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Coordination processes in conversation:
The cases of gaze in greetings and storytelling in teaching

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"Coordination processes in conversation: The cases of gaze in greetings and storytelling in teaching"

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Abstract

Throughout human evolution, face-to-face conversational interaction has been the primary means of communication in everyday life. It is the fundamental setting for human interaction and so ideal to gain insights into the nature of communication (Schegloff, 2007). Humans communicate primarily to solve problems of cooperation, and these cooperation problems are a source of evolutionary pressure that has shaped the nature of social interaction. This thesis focuses on the cases of two recurrent coordination problems in communication, and the behavioural adaptations specialised to resolve them. One recurrent interactional problem we face is how to begin face-to-face social interactions (Pillet-Shore, 2018). Contrary to what we might first think, social interactions do not begin by people simply starting to speak, instead they must engage with each other methodically through a combination of verbal and non-verbal cues in order to get into the interaction (Mondada et al., 2020). Gaze is specialised during greeting behaviour to solve this problem by initiating social interaction. Another recurrent interactional problem faced by all human cultures is passing on information and skills to prevent them from dying out from one generation to the next. This is commonly achieved through the social activity of teaching (Kline, 2015), particularly through the specialised teaching method of storytelling (Scalise Sugiyama, 2017). The cases of gaze in greetings and storytelling in teaching illustrate how humans have adapted to facilitate social interaction, providing broad insight into coordination processes in communication.

Keywords: cultural transmission, teaching, storytelling, eye tracking, conversational openings

Abstract

Tout au long de l'évolution humaine, l'interaction conversationnelle en face à face a été le principal moyen de communication dans la vie quotidienne. Il s'agit du cadre fondamental de l'interaction humaine, ce qui est idéal pour comprendre la nature de la communication (Schegloff, 2007). Les humains communiquent principalement pour résoudre des problèmes de coopération, et ces problèmes de coopération sont une source de pression évolutive qui a façonné la nature de l'interaction sociale. Cette thèse se concentre sur les cas de deux problèmes récurrents de coordination dans la communication, et les adaptations comportementales spécialisées pour les résoudre. L'un des problèmes interactionnels récurrents auxquels nous sommes confrontés est de savoir comment commencer les interactions sociales en face à face (Pillet-Shore, 2018). Contrairement à ce que l'on pourrait penser, les interactions sociales ne commencent pas simplement par la parole, mais par une combinaison d'indices verbaux et non verbaux afin d'entrer dans l'interaction (Mondada et al., 2020). Le regard est spécialisé pendant le comportement de salutation pour résoudre ce problème en initiant l'interaction sociale. Un autre problème interactionnel récurrent auquel sont confrontées toutes les cultures humaines est la transmission d'informations et de compétences pour éviter qu'elles ne disparaissent d'une génération à l'autre. Ceci est communément réalisé par l'activité sociale de l'enseignement (Kline, 2015), en particulier par la méthode d'enseignement spécialisée de la narration (Scalise Sugiyama, 2017). Les cas du regard dans les salutations et de la narration dans l'enseignement illustrent la façon dont les humains se sont adaptés pour faciliter l'interaction sociale, fournissant un large aperçu des processus de coordination dans la communication.

Mots clés : transmission culturelle, enseignement, narration, eye tracking, ouvertures conversationnelles

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General introduction

Throughout human evolution, face-to-face conversational interaction has been the primary means of communication in everyday life. It is the fundamental setting for human interaction and so ideal to gain insights into the nature of communication (Schegloff, 2007)[1]. Humans communicate primarily to solve problems of cooperation, and these cooperation problems are a source of evolutionary pressure that has shaped the nature of social interaction. This thesis focuses on the cases of two recurrent coordination problems in communication, and the behavioural adaptations specialised to resolve them. One recurrent interactional problem we face is how to begin face-to-face social interactions (Pillet-Shore, 2018). Contrary to what we might first think, social interactions do not begin by people simply starting to speak, instead they must engage with each other methodically through a combination of verbal and non-verbal cues in order to get into the interaction (Mondada et al., 2020). Gaze is specialised during greeting behaviour to solve this problem by initiating social interaction. Another recurrent interactional problem faced by all human cultures is passing on information and skills to prevent them from dying out from one generation to the next. This is commonly achieved through the social activity of teaching (Kline, 2015), particularly through the specialised teaching method of storytelling (Scalise Sugiyama, 2017). The cases of gaze in greetings and storytelling in teaching illustrate how humans have adapted to facilitate social interaction, providing broad insight into coordination processes in communication.

Evolutionary adaptations to social interaction

Humans adapted in order to communicate more effectively in response to the evolutionary pressure of living as cooperative breeders in larger groups (Zuberbühler, 2011). The kin networks within which early humans coordinated social and ecological action (Hughes, 1988) were replaced by larger groups containing non-kin (Dunbar, 2004). Individuals within these larger groups relied on each other for food and labour, so cooperation became crucial for survival (Tomasello et al., 2012). This led to an increased capacity for social interaction and provided an interactional foundation for language (Levinson, 2006). Humans became finely tuned to the intentions of others (Grice, 1975), and not only

[1] References for the General introduction and General discussion are in the Global references section at the end of the thesis. References for each study are included at the end of each section.

their behaviour. Under these conditions, humans developed a unique set of features and abilities geared towards social interaction, such as a tendency to enjoy spending time with others, or voluntary control of face muscles and vocal chords (Levinson, 2006).

Multimodal adaptation

More frequent involvement in cooperative tasks meant increased use of simple communicative behaviours such as gesture, posture, movement, vocalisations and facial expressions (Donald, 1993). Human communication is characteristically multimodal, in that it integrates different signalling modalities, often tied together with very tight coordination (Holler & Levinson, 2019). Gesture and speech co-evolved as one multimodal communication system (Levinson & Holler, 2014). The physical arrangement of bodies is key to conversational coordination. For example, a free-standing conversational group with several participants will typically all face inwards, orienting themselves to create a shared space facilitating a common focus of attention that they then cooperate to sustain (Kendon & Ferber, 1973). A person's level of engagement in a conversation can be inferred by their posture, with the orientation of the legs indicating the dominant involvement, then the torso, and finally the head (Robinson, 1998). As with all social animals, humans synchronise their movements to regulate social interaction (Wiltermuth & Heath, 2009) and this synchronisation promotes liking (Bernieri et al., 1994).

The physiological features of modern humans developed under social constraints, and this is particularly evident in the case of the eyes. Humans have a large white sclera (Kobayashi & Kohshima, 2001), making it easier to detect gaze direction, and therefore infer intention. Gaze has a dual function, as we simultaneously use our eyes to gather information about our environment and signal information about our own internal state. Humans are sensitive to gaze and this facilitates social behaviour (Grossmann, 2017). There is an adaptive advantage to quick detection of being looked at, known as the face-in-the-crowd effect (Baron-Cohen, 1996). Faces, and eyes specifically, are the first and most frequently fixated area during social interaction (Birmingham et al., 2008; Buswell, 1935; Yarbus, 1967) and this preference develops early in life (Symons et al., 1998). The eyes automatically attract gaze, we cannot inhibit this even when instructed to (Laidlaw et al., 2012). One's gaze direction

can automatically cue the spatial attention of others (Hessels, 2020). It has been estimated that we are sensitive to sub-millimetre displacements of another person's iris (Cline, 1967; Gibson & Pick, 1963). The eye region is very important for identity recognition (Sekiguchi, 2011) and gaze enhances cooperation during social interaction (Freire et al., 2004). Gaze is highly attuned to the interactive context (Hessels, 2020), perhaps owing to the equilibrium of approach versus avoidance forces associated with gaze. The avoidance forces of gaze stem from arousal as a result of threat perception, as being the object of another person's attention could also mean that we are under attack. This is the case in many other species (Emery, 2000). The approach forces of gaze stem from the fundamental human need to belong (Baumeister & Leary, 1995), as being looked at indicates we are the object of another person's attention (Conty et al., 2016). Gaze therefore also causes positive affect as it can indicate social inclusion (Wirth et al., 2010). Balancing these two forces during social interaction is complex, especially when there are multiple participants, and given that we only have one pair of eyes each. This makes gaze a precious resource that we must constantly monitor that we are allocating appropriately (Rossano, 2012). Humans have therefore physiologically and behaviourally adapted their gaze in response to the evolutionary pressures to communicate more effectively.

Adaptation of language use

The need to cooperate and live in larger groups may have also boosted the transition to more elaborated forms of language use (Donald, 1993), such as storytelling. These larger groups required enhanced coordination and cooperation strategies in order to prevent problems such as free-riding and remain socially cohesive (Carpenter, 2007). Language provided a tool through which social interaction could be facilitated (Fusaroli & Tylén, 2012; Tylén et al., 2010). Disappearing kin networks were replaced with linguistic kin networks (Allen, 1989), enabling the tracking of a significantly larger number of group-members and facilitating social cohesion. Mutual reliance for food and labour across members of a group engendered the need to refer to things not in the here-and-now, for example, information about a distant food source (Bickerton & Szathmáry, 2011). This ability to communicate about things not spatially or temporally present is called displaced reference (Hockett, 1960), and is a ubiquitous feature in all human languages (Lameira & Call, 2018). The need to communicate under

displacement helped shift early hominin communication from referring to things immediately present (which can also be shared through co-presence) to a system based on the intentional transmission of conceptual references. Through language, large amounts of information can be compressed and transmitted to others without the need to experience it first-hand. The development of language co-occurred with extra hours granted by firelight (Wiessner, 2014). Firelight affected circadian rhythms, and added around four hours to the day (Dunbar, 2014). These extra hours could not be used for productive work such as foraging or making tools due to poor light levels, so created time for social interaction (Wiessner, 2014). During this time, social bonds and coalitions among non-kin could be created and maintained through language (Dunbar, 2017). The future-directed cooperation needed to coordinate larger groups was therefore crucial to the emergence of more complex forms of language.

One of the more elaborated forms of language that may have emerged during this time is narrative (Donald, 1993), known in its conversational form as storytelling (Mandelbaum, 2013). During storytelling, narrators recount sequences of past events, and explain how protagonists' actions contribute to the changing of an initial situation (Bruner, 1991; Labov & Waletzky, 1967). Telling and listening to stories enables the compression of time without any physical exertion, making it an easier way to gain knowledge than through trial-and-error (MacDonald, 2007; Sugiyama, 2001). For example, knowledge about animals is important in hunter-gatherer societies, but encounters with animals during hunting are rare and can be dangerous (Sugiyama, 2001). An easier way to obtain this crucial survival information is through listening to other hunter's animal encounters related as stories, and this is reflected in the ethnographic record that indicates the prominence of animal information in the oral traditions of many hunter-gatherer societies (Hewlett, 2017). Modern hunter-gatherers allow us to understand some of the conditions believed to have characterised our evolutionary past, enabling us to infer that storytelling is adaptive (Smith et al., 2017), as it may have been used by ancestral humans to transmit this type of survival-related information (Sugiyama, 2001).

