the literature to the lifespan perspective in this regard, by organizing them around “mental states and actions” and “human-like features.” This division arises from the consideration that a representational ToM derives from the infants’ early understanding of the bodily cues of the mental states. In other words, the bodily roots of ToM remain through the lifespan, as the basis of more advanced representational mentalistic skills.

Mental States and Actions

Regarding the first element of the division that we set as the basis of robot attributions of features “like-me,” the research examines aspects of robotic actions that lead participants to believe that the actions imply mental states.

In this sense, a seminal study by Meltzoff (1995) investigated the reenactment of intended acts, performed by human beings versus robot-like devices, in a group of 18-month-old infants. An emerging sense of the person is revealed by the fact that infants did not reenact the action performed by the robot-like device, probably because they did not recognize its intentions and goals.

Itakura, Ishida, et al. (2008) studied this topic further, in children aged 24–35 months, and showed that the children were inclined to imitate goal-directed actions where the goal is not achieved; these failed actions implemented by a robot were imitated only when the robot's action was preceded by eye contact between the robot and an adult present at the scene. When the robot's eye contact with the adult was missing, the child did not mimic the robot's behavior. According to the authors, this evidence shows that it is not human-like morphology, but rather human-like behavior, through eye contact, that plays an important role in inducing children to imitate the goal-directed behavior of a nonhuman agent.

The theme of imitation of goal-directed actions relates to research on mirror neurons⁷, which seem to play an important role in understanding others' actions and, more generally, in social competence. On this basis, Moriguchi, Matsunaka, Itakura, and Hiraki (2012) initially elaborated that the actions are somehow related to perception, and that many human brain areas devoted to the execution of actions also function by observing other human actions, rather than robotic actions. The authors then built on this evidence through a research paradigm verifying whether, and how, actions taken by a human arm or a mechanical arm may somehow interfere with the child's search for an object. A human arm and a mechanical arm sought and found an object in position A. The object was then moved to position B. The child who was asked to look for the object attributed a kind of "retrospective trust" to the human arm, compared to the mechanical arm; in fact, the number of errors committed in the search for the object was higher when the human action preceded the search. The same result had already been obtained in a group of 3-year-olds (Moriguchi, Kanda, Ishiguro, & Itakura, 2010), suggesting that the presence of a mental simulation mechanism would only be activated when the children imitated human actions.

Okumura, Kanakogi, Kanda, Ishiguro, and Itakura (2013a) confirmed this in a paradigm that verified the ability to anticipate the appearance of an object, using the information from a human gaze, rather than a robotic gaze. Through the use of an eye tracker, gaze-following and object anticipation were measured in two groups of 10- and 12-month-old children. Both groups let themselves be guided by

⁷ The mirror neurons are a subset of neurons in the human brain that respond when an individual performs certain actions, and also when the same individual observes others performing the same movements. In other words, actions performed by one person can activate motor pathways in another's brain responsible for performing the same action. Mirror neurons, or mirror mechanism, provide a direct internal experience, and therefore understanding, of another person's act, intention, or emotion. Mirror neurons may also underlie the ability to imitate another's action, and thereby learn, making the mirror mechanism a bridge between individual brains for communication and connection on multiple levels (Rizzolatti, Fogassi, & Gallese 2006).

the human gaze and the robotic gaze; however, only the human gaze had an anticipation effect, and only for the 12-month-old children.

In the context of studies that analyze the importance of the perception of biological motion as the precursor of ToM (Frith & Frith, 1999), Breazeal et al. (2016) considered a group of 3- and 5-year-old children. Note that the ability to use a robotic informant with epistemic aims (name exotic, non-familiar animals for children) is strongly influenced by the nonverbal contingency of the informant (head movements, gaze shifts, arm movements, and facial movements) typical of human face-to-face interactions. From this perspective, Carter and Pelphrey (2006) explored, with functional Magnetic Resonance Imaging (fMRI), neural activations, corresponding to the perception of the movement of four different agents – human, robot, mechanical assembly, and grandfather clock – in 7- to 10-year-old children. The results showed different activations, according to the human-like nature of the perceived biological movement, that is, a motion made by a human or a robot. This brain network also included some components of the mirror neuron system. Replicating the evidence obtained on adults, these findings show that some portions of the neural circuit involved in the embodied simulation are recruited in the perception of the biological movement also enacted by a robot.

We now shift from studies that analyze indirect indicators of the attribution of human-like features to studies that explicitly analyze this attribution. Kahn et al. (2012) interviewed children aged 9, 12, and 15 years, and evaluated the attribution of social, mental, and moral features to robots previously observed in nine different interactive situations with the subject and the experimenter. The authors found an interesting developmental trend: 9- and 12-year-olds perceived the robotic partner as a more mental, social, and partially moral entity than did the 15-year-olds. Therefore, in the construction of robotic partners suitable for participants of preadolescent age, with different purposes (from play to education), it is important to analyze, in detail, what interactive features are strengthened, so that the robot is perceived as the holder of mental, social, and moral characteristics, even by teenagers. Similar results regarding the attribution of mentalistic features to robots, following the observation of goal-directed actions, were obtained using a semi-structured interview of participants aged between 5 and 16 years (Beran, Ramirez-Serrano, Kuzyk, Fior, & Nugent, 2011). The participants tended to attribute behavioral, cognitive, and affective features to robots observed in the execution of a block-stacking task, a construction game in which the robot stacked blocks of wood to form two towers. In carrying out these activities, the robot manifested autonomy through a series of behaviors, such as looking at the child's face, performing accidental actions, and so on. Reminiscent of Piagetian animism, there was also an effect of age such that younger children (under 12 years of age), more

than the older children, believed that robots possess a large number of human attributes (Piaget, 1954).

Chaminade et al. (2010) used behavioral and fMRI methods to explore emotion depiction (anger, joy, and disgust) in gestures acted by human beings and humanoid robots in a sample of young adults. Results showed higher emotion ratings for anger and disgust expressed by the human; no differences were found for joy. Neural evidence suggested less empathy from viewing the humanoid robot: in fact, the activation of the left anterior insula (perception of disgust) and the orbitofrontal cortex (perception of anger) was lower for robot stimuli than for human stimuli. Finally, the higher activation in the occipital and posterior temporal cortices with robot versus human stimuli probably arose from the additional visual processing linked to the perception of a behavior acted by the humanoid robot.

An ingenious way to look directly at the interaction between human and robot is to use economic interactive games. One of the most used interactive games is the Ultimatum Game: one player (responder) receives a monetary offer from another player (proposer), who has to divide the amount. The responder has the option of accepting or rejecting the offer. If the responder accepts the offer, the two participants split the sum of money; however, if the responder rejects the offer, both players receive nothing (Güth, Schmittberger, & Schwarze, 1982). Nishio, Ogawa, Kanakogi, Itakura, and Ishiguro (2012) had young adults play the Ultimatum Game with a robotic partner. Results showed that fairness-oriented behavior increased when “mentalizing stimuli” accompanied cues from the physical appearance of the robotic partner, such as the expression of utterances between experimental sessions (see also Castelli, Massaro, Sanfey, & Marchetti, 2010, for results in a sample of children with a human and a nonhuman partner).

Ultimately, the works presented in this section show that children and adults perceive an experience with an artificial partner as social when the artificial partner can express intentions and goals through behavioral cues that are typical of interactions among humans.

Human-Like Features

With regard to “human-like features,” the research focuses on the configuration of body features being indispensable to humanoid anthropomorphization. It seems that, very soon, human beings will be able to relate to robots according to a principle of similarity to themselves. A first question is

whether biological and psychological characteristics are attributed to robots similarly or differently from other living organisms, and other material entities. Kamewari, Kato, Kanda, Ishiguro, and Hiraki, (2005) showed that 6.5-month-old infants exhibited the ability to attribute agency to human and humanoid-robot motions, but not to a robot without a human-like appearance. A sophisticated teleological representation is assumed in interpreting actions during the early stages of an infant's life, insofar as the agents are human-like. This first result is strengthened by two studies that take into account two human features considered crucial in characterizing one's social nature – eyes and voice.

The first study by Okumura et al. (2013a) showed that the presence of eyes in a robot is crucial for 12-month-old children to have their attention directed by the movement of a robot. In fact, when a robot without eyes was set in motion, this movement was not as informative to the child. The authors interpreted this result by assuming that the presence of eyes was a crucial indicator for the attribution of a mind at this age. The second study by Okumura, Kanakogi, Kanda, Ishiguro, and Itakura (2013b) showed that, for children aged 12 months, the gaze of a robot can be effectively used to learn an object if it is accompanied by a verbalization (not a simple nonverbal sound).

Moving from the preverbal to the verbal age, results obtained by directly questioning the participants about the characteristics of the robots are consistent with the early propensity to attribute human-like characteristics to humanoids. With development, other elements, in addition to the look, become important in deciding whether a partner has human-like characteristics. Katayama, Katayama, Kitazaki, and Itakura (2010) compared humans, robots, animals, and cultural artifacts to study the possible recognition of biological and psychological features in robots by children aged 5 and 6 years, and by adults. While the adults' attributions were quite heterogeneous, both 5- and 6 year-olds attributed a variety of biological but not mentalistic features to robots. Somanader, Saylor, and Levin (2011) asked a sample of 4- and 5-year-olds about the presence of representational, biological and mechanical characteristics in a human being, and in cultural artifacts (i.e., a robot and a TV). They found that the children attributed more representational and biological features to the human being than to the cultural artifacts, and to the robot more than to the TV. They also found that such attributions were more likely to be given to the robot if they did not see that the robot was controlled by a remote. These data reverse the trend found in a previous study, by Saylor, Somanader, Levin, and Kawamura (2010), in which robots and other familiar artifacts, including a TV, were classified as the same thing in terms of biological and representational properties. The authors assumed that the difference between the results of the two studies was due to their efforts to formally anthropomorphize the robots.

Manzi et al. (2017) explored the mentalistic value of faces in anthropomorphic agents compared to human faces through a dichotomous morphing, or gradient, of progressive anthropomorphism. The authors showed that 7- and 9-year-old children ascribed more mental state (e.g., sensory, perceptive, emotive, will, imaginative, and epistemic attributes) to the human face than to a robotic face.

Fiore et al. (2013) explored which elements contributed to creating an impression of the social presence of an agent in a group of late teenagers. To this end, they analyzed the way human beings interpret social cues exhibited by robots, in terms of proxemic behavior (the distance that the robot travels within the human's space). This was investigated by placing the robot and the participant in a hallway-crossing scenario. In this scenario, the authors varied the level of proximity the robot would permit the human in establishing whether to cross paths, and if the robot waited until the participant had passed. The authors also measured the role of the gaze, performed at three levels of direction (congruent with the robot's movement, human-oriented, and variable). The results showed that the robot that waited until the participant passed was evaluated as an agent more socially present than the robot that crossed the path without waiting. Furthermore, gaze did not play a significant role as a social cue in this situation.

Krach et al. (2008) explored human-robot interaction with a group of young adults, using the interactive game the Prisoner's Dilemma and fMRI. In the game, two players must decide whether to cooperate with each other or defect. They may gain a defined sum of points, depending on their own, and their counterpart's decision. A unilateral win is maximized by defection, if the counterpart cooperates, but both players are punished if they defect. Relying on mutual cooperation involves the risk of being deceived. In this study, the game included four different partners, each with an increasing level of anthropomorphization (computer, functional robot, anthropomorphic robot, human). Anthropomorphization was operationalized by following Epley, Waytz, and Cacioppo (2007), who included cues relating explicitly to physical aspects and mental states (elicited agent knowledge, effectiveness motivation). Participants were asked to evaluate the game partner for fun, intelligence, competitiveness, and sympathy. Results showed a linearly increasing attribution of fun and intelligence as the partner appeared more human-like. Interestingly, the anthropomorphic robot and the human were perceived as equally competitive, and more competitive than the computer and the functional robot. Moreover, the authors of the study pointed out that higher levels of human-likeness

were positively correlated with a greater activation of the ToM network, that is, the brain areas⁸ that the literature has shown to be specifically recruited when people interact with a social partner.

Takahashi et al. (2014) focused on the neural bases of human–robot interaction when participants were involved in an economic interactive game (Matching Pennies) with several partners: human, human-like android, mechanical robot, interactive robot, and a computer. The game was played between two players: a participant and an opponent. They had to press a button corresponding to the left or the right side of their bodies. The win situation was reached only when the same side was selected by both participant and opponent. The partners were evaluated concerning two dimensions: mind-holderness (having mental functions) and mind-readerness (being intelligent). As predicted by game theory, the more robotic partners were thought to be mind-readers the more the human opponents changed their play strategies, increasing the level of entropy of exchanges through random choices. fMRI data showed the involvement of different subsets of the social brain, according to the attribution of mind-holderness (dorsal aspect of the temporoparietal junction, medial prefrontal and posterior paracingulate cortices) or mind-readerness (ventral temporoparietal junction and the temporal pole).

Broadbent et al. (2013) studied how the facial characteristics of a robot may influence recognition of the robot's qualities, such as mind, personality, and eeriness, using a sample of young adults involved in a simulated healthcare environment. They employed three robots, respectively showing lack of face, silver face, and human face. The results showed a clear preference for the robot with the human-like face, which was rated as having the most mind and personality, and the lowest eeriness. This specific result relates to the uncanny valley, demonstrating just how subtle the boundary is between a pleasant likeness to the human and a disquieting one.

Similarly, Martini, Gonzalez, and Wiese (2016) studied whether specific degrees of humanness were needed to attribute different typologies of internal states to non–human agents. Interestingly, they found that the threshold “having a mind” must be reached, before being able to ascribe any other kind of internal state. The more the non–human face resembled that of a human, the more this threshold was overcome.

⁸ The ToM network includes the medial prefrontal cortex (mPFC), parts of precuneus and posterior cingulate cortex, the temporoparietal junction (TPJ), the posterior superior temporal sulcus (pSTS) bilaterally; some studies also include the bilateral anterior temporal lobes and areas in the amygdala (Schurz, Radua, Aichhorn, Richlan, & Perner, 2014).

Considering the studies reviewed so far, it is useful to emphasize the great importance given to the face and eyes when considering the physical features capable of representing an agent in anthropomorphic terms. This evidence confirms the great amount of data from ethology, evolutionary psychology, and even studies of aesthetic perception, in support of the great power of the human face in creating a sense of social interaction (Brooks & Meltzoff, 2005; Call & Carpenter, 2001; Emery, 2000; Itakura, Agnetta, Hare, & Tomasello, 1999; Massaro et al., 2012; Moore & Corkum, 1998; Morales, Mundy, & Rojas, 1998; Savazzi et al., 2014; Slaughter & McConnell, 2003; Tomasello, Hare, & Fogleman, 2001; Tomasello, Hare, Lehmann, & Call, 2007).

In conclusion, the information presented in this section shows that interaction with artificial agents is more preferred, and perceived as human-like, when the artificial agent presents aesthetic features that reproduce those of humans, with particular relevance to face and gaze.

Human Beings and Robots: Preliminary Steps Toward Intersubjectivity

The studies reviewed identify features pertaining to mentalizing cues and physical appearance as important bases of the “like me” experience with humanoids. Recent research also suggests that Meltzoff’s (2007a, 2013) “like me” framework can be extended to encompass other dimensions on which human perceivers make “like me” attributions. These dimensions pertain to the nature of the interaction, and other, deeper factors that are just beginning to be explored. A minority of studies delineates an emerging trend of research in this field. These are investigations across the lifespan that consider the role of attitudes and expectations of the human partner, involved in different interactive contexts, in determining preferences and acceptance of the humanoid partner.

Meltzoff, Brooks, Shon, and Rao (2010) explored the hypothesis that 18-month-old infants may use information gained from observing human–robot interactions as evidence about whether the robot is a perceiver. The results showed that the infants attributed mind to the robot, based on the socially-communicative interactions the robot engaged in. This study also demonstrated that the nature of the interaction, and not only the robot’s behavior, mattered.

Tanaka et al. (2007) studied the relationship between 18- to 24-month-old children and a robot, through a long-life immersion technique (45 sessions of approximately 50 min each, spanning 5 months, in the children’s play area). One of the great problems of human–robot interaction is the

duration; long-term study is difficult. Children tire, even though they initially have great interest. The experiment aimed to verify relationship tenure for a time longer than the 10-hr barrier, comparing the employment of a robot able to manifest an entire repertoire of behavior (walking, head- moving, dancing, sitting down, standing up, lying down, hand gesturing, and giggling) to a robot able to manifest only predictable behavior. The relationship improved when the robot was programmed to manifest the entire repertoire of behaviors (27 sessions), worsened when the robot exhibited predictable behavior (15 sessions), and improved again when the robot began to manifest its entire repertoire. The development of socialization strategies correlated positively with frequency of contact with the robot.

Contextualizing the relationship in an educational setting, Movellan, Eckhardt, Virnes, and Rodriguez (2009) showed that interaction between 18- to 24-month-old toddlers and a low-cost sociable robot in an Early Childhood Education Center can significantly enhance word-learning. This evidence is promising, in view of the use of these humanoids with educational and didactic purposes, based on the intersubjective sharing of significant goal-oriented activities. Similarly, Tanaka and Matsuzoe (2012) employed a care-receiving robot to support foreign language learning in 3- to 6-year-old children. These authors showed that the care-receiving role, and not only the teaching role, could be successful in a teaching context. In fact, the condition in which a robot gave wrong answers improved the children's English verb acquisition more than the condition without the robot. Taking into account the relationship between peers, Westlund and Breazeal (2015) introduced a robot, programmed to behave as a peer, to a group of 4- to 6-year-old preschoolers in a storytelling context. The robot was able to lower its linguistic competence in order to match the child's current ability. The evidence showed that a storytelling robot capable of adapting to its partner in terms of language competence, was effective in supporting the oral language development of the child. Robots would seem to have educational skills not only as storytellers, but also as sympathetic listeners. Conti, Di Nuovo, Cirasa, and Di Nuovo (2017) compared a humanoid robot story- teller to a human teacher storyteller in a group of preschoolers. The authors evaluated how the storytellers' social behaviors influenced the children's memorization of the story. Results showed a similar performance in memorizing the details of the story when the storyteller was a robot or a human with an expressive behavior (expression of appropriate emotions with the body and with the voice). The expressive robot was even more efficient than a static inexpressive human storyteller (fixed gaze, motionless body, monotonous voice).

Park, Gelsomini, Lee, and Breazeal (2017) investigated the adaptive capacities of robots as listeners in: giving feedback that informed children about the presence of an active listener, given the abilities

of gazing, leaning forward, nodding, smiling, eye-widening to emulate eyebrow movement, and short utterances. The authors tested two robotic relational styles: a contingent style of the robot capable of reflecting the nonverbal behavior of the child; and a non-contingent style of the robot that emitted random, nonverbal behaviors. Based on children's gaze patterns, the results showed that the contingent robot most relationally engaged the children.

Human-robot interaction research ranges from ToM precursors to social skills of the elderly. Iwamura, Shiomi, Kanda, Ishiguro, and Hagita (2011) focused on the use of a robot by a group of elderly shoppers in a supermarket. They found that an assistive robot that also engaged in non-shopping-oriented conversation was preferred to a robot capable only of functionally oriented conversation. Sabelli, Kanda, and Hagita (2011) introduced a conversational robot into an elderly care setting for 3.5 months, and analyzed its main interactive exchanges with the elderly and the staff using an ethnographic methodology. Three of the six identified trends (basic social interaction, telling robot information, and emotional elements) pertained to the socio-relational/mentalistic dimension.

Again working on the relationship between robots and the elderly in a retirement village, Stafford, MacDonald, Jayawardena, Wegner, and Broadbent (2014) analyzed the attitudes to use mind agency, and attribute mind agency to the robots. The evidence showed that older people preferred to interact with robots to which they attributed less mind agency. These findings were rather counterintuitive because they question the presumed importance of mental state attribution in effective social exchanges. It is likely that the elderly were frightened by the robots because of an overestimation of their cognitive capacities which decreased with actual use.

Gross et al. (2012) presented preliminary results of the implementation of a companion robot for elderly people with Mild Cognitive Impairment (MCI). The evidence emphasized how satisfied the elderly were when interacting with a robot that could support them in executing daily tasks. This work opens up the use of robots in the context of caring for people with neurodegenerative diseases. It also places the importance of assessing the effectiveness of such long-term interventions (weeks or months), and fostering relationships with a truly autonomous robotic partner (hypothetically endowed with a wide behavioral repertoire), as the first point in the agenda for future research.

The studies presented in this section, many of which were conducted in extra-experimental settings, show the importance of a detailed analysis of the contexts in which human-robot interactions take place to fully understand the intersubjective nature of the human-robot interaction.

Conclusions

This review aimed to analyze human–robot interaction from two vantage points: (1) the human attribution of mental states to the robot and (2) the human recognition of the robot as “like-me.” The experience that the robot is “like me” is based mainly on the physical appearance of the robot, and its behavior; however, another aspect emerges that pertains neither to humans, nor to humanoids, but which is a characteristic of their encounters. This aspect is the intersubjective level of the exchange. This dimension contributes some design features of the humanoids, which cannot be conceived as simple artificial instruments for the extension of human abilities. The more a humanoid partner/companion can go beyond a functionally and mechanistically perfect performance, the more it seems “like me.” In other words, an exchange is especially meaningful if it happens with a partner with a human-like capacity to be engaged in somewhat unpredictable, intersubjective exchanges. From our point of view, this unpredictability depends on the subjective nature of the human knowledge and representations of the world. During social exchanges, partners share mental states and representations of the world. The construction of intersubjectivity is based on mutual recognition of the subjective nature of such states and of such representations.

In light of these considerations, this somewhat unpredictable meeting of minds can take different directions, and can be conceptualized in different ways. For example, it can be seen as the optimal level of frustration (Kohut, 1977). All human exchanges with significant partners are characterized by an alternation of gratification and frustration. However, this fact does not compromise human exchanges, provided that the frustration is remediable. A second possible way to conceive the somewhat unpredictable meeting of minds is that of the imperfect contingency (Bigelow, 1998). There is no optimum level of contingent responsiveness in early relationships with caregivers; rather each of us experiences an imperfect contingent responsiveness through parental interactions (i.e., the partners occasionally find the level of relational contingency adequate to the ongoing interaction). This responsiveness influences future exchanges with nonfamily partners. A further possible conceptualization is marked mirroring (Gergely, 2007; Gergely & Watson, 1996), which happens during a child’s affect-regulative interactions. The adult offers the child a reflection of an experience of the world, and of the emotional states of the child itself, and at the same time, the adult informs the child that this reflection is not expressing her/his own feelings. A final interesting conceptualization is offered by the work of Tronick and Beeghly (2011). They stated that interactions consist of a flow of matching and mismatching of meaning, and the reparation of mismatches to

matches. Intersubjective attunement would emerge from the experience of reparation, which in turn would create the experience of connection and shared states.

In the Vygotskian theoretical framework, the unpredictability and possibility of relational mismatching takes on a particularly interesting form in the Zone of Proximal Development (“the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers”: Vygotsky, 1978, p. 86). In fact, cognitive discrepancy, if salient in intersubjective exchange, can become a powerful engine of learning and development. From this point of view, one of the most intriguing challenges for future humanoids is the possibility that they provide the partner stimuli, inputs, and interpretations that moderately surpass the present partner’s abilities, constructing bridges toward more advanced forms of understanding and capabilities. Looking at the future, our reflections allow us to glimpse the theme of technological singularity. It consists of the invention of a super-artificial intelligence that would result in a sudden “evolutionary” change, able in principle to overcome human intelligence (Eden, Moor, Soraker, & Steinhart, 2012). All this is possible if we consider the intersubjective nature of developmental and educational interactions in which both partners contribute to change and learning. ToM – which has as its core concept the “meeting of minds” – seems to us a theoretical perspective that is particularly well suited to understanding intersubjective interactions.

The end of the Blade Runner movie sums up this possible scenario of potentially open, flexible, and plastic exchanges between human beings and humanoids metaphorically. In fact, it shows as plausible a future of love between Rick Deckard, the replicant hunter, and Rachael, the first replicant without an a priori expiration date. Ultimately, the beauty of uncertainty, more than any other quality, made Rachel special, and therefore very humanlike.

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Chapter 3

It does not matter who you are: fairness in pre-schoolers interacting with human and robotic partners

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Abstract

The relationship between humans and robots is increasingly becoming focus of interest in many fields of research. The studies addressing the various dynamics underpinning the human-robot interaction have, up to date, mainly investigated this relationship analysing adults' behaviour when interacting with different forms of robotic agents. With this study, we present results assessing the human-robot interaction, in which children are the interactive partners. The child-robot interaction was studied – for the first time – observing thirty-one children aged 5 to 6 years playing the Ultimatum Game (UG) with either another child or with a humanoid robot. First, we found that children did recognize the robot as a distinct entity, as assessed through the children's attribution of mentalistic, emotional and physical properties to the interactive agents. Nevertheless, consistently with literature on adults, the results on the UG revealed a very similar behavioural approach when the child played with the other child and with the robot. We finally analysed the children's justifications for their behaviour at the ultimatum game and found that very young children tend to consider “fair” only the divisions that are exactly equal (5-5 divisions) and to justify them either in mere mathematical terms (outcome) or in terms of equity. These results are discussed in terms of Theory of Mind, as well as in light of developmental theories underpinning children's behaviour at the ultimatum game.

Introduction

The introduction of social robots - defined as “autonomous or semi-autonomous robots that interact and communicate with humans by following the behavioural norms expected by the people with whom the robot is intended to interact” (Bartneck & Forlizzi, 2004) - is deeply affecting our society in different fields of the human life. The robots used in industrial processes, for instance, are modifying the job roles and rules [Argote et al., 1983; Kang et al., 2008; Lin et al., 2011; see also European Union, 2017). Prospectively, the introduction of robots in other contexts, such as households, education, care assistance, manufacturing, etc., will also presumably have an increasingly significant effect on human activities and roles. In this perspective, several researches are working towards the implementation of robots in the attempt to make them increasingly similar to the human being [Asada et al., 2001; Di Salvo et al., 2002; Hoffman & Ju, 2014; Robins et al., 2005). The humanoid robots – the ultimate realization of such attempts – are characterized by human-like physical features, behaviours and cognitive processes. The mode and quality of the interaction between humanoid robots and humans will thus possibly change because of the robots’ similarities with humans that call to mind the idea of “they are more like-me” (Meltzoff & Brooks, 2001). The underlying rationale for the implementation of this new generation of robots is to create social partners in everyday life (Kanda et al., 2012), although the other side of the coin that researchers have to deal with in the robot human-likeness is the Uncanny Valley effect (Mori, 1970; Mori et al., 2012). This means that the more a robot has human features and behaves like a human, the more its “eeriness” will induce negative feelings in the interlocutor (Burleigh et al., 2013; Fink, 2012; Gray & Wegner, 2012; MacDorman, 2006; Mori et al., 2012; Sandoval et al., 2016; Scassellati, 2005).