As well as enabling the transfer of survival-relevant information, the activity of storytelling itself fosters social cohesion, which also has adaptive benefits. Storytelling is a means of creating and cementing social bonds, and fosters the integration of individuals into groups from early childhood onwards (Fivush et al., 2018). Storytelling develops early in ontogeny and emerges at the same time as

an array of cognitive abilities oriented towards sociality (Salmon & Reese, 2016). Good storytellers are valued social partners (Smith et al., 2017), as storytelling is a pleasurable activity (Mellmann, 2012) in part because it helps us to make sense of the world around us through sensemaking. Sensemaking is a process that enables people to attribute meaning to their experiences (Weick, 1995). The human cognitive system usually structures perceptual meaning top-down through arranging our experiences into knowledge structures such as schemas, scripts or frames (Goffman, 1974; Mandler, 1984). However, events often do not meet our expectations, and the surprise of incongruence produces negative arousal (Proulx et al., 2012) that we are motivated to resolve through re-conceptualising the event. Storytelling enables us to place events into a coherent sequence and establish causal links between them, meaning we can update our knowledge structures accordingly. This type of sensemaking is a key component of how people learn through storytelling in everyday contexts (Orr, 1996; Wenger, 1999). Although some evidence indicates that storytelling is a highly memorable format (Sperber, 1985) that can enable the accurate transfer of information across generations of individuals over a long time span (Rubin & Umanath, 2015), there is also much evidence that the sensemaking that occurs through storytelling often involves the transformation of information. For example, memory biases enhance memory conformity with other people as stories are retold over time, regardless of the truth-value of the information in circulation (Stubbersfield et al., 2017). Sensemaking through storytelling can facilitate the creation of an overarching identity and thus the definition of an ingroup and an outgroup (Feinberg et al., 2014). This is shown at multiple levels of social groups, for example in how founding myths establish a sense of nationhood (Anderson, 2006) or how stories construct family histories (Fivush et al., 2018). Storytelling is therefore an adaptive behaviour as it fosters social cohesion.

Coordination problems addressed by this thesis

Coordination problem 1: How to open social interactions?

A recurrent problem that we encounter in face-to-face social interactions is how to initiate them. Gaze is a coordinational tool that helps us resolve this problem. Contrary to what we might first think, social interactions do not begin by people simply starting to speak, but must be initiated before

they get started. The start of a social interaction is a process, not a precise moment in time (Mondada et al., 2020), during which we use multimodal resources, especially gaze, to signal desire to interact and gain clearance to approach others. Humans are not alone in this, as many other species also display greeting behaviours (Fedurek et al., 2019; Laporte & Zuberbühler, 2010). Any joint activity can be divided into three distinct phases: an entry, main body and exit phase (Clark, 1996). Greetings play an important role in the entry phase and have several important functions, such as to define identities and re-establish continuities so that the main body phase may begin (Clark, 1996). Yet greetings are complex sequences in their own right that must be coordinated on-the-fly by participants. In order to interact it is necessary to come close enough to the other person for speech to be heard and for the face to be seen (Goffman, 1963). However, this can be problematic as approaching a person can be perceived as a threat, as is shown in skin conductance responses (Hietanen et al., 2008; Nichols & Champness, 1971; Pönkänen et al., 2011). This stems from the territorial behaviour developed in ancestral environments with the purpose of controlling access to food, water and shelter, which became of increased daily importance once humans were living among non-kin (Hughes, 1988). To neutralise this threat response, we engage in greeting behaviour to coordinate the possibility and purpose of social interaction (Goffman, 1963). In most densely populated urban environments, strangers treat each other with civil inattention by scanning others with brief direct gaze, and then averting their gaze in order not to impose on each other (Goffman, 1963). Equally, when we do wish to start talking to someone, we seek out mutual gaze as a pre-interactional step in order to give clearance for further interaction (Cary, 1978; Krivonos & Knapp, 1975). Then we perform distant salutations such as waving and smiling, and then avert our gaze as we walk towards the other person, often while engaging in "non-threatening" body signals such as self-grooming or body-crossing (Kendon & Ferber, 1973). Once we are near enough to perform the close salutation, that often includes bodily contact such as a handshake or hug, mutual gaze is re-established. Greetings involving physical contact require gaze to coordinate movement (Land & Hayhoe, 2001), but as we have seen gaze is also an important social signal. So how do humans deal with this dual use of gaze? This can be described as a resource allocation problem. At the same time, signals from other modalities such as vocalisations must be incorporated in a prosocial way. Gaze is therefore a crucial signal in the initiation of social

interactions, but it is not clear how we balance the multiple motor and social functions of gaze to achieve greetings while also integrating behaviour from other modalities.

Coordination problem 2: How to transmit skills and information?

The challenge of transmitting knowledge to the next generation is faced by all human cultures (Bowles & Gintis, 2013). This problem is commonly resolved through the social activity of teaching. Cumulative cultural evolution is a key phenomenon in human cultural transmission, whereby behaviours or artefacts tend to improve over generations (Caldwell et al., 2017), and it is crucial in order for culture to accrue. Cumulative cultural evolution requires precise copying to prevent loss of advancements (Tomasello, 1999), but also requires innovation in order to improve on previous solutions. These are known as the dual engines driving cumulative cultural evolution (Legare & Nielsen, 2015), and much research aims to understand the mechanisms behind the decision to stick with a current solution (copy) or switch to a different one (innovate) (Rogers & Fay, 2016). There are many different types of social learning that individuals may use to inform this decision. Teaching underpins human culture (Galef, 1992) and can be defined as a form of cooperative behaviour that has evolved to promote learning in others (Caro & Hauser, 1992). We seek socially transmitted solutions to the vast majority of obstacles in our lives (Whiten et al., 2009). Teaching is widely understood to have an important role in cultural transmission (Caldwell et al., 2017), the process by which individuals forming a society or culture tend to learn and pass on information. The term 'teaching' refers to a wide range of these social learning situations. Some of these, such as observational learning, exist in many species as they can occur by chance observation of an individual using an object (Kline, 2015). However, in many situations no materials are present and so physical demonstration is not possible. This requires displacement, the ability to communicate about things not spatially or temporally present (Hockett, 1960). Humans are unique in their ability to teach in these abstract situations and this is perhaps one of the keys to our particular trajectory of cultural evolution (Burdett et al., 2018; Kline, 2015; Zlatev et al., 2020). Teaching under displacement requires the communication of concepts via language (van Schaik et al., 2019), enabling teaching to occur in an almost infinite range of contexts.

Language-based teaching can promote both copying and innovating in cumulative cultural evolution as it is inherently flexible (Burdett et al., 2018). Skills too complex to learn by observation can be communicated conceptually through language-based teaching, and teaching is often associated with precise copying (Lewis & Laland, 2012). Feedback and active participation in face-to-face conversational teaching support this. Collaborative accounts of dialogue have shown the importance of feedback to ensure information is better understood (Clark, 1996; Schober & Clark, 1989). Interactivity slows the rate of information loss over generations for manual tasks such as knot-tying (Caldwell et al., 2017) and stone-knapping (Lombao et al., 2017; Morgan et al., 2015). Innovation is also promoted by teaching as it provides the opportunity to socially appraise solutions, and teachers can suggest ways in which information can be modified (Burdett et al., 2018). Content bias (perceived effectiveness of a solution) is instrumental in the decision to transmit one's own solution over someone else's (Tamariz et al., 2014). Access to socially transmitted information during teaching enables better evaluation of an artefact and thus a better-informed decision about sticking vs. switching. This could enable group-level coordination and help maintain the optimal balance between innovation and copying.

Storytelling is a language-based teaching method that plays an important role in cumulative cultural evolution, as it affects the balance between copying and innovating in several ways. There is evidence that the interactive aspect of face-to-face storytelling slows the rate of information loss as information is passed down chains of individuals (Tan & Fay, 2011). This may be because storytelling is vivid and memorable due to use of direct reported speech (Holt, 1996; Mandelbaum, 2013) and mimicry as a narrator re-enacts the story (Sidnell, 2006). Storytelling is thus an effective way to learn vicariously from other people's experiences. In addition, storytelling promotes innovation as it often arises from people trying to make sense of events. When teaching under displacement, teachers cannot rely on the affordance of present objects that can be shared through co-presence. Instead, the past and future must be constructed through mental and linguistic representations (Hockett, 1960). Storytelling is a pervasive way to achieve this (Bruner, 1991). Members of work communities tell stories as part of their everyday knowledge integration (Bangerter et al., 2011), indicating storytelling is specialised for communicating about non-routine, uncertain or novel situations (Bietti et al., 2018). Sensemaking

through storytelling allows individuals to simulate alternative solutions to a problem through "cognitive play" (Boyd, 2009). This relates to the collective innovative brain (Muthukrishna & Henrich, 2016), by facilitating the group-level coordination of copying and innovating strategies. Analysis of storytelling as a teaching method can therefore shed light on how learning strategies are balanced in cultural transmission.

This thesis

Main goals

Several aspects of the previous sections warrant further investigation. Firstly, it is clear that gaze is an important tool for the coordination of social interaction generally (Rossano, 2012) and of greeting behaviour specifically (Cary, 1978; Krivonos & Knapp, 1975). However, exactly how does gaze tie in with other non-verbal and verbal modalities over the course of a greeting? Gaze has not yet been empirically measured under lab conditions during the approach when people move towards each other in preparation for the close greeting. Investigation of gaze behaviour during the approach would shed light on how people balance multiple uses of gaze. On the one hand, gaze is necessary to fulfil a variety of motor functions (Land & Hayhoe, 2001; Niechwiej-Szwedo et al., 2021). Research on human movement has started to shed light on how basic motor functions differ when we are in the presence of others (Becchio et al., 2012; Becchio et al., 2010; Sacheli et al., 2012). Similar research in the context of greetings would be informative. On the other hand, gaze has social functions, primarily balancing the approach and avoidance forces of direct gaze (Argyle & Dean, 1965). Greeting is a particularly relevant time to investigate the balance between these two forces as it is key to define identities and establish the tone for the rest of the interaction (Schegloff, 1979). Understanding how people collaboratively resolve the resource allocation problem of gaze and how gaze fits into the multimodal coordination of greetings are the research questions motivating the first half of this thesis.

Secondly, social learning is important to cultural evolution (Heyes, 2012). Some forms of social learning such as observation or imitation are prominent in many species (Thornton & Raihani, 2008). However, teaching is a form of social learning prominent only in humans and perhaps one of the keys to our particular trajectory of cultural evolution (Burdett et al., 2018; Kline, 2015). Further

analysis of the content and functions of teaching in cultural transmission is therefore required, especially under the condition of displacement. To start with, there is debate surrounding the usefulness of teaching in this context. Other non-social learning mechanisms such as emulation, i.e., reverse-engineering artefacts by copying them, can be equally as powerful (Caldwell & Millen, 2009; Zwirner & Thornton, 2015). A direct comparison of the benefits of teaching over and above emulation would therefore be useful. It is not clear how teaching influences the balance between the dual engines of cultural transmission, copying and innovating (Legare & Nielsen, 2015). Studies of teaching with copying goals, measuring rate of loss from an original artefact, and improvement goals, measuring increase in functional efficacy of objects, are required in order to shed light on this (Caldwell & Millen, 2008). The ethnographic record indicates that storytelling is a language-based teaching method that facilitates skill transmission (Scalise Sugiyama, 2017). Investigating the content and functions of teaching, and specifically storytelling, is therefore the central research question motivating the second half of this thesis.

Methodology

This thesis has been divided in two parts using different methodological tools to address each research question. The first part, titled 'Opening social interactions' (Studies 1 and 2) uses dual mobile eye tracking methods. The two empirical studies in the second part, titled 'Cultural transmission in social interaction' (Studies 4 and 5) use a transmission chain method optimised for the study of teaching. These methodological choices were based on several considerations.