Besides the contexts above mentioned, the implementation of robots is also aimed at aiding different scientific fields, such as anthropology, psychology, ethics, sociology, engineering, informatics, mathematics, physics, etc. (Saygin, 2011; Scassellati, 2003), for example, suggests that the use of the human-like robot could be useful for the study of typical and atypical human social development, allowing to test cognitive, behavioural and development models. In this sense, and from a multidisciplinary perspective, knowledge from developmental psychology is crucial to the implementation of these models since it contributes to the understanding and identification of the precursors underlying human sociality and their ontogenesis. In this respect, Itakura (2008) proposed a new research domain that connects developmental psychology and the study of human-robot interaction. This new investigation field was named Developmental Cybernetics (DC; 2008): it explores the child-robot interactions through the construction of theoretical frameworks that

characterize the design of the robot with the aim to facilitate these interactions (Itakura, 2008; Itakura et al., 2008b). Several studies used the Advanced Telecommunications Research Institute International (ATR) humanoid robot Robovie that can generate human-like behaviours (Ishiguro et al., 2001; Ishiguro et al., 2003). This humanoid robot has been used to test interactions with children in different contexts (Kahn et al., 2012; Kanda et al., 2004). Kanda and colleagues (2012), for example, introduced Robovie to 6th-graders to teach them how to use a Lego Mindstorms. This research showed how Robovie's human-like behaviours contribute to build a human-robot relationship, which goes beyond the more simple human-robot interaction.

Developmental Cybernetics hypothesizes that children can understand the non-human agent through mentalization, and that the construction of social intelligent agents could shed some light on the development processes and mechanisms of the child's mind (2008). In this respect, within the DC approach, Itakura (2008) proposes three abilities, which are critical for making a robot a social agent: Theory of Communication (Itakura, 2012; Itakura, 2013; Nitsch & Glassen, 2015), Theory of Body (Minato et al., 2006; Morita et al., 2012) and Theory of Mind (Itakura, 2008; Itakura et al., 2008a,b). With respect to the Theory of Mind (ToM), it has been proposed that ToM represents an important psychological ability for the study of the human-robot interaction [for a review, see Marchetti et al., 2018). In fact, ToM is essential for the development of social competences, in that it represents the ability to understand one's own and other people's mental states (intentions, emotions, desires, beliefs), and to predict and interpret one's own and others' behaviours on the basis of such meta-representations (Park et al., 2017; Piaget, 1929; White et al., 2009). Several ToM studies show that there are many different behaviours and cognitive processes that are linked to this human skill: imitation, joint attention, pointing, and gaze-following, just to mention a few. (Bandura, 1991; Brooks & Meltzoff, 2002; Camaioni et al., 2004; Charman et al., 2000; Meltzoff, & Gopnik, 1993; Meltzoff & Brooks, 2001).

The researches in the field of child-robot interaction have been increasing in the last decades. Generally, these researches explore what features should be implemented in the robot in order to establish a better interaction between humans and robots. Several studies have been conducted to analyse the effect of different ToM precursors on the interaction between humans and different non-human agents, including humanoid robots [Boucenna et al., 2014; Boucenna et al., 2016; Breazel et al., 2016; Chaminade et al., 2010; Fogassi et al., 2005; Itakura et al., 2008a; Kanngiesser et al., 2015; Meltzoff et al., 2010; Moriguchi et al., 2012; Mutlu et al., 2012; Okanda et al., 2013; Okumura et al., 2013; Rizzolatti et al., 2001; Sloane et al., 2012; Wellman et al., 2001). Generally, the results of

these studies have shown that children tend to attribute mental states to a humanoid robot (Beran et al., 2007; Breazeal et al., 2016; Kahn et al., 2004; Manzi et al., 2017; Moriguchi et al., 2012; Nishio et al., 2012; Park et al., 2017). Already Piaget (1929) suggested that children younger than six-years-old tend to attribute consciousness to objects - namely the capability to feel and perceive - and that children consider “alive” also the things that are inanimate for the adult, *if* these objects serve a function or are used to reach a goal: a phenomenon called animism. In their study, Katayama and colleagues (Katayama et al., 2010) showed that when five and six-years-old children had to attribute biological and psychological proprieties to a human or a robot, children generally discriminated between the two agents, though ascribing some human traits also to the robot. Thus, in line with Torta and colleagues (Torta et al., 2013) idea, when young children interact with artefacts, these acquire the status of relational artefacts: children believe the artefacts – like the robots – to be “alive” and to have an “intention”.

Interaction skills in social contexts are typically studied through use of interactive games deriving from the Game Theory (Camerer, 2013; Villani et al., 2013). One of such games is the Ultimatum Game (Güth & Kocher, 2014; Güth et al., 1982). Used with children, the Ultimatum Game (UG) serves to delineate development in terms of equity and negotiation ability in decision-making, thus focusing on sensitivity to fairness and aversion to inequality (Fehr & Schmidt, 1999). The UG involves interacting with at least another agent, and it is related to the development of ToM in that it activates the ability of mental comprehension, detection and anticipation of the other’s behaviour (Catelli et al., 2014a,b; Castelli et al., 2017; Hoffman & Ju, 2014; Lombardi et al., 2017; Marchetti et al., 2011; Marchetti et al., 2008; Massaro et al., 2017; Srinivasan et al., 2013; Turkle, 2004). In the UG, the subject can play as either the proposer or the receiver. In the *proposer* situation, the subject decides how to allocate resources; in the *receiver* situation, the subject decides whether to accept or refuse a proposed division of goods. The general rule underlying the UG is that the proposer makes an offer, proposing a certain division of goods between him or her and the other player. If the receiver refuses the offer, neither players get anything, whereas if the offer is accepted, both players obtain the proposed division. Using the UG, it is then possible to study interactive behaviour in reciprocal situations from a developmental perspective, comparing behaviour at different ages. Starting from infancy, some studies suggest that infants are responsive to an unequal resource distribution already at 19-month-olds (e.g., Seyama & Nagayama, 2007). Fehr and colleagues (2008) showed that sensitivity to fairness increases from 3 to 8 years of age, and that selfish behaviour decreases from 3-4 years to 5-6 years, although most of 5-6 year olds still tend to not share (78% of the sample).

Additionally, school age children (>7 years) generally behave more fairly when distributing resources and share more than younger children (Fehr et al., 2008;House et al., 2013).

Only few studies have employed the UG paradigm with robots, and – even so – uniquely in interaction with adults. There is in fact not research specifically addressing the relation between robot and children in a UG game. Research on adults generally shows that participants are more likely to behave in a similar fashion when playing the UG with another human or a robotic agent, and this similarity increases the more the robotic agent presents human-like features. Terada and Takeuchi (2017), for example, reported that rejection scores in the ultimatum game were higher in the case of a computer opponent than in the case of a human or robotic opponent, suggesting that people might treat a robot as a reciprocal partner as when playing with another human. Nishio and colleagues (2012) also tested university students while playing the UG with four different artificial agents, which differed in the degree of similarity with humans. In their study, there were four conditions: computer terminal (Computer condition), humanoid robot (Humanoid condition), android robot (Android condition) and human (Human condition). They included a mentalizing stimulus for each agent, which consisted of four shorts interactional sentences pronounced by each agent when meeting the subject, e.g., “how are things going?”. Furthermore, the authors administered a post-experimental questionnaire in order to test how participants perceived the agents (i.e., human likeness, or machine likeness). The authors examined the number of rejections of the agent’s proposals and the number of the agents’ fair and unfair proposals, both measures used as indicators of recognition of the agents as social entities. The results showed that, when the agent looked like a human, the fairness of the proposals and the refusal rate were similar to when interacting with a human, and particularly, when introducing the artificial agent after the interactional sentences. Additionally, Nitsch and Glassen (2015) analysed a group of young adults, who played the UG with a human agent and with a humanoid robot behaving so as to be perceived animated or apathetic. The results showed that the participants that played in the animated robot condition perceived the interactions more positively and human-like than in the apathetic condition. Robins and colleagues (Robins et al., 2005) also studied reciprocity in the human-robot interaction in a sample of young adults through the UG and the Prisoner Dilemma. The results showed that the participants were equally reciprocal with the human and the robot, despite the fact that the robots collaborated more with humans in the Prisoner Dilemma task, indicating that the human-human interactions are nevertheless privileged with respect to the human-robot interactions. Finally, Takagishi and colleagues (2010) examined the effect of different robots’ facial expressions in the UG, and showed that emotional expressions had an effect on the offers made by the participant to the robot compared to offers made to a computer displaying a simple line drawings face.

Altogether, the results from the studies here described suggest - in adult subjects - a proclivity to interact with robotic agents in a very similar fashion as when interacting with other humans.

As far as children's behaviour is concerned, there are no studies so far addressing children's decision making during an interactive and reciprocal social situation with a robot. In the present study, we made an attempt to fill this developmental gap exploring interactive behaviour during the UG when a child played with either another child (human agent) or with a robot (humanoid robot). Our sample children were aged five-to-six years. At this age, children show to have an acquired ToM capability of – at least - first order (Wardle et al., 2002). First order ToM entails a recursive thinking, which implies the meta-representation or the representation of a mental representation, of a low level of complexity, of the kind of: “I think that you think...”. In this respect, we hypothesized that children aged 5-6 years were able to discriminate between *agency* (human agent and humanoid robot) on the basis of mental states attribution. However, we were not able to advance any predictions in terms of differences in children's decision-making strategies when playing with a human and a robot, since no such literature exists specifically referred to the UG.

In this study, the children played both as proposers and as receivers. Additionally, children's performance on the UG task as a function of *agency* was evaluated against several socio-demographic, as well as, cognitive factors. Finally, an analysis of the children's justifications for their behaviour, both when playing as proposers and receivers, was carried out, outlining – for the first time – some response patterns that characterize the rationale underlying these children's game strategy.

Method

Participant

Thirty-three (33) Italian kindergarten children participated in the experiment. Two children were excluded from the study: one failed the First-Order ToM task and the other one failed the Inhibition task (see below). Data analysis was therefore carried out on 31 children (males=18, females=13; mean age = 70.8 months, SD=2.99). The children attended three different schools of Milan and Turin areas. The children's parents received a written explanation of the procedure of the study, the measurement items, and the materials used and gave written consent. Children were neither referred to social services nor reported by teachers for leaning and/or socio-relational difficulties. The study was

approved by the Local Ethic Committee (Università Cattolica del Sacro Cuore, Milan).

General Procedure and measures

The children were tested individually in a quiet room in the kindergartens. Administrations were carried out by a single researcher both in the morning and afternoon during normal activity. The children were assessed in two experimental sessions in different days within two weeks timeframe. The administration of the tasks in two independent sessions was done not to overly tire the children with an excessively long procedure as well as not to significantly disrupt the child's normal school activity.

In the first session, the children were administered the following tests: the First-Order False-Belief task, and two First-Order False-Belief videos, assessing first-order Theory of Mind; two Strange Stories, assessing advanced Theory of Mind; and the Attribution of Mental States scale. In the second session, the children were administered the following tests: the Family Affluence Scale, assessing the socioeconomic status; two executive functions tests, assessing the ability to inhibit behaviour and working memory; further two First-Order False-Belief videos; further two Strange Stories; and the Ultimatum Game, assessing fairness.

The tests were so distributed within sessions to balance the total time required to complete the whole battery, which was of approximately 45-50 minutes. In fact, each session lasted about 25 minutes. Within each session, the administration of the tests was randomized across children.

Socioeconomic status

To assess the children's socio-economic status, we used the Italian translation of the Family Affluence Scale (FAS; Boyce et al., 2006). This test is composed of four items measuring family wealth, and more specifically: 1) family car ownership (score range = 0–2); 2) own bedroom (range = 0–1); number of computers at home (range = 0–3); how many times they went on holiday during the past year (range = 0–3). The FAS total score was obtained adding up the four-item scores (total range = 0-9).

Executive functions (Inhibition and Working Memory)

We tested the children's executive functions using the Inhibition "A Developmental NEuroPSYchological Assessment" subtest (NEPSY II; Korkman et al., 2007), testing the ability to inhibit automatic responses in favour of novel responses and the ability to switch between response types. The child looks at a series of black and white shapes or arrows and names either the shape or direction or an alternate response, depending on the colour of the shape or arrow. In the present study, we used the combined scores of the Inhibition NEPSY-II subtest, which associates accuracy and speed of response.

Furthermore, we used the Backward Digit Span, testing working memory. Concerning the Backward Digit Span, the experimenter presented orally number sequences and the child was required to repeat them in reverse order. The test started with three sequences of two digits, gradually introducing triples of sequences of increasing length, to a maximum possible length of eight digits. The test stopped when the child failed all three sequences at the same length. The score was calculated as follows: children received 1 when they reversed at least two out of three sequences; if successful, the child passed to the next longer series, scoring 0.33 reserving at least one out of three sequences. The decimal scores were then summed to obtain the main score (e.g. $1+0.33 = 1.33$) until the children reached 1 (e.g. $1+0.33+0.33+0.33 = 2$), if necessary.

First-order false belief task

To assess first-order ToM, we used the story of the classical *Unexpected Transfer* task (Wimmer & Perner, 1983). The experimenter told the story using: two dolls (one male and one female), one ball, one box and one basket. The story is about two siblings playing with a ball in a room. One of the children puts the ball in a box and leaves the room. Meanwhile, the other child takes the ball out of the box, puts it in the basket and goes away. Finally, the first character comes back in the room and wants to play with the ball. At the end of the story the experimenter asks the child the following questions: "What is the first place where he will look for a teddy bear?" – referring to the first character (First-Order False Belief question); "Where did the child put the ball before going upstairs?" (control memory question); "Where is the ball really?" (Reality control question).

The answers to the two control questions (memory and reality) were used to filter the children's performance: children who did not pass them scored 0 and their performance on the First-Order False Belief question was not evaluated. If the children passed the control questions, the test question about the false belief scored 1 if correct and 0 if incorrect.

First-order false belief task: Video Stimuli

To assess children on the First-Order False Belief, we introduced – besides the commonly used task as described above – a new instrument, namely eight videos representing the classical story, this time introducing also the Robovie as a new character. More specifically, we used a story similar to the classical *Unexpected Transfer* task (Wimmer & Perner, 1983) as the script of the videos. The videos started presenting two characters (two children, two robots, or a child and a robot) in a room with two different boxes of a different colour (blue and pink) placed in front of them. Subsequently, one of the characters put a teddy bear under one box (the same for all videos) and then left the room. When the other character was alone in the room, he or she moved the teddy bear under the other box and left the room. Finally, the first character returned into the room to take the teddy bear. A voiceover narration described the story in each video.

The videos were recorded with five different actors: two children (C1 and C2) and three Robovies of different colours (White Robovie, WR; Green Robovie, GR; and Red Robovie, RR). Moreover, the five actors could play two different roles: the character who made the transfer (MtT) and the character who underwent the transfer (UtT). We used the WR for the human-robot videos and the other two Robovies (GR and RR) for the robot-robot videos. Thus, we videotaped eight different videos crossing the two children, the three Robovies, and the two roles. We created two different protocols, which were randomly assigned to the children. The first protocol was composed of four videos: 1) C1 playing the MtT role with C2; 2) C1 playing the MtT role with WR; 3) WR playing the MtT with C1; 4) GR playing the MtT with RR. The second protocol was composed of the following four videos: 1) C2 playing the MtT role with C1; 2) C2 playing the MtT role with WR; 3) WR playing the MtT with C2; 4) RR playing the MtT with GR. Within each protocol, the videos were presented randomly. We used the same scoring criteria as that used for the First-Order False Belief task (see above). The videos can be found in Electronic Supplementary Material.

At the end of the story, the experimenter asked to the child the following questions: “What is the first place where she will look for the teddy bear?” (First-Order False Belief question); two control questions (Memory and Reality as described above).

Strange Stories

We assessed the children's advanced ToM using the Strange Stories task (Happé, 1994; Westlund et al., 2017), whose Italian translation had been already used in other studies (Cattaneo et al., 2007; Lillard, 1994). This task evaluates the ability to make inferences about mental states by interpreting non-literal statements. We selected a subgroup of four mentalistic stories involving double bluffs, misunderstandings, white lies, and persuasion. After reading the stories, we asked the children to explain a character's behaviour without a time limit. The experimenter transcribed *ad verbatim* the child's answers. Scoring was based on the general guidelines (Westlund et al., 2017): 0 for incorrect answers, 1 for partially correct answers, and 2 for full and explicit answers. Two raters independently coded 30% of the responses. The inter-rater agreement was substantial (Cronbach's Alpha = .96). Disagreements were resolved through discussion between the raters. Total scores ranged from 0 to 8. The analysis of the children's performance on the strange stories showed a quite poor general performance. In fact, the children scored very low, ranging from 0 to 3 out of a total possible score of 8.

Attribution of States

The Attribution of States is a measure of states attribution that the child has to make looking at pictures depicting a character. The Attribution of States (AoF) is an *ad-hoc* questionnaire that was drawn from the questionnaire described in Martini and colleagues (Martini et al., 2016). This test was aimed at assessing what features the subject (the child) ascribed to the interactive agent (another child or the robot) in mental, emotional and physical terms. In this study, the experimenter first showed to the child two pictures depicting a child and a robot and then asked the child - as a control question - what was depicted in the picture (Reality question): if the child correctly recognized the child and the robot, the test went on; if the child responded incorrectly, the experimenter corrected the child making sure that he or she was fully aware of the agent's identity and then proceeded with the test. No children failed in the Reality question; that is, all of the children correctly recognized the child and the robot at first instance.

The presentation order of the two face pictures was randomized across children. After presenting the picture and asking the Reality question, the experimenter asked the child 25 questions referred to the agent's mental states. The child had to respond "Yes" or "No" to each question. The 25 questions were grouped in five different categories of mental states: Epistemic, Emotional, Desires and Intentions, Imaginative, and Perceptive. The total score was the sum of the "Yes" answers (score range = 0-25); the five partial scores were the sum of the "Yes" answer to each category (score range

= 0-5).

Ultimatum Game

A standard version of the Ultimatum Game (UG; Güth et al., 1982) was used to evaluate fairness. During the game, the child (playing as proponent) could decide how to distribute 10 stickers between him or her and a passive player, represented by a graphic representation of either a child – human agent (e.g., Castelli et al., 2010) or a robot. The graphic representation of the other child corresponded to a male figure when the child was a boy, whereas it represented a female when the child was a girl. The stickers depicted known animals by the children (e.g., dogs, cats, tigers, lions, birds, fishes, etc.). The minimum amount of stickers that could be offered during the game was 1, and the maximum amount was 9. After playing the UG, the child was actually given a final amount of stickers

During the UG, the children played one round as proposer and five rounds as responder, for a total of six rounds. Playing as proposer, the child could decide how to divide the stickers with the other child or the robot (graphic representation) and, playing as responder, the child could decide whether to accept or refuse the proposed division. In case of acceptance, both players received the respective proposed amounts; in case of refusal, neither player gained anything.

When playing as responder, each round (5 in total) corresponded to a specific type of proposal, ranging from a division of 5-5 (fair) to a division of 1-9 (highly unfair). The rounds were randomized across children. For each round, the child could accept or refuse the offered amount, receiving a score 1 in case of acceptance and 0 when refusing the offer. The total amount accepted was also calculated (range = 0-15) when the child played as receiver, which corresponded to the total gain for each child. Similarly, when playing as proposer, the total amount proposed was also calculated for each child (range= 0-9).

UG procedure

Before starting the game, the experimenter explained the game rules presenting four different examples in a graphic format: 1) an adult playing as proposer with a child, who accepted the offer; 2) an adult playing as proposer with a child, who refused the offer; 3) a robot playing as proposer with a child, who accepted the offer; 4) a robot playing as proposer with a child, who refused the offer.

During the game, the researcher played “the other child’s/robot’s” role, proposing, accepting, or refusing offers. The children’s performance at the Ultimatum Game was evaluated in a single session lasting approximately 10 minutes in total.

At the end of the game, the children were asked the reasons that they placed a certain offer (proposer) or accepted/refused a certain proposal (receiver). The children’s answers were classified according to three criteria: 1) outcome – the justification refers uniquely to the *amount offered or received* without commenting on or referring to the other player in mental terms (e.g., “because I like that he does not have anything and I have them all”; “because I wanted to win”); 2) equity – the justification includes terms that refer explicitly to the *construct* of equity, independently of whether the amount offered or received was equal or unequal (e.g., “because in this way we are even”; “because it was nicer to give him three and I like to share them”); 3) mentalistic – the justification includes terms that *refer to the other player in mental terms* (e.g., “because he would like me to receive more”; “he believed that I would win”)⁹.

Results and Discussion

All of the continuous variables were normally distributed with skewness between -1 and 1.

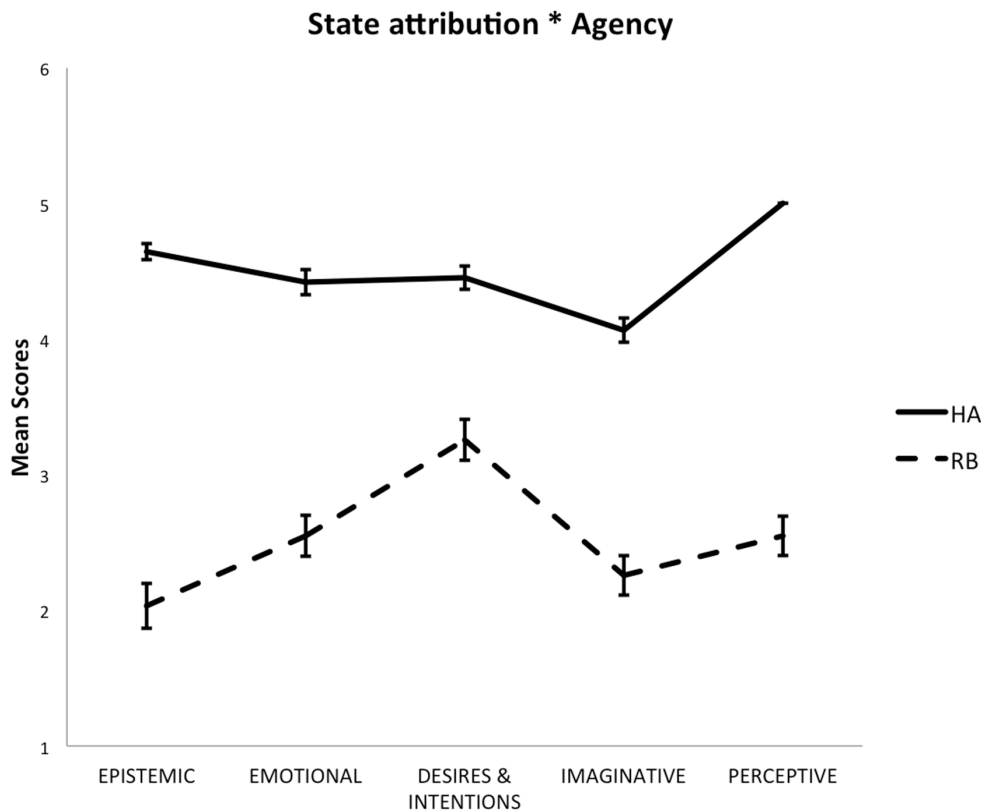
Attribution of States Scale

With this analysis, we compared the attribution of states - as described in the methods session - to the human agent (the other child) and to the robot. The inspection of the boxplots revealed a tendency towards maximum scores (5) in the case of state attribution to the human agent - particularly with respect to the perceptive state, where we observed a ceiling effect - and a normal distribution in the case of states attribution to the robot. A repeated measures general linear model (GLM) was carried out with five levels of *state* (epistemic, emotional, desires and intentions, imaginative, perceptive), and two levels of *agency* (human vs. robot) as the within groups factors. The results showed a main effect of *state* ($F_{4,120}=5.94$, $p<.0001$, $partial-\eta^2=.17$, $\delta=.98$), a main effect of *agency* (HA>RB; $F_{1,30}=53.82$, $p<.0001$, $partial-\eta^2=.64$, $\delta=.1$) and a significant interaction *state*agency* ($F_{4,120}=7.90$, $p<.0001$, $partial-\eta^2=.21$, $\delta=.1$). Post hoc analyses (Bonferroni corrected) showed that the states that scored higher were desires and intentions – which scored significantly higher than both epistemic

⁹ Ad verbatim translation from Italian.

($M_{diff}=.69, p<.01$) and imaginative ($M_{diff}=.52, p<.05$) – and perceptive state, that scored significantly higher than imaginative state ($M_{diff}=.61, p<.01$). Additionally, the analyses showed that the interaction effect stemmed primarily from differences between *states* within *agency* (HA, RB). More specifically, with respect to states attribution to HA, the epistemic state scored higher than imaginative state ($M_{diff}=.58, p<.01$); whereas the perceptive state scored higher than all the other states ($p<.05$) except for the epistemic state, which just failed to reach significance ($M_{diff}=.36, p=.055$). With respect to state attribution to RB, the results showed that desires and intentions received higher scores compared to the epistemic and imaginative states ($M_{diff}=1.23, M_{diff}=1.00$, respectively; $p<.001$). These results are summarized in Figure 1.

Figure 1: Mean scores obtained by the children during the attribution of states (epistemic, emotional, desires and intentions, imaginative, and perceptive) to the human agent (HA) and to the robot (RB). The bars represent the Standard Error of the mean.



The results on the attribution of states to HA and RB revealed that children clearly attributed different states on the basis of agency, with HA receiving higher scores on all states attribution compared to RB. This shows that children had a correct perception that the other child had epistemic and emotional

states, intentions and desires, an imagination and perceptive properties, which are different from that of a robot, therefore considering this latter as a distinct entity.