The methodological rationale of the eye tracking studies is to combine the precision of laboratory conditions with naturalistic observation. Advances in mobile eye tracking technology mean that gaze behaviour no longer needs to be studied in static, screen-based paradigms. Eye tracking glasses (ETGs) allow the tracking of gaze as a participant engages in face-to-face conversation, and fitting both participants with ETGs provides an enriched dataset that resembles real-life interaction (Broz et al., 2012; Ho et al., 2015; Rogers et al., 2018). However, these studies focus only on the main body of interaction, not on the way conversations are initiated. Our study fits participants with ETGs in separate locations before they are brought into the same room, documenting their gaze behaviour

from the moment they are revealed to each other and during the approach as well as close greeting. Early research on greeting behaviour (Argyle, 1975; Goffman, 1963; Kendon & Ferber, 1973) and more recent conversation analytic research (De Stefani & Mondada, 2018; Harjunpää et al., 2018; Mondada et al., 2020; Mortensen & Hazel, 2014; Nilsson et al., 2018; Pillet-Shore, 2018) relies on estimation of gaze direction from video recordings. However, eye movements are quick, so difficult to accurately measure from mere observation, with saccades being made at a rate of 3 to 4 per second (Hessels et al., 2018). Studies 1 and 2 take full advantage of the mobility ETGs afford and provide a level of precision beyond existing research. Another important methodological consideration is the use of two naïve participants. Handshakes have been studied in the lab before, but often in ways that do not resemble genuine face-to-face interaction. For example, participants watch videos of virtual avatars (Dolcos et al., 2012; Katsumi et al., 2017), role-play a handshake wearing sensored gloves (Melnyk & Hénaff, 2019) or shake the hand of a confederate who has been instructed to 'act neutral' (Åström, 1994; Nagy et al., 2020; Stewart et al., 2008). Considering the inherently collaborative nature of social interaction (Bavelas & Coates, 1992; Clark, 1996) and the hazards of using confederates in studies of communication and dialogue (Kuhlen & Brennan, 2013), the use of two naïve individuals is preferable.

The methodological rationale of the cultural transmission studies is to design paradigms specialised for the analysis of teaching content during skill transmission. The transmission chain method allows for experimental investigation of how cultural products (i.e. information or artefacts) are modified when passed through a succession of individuals (Fay et al., 2018). Existing lab-based transmission chain studies only allowed very restricted forms of 'teaching' to occur, For example, emulating other participant's objects (Derex et al., 2019; Derex et al., 2013; Fay et al., 2019), or observing their actions without being able to interact (Wasielewski, 2014). When face-to-face, interactive teaching is allowed, it commonly occurs while the teacher (Caldwell & Millen, 2009) and / or the learner (Morgan et al., 2015; Osiurak et al., 2020; Zwirner & Thornton, 2015) is simultaneously engaged in the task. Our studies separate teaching from task performance and remove time constraints in order to better observe and analyse teaching content. Studies of skill transmission can either have

copying or improvement goals (Caldwell et al., 2017), and Studies 3 and 4 of this thesis investigate teaching in each scenario respectively. Choosing the right task with an appropriate complexity level is a challenge faced by all cultural evolution studies (Miton & Charbonneau, 2018). Some studies use simple tasks such as making paper aeroplanes (Caldwell & Millen, 2009; Fay et al., 2019) whereas others use more complex ones such as stone-knapping (Lombao et al., 2017; Morgan et al., 2015). Stone tools have long been central to debates in human cognitive evolution because they survive so well in the archaeological record. However, there were likely many more, arguably equally as important artefacts that were made out of perishable raw materials. One of these is the mobile container, central to the development of foresight by enabling the transport of raw materials such as foraged food and of tools to solve multiple future problems (Fisher, 1979; Langley & Suddendorf, 2020). By choosing two different types of mobile container building, basket weaving in Study 4 and basket construction from various materials in Study 5, this thesis helps build the case for mobile containers in human cognitive evolution studies.

Overview of thesis

The following five sections present the four empirical studies (Studies 1, 2, 4 & 5) and one theoretical paper (Study 3) carried out for this thesis, as outlined below.

Part one of this thesis, 'Opening social interactions' comprises Studies 1 and 2, which focus on the case of handshake greetings. Both studies are derived from the same experiment, where pairs of unacquainted participants were fitted with eye trackers separately, then introduced in the lab under the premise that they would play a game. The period of analysis included the approach, spanning from the moment participants were revealed to each other until the moment they had completed the close greeting.

Study 1 documents the methodical organisation of handshake components from both verbal and non-verbal modalities. Greetings could be clearly divided into two distinct stages, supporting early interactionist and conversation analytic observations of distant and close salutations (Kendon & Ferber, 1973). Participant's gaze behaviour was organised methodically throughout the greeting. For example, participants did not gaze at each other's faces continuously throughout the approach,

suggesting that gaze aversion is an important tool in the regulation of intimacy during greeting behaviour (Ellsworth & Carlsmith, 1973). Several observations were made concerning organisation of greeting vocalisations. Greeting vocalisations were carried out with close timing (De Ruiter et al., 2006), and this varied according to interpersonal distance, as distant salutations had larger gaps while close salutations involved more overlap. Repair was not initiated after overlapping talk and a lack of reciprocity was observed in adjacency pairs, showing some violation of conversational coordinational principles (Tsui, 1989). Use of laughter related to both temporal aspects of the greeting and the role of the participant (i.e., whether they were approaching or being approached). These asymmetries shed light on the way laughter is used as a tool to coordinate the start of social interactions. Results also suggested gender effects, such as men gazing more at faces and women laughing more.

Study 2 investigates the use of gaze during handshake greetings in more detail. The analysis hones in on the problem of how people allocate the scarce resource of gaze in the face of multiple functions (Argyle & Dean, 1965). Like many other greetings that involve physical contact, handshakes rely on gaze to coordinate movement (Land & Hayhoe, 2001). Yet gaze is also an important social signal, as we must balance the affiliative need to look into the eyes of others with the avoidance force to look away in order to reduce threat (Argyle & Dean, 1965). The visibility of direct gaze is manipulated with the use of shaded inserts in three conditions: both transparent, both shaded or one of each type of shades. Regardless of condition, participants gazed at their partner's hand around half a second prior to the grasp, confirming motor coordination functions of gaze (Sacheli et al., 2012). Participants gazed more to faces with blocked eye visibility, suggesting that participants in this condition experienced less arousal and avoidance forces caused by direct gaze and so did not have to avert their eyes in order to break the intensity of mutual gaze. Unexpected gender effects were revealed, as men's faces were looked at differently according to the gaze of the observer: men were looked at by other men a lot while women looked at men's faces very little. Gender also had a strong effect on participants' reported liking and rapport, as both men and women rated women more highly. Our results thus suggest that people approach men differently than they do women, and also form impressions differentially on the basis of gender in the context of handshake greetings.

Part two of this thesis, 'Cultural transmission in social interaction' comprises a theoretical paper focusing on the case of storytelling in teaching (Study 3) and two experiments (Studies 4 and 5). The theoretical paper reviews experimental and ethnographic literature to make the case for storytelling as an adaptive tool for collective sensemaking (Bietti et al., 2019). Studies 4 and 5 are each experimental transmission chain studies involving the complex manual skill of basket-making.

The theoretical paper (Study 3) investigates the wider role of storytelling as a key element in the creation and propagation of culture. The specific adaptive value of storytelling over and above language use in general is determined as making sense of non-routine, uncertain, or novel situations. This enables the collaborative development of previously acquired skills and knowledge (Orr, 1996; Wenger, 1999), but also promotes social cohesion by strengthening intragroup identity and clarifying intergroup relations (Anderson, 2006). Storytelling is provides a type of social glue that is particularly crucial at times when societies experience fast, unforeseen changes in the cultural niche, during which groups need to protect or modify existing world views to make sense of events around them (Proulx et al., 2012).

Study 4 investigates the transmission of basket-weaving skills in the context of precise copying goals. The experimental design allows for a clear, within-subject comparison of the effects of teaching and emulation over and above emulation alone, as the same initial artefact develops with and without social interaction over two generations. The specific features of teaching are analysed as well as in what forms they occur and their subsequent impact on skill transmission. Teaching only improved task performance over emulation alone for the second-generation participant, not overall. This indicates that emulation is a powerful method of cultural transmission that can be as effective as teaching (Zwirner & Thornton, 2015). Participants used storytelling as teaching method (Williams et al., 1999), particularly to convey non-routine information that is, information that violates expectations (Bietti et al., 2019). Although storytelling did not improve basket fidelity, its presence and intergenerational increase suggests it plays a role in cultural transmission. A third of the intergenerational increase in storytelling consisted of vicarious memories, as they related to the experiences of previous participants rather than personal experience (Pillemer et al., 2015). Overall,

this section highlights the vulnerability of face-to-face cultural transmission to distortion rather than precise copying, yet suggests these distortions themselves may have important functions.

Study 5 investigates the transmission of basket-building skills in the context of improvement goals and the coordination of learning strategies (i.e. choice to copy or to innovate). The content of teaching is analysed in further detail under two conditions: in the presence of the artefact (no-displacement condition) and in the absence of the artefact, (displacement condition). This manipulation was chosen to investigate abstract situations in which only humans are adept teachers, as they require the communication of concepts via language (Gärdenfors et al., 2017). Participants built baskets to carry as much rice as possible from various materials before teaching the next participant in line (Zwirner & Thornton, 2015). The efficacy of baskets increased over generations in both conditions, providing evidence of cumulative cultural evolution. Displacement affected strategy use by increasing innovation. Teachers' talk was equally distributed across three categories: instructional, experience-based and storytelling. As in Study 4, teachers used storytelling more to discuss non-routine events (those departing from expectations) than they did other types of teaching, especially without displacement. Exposure to non-routine storytelling during teaching increased subsequent innovation, indicating possible benefits of storytelling on collective reasoning and appraisal of alternative solutions.

Finally, the main findings are summarised in the General discussion. Theoretical implications are considered and potential avenues for future research are highlighted.

Part One: Opening social interactions

Study 1

Coordination of handshake greetings: An eye tracking study

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Abstract

Handshake greetings are a resilient social practice that serve to regulate wider social interactions. However, they are also complex sequences that must be coordinated on-the-fly. Gaze is crucial to this process as it enables both motor coordination and interpersonal functions, however the precise time course of gaze allocation in this context is poorly understood. This study introduces pairs of previously unacquainted participants wearing eye tracking glasses (ETGs) to measure precisely how gaze ties into other verbal and non-verbal greeting behaviours, thus combining the precision of laboratory conditions with naturalistic observation. This sheds light on the precise methodical organisation of greetings, and provides empirical support for early interactionist observations, such as the existence of two distinct salutations and the use of gaze aversion to balance prosocial and motor functions during the approach. Insight is provided regarding the systematic coordination of greeting vocalisations, and the extent to which they adhere to conventional models of conversational turn-taking. Use of laughter as a tool to coordinate conversational opening is investigated in an unprecedented level of detail, showing a temporal pattern and asymmetries of role. Gender effects are also analysed but mostly found to be weak in comparison to other factors.

Introduction

Impromptu face-to-face social interactions occur for a purpose. For example, one needs to ask directions of passers-by in an unfamiliar city (De Stefani & Mondada, 2018). However these interactions do not begin by people simply starting to speak. They must first be initiated through the tight-knit coordination of many verbal and non-verbal processes, part of which involve greeting sequences. Handshakes are a frequent component of greetings. Although recently restricted due to changing hygiene practices of the COVID-19 pandemic, they are a resilient social practice that is likely to return in the close future (Hamilton, 2019; Matschke & Rieger, 2020). To perform a handshake we must simultaneously manage numerous coordinative actions, such as navigating the physical environment as we approach others and synchronising our movements with theirs. Gaze plays an important and complex role in these processes, because it is allocated to both motor coordination and interpersonal functions (Argyle & Dean, 1965; Niechwiej-Szwedo et al., 2021). However, the precise time course of gaze allocation during the greeting process is poorly understood. This study introduces pairs of previously unacquainted participants wearing ETGs to measure precisely how gaze ties into other verbal and non-verbal greeting behaviours.

Greetings

Greetings are fundamental sequences by which would-be conversational participants gain access to each other. Before entering into interaction, several coordination problems need to be solved, including clarifying identities and intentions of the participants (Clark, 1996). This leads to the build-up of joint commitment (Bratman, 1992), as individuals come to understand they have entered into an activity jointly with others that has consequences (Clark, 2006). When participants wish to end an interaction, they must coordinate on their willingness to end it, perhaps by summarising the encounter (“it was nice to see you”) and providing

reassurance of continuity ("see you soon") (Clark & French, 1981). The need to coordinate understanding about joint commitments thus gives rise to entry and exit phases (Clark, 1996). Greetings play an important role in the coordination of the entry phase and are defined as gestures or utterances by which people signal to each other that they have been seen (Kendon & Ferber, 1973). Greetings serve to coordinate the possibility and purpose of the social interaction, and re-establish continuities so that the main body phase may begin (Clark, 1996). Although seemingly banal, we require greetings to transition from mere co-presence to ratified social interaction: from unfocused to focused interaction (Goffman, 1963). Greetings serve to recognise others as proper conversational partners in order to construct and maintain interpersonal relationships with them. The act of greeting confirms that relationships exist, and the nature of each greeting indicates the level of accessibility involved in that relationship. Many rites of passage involve greeting behaviour, to recognise individuals in a new role and provide reassurance of relationship continuation (Goffman, 1963), as in for example graduation ceremonies or weddings. Greeting behaviour is constantly evolving in light of changing cultural circumstances, but always in ways that preserve fundamental social functions (Mondada et al., 2020). Greeting is thus a crucial normative practice that helps regulate social interaction in many ways.

In addition to the social functions they serve, greetings are also complex sequences in their own right that must be coordinated on-the-fly by participants. In the sections that follow, several non-verbal and verbal components of greeting behaviour will be explored, before focusing on handshake greetings as the subject of this study.

Approach

The most rudimentary aspect of face-to-face greeting behaviour is the approach. In order to interact with someone, it is necessary to come close enough for speech to be heard

and faces to be seen, i.e., to become co-present (Pillet-Shore, 2018). We use the movement and orientation of our bodies to mark the boundaries of a social interaction, with shifts of position used to signal the start and end of different phases of the encounter (Argyle, 1975). This requires considerable interactional work, as people must negotiate surrounding obstacles to shape the interactional space (Mondada, 2009), while also responding to each other's movements. Incursions of another conspecific into personal space is stressful, as shown by galvanic skin response studies (Argyle, 1975; Nichols & Champness, 1971). This has evolutionary origins in territorial behaviour, which serves the adaptive purpose of controlling access to food, water and shelter, in humans and non-humans (Argyle, 1975). To counteract this, strangers in modern urban environments treat each other with civil inattention, paying minimal attention as a form of courtesy (Goffman, 1963). It is thus possible to be in *bodily* contact without being in *social* contact, as for example when packed together with strangers on a busy train. To start a social interaction, people regulate their behaviour in certain ways during the approach in order to neutralise the territorial threat response, for example, by walking at an appropriate pace (De Stefani & Mondada, 2018) and maintaining a pleasant facial expression (Argyle, 1975). Two salutations are performed on either end of the approach: the distant salutation and the close salutation (Kendon & Ferber, 1973). The distant salutation typically consists of an exchange of glances, and a signal of recognition that may be verbal or non-verbal. Verbal examples include change of state tokens such as "ah" or "oh" (De Stefani & Mondada, 2018), and non-verbal examples include waving hands, tossing the head back or flashing the eyebrows (Greenbaum & Rosenfeld, 1980). The distant salutation exists in order to give clearance to move towards the other person, providing a warning of our intention to approach them. The close salutation is typically then performed once people have moved together, often involving bodily contact, such as a hug, kiss, handshake or fist-bump (Kendon & Ferber, 1973; Mela & Whitworth, 2014).

Another crucial aspect of physical coordination during greetings is synchronisation. Humans, like other social animals, are attuned to physical coordination and use movement to form and maintain relationships. During the approach we may synchronise our body movements with others to hint that we wish to greet them, which allows us to avoid potential face threats by ensuring we only initiate the distant salutation once we are confident it will be returned (Kendon & Ferber, 1973). Non-verbal coordination is crucial to the formation of rapport (Chartrand & Bargh, 1999; Grahe & Bernieri, 1999), as it promotes affiliation through shared attention (Schroeder et al., 2019). Engaging in a similar flow of body movement enables individuals to make visible and regulate their involvement with one another (Vesper et al., 2017). Boundaries of face-to-face social interaction, of which the transition is from not interacting to interacting are thus not pre-existing points in time, but are instead negotiated through a variety of approach behaviours.

Gaze

Gaze is a crucial component of greeting behaviour that people use to balance social and motor functions. Mutual sighting is a precursor to social interaction (Cary, 1978; Krivonos & Knapp, 1975). If people do not wish to greet, they avoid eye contact (Goffman, 1963), and if they do wish to greet, they persist until eye contact is achieved (Goodwin, 1981). Mutual gaze is crucial to both the distant and the close salutation (Argyle, 1975; Kendon & Ferber, 1973). Use of gaze also relates to physical positioning, as we simultaneously balance social functions of gaze with motor functions, by using our eyes to survey our surroundings and fixate our gaze on objects before we manipulate them (Land & Hayhoe, 2001). During social interaction there exists a conflict between the forces to look into the eyes of other people and the forces to avoid looking into their eyes (Argyle & Dean, 1965). The forces to look stem from the fundamental human need to belong, which can be gratified by gaze as it signals attentional and social inclusion (Wirth et al., 2010). The forces

to look away stem from the increased physiological arousal direct gaze causes (Pönkänen et al., 2011), as too much direct gaze signals threat in animals and humans (Ellyson et al., 1981; Emery, 2000). Due to this, people to people do not continuously look at each other during greeting approaches, but avert their gaze continuously as they move closer (Kendon & Ferber, 1973). This includes a sharp gaze aversion at roughly ten feet distance (Kendon & Ferber, 1973). Gaze aversion is therefore another effective way to neutralise threat response by reducing interpersonal distance. Most existing naturalistic studies of greeting behaviour rely on estimation of gaze direction (De Stefani & Mondada, 2018; Harjunpää et al., 2018; Mondada et al., 2020; Mortensen & Hazel, 2014; Nilsson et al., 2018; Pillet-Shore, 2018), so it remains to be seen precisely how gaze is used as a coordinational tool in this context, and how it is synchronised with other greeting components.

Vocalisations

Vocalisations are used systematically during greetings. Early research based on telephone conversations established typical sequences of talk such as identification and exchange of verbal salutes (e.g., “hi”, “hello”), followed by “how-are-you” enquiries (Hopper & Doany, 1989; Schegloff, 1968, 1979). Each of these parts is organised in adjacency pairs, meaning that occurrence of the first utterance makes the second relevant and, if not provided, noticeably absent (Schegloff, 2007). Adjacency pair parts may be arranged into one or more sequences (Kendrick et al., 2020). Participants tailor greeting vocalisations according to the current state and character of their social relationship, for example by adapting their prosody (Pillet-Shore, 2012). The adjacency pair format thus allows participants to engage in joint activity having displayed mutual recognition and understanding (Duranti, 1997). The exact timing of adjacency pairs is based on the principle that speakers manage who speaks when using sequences of communicative moves known as conversational turns (Sacks et al., 1978). Turns are a scarce resource (Sacks et al., 1978), and speakers do not wait until they detect the

end of a speaker's turn; rather, they anticipate this moment, resulting in a gap or overlap of less than one second (De Ruiter et al., 2006). This timing has been well-established in conversation occuring in the main body (Heldner, 2011), but has not yet been investigated in the context of greeting vocalisations in the entry phase. Another aspect of conversational organisation is that people encounter miscommunication problems frequently (Healey et al., 2018), such as overlapping speech. Typically, one of the speakers will initiate repair to clarify (Boström, 2021), and some of these repair mechanisms are universal across human languages (Dingemanse et al., 2013). In the case of overlapping greetings, then, we may also expect to observe repair, but this has not been investigated to date.

However, there is also evidence suggesting that greeting vocalisations may not adhere to these basic models of conversational organisation. The adjacency pair format cannot always account for greeting structure as conversations often do not proceed in a tidy fashion (Tsui, 1989). For instance, one part of an adjacency pair may go unspoken, especially in the context of greetings (Collett, 1983; Duranti, 1997; Goffman, 1963; Youssouf et al., 1976). The form and content of greeting vocalisations varies greatly between cultures and contexts (Béal & Traverso, 2010; Duranti, 1997; Emeka-Nwobia, 2020; Michno, 2017; Youssouf et al., 1976), so often do not fit with original sequences of talk observed in early research (Hopper & Doany, 1989; Schegloff, 1968, 1979). Other factors such as interpersonal distance are likely to affect the timing of greeting vocalisations but these have not yet been explored. In terms of repair, conversation often serves to maintain pleasant social relations rather than accurate information transfer, so many incoherencies actually go unchallenged in everyday talk (Galantucci et al., 2020). This fits with the argument that language originally evolved as a form of "vocal grooming" (Dunbar, 2017). It is therefore not clear whether the precise timing and sequential organisation of greeting vocalisations respects conventions of conversational coordination or violates them.

Laughter

Laughter is a frequent non-linguistic vocalisation during social interaction. Numerous studies have observed laughter as part of greetings (Béal & Traverso, 2010; Duranti, 1992; Gafaranga & Britten, 2003; Laurier, 2012; Mondada et al., 2020), but few have studied laughter in detail in this context. Laughter probably evolved from ancestral ape play vocalisations (Mazzocconi et al., 2020), and still signals positive affect and cooperative intent today. The coordination functions of laughter in conversation are well understood, for example its role in the negotiation of turn-taking (Bachorowski & Owren, 2001; Glenn & Holt, 2013; Grammer & Eibl-Eibesfeldt, 1990). Asymmetries of laughter exist according to role and environment in many contexts (Brosy et al., 2020; Haakana, 2002). As with other vocalisations, laughter may also occur in adjacency pair format, with laughter itself inviting a laugh response (Jefferson, 1979). Possible functions of laughter in greeting behaviour may include showing affiliation and momentary rapport between the unacquainted (Glenn, 2003; Lavin & Maynard, 2001), and reducing possible stress or embarrassment caused by violation of norms such as invasion of other's space (Mazzocconi et al., 2020). Yet the precise timing of laughter in greetings remains to be seen.