Within agency, children tended to ascribe poor imagination to both the child and the robot. This is in line with evidence showing that young children's imagination abilities mature gradually (Harris, 2000; Harris & Leivers, 2000; Lillard, 1994; Lillard, 2013). Interestingly, the differences observed within the attribution of states to the robot indicate that children tended to ascribe desires and intentions also to the robot, although to a significantly lesser extent than to the human agent. Desires and intentions attribution to the RB, in fact, received greater scores than all the other states, and substantially more than the epistemic and imaginative states. During video watching (see methods), the children observed the RB in action, and this may have led the children believe the robot as having intentions. In fact, also from a neurophysiological perspective, movement and intentions go hand in hand [see, for example, Gray & Wegnaer, 2012; Premack & Woodruff, 1978) as also suggested by psychophysiological evidence with children (Cavallini et al., 2013). All the same, in the present study, while attributing intentions to the robot, the children ascribed to the robot a low ability to think, understand, and decide (epistemic attribution). These results, apparently in contrast, are on the other hand much in line with the idea of animism introduced above, and namely with young children's tendency to attribute a living soul to plants, inanimate objects, and natural phenomena, while being aware that these entities are non-living. The fact that this idea applies to objects only *if* these objects serve a function or are used to reach a goal (see Katayama et al., 2010; Perner & wimmer, 1985; Turkle, 2004], further supports the movement and intention interpretation just described (Chaminade et al., 2010; Sandoval et al., 2016).

Ultimatum Game

The main aim of the present study was to assess whether the child behaves differently when acting with a human agent or with a robot during an interactive situation. We therefore had the child playing the UG with either another child or with the robot, as both proposer and receiver.

Proposer

A t-test comparing the total amount offered to the other child or to the robot when the participant played as proposer showed no significant difference in the total amount offered (HA: $M=3.71$, $SE=.31$; RB: $M=3.55$, $SE=.35$; $p>.05$). Additionally, a high internal consistency (Cronbach $\alpha =.85$)

was observed between each individual child's behaviour when playing with the human agent or the robot. Table 1 reports the children's proposed divisions to HA and RB.

Table 1: Statistics of children's offers when playing as PROPOSERS; ns = not significant; na = not applicable.

	HA – RB	HA – RB	HA vs. RB
Proposed Division	N	%	Sign (<i>p</i>)*
1-9	0 – 0	0 – 0	na
2-8	0 – 0	0 – 0	na
3-7	0 – 1	0 – 3	na
4-6	5 – 5	16 – 16	ns
5-5	7 – 4	23 – 13	ns
6-4	9 – 7	29 – 23	ns
7-3	3 – 5	10 – 16	ns
8-2	2 – 3	7 – 10	ns
9-1	5 – 6	16 – 19	ns
tot	31 – 31	100 – 100	

**Wilcoxon rank test*

These results are in line with the literature [e.g., 28] showing that pre-schoolers tend to make offers that favour their own gain, although the frequency of children that made offers towards fairness (i.e., ranging between 4-6 and 6-4) was quite substantial (68% towards HA; 55% towards RB). Additionally, these results extend previous findings showing that five-year-old children's behaviour and game strategy is consistent independently of whether the child plays with another child or with a robot, in line with the large body of existing literature on adults, as fully introduced above.

Receiver

Within this analysis, we summed up all acceptances when the child played as receiver, therefore calculating the total amount gained by each child. A t-test comparing the total acceptances from the other child and the robot showed no differences in the total amount accepted as a function of *agency* ($t=.75$, $p>.05$), indicating that the children accepted similar amounts when playing with HA ($M=10.97$, $SE=.77$) and with RB ($M=10.45$, $SE=.95$). This result is congruent with the data above described, showing children's tendency to adopt a similar game strategy when playing with the other child or with the robot.

Specifically comparing the children's acceptances of each proposed division from HA and RB, our results confirmed no differences in the frequency of acceptances as a function of agency within division (for statistics, see Table 2). Additionally, comparing the frequency of acceptances between successive divisions for both HA and RB, the Wilcoxon test showed not significant differences for the child (i.e., 5-5 vs. 6-4; 6-4 vs. 7-3; etc.; $p > .05$), whereas we observed significant differences for the robot. More specifically, acceptances of the 6-4 division were significantly lower than acceptances of the 5-5 division (71% vs. 90%, $p < .01$), as well as acceptances of the 7-3 compared to the 6-4 divisions (52% vs. 71%, $p < .01$). This latter result shows a significant, although minor, tendency of children to accept slight unfair offers more from another child than from the robot.

Table 2: Comparison of refusals and acceptances of proposed divisions during the UG when the child played as receiver with another child (HA) and with the robot (RB) (N=31). *P-values* were non-significant (ns) at a value of .05.

		HA	RB	<i>HA vs RB</i>
Division		N (%)	N (%)	Sign (<i>p</i>)*
5-5	Refuse	3 (10)	3 (10)	ns
	Accept	28 (90)	28 (90)	
6-4	Refuse	7 (23)	9 (29)	ns
	Accept	24 (77)	22 (71)	
7-3	Refuse	12 (39)	15 (48)	ns
	Accept	19 (61)	16 (52)	
8-2	Refuse	16 (52)	13 (42)	ns
	Accept	15 (48)	18 (58)	
9-1	Refuse	14 (45)	15 (48)	ns
	Accept	17 (55)	16 (52)	

*McNemar's Test

Correlations

Pearson's correlations were carried out between the total scores at the ultimatum game when the child played with the other child and the robot, as both proposer and receiver. The results showed, as expected, a substantial correlation between the total amount proposed to the other child and the robot ($r^2 = .56$, $p < .01$), as well as a strong correlation between the total amount accepted by the other child and the robot ($r^2 = .49$, $p < .01$). Additionally, the scores obtained at the UG were further correlated with demographic, cognitive, and socio-economic variables: age (months); the child's gender; working memory scores; the ability to inhibit behaviour scores; the intentionality test scores; and the Family

Affluence Scale scores. These correlations are summarized in Table 3. In general, no significant correlations were observed between the scores obtained at the UG and any of these variables ($p > .05$).

Table 3: Correlation analysis between the total scores at the Ultimatum Game when the child played as proposer with a robot (1) and the child (2) and when the child played as receiver with the robot (3) and the child (4). These scores at the UG were correlated with demographic, cognitive, and socio-economic variables: Age (months); child's Gender; working memory (WM) scores; ability to inhibit behaviour (INHI) scores; Intentionality Test scores (IT); and Family Affluence Scale (FAS) scores.

Pearson Correlations

		1	2	3	4	Age	Gender	WM	INHI	IT	FAS
1)	Total Offer to the Child	1	,746**	0,298	0,179	0,218	-0,085	0,186	0,01	0,146	0,213
2)	Total Offer to the Robot		1	0,191	-0,015	0,224	-0,004	0,202	0,024	0,233	0,237
3)	Total Acceptance from the Child			1	,700**	0,069	0,285	0,151	0,293	0,354	0,165
4)	Total Acceptance from the Robot				1	0,047	0,329	0,251	-0,1	0,255	0,195

** Correlation is significant at the 0.01 level (2-tailed).

Analysis of the children's justifications at the UG

After the child played the UG in both the proposer and receiver roles, the experimenter asked him or her to explain the reasons for his or her division. The children's answers were classified as "outcome", "equity", or "mentalistic" (for details, see methods). Two independent judges evaluated the children's justifications.

Proposer

The inter-rater reliability scores were substantial both when assessing the child's justifications when playing with the other child (Cronbach's Alpha = .88) and when playing with the robot (Cronbach's Alpha = .91).

Analysing the frequencies of children who gave a specific justification to their behaviour for each division when making an offer, the results showed an even distribution of justification type (amount, equity) when the children offered a precise fair amount (division 5-5), whereas a skewed distribution of justification type toward "amount" when the children started placing offers that privileged their

own gain. This was independent of whether the child played with the HA or the RB. A summary of the frequency distribution of justification types for each proposed division is presented in Table 4A.

Receiver

The inter-rater reliability scores were calculated for each proposed division (5-5; 6-4; 7-3; 8-2; 9-1). The results showed substantial agreements both when assessing the child's acceptance/refusals justifications interacting with the other child (mean Cronbach's Alpha = .83; min=.82, max=.84) and with the robot (mean Cronbach's Alpha = .83; min=.80, max=.84).

With this analysis, we compared the frequency of children that provided a justification when accepting or refusing each proposed division. Justification types were different when the child received a 5-5 or a 6-4 division, independently of *agency* (HA, RB). When receiving a 5-5 division, the justifications were either based on "outcome" (HA: N=13; RB: N=14) or on "equity" (HA: N=18; RB: N =16); only one child presented a mentalization-based justification when interacting with the robot. When faced with a 6-4 division, the majority of children (HA: N=26; RB: N =28) presented a justification for their acceptance or refusal based on "outcome"; five children presented a justification based on "equity" and none based on "mentalization" when interacting with the other child; only one child presented a justification based on "equity" and two children a justification based on "mentalization" when interacting with the robot. A summary of the frequency distribution and statistics of acceptances and refusals of each proposed division and type of justification is presented in Table 4B. In general, these results suggest that, when children received a division proposal skewing towards unfairness, the equity and mentalization-based justifications decreased substantially ($\chi^2_{(4)}=16.47, p<.001$), in favour of the outcome-based justification.

The analysis of the children's justification for their behaviour - both when playing as proponents and when playing as receivers - indicates that children tend to regard fair (and hyperfair) divisions either in terms of outcome or in terms of equity-based reasoning, with an approximately equal split. When the division starts skewing, even slightly (i.e., 6-4 division), towards unfairness, the types of justifications offered remarkably bias towards an outcome-based reasoning. It is noteworthy observing that mentalistic-based justifications were very poor, if not even inexistent, in all proposed scenarios. This general behaviour was observed both when the child played with the other child and with the robot, indicating no differences in the type of reasoning underlying specific choices as a function of agency.

On the whole, the results on the UG suggest that children aged five years behave quite fairly, though showing a tendency towards favouring their own gain placing and accepting unfair – and even *very* unfair – divisions, in line with current literature describing pre-schoolers' behaviour during the UG (see, for example, Lombardi et al., 2017). Lack of behavioural differences as a function of agency (HA vs. RB) further appears to indicate that the children at this age tend to disregard to other's mind when making choices, following a very consistent strategy throughout the game on the basis of other criteria (e.g., tendency to maximise gains) or personal traits (e.g., disposition to fairness). This is particularly true if considering the fact that the robot was indeed considered an entity different from the human agent (the child), so as observed from the analysis of the states attribution described above. This idea of a much ego-centred behaviour is further supported by the analysis of the children's justifications for their decisions when placing specific offers (proposers) and when accepting or refusing certain offers (receivers). In fact, analysing the frequencies of children who gave a specific justification for their behaviour, the results showed an even distribution of justification type (amount, equity) when the children offered or accepted a fair amount both to/from another child and to/from the robot; whereas we observed a remarkably skewed outcome-based justification when the children offered or accepted/refused unfair divisions. These latter results are further discussed below.

General Discussion

This study investigated 5 year-olds' behaviour at the ultimatum game. The aim of this study was to compare young children's game strategy when they played with another child (human agent) and with a robot. The results showed that children's game strategy was very similar when playing with the other child and with the robot, independently of the role played (proposer or receiver). The children were quite conservative both when offering and accepting proposals, that is, the children generally tended to offer and to accept fair divisions (5-5), although almost half of children proposed and accepted also unfair divisions, ranging from 6-4 to 9-1. These results are in line with the developmental literature on UG. For example, Benenson and colleagues (2007) observed that children aged 4 years donated less than 6 and 9-years-old, showing that sensitivity to fairness increases with age. Furthermore, a recent research by Lombardi and colleagues (Lombardi et al., 2017) showed that, at 6 years, children displayed a more selfish behaviour than children aged 8 and 10 years, highlighting that younger children tend to maximize their gain accepting also unfair offers.

Importantly for the present purpose, no significant differences were observed between offers and

acceptances made to or received from the other child or the robot. In this respect, children's behaviour observed in this study when interacting with the robot is comparable to the adults' behaviour reported in several studies. Terada and Takeuchi (2017) for example, showed that, when playing the UG, adult participants took approximately the same time to decide how to distribute goods between a human and a robot. In the study by Kahn and colleagues Kahn et al., (2012), the frequency of acceptances and refusals became closer to that toward a human when the robot had more human-like features. Similar results were also found by Rosenthal-von der Pütten and Krämer (2014). On the whole, these results suggest that, when bargaining, the other player is regarded independently of agency: the other player's mind appears to be a reflection of our own mind and strategic thinking, whether or not the other has a mind at all, such as in the case of a robot.

With respect to the acceptance of offers made when the child played as receiver in the present study, although behaviour was comparable when the child played with another child or with the robot, it is worth noting that the results showed a significant, although minor, tendency of children to accept slight unfair offers more from another child than from the robot. In this respect, one may suggest that children's expectancy from a robot is to be a totally fair player – since it does not have a mind of its own that can work strategically. In this light, divergence from this initial expectation is less accepted compared to situations in which children play with a human peer. In this latter case, in fact, the other player (the human) - having a mind - is supposed to be able to apply a game strategy and, eventually, to be also unfair. Alternatively, but not mutually exclusive, one may suggest that the child believes to have a distinctive status compared to the robot that, as assessed through the test of attribution of states, is perceived as a different entity with respect to a child at all levels: epistemic, emotional, imaginative, and physical. Also in this light, unfair offers would be less accepted when made by a robot than by a peer.