Handshakes

Handshakes are a common form of close salutation that require coordination and shed light on gendered aspects of greeting behaviour. Handshakes signal interpersonal trust and peaceful intent in many cultures (Burgoon, 1991; Hall & Hall, 1983). To achieve appropriate aim, strength and grip, people synchronise their muscle forces and joint motions with those of others (Melnyk & Hénaff, 2019). Typically the right hand is used, with hands being raised and lowered three times over a period of approximately three seconds (Nagy et al., 2020), the first stroke having greater amplitude than those that follow (Kendon & Ferber, 1973). Mutual

gaze occurs during the grasp (Bangerter et al., 2017). Just before the hand disengages and retracts there is a brief pause in the movement (Kendon & Ferber, 1973). Grasp duration depends on context, as consolation and congratulatory grasps are longer than those performed in greeting, farewell, gratitude and agreement contexts (Huwer, 2003; Melnyk & Hénaff, 2019). Observing smooth handshake coordination results in positive evaluation of the social interaction (Schroeder et al., 2019) and problems in coordinating one aspect of handshaking behaviour upstream can have downstream effects (Nagy et al., 2020).

Handshakes are more frequently observed between men (Greenbaum & Rosenfeld, 1980; Hall & Hall, 1983; Kendon & Ferber, 1973), and much research suggests a bias exists towards male handshaking (Bernieri & Petty, 2011; Chaplin et al., 2000; Katsumi et al., 2017). While men routinely practice handshaking in a wide range of contexts, women mainly shake hands to greet or convey warmth (Åström, 1994). Women's handshakes are less vigorous and involve more eye contact (Åström, 1994) and longer grasps (Melnyk & Hénaff, 2019) than men's. However, women are not negatively evaluated because of their handshaking technique (Stewart et al., 2008). Overall, gender effects in handshaking remain unclear as many findings are conflicting, as is also the case for non-verbal behaviour more generally. There are purportedly gender differences in laughter (Glenn, 2003; Mehu, 2011; Provine, 1993) and the regulation of interpersonal distance (Åström, 1994; Breed, 1972; Petri et al., 1974). However, these gender differences are difficult to explain (Glenn, 2003), and are likely to be a gloss for much more complex patterns of behaviour (Jefferson, 2004).

This study

This study aims to shed light on the coordination of handshake greeting components by using eye tracking technology to combine the precision of laboratory conditions with naturalistic observation. This allows documentation of gaze behaviour and how it ties into

other verbal and non-verbal greeting components on a millisecond-by-millisecond basis. Naturalistic studies of gaze during entry phases estimate gaze direction using video recordings rather than precisely measure it (De Stefani & Mondada, 2018; Harjunpää et al., 2018; Mondada et al., 2020; Mortensen & Hazel, 2014; Nilsson et al., 2018; Pillet-Shore, 2018). Handshaking research often does not resemble real-life social interaction, as it is based on virtual avatars (Dolcos et al., 2012; Katsumi et al., 2017). Where a genuine face-to-face handshake occurs, it often involves one naïve participant shaking hands with a confederate that has been instructed to 'act neutral' (Åström, 1994; Nagy et al., 2020; Stewart et al., 2008) or two participants being instructed to perform handshakes out of context (Melnyk & Hénaff, 2019). This study thus investigates genuine, not role-played, handshake greetings between two previously unacquainted individuals wearing eye tracking glasses.

There are two research questions motivating this study. The first is: What are the components of a handshake and how are they coordinated? (Research Question 1, RQ1). According to the design of this study, one participant is already the room (approached) while the other participant moves towards them to perform the greeting (approacher). This relates to the second research question: How does a participant's role (approacher vs. approached) affect coordinative behaviour in a handshake greeting? (Research Question 2, RQ2).

Methods

Participants

168 native French speakers (59% female, 89% right-handed, M= 24 years, SD = 4.72) were recruited at the University of Neuchâtel. All participants had normal to corrected vision (contact lenses permitted). Data of 21 pairs could not be used because they did not shake hands when introduced. Eye tracker data of a further 26 participants could not be used due to equipment failure. For the eye tracking data, this resulted in a final sample of 100

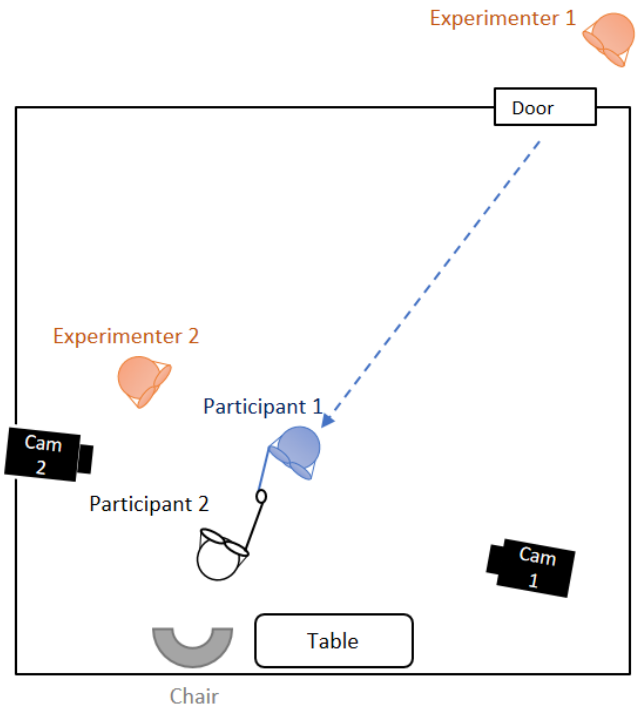
participants; however, for other measures, such as vocalisations, all 126 handshaking pairs could be used. Each participant was paid 6 CHF and the whole session lasted for around half an hour. To maximise sample size for this study, all participants were included in the analysis regardless of the experimental manipulation as this is not the object of the current study (see Design section below).

Apparatus and materials

The recordings were made in a room with layout depicted in Figure 1. Each participant wore mobile eye tracking glasses (ETGs) to measure their eye movements (SMI, sampling rate 60 Hz) and were additionally recorded by two video cameras positioned to capture a close-up and full-body view of the handshake greeting.

Figure 1

Experimental set up



Design

This study has a between subjects design with three different conditions: 1) both participants wearing clear lenses, 2) both participants wearing shaded lenses and 3) one participant wears clear lenses and the other wears shades. In condition 3, the position of the participants was counterbalanced: half of the time Participant 1 had shades and half of the time Participant 2 had the shades, in a randomised order. This experimental manipulation is not the object of the current paper.

Procedure

Participants simultaneously arrived in separate rooms on different floors of the building under the guise of a study on visual scene perception that involved playing a game of Jenga- a game where participants aim to move wooden blocks arranged in a tower without causing it to topple over. They were each greeted by an experimenter who introduced themselves and explained they would be fitted with an eye tracker to then play Jenga with another participant who was being prepared in a different location. Participants gave their informed consent and then experimenters fitted them with the ETGs, performed three-point calibration and started the recording. Experimenter 1 brought Participant 1 to the experimental room pictured in Figure 1, and knocked on the door before opening it. Experimenter 1 gestured for the Participant 1 to enter and then closed the door behind them. Experimenter 2 then beckoned in Participant 1 and asked the participants to introduce themselves to each other. Participants were then directed to sit down at the table and told they could begin playing Jenga. After two minutes had elapsed on a stopwatch, participants were told they could stop playing Jenga. Their ETGs were removed, they were placed at separate ends of the room to complete the questionnaire and then were debriefed, paid and allowed to leave.

Measures

Eye tracker footage from both pair members and the side camera that best captured the handshake greeting was synchronised in video editing software Adobe Premiere Pro. Waveform audio files were extracted from the ETG recordings. All of these files were then imported into ELAN 5.9 (Wittenburg et al., 2006) for analysis. The gaze direction of each participant was analysed manually frame-by-frame in ELAN (the videos recorded by the ETGs that mark gaze direction in each frame using a cursor, see Figure 2). The period of time analysed was from the moment participants were first revealed to each other by the door opening to the moment that the last handshake retraction ended. During this time period, the respondent's gaze direction was analysed into one of six categories:

- Face: Fixation on the face and neck region of the other participant.
- Body: Fixation on the body of the other participant.
- Hand/arm: Fixation on the right arm of the other participant, from shoulder to fingertips.
- Experimenter: Fixation on any part of experimenter's face or body.
- Elsewhere: Fixation on any object not included in the above categories (e.g. door, table, boxes).
- Insufficient data: The performance of the eye tracker was too poor meaning that the gaze fixation cursor was not visible or intermittently visible.

Speech was transcribed, and its onset and duration identified in ELAN, as well as bodily movements, classified as either walking, standing up, sitting, and handshake raise, grasp and retraction, see Figures 2a and 2b.

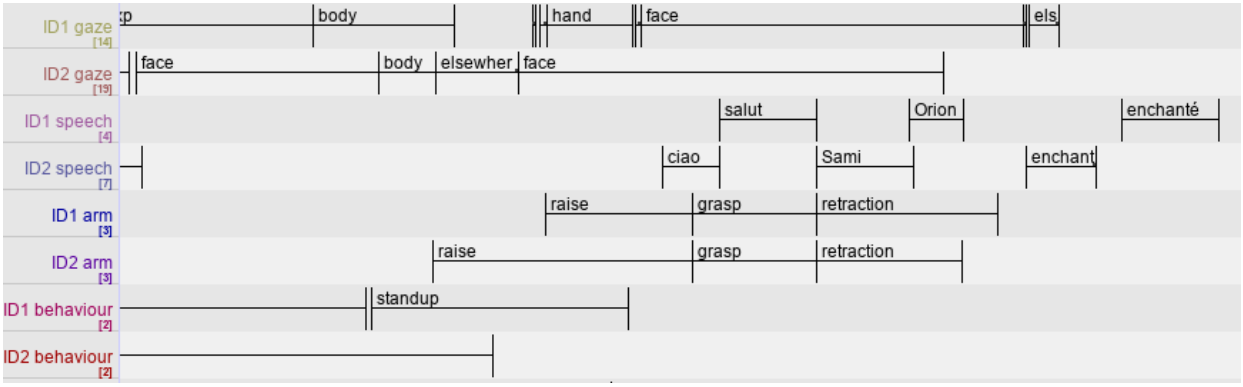
Figure 2a

Still of ETG video footage

Note. Left pane depicts point of view of participant already in room (ID1, shown on right), while right side depicts point of view of approaching participant (ID2, shown on left). Gaze fixation shown as circular blue and orange cursors.

Figure 2b

A visual representation of gaze, speech and bodily movements as measured in ELAN



Note. This data corresponds to the handshake greeting depicted in Figure 2a.

The post-experimental questionnaire included two scales that were translated into French. Likeability was measured using the 11-item Reysen likeability scale (Reysen, 2005). Example items include: “This person is friendly”, “This person is warm” and “This person is similar to me”, (1 = *very strongly disagree*, 7 = *very strongly agree*). Five of the items were reverse-scored, and so their scales were inverted for analysis. Rapport was measured by the 18-item Rapport questionnaire (Bernieri et al., 1994). Example items include: ‘The interaction was involving’, ‘The interaction was cooperative’ and ‘The interaction was positive’, (0 = *not at all*, 8 = *extremely*). Participant’s ratings for each scale were averaged separately to create

mean likeability and rapport scores in relation to how they felt towards their pair, with a higher score indicating increased likeability and rapport.

Results

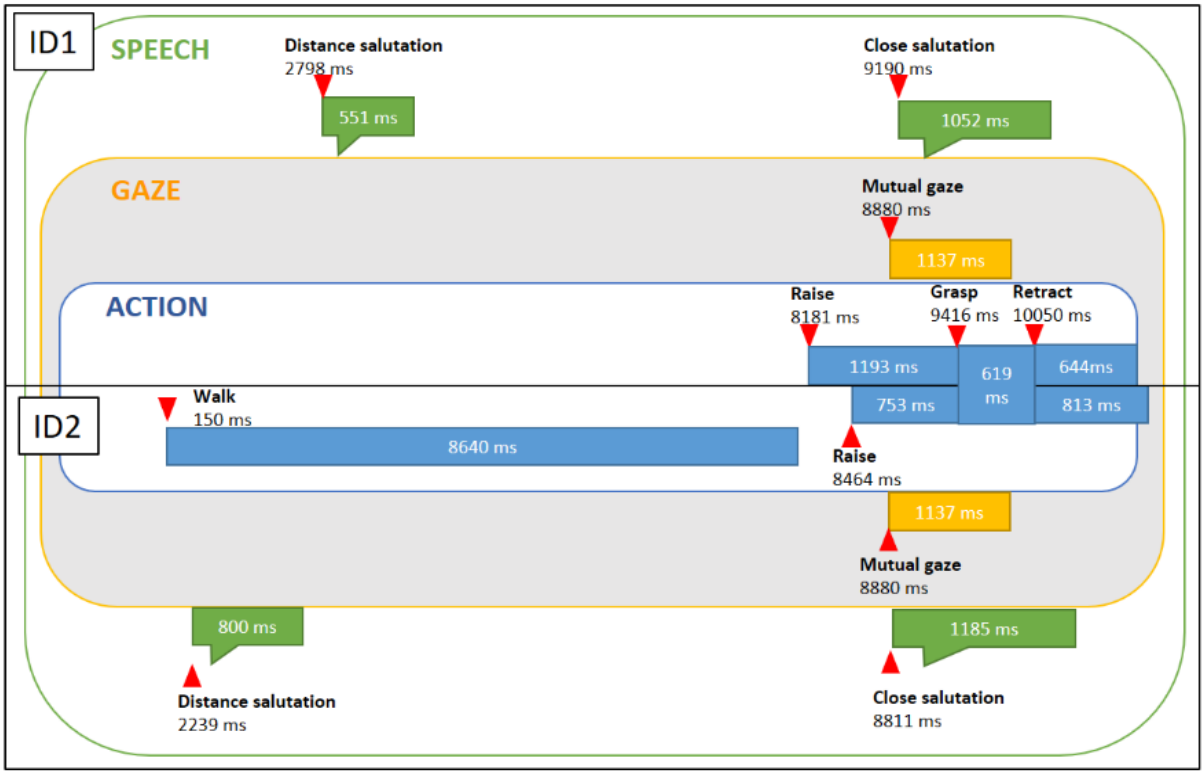
The first section of analysis provides an overview of handshake component coordination, then investigates each component in detail. The second section of analysis focuses on how greeting behaviour differs according to participants position in the room (approaching vs. approached). Finally, gender differences are considered.

Handshake component coordination (RQ1)

The main components of handshake greetings are depicted in Figure 3. The greeting can be divided into two stages, the distance salutation during the approach of ID2 and then the close salutation that occurs simultaneously with the handshaking action and mutual gaze.

Figure 3

Composite figure showing timing of handshake components



Note. Spans from the moment participants were revealed to one another until the end of hand retraction. The Speech section refers to vocalisations during the distant and close salutation. The Gaze section shows periods of mutual gaze during which the eye tracking data detected that participants were engaged in eye contact. The Action section refers to physical movement of the body to approach the other person (Walk) and to movements comprising the handshake (Raise, Grasp and Retract). Each section is split into two, with the top half representing ID1 and the bottom half referring to ID2. All onset values (▼) and durations (▬) relative to first sighting. Each onset value and duration is calculated as an average of all cases. In cases where close greetings consisted of multiple vocalisations, duration was totalled and a within-person average onset time was calculated.

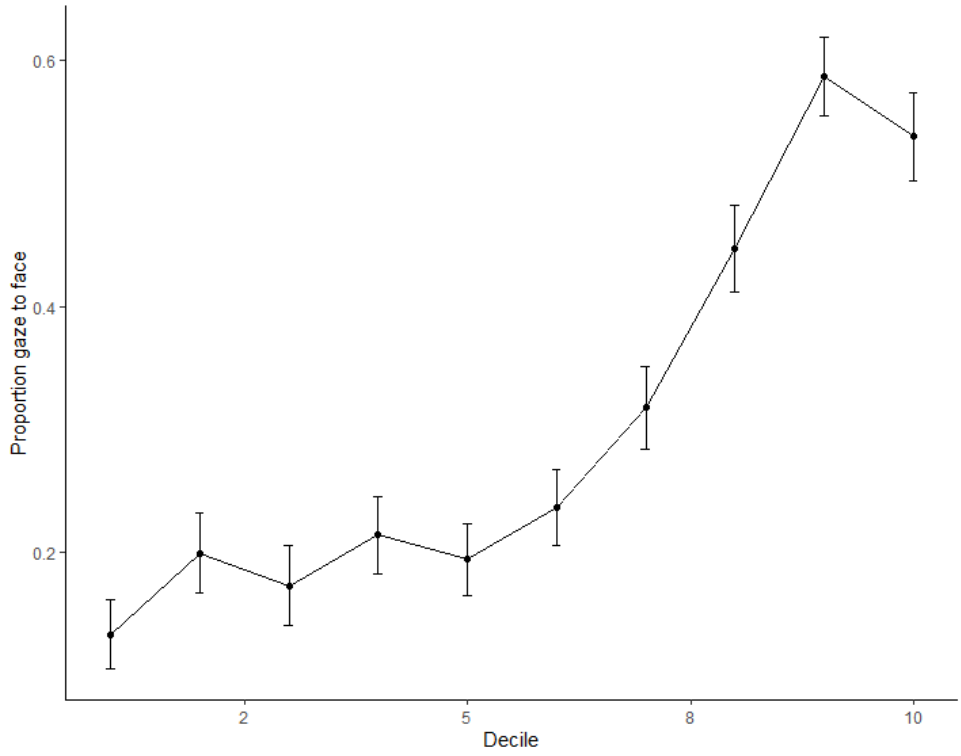
Gaze

Proportional face gazing time increased over the course of the greeting, see Figure 4. This culminated in mutual gaze, the onset of which (M = 8880, SD = 1964) correlates strongly with handshake grasp onset (M = 9416, SD = 1629), r = .88, p < 001, n = 84, and close

salutation onset (M = 9001, SD = 2530), r = .60, p < 001, n = 84. Duration of mutual gaze did not correlate with either rapport (r = -.12, p = .28, n = 79) or liking (r = -.14, p = .22, n = 79).

Figure 4

Mean proportional gaze to face time per decile



Note. Proportion gaze to face is calculated as (msec gaze to face / msec decile length). Each decile is calculated as one tenth of each pair's total greeting time (GT= msec from first reveal to end last retraction). Both ID1 & ID2 included. Error bars = *S.E.*

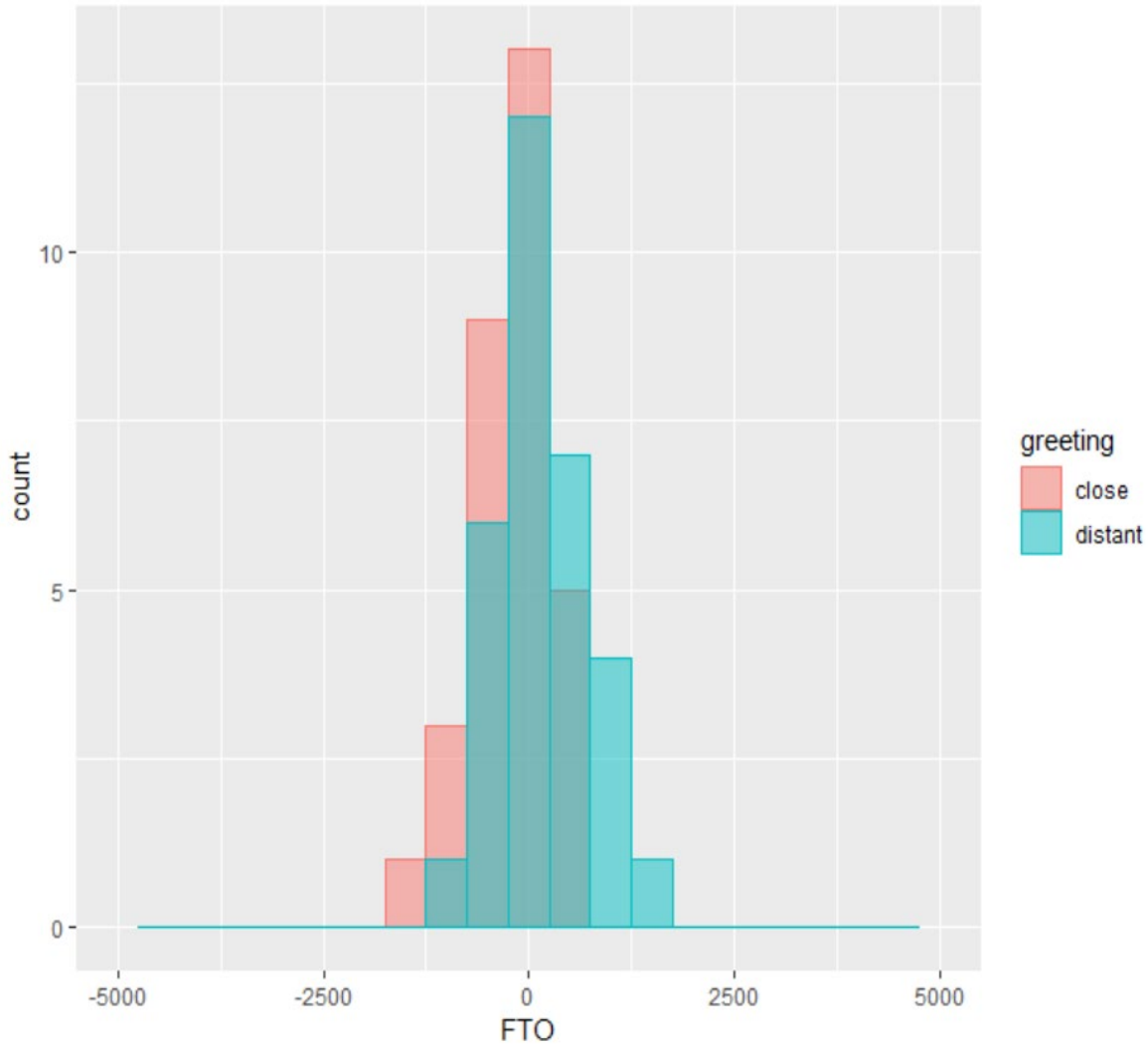
Vocalisations

Both pair members vocalised a distant and a close salutation in 49% of cases. Distant salutations were performed ~ 2519 msec after the moment participants were revealed to each other, during the approach of ID2. The onset of close salutations (M = 9001, SD = 2530) correlated strongly with the onset of the handshake grasp (M = 9416, SD = 1629) r = .67, p < 001, n = 120. Over half of close salutations involved temporal overlap (32 / 62 pairs, 52%)

between ID1 & ID2, see Figure 5. This overlap was typically not followed by repair, which only occurred in 2 / 62 pairs, 3%.