Finally, with respect to the results from the analysis of the children's justifications at the UG, it is interesting to observe that the reasons provided by the children for their behavior, both when playing as proposers and responders, suggest that children aged 5 years tend to consider fair only a division that is exactly fair (5-5). A slight skewed division towards unfairness (i.e., 6-4) already falls within the range of categorization that characterizes very unfair proposals, regardless of whether the proposals are made or received. Additionally, it is noteworthy to observe that fair or slightly hyperfair divisions are typically justified in either outcome or equity terms, whereas unfair offers are mostly justified in terms of quantity. Mentalization-based justifications are poorly made for all divisions, although – in these cases – it is curious to observe that, when playing as proposer, mentalization–

based justifications are uniquely confined to the most fair divisions (4-5; 5-5; 6-4). In general, these observations may suggest that children, particularly in the case of unfair offers, tend to not use mentalization-based explanations in order to reduce the distress stemming from the discrepancy between a “socially-expected” equal behaviour and the actual “selfish” behaviour. This interpretation can be further extended to the outcome-based justifications predominantly used to explain unfair offers that, in a certain sense, may serve to resolve a social cognitive conflict [e.g., 3], ultimately reducing the distress caused by the experimenter’s explicit enquiry.

Concluding remarks and limitations of the study

This study showed for the first time that young children's fairness is not affected by whether the child plays with another child or with a robot. In particular, it appears that children's decisions during social interactions are self-centred and poorly oriented towards the other's mind. Future studies could address the same issue focussing on different ages so to highlight the development of behavior in late childhood, when higher mentalistic abilities are maturing and eventually acquired. Additionally, we showed that the analysis of the justifications of children's behavior may be enlightening with respect to the child's actual psychological understanding of constructs, such as that of fairness.

It is important to stress that the present results, and in particular those referring to the behavioural differences here reported when the child played as receiver with the other child and with the robot, need to be confirmed with a more ample sample. Confirmation of these results could highlight a distinctive attitude towards a non-human interactive partner that emerges quite early in childhood and that may change during adulthood.

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Chapter 4

Object Use in children with autism: Building with Blocks from a Piagetian Perspective

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Abstract

Aim: This study focused on the manipulation of objects by children with suspected autism spectrum disorder. The aim was to demonstrate how objects can be seen as active agents of interpersonal exchange in face-to-face interactions.

Participants: Three children with suspected autism spectrum disorder (aged 18, 20, and 24 months) were selected as representative of the sensorimotor stage of development.

Methods: Starting from Piaget's classical approach to the sensorimotor and symbolic developmental stages, the study moved toward a socio-material interpretation in which some patterns of interaction involving object manipulation seem to create a space that supports adult-child communication. In videotaped observations of verbal and non-verbal signs during an (organized) free play session, each child manipulated seven small blocks of colored plastic in the presence of an adult. The observations were informed by a checklist of 14 items, including eye contact and building a tower of toy blocks from section B of the CHAT (*CHecklist for Autism in Toddlers*) instrument.

results: Based on a broad Piagetian perspective and recent work in the field of socio-materiality, key observations included the following: (1) sensorimotor and realistic play was observed in all three children; (2) there were some intriguing indications that objects serve as concrete mediators in the intersubjective space between adult and child; (3) some of the children's attention patterns were visibly mediated by the object.

Discussion and conclusion: All three children exhibited a particular sequence of actions. First, they manipulated the blocks through active experimentation; second, there was an apparent pause, during which, the children were in fact examining the blocks to determine how best to continue the interaction; and finally, the children monitored adult attention by means of eye contact or by restarting manipulation of the blocks. As this last step in the sequence indicated that the object became a mediator of reciprocal attention, this interpersonal process was labeled "attention mediated by object."

Introduction

According to Piaget (1928, 1952, 1954), children with autism achieve object conceptualization skills by the fifth stage of sensorimotor development. As several studies advise caution in using the *stage* concept to describe typical and atypical psychological development, it seems useful to characterize these psychological processes in terms of specific activities that the child can plan and implement when acting on their physical and social environment. For example, as a predictive index, the number and type of different actions produced by children with autism during a recreational activity may not always follow the same stages as in typical development, and this can also be correlated with the severity of autistic functioning (McDuffie et al., 2015). In fact, while imitation difficulties may reflect a possible delay in psychological development, not all pre-scholars with autism have problems with imitation or symbolic play (Vanvuchelen et al., 2011). Within the broad line of research that raises questions concerning object canonicity, we identified some interesting elements related to the socio-material function of mediation during communication.

It is known that canonical functions of objects are introduced by other people present in the child's world (Leontiev, 1981; Costall, 1997; Rodríguez and Moro, 2008; Barthélémy-Musso et al., 2013). Indeed, Sinha (2009) suggests that the canonical functions of the object are acquired as a normative phenomenon during social interactions, although cognitive understanding of that status is a prerequisite. Additionally, Sinha (2015) (p. 12) points out that “the materiality of meaning and meaningfulness of materiality is central to approaches in cognitive science emphasizing the importance of objects in extended cognitive embodiment.” In particular, there is evidence that canonical functions are acquired during child–adult interactions (Rodríguez and Moro, 1998; Sinha and Rodríguez, 2008; Moro, 2011, 2014). Several studies have reported how, under certain conditions (for example, impaired interpersonal relations or attentional focus), objects become mediators of social interaction (Williams et al., 1999; Dimitrova, 2014; Moro, 2014). Cárdenas et al. (2014) highlighted the importance of the reciprocal nature of these interactions by showing how they emerge from communicative and triadic contexts (adult–child–object). The crucial role of the adult in the acquisition of object use is observable from early infancy (Moreno-Núñez et al., 2017). Moreover, during child–object–adult interaction, the child's visual attention is more focused when interacting with an experienced caregiver than with an unfamiliar adult (Miller et al., 2009; Miller and Gros-Louis, 2013). Miller and Gros-Louis (2017) also showed that the child's attention is influenced by partner social style. Tomasello et al. (1993) and Tomasello (2016) highlighted different kinds of learning, such as imitative, instructed, and collaborative. For instance, imitation is important for

learning that involves others and objects, as it facilitates understanding of the normative expectations of a given cultural group (Tomasello, 2016). Sinha (2009) suggested that children apprehend canonical functions primarily by cognitive means, thereby accessing the normative identity of the cultural group. Bruckner and Yoder (2007) reported that, even among children with autism, object use can be linked to emergent functions in the preoperational stage, such as imitation and attention to the other person.

Most of the existing research suggests that imitation is impaired in children with autism (Charman and Baron-Cohen, 1994; Rogers, 1999; Rogers et al., 2003; Williams et al., 2004). Indeed, Smith and Bryson (2007) noted that children with autism exhibit difficulty in imitating any unconventional use of objects but are able to imitate canonical object use. By imitating this canonical use, children with autism access part of the cultural group's heritage. With respect to manipulative play activities, Kanner (1943) was among the first to note that, despite differences and limitations, children with autism exhibit a number of functions related to the use of canonical and non-canonical objects. Trevarthen and Hubley (1978) described the dynamics informing subject–subject–object triangulation (the theory of “secondary intersubjective tuning”). Typical children alternate their eye gaze between the object being viewed and the other person, so engendering joint attention. However, in atypical development, and especially for those on the autistic spectrum, an abnormality has been observed in the development of behaviors related to joint attention. Palacios and Rodríguez (2015) showed that in typical children aged 9–15 months, the symbolic use of an object develops within a triadic context. Ungerer and Sigman (1981) assessed the use of everyday objects in a group of children with autism ranging in age from 39 to 74 months in a structured and free play session and found that most were unable to use an object according to its designated function. Williams et al. (2005) interviewed parents of 10 children with autism (MA = 62.2 months; SD = 19.9) who reported problems relating to the use of an object, such as an interest in some unusual aspect of the object, an unusual way of using the object, or difficulty in generalizing object use. Custance et al. (2014) suggested that imitative deficits in children with autism can be reduced by means of object-related activities, especially if there are no time limits on use of the object. Object-related activities promote joint attention, motor imitation, and intentional communication with a social partner (Bruckner and Yoder, 2007), and there is evidence that interventions focused on play involving different objects can promote social and imitative behaviors (Brown and Murray, 2001; Stahmer et al., 2003; Lee et al., 2017). Swettenham et al. (1998) observed three types of attentional behavior: (1) between an object and another object, (2) between an object and a person, and (3) between one person and another. Children with autism showed relatively more attention to interactions between an object and another

object. In our recent studies, we have observed the important role of the object in activating attention in the child with autism, and we describe the phenomenon as “attention mediated by the object,” which may be a precursor of joint attention (Iannaccone et al., 2016; Manzi and Savarese, 2017; Savarese et al., 2017).

The observational study reported here incorporates a sociomaterial perspective, referring in particular to the mediating role that objects seem to assume in the interaction between children and adults, which has to date been neglected in the scientific literature. Using a selected set of objects, the study analyzed the child with autism’s ability to manipulate those objects and to evaluate their symbolic use. Starting from presentation of the object, a further objective was to identify the type of game engaged in by the child. During interaction with an adult, we observed first whether there was eye contact; second, whether this changed how the child used the object; and third, whether the canonical use of the object was an important element in the child–adult interaction.

Material and Methods

Participants

We used the tower building item from section B of the “CHecklist for Autism in Toddlers instrument” (*CHAT*; Baron-Cohen et al., 1992). It was developed to help identify children who are at risk of developing social-communication disorders (scoring “high risk of autism”). It was administered to filter participants and one child aged 22 months did not pass this item. Children aged 18 months are capable of tertiary circular reactions and can stop and restart a sequence of actions at any intermediate step, which is crucial in building a tower of blocks. Children older than 18 months can use symbolic mental representations. The selected age range, therefore, allowed us to observe the early development of symbolic functions.

The study’s participants were three non-verbal male children with suspected autism spectrum disorder. The suspected diagnosis of autism was identified through the use of the CHAT instrument.

Their different ages encompassed the transition from sensorimotor to preoperational stage; participant 1 was aged 18 months, participant 2 was aged 20 months, and participant 3 was aged 24 months.

Methods

The study employed videotaped observations (with one camera) of verbal and non-verbal signs during an organized free play session, in which each child played with seven small blocks of colored plastic in the presence of an adult (a different experimenter was used for each observation). The observations were conducted on the basis of a checklist consisting of 14 items (see Appendix A), including eye contact and the building of a tower of toy blocks from section B of the CHAT procedure.

The blocks were selected not only because of their use in the CHAT procedure but also in accordance with the empirical tradition of Piaget (1962) and Reifel (1984), who have shown the importance of toy blocks in the child's cognitive development. The interaction sequences from the video recordings were transcribed in full for microgenetic and semiotic analysis, primarily examining the children's non-verbal signs (gestures and posture) during interactions with the objects. Adult intervention was also analyzed in terms of non-verbal signs (gestures and posture), again focusing on sequences of microgenetic and semiotic actions. Sequences were selected using the following criteria: the presence of gestures, actions, or both, where (1) the adult intervened and the object became a mediator of the interaction, and (2) the object mediated the attention between child and adult. The observations of child and adult occurred simultaneously.

Ethical issues

This study was carried out in accordance with the recommendations of AIP (Associazione Italiana di Psicologia), and all of the children's parents gave written informed consent in accordance with the Declaration of Helsinki. As there is as yet no psychological ethics committee at the University of Salerno, the protocol was approved by the external experts group from the University's "Centro di Counseling Psicologico" (Counseling Center). While the Center is not specifically responsible for ethical approval, the external experts group supervises research carried out by psychological researchers at the University. In Italy, few universities have a psychological ethics committee, and these generally offer degree courses in psychology or have a psychology department or institute. The University of Salerno has not activated degree courses in psychology and has no such department. We would like to thank the external experts, Dr Oreste Fasano (Psychologist), Dr Nadia Pecoraro (Psychologist), and Dr Monica Mollo (Lecturer in Psychology).

Results

The interactions with the blocks helped to observe behaviors that related to the blocks' physical attributes and the child's competence to establish relations with them. This playful manipulation of

objects probably helps planning and coordinated action, stimulating and strengthening the child's ability to interact with the outside world. At the same time, these activities allow children to imagine new construction scenarios (Harris, 2000). In the presence of potential partners or competitors (children or adults), the child's management of play activities and their implementation of communication strategies can also be observed. For example, the 18-month-old touched and handled all seven blocks, the 21-month-old touched and handled six blocks, and the 24-month-old touched and mechanically stacked all seven blocks.

Based on their independent observations, the two researchers agreed that the three children's symbolic use of objects (see **Table 1**) could be assigned to the first level of symbolic play as proposed by McCune-Nicolich (1981), based on Piaget's sequence (1972), because the children played using sensorimotor schemes. In addition, unlike the 24-month-old, the 18- and 20-month-old played a realistic game. Pretend and symbolic play was not observed in any of the three children's behaviors.

Table 1. *Use of Objects*

	Child 1: 18 months	Child 2: 20 months	Child 3: 24 months
Realistic play	Yes	Yes	No
Pretend play	No	No	No
Symbolic play	No	No	No

Based on observations of the "Can the child build a tower of blocks?" item in section B of the CHAT instrument (see **Table 2**), it was established that all three children used the objects in a manner similar to that described by Piaget as part of the manipulative activities of sensorimotor functioning. The children showed active exploratory behaviors as the toy blocks were manipulated, sorted, and stacked.