Figure 5

Floor Transfer Offset (FTO) for distant and close greetings

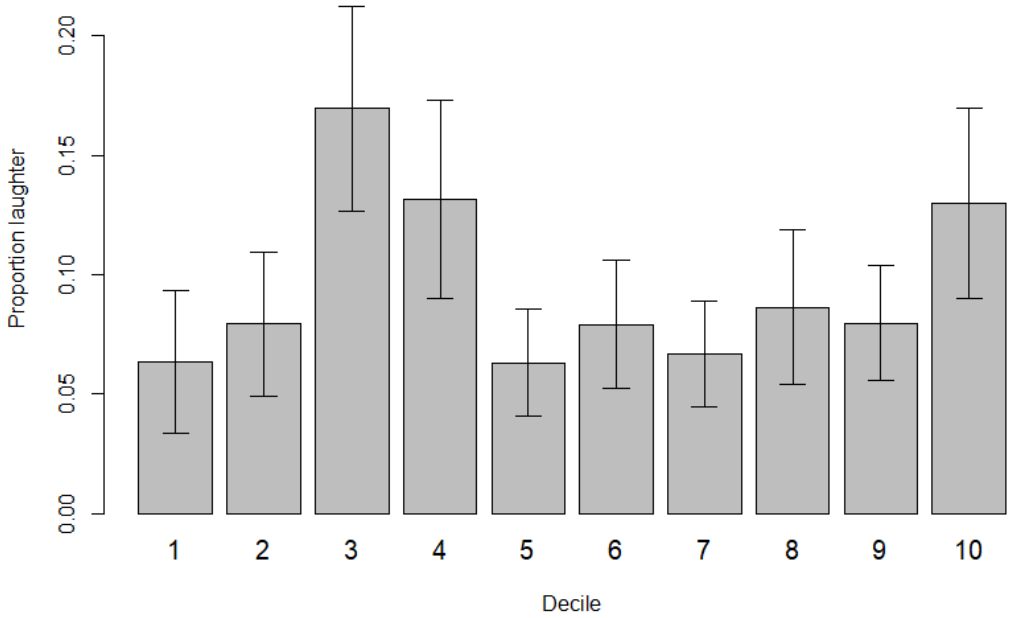


Note. FTO is measured in msec for all cases where participants vocalised for both distant and close greeting (N = 31 pairs). Positive skew indicates gaps while negative skew indicates overlap.

Laughter was another vocal component of greeting behaviour. Laughter peaked during the approach (30-40% of the way through the greeting time) and at the end of the close greeting (over 90% of the way through), see Figure 6.

Figure 6

Proportion of laughter per decile



Note. Proportion of laughter is measured as presence or absence of laughter in that segment / total no. of segments containing laughter for each pair. Each decile is a temporal unit equal to greeting time (msec) / 10. Both ID1 & ID2 included. Error bars = *S.E.*

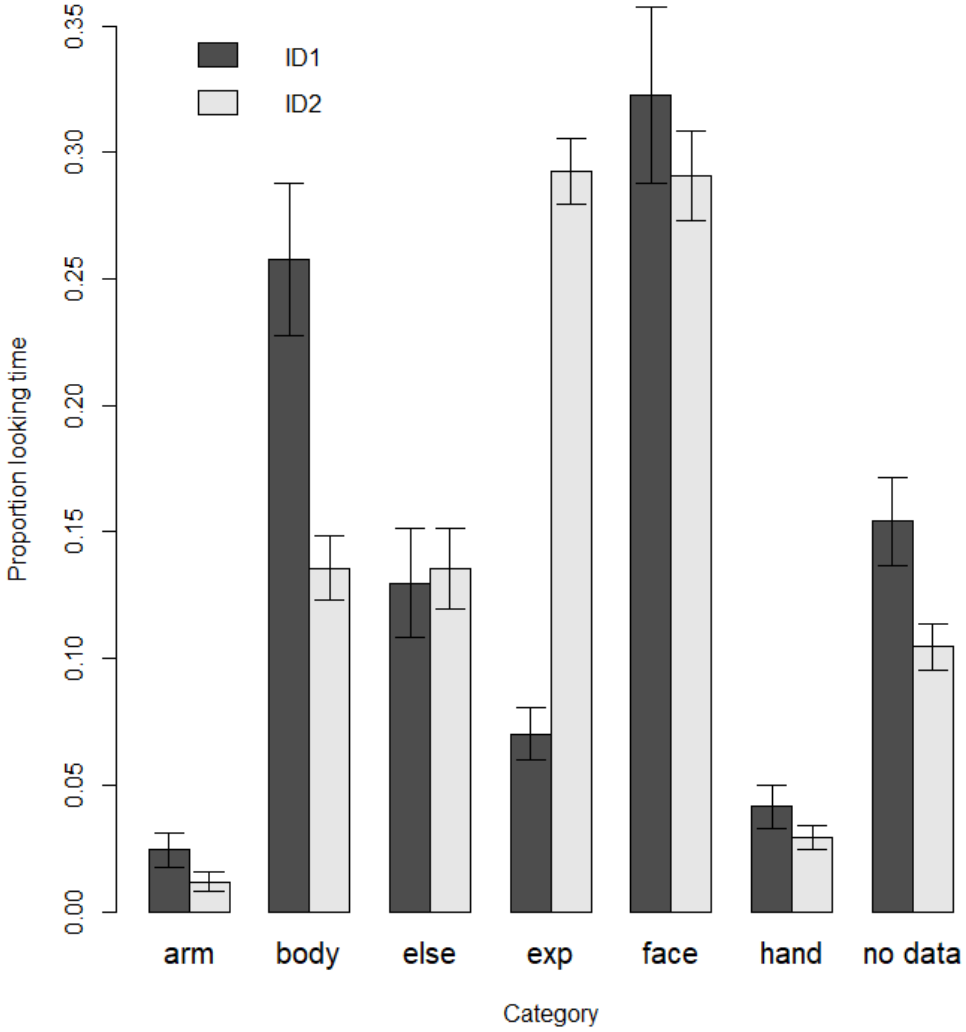
Approaching vs. approached participants (RQ2)

Gaze

Participant's position affected the proportion of time spent gazing at two different categories. Approaching participants (ID2) gazed significantly more at the experimenter (M = 0.29, SD = 0.09) than those already in the room (ID1, M = 0.07, SD = 0.07), $t(98) = 13.24$, $p <$ .001. Approaching participants (ID2) also gazed less at their partner's body (M = 0.14, SD = 0.92) than those already in the room (ID1, M = 0.26, SD = 0.21), $t(98) = 3.89$, $p <$ .001. However, gaze to the face, hand/arm and elsewhere was not affected by position, see Figure 7. Proportional face gazing time interacted with position over the course of the greeting, see Figure 8.

Figure 7

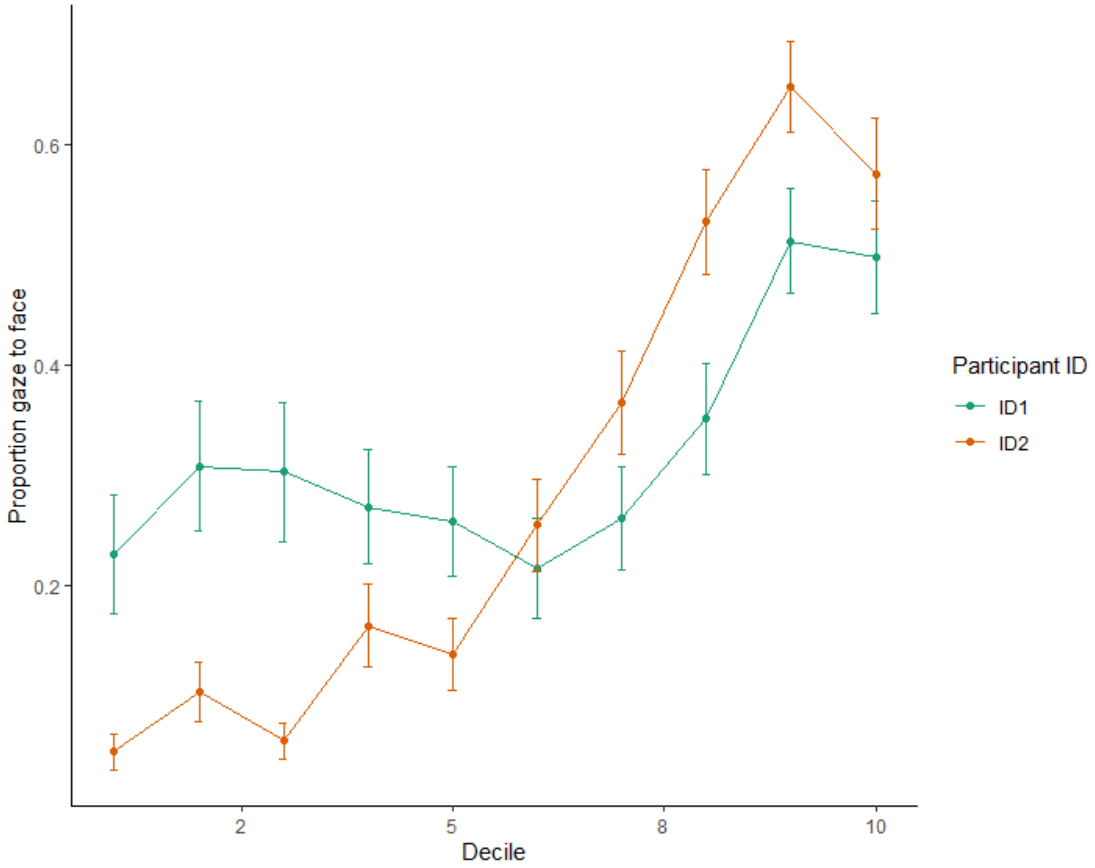
Proportion looking time by category and position



Note. Proportion looking time is calculated as msec fixation per category / msec total fixation for all categories). Position is measured as ID (ID1 = already in room, ID2 = entering room). Error bars = *S.E.*, *N* = 101. Category 'else' = gaze elsewhere, 'exp' = gaze at experimenter, 'no data' = gaze direction not detected.

Figure 8

Mean proportional gaze to face time by decile and position



Note. Proportion gaze to face time is calculated as msec gaze to face / msec decile length. Position is measured as ID (ID1 = already in room, ID2 = entering room). Each decile is calculated as one tenth of each pair's total greeting time (GT= msec from first reveal to end last retraction). Error bars = *S.E.*

Vocalisations

Both members of the pair did not always perform the distant and close salutations, see Table 1. For distant salutations there was almost as many cases of incomplete adjacency pairs (ID2 only, 44%) as complete adjacency pairs (both ID1+ID2, 50%). For close salutations, both members of the pair said their own name in 81% of cases. However, "enchanté" ("nice to meet you" in English) was more often said by one member of the pair (31% of cases) than by both (24% of cases). In terms of laughter, ID1 (already in room) laughs proportionally more than ID2 (approaching), see Figure 9. ID1's laughter peaks in the final 10% of the interaction

while ID2's laughter peaks once they have started to move towards the other participant ~30% into the interaction.