Table 2. *CHAT Section B: non-key items.*

	Child 1: 18 months	Child 2: 20 months	Child 3: 24 months
Tower of Blocks	Yes	Yes	Yes
Eye-Contact	Yes	Yes	No

In observations of the Eye Contact item of CHAT section B, the 18- and 20-month-old made visual contact with the adult, but the 24-month-old showed no eye contact. In the child-object- adult or

simple child–object interactions excerpted below, a set of seven colored plastic blocks was placed in front of the child. Transcription commenced when the child began to manipulate the blocks.

Observational results

In this section, we describe the observations we made of children with autism in relation to the types of object use (see **Table 1**). Crucial episodes were selected to illustrate the characteristics of the interactions between the children and the adults.

Generally, adults help children to interact with objects. In the observation of Child 1, the child was able to perform a complex series of actions on the object during the interaction. The child grabbed the object, manipulated it to orient it, dropped it, balanced it, and connected the different objects by stacking them. Here, the adult's help was crucial, as the elements of the child's interaction with the object were changed; at the same time, the object became a mediator in transforming the interactive arrangement between the child and the adult. The adult's hand in direct contact with the object became a source of interest to the child, who focused on this subject–object hybrid.

Observation 1. Child 1. Difficulties in the use of the material features of the object induced the intervention of the adult.

The child cries because the blocks he had begun to stack fall; while he cries, he holds two blocks in his hands and tries to put them on a block on the table. The adult comes over and gets behind the child. The child tries to lay block 1 but fails because he is shaken by tears. The adult places the existing block in a better way. The child looks attentively at the adult's hand and places block 1. The adult takes block 1 with the child and helps to place it in the right position in balancing it.

(...) With his hand, the adult moves block 4 (stacked by the child) to achieve better balance. The child observes the adult's hand. The child leaves block in his left hand alone and, continuing to watch the stacked blocks, extends his right arm to grab block 6. He places block 5 onto block 4 and, without looking, tries to grab block 6.

The child's initial frustration on being unable to stack the blocks led to an intervention by the adult, who was seated on the ground behind the child. The adult intervened when the child played with the blocks, and the object became a mediator of interactions and interpersonal activity.

Observation 2. Child 1. The previous help of the adult activated the attention of the child.

Once block 4 is in his left hand, he stretches his right arm and grabs block 5 before positioning block 4. While watching block 5, the child places block 4 and leaves it on block 3a; in the meantime, he brings block 5 closer to his body. After leaving block 4, the child takes a step back to turn to the adult, and they look at each other.

(...) He places block 6 onto block 5 and leaves it. Having left block 6, he turns to the adult, and they look at each other.

The child continued to play with the blocks, which became a mediator of attention between the child and the adult. After his intervention, the adult facilitated the stronger relational attractiveness of the object, as it became a transformative element in the initial environmental arrangement.

Observation 3. Child 1. The child used the material features of the object correctly after the intervention of the adult.

The child stretches his right hand and grabs block 4. The child then passes block 4 to his left hand, no longer looking at block 4 and directing his gaze to block 5. Meanwhile, the child keeps block 5 in his right hand. Holding the new block, the child turns to the stacked blocks and simultaneously raises his right hand (with block 5). He raises both arms above his head and grabs block 5 with both hands.

The child combined the object's socio-material properties by combining the material properties of the object with the social structures inherent in the object itself.

Furthermore, a series of interesting gestures was observed in the child–object interaction. When the child took the block and raised it over his head, even though the blocks on which the held block was to be placed were much lower in height, the child may have been planning to build a much higher structure with different characteristics to the existing one. One may take these behaviors as possible evidence of an imaginative process. This can also be seen as an explanation of the socio-material link, as imagining a structure beyond what is immediately present may indicate the child's ability to combine the material properties of objects. As the adult intervened, he became an example for the activity of the child. In the child–adult interaction, the object became a mediator of attention.

In the observation of Child 2, the child's manipulative skill was organized in a complex series of actions. He eyed the objects, planned to grab and stack them, rotated the objects in both hands, left, and again grabbed the objects. The material characteristics of the objects were explored. The adult intervened when the child played with the blocks, and the clock (the object) became the mediator for the joint attention of the child and the adult.

Observation 4. Child 2. The child began to actively explore the objects.

The child moves the blocks in front of him (almost shuffling them), watching them carefully. Still looking at the five blocks in front of him, he moves his right hand and touches block 1, which is not present in his visual field.

The child explored the material features of the blocks, and through these actions, which blended complex activities, the child seemed to experience the object adapting and being adapted by its constituent elements. In building a tower of blocks, the child's aims and imaginative action planning appeared to converge. Thus, even though a symbolic game could not be identified, it seems that sensorimotor play and realistic play were present.

Observation 5. Child 2. The child used the material features of the object.

He raises block 1, keeping his eyes on it while grabbing block 2 with his left hand. He turns block 2 around, changing the side that rests on the ground; in the meantime, his right hand brings block 1, moves it in the air, and passes it over block 2. He is about to place block 1 but brings it back close to himself, touching it with his left hand and resting it on block 2.

Here, the child experienced the features of the object. The adult intervened several times during these child-object interactions. The subject-object hybrid identified during the observation of Child 1 is also present here. During the first stage, the child's attention was focused on the transformative mediation of the subject-object hybrid, highlighting how this inextricable relationship drives the modification of the initial environmental arrangement. The child's actions can be seen to occur in a synchronic and harmonic circle of the imitation of the adult's actions.

Observation 6. Child 2. The socio-material features emerged during the child-adult interaction.

The adult places his hand in the child's visual field by moving a block over to him; putting it onto the floor, the adult begins to stack the block. Throughout the sequence, the child is

attracted by the adult's hand manipulating the block. He directs his gaze to block 1 and grabs it; continuing to watch it, he takes it with both hands. The adult begins to stack the blocks. The child manipulates block 1, which he holds in his two hands. He rests block 1 and leaves it. Directing his gaze to the blocks in front of him, he watches the adult, who stacks blocks.

(...) The adult takes the blocks that the child had put in rows and stacks them on top of each other. The child again takes block 4 with both hands. The child carefully observes the adult's movements while stacking. Still with block 4 in his right hand, crawling and with momentum, the child approaches the blocks stacked by the adult. The child grabs block with both hands, looks at it, and manipulates it. He turns block 4 in the direction that seems to enable stacking. He watches the blocks being stacked by the adult and, with his right hand, places block 4 onto the stack of blocks.

The subject/adult-object hybrid appeared to represent the transformation of the subject/adult-object-subject/child relationship, leading to revised planning of the action and thereby structuring of general aims. As well as becoming a mediator of the child's exploration of the surrounding environment, the object also rewrote the relational terms. This last step seems to follow the socio-material perspective, as the social structure of the object was intertwined with its material characteristics.

In observation of Child 3's sequence of actions, the attractiveness of the object overrode the ability to create a contact area with the adult who remained peripheral, or as a mere spectator of the child's construction. Actions have a regularity of performance: blocks are looked at, the hand gets ready to grab, the arm is stretched out to get to the object, the object is grabbed, the child identifies where to put the object, and eventually rests it in balance for stacking.

Observation 7. Child 3. The child used only the material features of the objects.

The child grasps block 1 with his right hand and rests it on a raised board, which has a width equal to the side of the block. He looks closely at block 1 and grabs it with both hands as if to be sure it is in balance. He pulls his right hand away from block 1 and, holding himself with his left hand, leans over the board to see what is there. He directs his eyes to where the blocks are located. He lowers himself, leaning with his left hand on the board and gripping block 2 with his right hand. He gets up and, watching block 1, rests block 2 onto block 1. He removes his right hand from block 2, lowers his body to take block 3, and grabs it with his right hand. He gets up and places it onto block 2, leaving block 3.

Following this regularity of actions, which converged in a purposeful activity, we can assume that the child has completed the main stages of sensory–motor skill development and understood the object’s material characteristics. Additionally, the social function inherent to the object appears to be linked to its use.

In fact, the building of the tower was achieved through structured planning and with a constant imaginative tendency. What is lacking seems to be an understanding of the possibility to use the object as a social agent, because the adult was present only as a spectator.

Based on the regularity of actions that converged in purposeful activity, we can assume that Child 3 had completed the main stages of sensorimotor skill development and was able to understand the object’s material characteristics. Further, the objects’ inherent social functions appeared to be linked to their use. In fact, the building of the tower was achieved through structured planning and with a constant imaginative tendency. The adult did not intervene when the child played. In the child–adult interaction, what seemed to be lacking is an understanding of the possibility of using objects as social agents, as the adult was present only as a spectator.

Searching for constants in analyzing the filmed sequences of the three children, their successive actions were identified; initially, each actively manipulated all the blocks. This activity preceded an apparent break, but during that phase, the child observed the objects to determine how to continue. Immediately thereafter, the child either sought the adult’s attention through eye contact or resumed the interrupted object manipulation.

At the beginning of the game, the children moved, shook, and turned the items several times, and this correlated with activation of their hand movements. Here, we probably witnessed the typical secondary circular reactions of the sensorimotor stage. After the break and the search for mutual attention and/or eye contact with the adult, the children then proceeded (by trial and error) to build the tower of blocks, modifying their existing schemes in so doing. This was indicative of tertiary circular reactions.

Discussion and Conclusions

Consistent with a theoretical perspective emphasizing the role of social and material dimensions in psychological development and activities (Iannaccone, 2015), our analysis highlights two important implications in our observations of object manipulation. First, consistent with the Piagetian

perspective, the observations highlighted object manipulation and action planning identifying the presence of secondary and tertiary circular reactions (Piaget, 1972). In relation to the game, invoking the McCune-Nicolich model (1981), all the children exhibited sensorimotor play, in which the object was manipulated and understood in terms of its material characteristics.

The second implication relates to how, in some action sequences, the material and social characteristics of the objects contributed to shaping partner interactions between child and adult. This aligns with several empirical studies of the social uses of objects (conventional, canonical, and symbolic) (John-Steiner and Mahn, 1996; Moro, 2011). In such interpersonal situations, the activities of participants (child and adult) are clearly affected by the setting's physical and social affordances. In particular, during child–parent interactions (Moro, 2014), triadic child– object–adult interactions (Moro, 2011) seem to create relevant socio-material scenarios that frame communicational activities. In our observations, two of the three children in fact exhibited a kind of object management mode that seemed to replace eye contact with the adult. In some sequences of actions, child and adult managed to coordinate action planning through object manipulation, child exploratory activity, and adult scaffolding. For example, the child observed and touched the objects to encourage play activities; the adult touched the object with his hand, and this action frequently became a source of interest for the child. The child looked for the adult's attention through eye contact, and the child began to manipulate the object. In activities of these kinds, it seems evident that the objects can serve as mediators in communicative interactions with the adult. As well as taking into account the social function of objects, the observed children were already considering the socio-material characteristics of the play situation, as adults and children engaged in managing a kind of “socio-material space” as proposed by Rodríguez et al. (2015). In fact, from the first year of life, adults produce a shared space with objects that serve as effective tools of communication with children. Our findings in relation to the object as a tool for adult–child interaction align with Moreno-Núñez et al. (2017), confirming that the first shared understandings between adult and child take place around the object and its uses. Finally, in considering these first results, we can imagine relevant challenges for a new developmental psychology based on further related research.

Our observations of these interactions do not focus on direct joint attention but identify a kind of psychological process that we call “activity mediated by the object.” Unlike Tomasello (1995), we consider the object itself as mediator, not only of the mutual attention between adult and child but of the dynamic relational exchange between partners.

In conclusion, our study reported the preliminary results of a larger analysis. In considering these first results, we can imagine relevant challenges for the developmental psychology of children with autism. Consistent with the results of studies on children with typical development, our study on children with autism shows that the socio-material features of objects represent factors that mediate the construction of child–adult interactions. Starting from the first intervention of an adult, an object becomes a mediator and promoter of interpersonal activities and space.

Ethic Statement

This study was carried out in accordance with the recommendations of AIP (Associazione Italiana di Psicologia), and all of the children’s parents gave written informed consent in accordance with the Declaration of Helsinki. As there is as yet no psychological ethics committee at the University of Salerno, the protocol was approved by the external experts group from the University’s “Centro di Counseling Psicologico” (Counselling Centre). While the Centre is not specifically responsible for ethics approval, the external experts group supervise research carried out by psychological researchers at the University. In Italy, few universities have a psychological ethics committee, and these generally offer degree courses in psychology or have a psychology department or institute. The University of Salerno has not activated degree courses in psychology and has no such department. We would like to thank the external experts, Dr Oreste Fasano (Psychologist), Dr Nadia Pecoraro (Psychologist), and Dr Monica Mollo (Lecturer in Psychology).

Author Contributions

The introduction was written by AI. The observational analysis was written by FM. The discussion of the results and the conclusions were written by GS.

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Chapter 5

Social Functions in Autistic Children and Interaction with/through Object: A Brief Report

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Abstract

The aim is to analyse the social functions of pointing, of imitation and of joint attention in presence of the object for the autistic children. We have built an ad-hoc observation check-list and we have conducted 43 observations with verbal ASD-affected children aged between 2 years and 6 years. The results show that a better use of the object is correlated to the manifestation of social functions analysed.

Introduction

In a socio-material perspective (Iannaccone, 2015), the object is composed of material features and social components coexisting together. Considering that the social interaction is impaired in autistic children; consequently, the interaction with the “social world of objects” is impaired as well (Iannaccone, et al., 2016). Some autistic children show deficits in the use of objects: alterations in manipulation, exploration and describing. Thus, autistic children which do not present impairment in the use of the object show more social functions than impaired children (Trevvarthen & Hubley, 1978; Tomasello, 1995; 2016).

The three social functions, pointing, imitation and joint attention analysed in the study and they all have in common the presence of the object in their definition. Thus, our aim is to analyse these functions not only taking into account the development of these by the autistic child, but also what role plays the object specifically in social and relational terms.

Method

We have built an ad-hoc observation check-list inquiring on 9 areas (each of which has specifying under-questions), which refer to 9 psychological theory constructs developed by the literature on autism and object. The main objective of this check-list is that of describing characteristics and socio-material functions of the object with reference to autistic subjects. In this check-list, there are different psychological constructs, but here we have analysed in detail three constructs: declarative function, imitation and attention. As we can see the check-list was made of different constructs but we will analyse these other constructs in future.

During each observation, an educator following the child for rehabilitation was present and the educator completed the check-list. Each observation lasted 26 minutes on average and has been transcribed on an ad-hoc check-list.

Children have been observed while interacting with an object, a small-sized plastic toy, they had chosen from a set of objects, for instance, toy cars, trains, toy animals and others. When we refer to “acted and interacted with and through the object” we arranged different constructs of the check-list, such as: Understanding of the use of the object, interaction through the objects etc. Which are the constructs refer to the manipulation, exploration and describing.

We carried out 43 observations with verbal ASD-affected children aged between the end of the sensory-motor stage (24 months) and the start of the pre- operational stage (68 months, namely 6 years). Moreover, the literature shows some results showing a link between a better use of the object

and those functions that emerge during the pre-operating period, such as imitation and attention to the other (Bruckner & Yoder, 2007).

We were two samples. The first sample composed of 18 children who acted and interacted with and through the object while the second sample composed of 25 children who acted and interacted with and through the object.

Results

Regarding the association between the sample 1 and the declarative function (Figure 1) shows that the 66.7% of the sample present this association while the sample 2 shows that only the 24% present this association.

Indeed, it is possible also for autistic children to use the imperative function of pointing, as for typical development children, and pointing is often the ground- breaking of a full declarative function (Camaioni et al., 2003).

Regarding the association between the sample 1 and the imitation (Figure 2) shows that the 94.4% of the sample present this association while the sample 2 shows that only the 60% present this association.

Concerning imitation, it has been suggested that the specific imitation deficit of autism could be reduced or even eliminated with the use of activities linked to objects (Vanvuchelen et al., 2013; Custance et al., 2014), especially when no timelines in the use of objects are given.

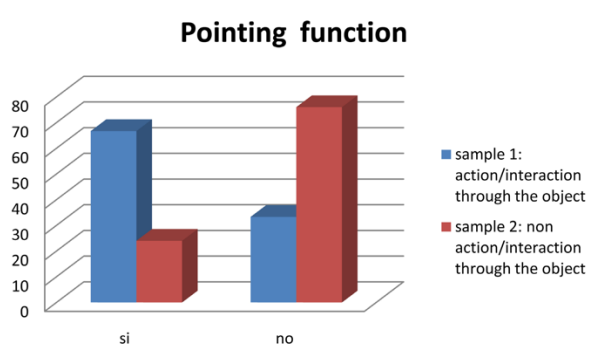


Figure 1. Pointing function

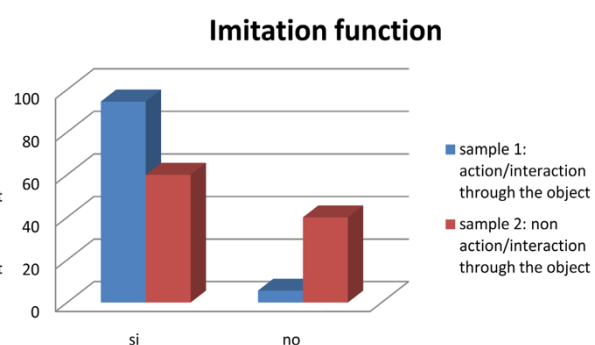


Figure 2. Imitation function

This would favour a higher joint attention, motor imitation and intentional communication with a social partner (Swettenham et al., 1998).

Regarding the association between the sample 1 and the Joint attention (Figure 3) shows that the 61.1% of the sample present this association while the sample 2 shows that only the 32% present this association.

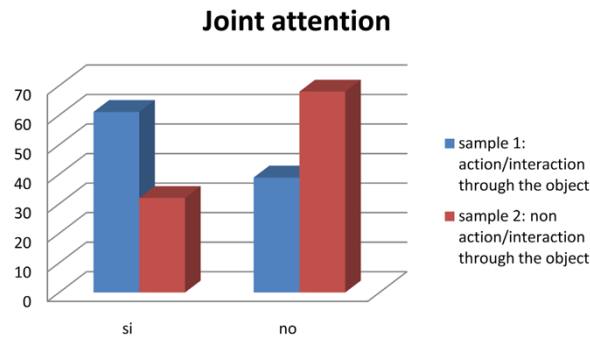


Figure 3. Attention to the adult function

Lastly, regarding joint attention it has been proved that manipulation of material objects can address the child's attention and favour the joint attention with both adults and peers (Korkiakangas & Rae, 2013).

Conclusion

The socio-material features of the object represent factors that mediate the construction of the interaction with the adult. Social functions contribute to this process are: the declarative function (relating to pointing), the imitative function, the function of joint attention.

In line with the literature (Bruckner & Yoder, 2007) on the child with typical development, our study with autistic children shows a link between a better use of the object and these functions that emerge during the pre-operating period, such as imitation and attention for interacting with people.

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Chapter 6

General Discussion

The aims of this thesis were: 1) to explore the intersubjectivity space that a child can establish with an object (the robot) that is also the interactive partner during the interactions; 2) to observe the role of the object as mediator of the child-adult interaction and as promoter of the construction of the intersubjectivity space. The first topic has been investigated in children with typical development while the second topic has been explored in children with atypical development, i.e. autistic children.

In this respect, there were designed two different interactional scenarios to evaluate the intersubjectivity: 1) concerning typical development it has been used an interactional situation involving humanoid robot in order to test the decision-making processes; 2) regarding autistic children the use of the object has been observed during an interaction with an adult mediated by an object, testing the role of the object as mediator and promoter of the interaction. The first situation, involving an innovative field of research, needed a review of the literature in order to understand which role can be assumed by the robot during the interactions with a human. Thus, it was important to analyse if human can ascribe a mind – mental states – to a robot, in particular in a life-span perspective in order to observe changes during the human development. The second scenarios used an original perspective to examine the interaction between autistic children and adults, showing that autistic children, despite their impairments in different areas of development, can create an intersubjective space with the adults. However, this is evident when child and adult use an object as mediator of this interaction.

The findings emerged from these scenarios arise two main questions:

Can a child treat a humanoid robot similarly to a human partner?

Futurologists hypothesised that in the next years robots will be introduced in different contexts of our everyday life such as household, elderly assistance, education etc, modifying the job market but also our social interactions. For instance, the use of robots in the educational context are inspiring new educational program. Moreover, children will be more conscious of the existence of the robots because robots become part of their everyday experience. Several studies underline the need to implement physical and behavioural features in order to make robots more sociable, promoting better

interactions. From Chapter 1 results that subjects ascribe mental states to a humanoid robot. However, the attribution of a mind is not similar at all ages, but it changes during the life-span. For instance, a recent study of Manzi and colleagues (2017) showed that children from 5 to 9 years of age distinguish a human from a robot as regards the attribution of mental states, in particular children ascribe different mental states to a robot at different age: younger children ascribe more emotional states compare to older children. However, several researches in the field of educational robotics show that children treat a robot as a companion and scaffolder in the educational contexts. These findings are evident in the study presented in Chapter 2. In fact, 5-years-old children ascribe less mental states to a robot compared to a human but despite these differences, they use similar strategy with human and robot when they play in an interactive game. This is a fundamental result because it means that children can treat a robot similarly to a human. Moreover, another innovative result of the study is the analyses of children justifications given to the Ultimatum Game. We observed that children tend to use justifications based on the outcome and not on the basis of mentalistic terms both for human and robot, showing how children behave like maximisers – according with the homo-oeconomicus theory – when they interact both with human and robot. In the human condition, children's justifications based on the 'outcome' given to the unfair divisions, both as a proponent and as a receiver, could be explained as the attempt to resolve a cognitive and social conflict (expected "social" fair behaviour VS real "selfish" behaviour). Moreover, in the robot condition, children's justifications based on mentalistic terms to unfair divisions, both as a proponent and as a receiver, can be explained as the social norms of equity might be less relevant (robot = "not perfectly like-me").

The literature review in Chapter 2 and the data of Chapter 3 represent an important finding for the HRI and cHRI because it is possible to infer that humans – from childhood to old age - tend to ascribe a mind to a robot and that besides 5-years-old children tend to treat a robot as social partner, using similar cognitive strategies both for human and for robot.

In conclusion, robots can be considered 'like-me' (Meltzoff, 2005, 2007a, 2007b, 2013) but it depends from: 1) the age of human partner interacting with a robot; 2) the methodological procedures, and particularly the nature offline (i.e., the AMS questionnaire used in Chapter 3) or online (i.e., the modified version of the Ultimatum Game used in Chapter 3) of the tasks employed; These final observations lead to reflect on the instruments used in research and this is even more important when the topic of research is new such as the HRI. In fact, it is essential to combine both offline and online measures, but also it is important use together ecological and laboratory tasks.

Can an object be a mediator and a promoter of the child-adult interaction also for autistic children?

We live in a social world composed by humans and objects. In the history of Psychology, the human-human interactions were largely investigated but few studies analysed the human-human interaction mediated by objects. In this regard, Piaget (1952, 1954) highlighted that children discover the world of the objects through a sensorimotor activity, which constitutes the basis of the cognitive development. Vygotskji (1962, 1978) showed that children with typical development use artefacts to interact with others, acquiring their knowledge about objects through the interaction with a scaffolder (peers or adults). Moreover, Moscovici (1976) examined the interpersonal relationships in a triadic perspective, highlighting that humans and objects are strictly connected. However, Linell (2009) proposed a dialogical interpretation of the objects, suggesting that it is important to understand the objects as external referent that can change human's perspective of the world. Several studies showed that an adult can be a scaffolder for the acquisition of the use of the objects in children with typical development (Moro, 2014). In Chapter 4 and 5 we demonstrated that also children with atypical development, in particular autistic children, can use the object to construct an intersubjectivity space during the interaction with the adult. The objects in these interactions acts as mediators of the child-adult interaction, creating a specific intersubjective space in which autistic children, despite their social impairments, are able of some social performances (i.e., ocular contact).

In Chapter 4 the results seem to demonstrate that the socio-material features of objects represent a key-element that mediates the construction of child–adult interactions, becoming a mediator and promoter of interpersonal activities and space. Chapter 5 shows a link between a better use of the object and the presence of social behaviors that emerge during the pre-operational stage, such as imitation and attention. However, it is important to highlight that the use of the object and the presence of social abilities largely vary in each autistic child because autism is a spectrum disorder that implies a wide range of phenotypes. Thus, the construction of intersubjectivity space has to consider the specific subjects of the interaction and their interpretation of the objects.

These findings lead to the conclusion that to understand how children with typical development interpret the use of the objects it is important that adults ‘share’ the child’s perspective in order to create an intersubjective space. If it is crucial in typical development, then it becomes even more essential in atypical development, in particular in autism that is a spectrum of disorders that imply a different kind of impairments in several areas of development. In fact, the adult has to consider that each autistic child constructs the intersubjectivity space in a subjective way, using all her/his skills.

In general, both as regards typical and atypical development, the adult should accept that each artefact is always reinterpreted by the child in a triadic relationship through a continuous and dynamic construction of the intersubjectivity.

Conclusion

The majority of the psychological research is inspired by everyday experiences and so I will try to give some examples of the key points of this thesis, starting from my life.

I am writing my thesis using my computer right now and its battery is almost discharged. I am saying “Why you do this to me?”. Despite my prayers, my computer will switch off if I will not put it in charge. What does this situation mean? I am ascribing intentions to my computer, in particular the intentions to turn off itself.

I remind that in UK when I was learning how to use a robot, I was staying in the Lab hours and hours without talk to anybody and so I was starting to talk to the robot, ‘praying’ it to work in the right way. It obviously continued to not work and to not reply to my questions and prayers (fortunately!).

I bought a toy for a son of two friends of mine when he was 6-moths-old. Then these friends moved to USA and sometimes we Skyped, but I did not see them for a long time. This summer when I came back to my hometown, I saw them after three years and the child still had the toy and when the mother said him that I bought it for him he smiled and give me the toy to play together.

The above examples highlight the two main points of this thesis: 1) we can ascribe mental qualities also to objects that have not ‘really’ a mind because we tend to project our internal states onto the external world; 2) we are fully immerse in a world of objects that give us the opportunity to create an interaction with another person beyond the time.

To attempt a tentative conclusion, the purpose of this thesis was to show that when humans build objects - from the classic ones to the more technological ones - they also achieve two further important objectives: to facilitate social interactions and to create an intersubjectivity space that includes both human and non-human partners. I sincerely hope my efforts have at least partially succeeded.

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