Table 1

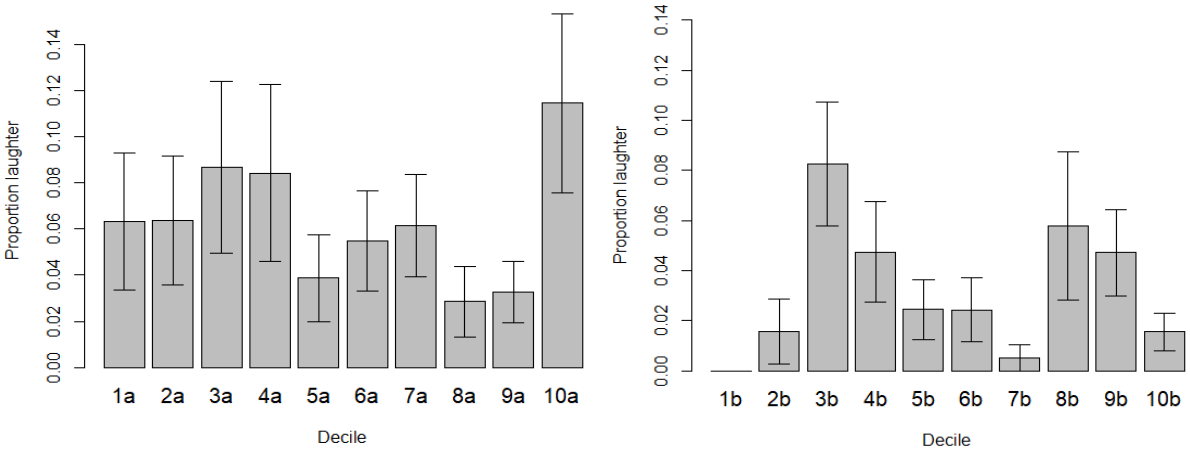
Number of pairs who performed distant and close salutations

	Distant salutation	Close salutation	
	Any	Says own name	"nice to meet you"
ID1 only	2	2	13
ID2 only	27	3	6
Both ID1 + ID2	31	50	15
Neither	2	7	28

Note. ID1 refers to participant already in the room. ID2 refers to participant entering the room. All types of distant salutation and the two most common components of close salutations are included.

Figure 9

Proportion of laughter by decile and position



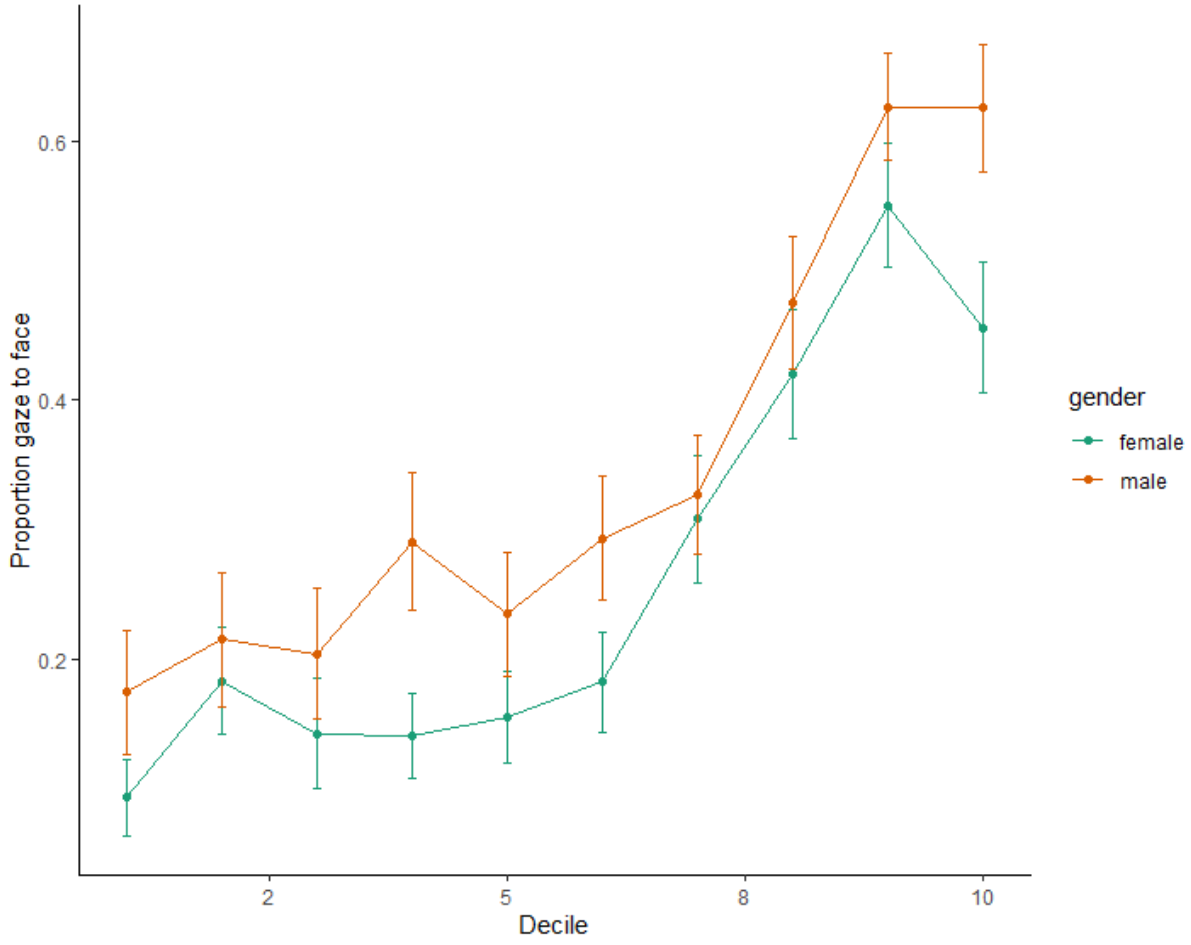
Proportion of laughter is measured as presence or absence of laughter in that segment / total no. of segments containing laughter for each pair. Each decile is a temporal unit equal to greeting time (msec) / 10. Thus, decile 1 refers to the period of time from 1-10% through the greeting. Position is measured by ID: Left hand barplot (Deciles 1a-10a) refers to ID1, participant already in room, right hand barplot (Deciles 1b-10b) refers to ID2, approaching participant. Error bars = *S.E.*

Gender

Male participants gazed proportionally more at faces ($M = 0.34$, $SD = 0.16$), than female participants did ($M = 0.27$, $SD = 0.15$), $t(98) = 1.92$, $p = 0.58$. This face gazing also followed a different temporal distribution, with men gazing more than women 40% through the interaction and in the final 10% of the interaction, see Figure 10. Gender did not significantly affect proportional looking time for any other category. Female participants laughed proportionally more ($M = 0.05$, $SD = 0.15$), than their male counterparts ($M = 0.04$, $SD = 0.15$), $t(74) = 1.77$, $p = .0.81$, particularly in the first 10% and last 20% of the interaction, see Figure 11.

Figure 10

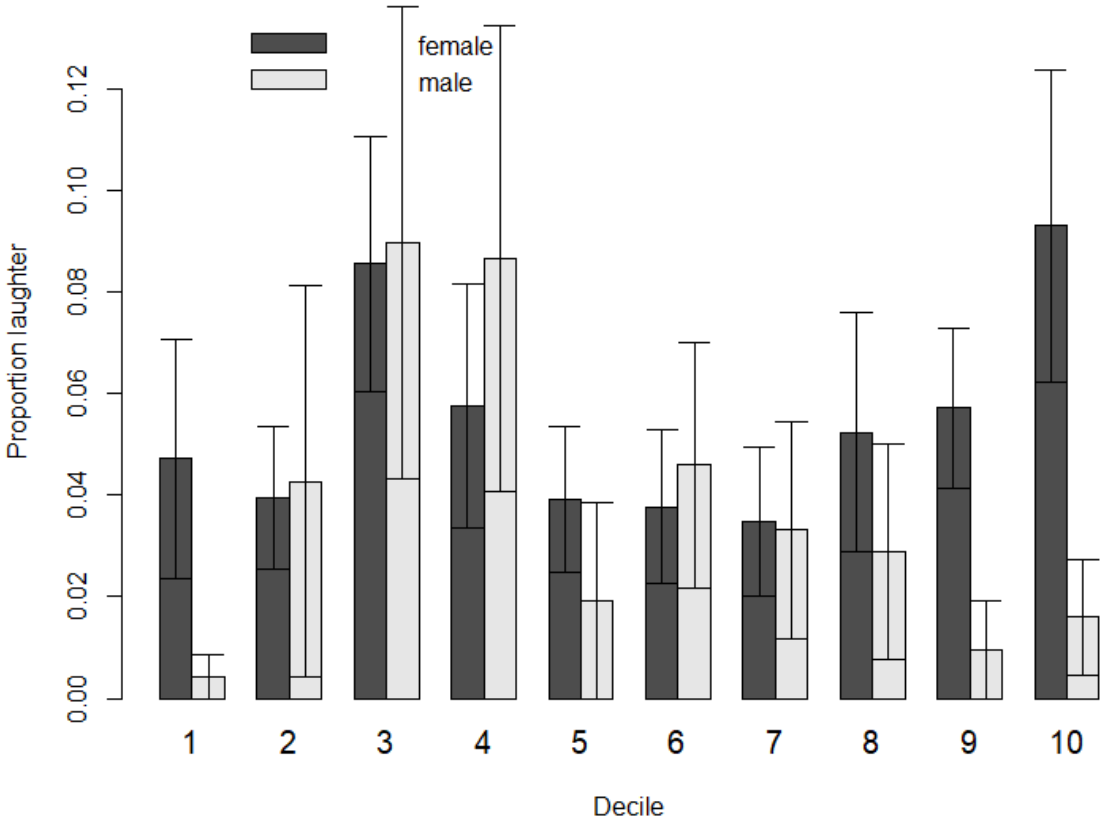
Mean proportional gaze to face time per decile by gender



Note. Mean proportional gaze to face time is measured as msec gaze to face / msec decile length). Each decile is calculated as one tenth of each pair's total greeting time (GT= msec from first reveal to end last retraction). Error bars = *S.E.*

Figure 11

Proportion of laughter per decile by gender



Note. Proportion of laughter is calculated as presence or absence of laughter in that segment / total no. of segments containing laughter for each pair. Each decile is a temporal unit equal to greeting time (msec) / 10. Thus, decile 1 refers to the period of time from 1-10% through the greeting. Error bars = *S.E.*

Discussion

This study documents the coordination of verbal and non-verbal components during handshake greetings, incorporating eye tracking technology. The results shed light on the millisecond-by-millisecond collaborative process by which face-to-face greetings are carried out. This adds to a growing body of multimodal research investigating how people navigate their surroundings to greet others (De Stefani & Mondada, 2018; Harjunpää et al., 2018; Mondada, 2009, 2018), going beyond what can be gleaned from telephone calls (Hopper & Doany, 1989; Schegloff, 1968, 1979). Unlike other lab-based studies of handshake greetings, we included the approach in our analysis, meaning participant's behaviour was measured from the moment they were revealed to each other. Owing to this, our findings can empirically support early interactionist observations that the entry phase can be divided into

two distinct parts: an initial distant salutation followed by a close salutation after the approach (Kendon & Ferber, 1973).

Gaze tied into the methodical organisation of the entry phase in several ways. Participants did not gaze at each other continuously during the approach, providing evidence of gaze aversion (Kendon & Ferber, 1973). During the handshake itself, mutual gaze was synchronised with both handshake grasp and verbal salutations, confirming prior research (Bangerter et al., 2017) and further advancing understanding of how handshake greetings are coordinated. There was no correlation between mutual gaze duration and liking or rapport, refuting the idea that the more eye contact the better (Exline, 1971; Mehrabian, 1972). Although some degree of eye contact is required for the handshake greeting, the duration does not appear to matter. Face gazing did however relate to physical positioning during the approach. Those already in the room gazed more at faces when at distance, while approaching participants gazed more at faces when at close range. This provides insight into how participants work together to balance the multiple uses of gaze during greetings yet also maintain an appropriate intimacy equilibrium (Argyle & Dean, 1965). The approaching participant had more motor functions to fulfil, as they had to scope out and enter novel surroundings, so the other participant took the opportunity to look at their face while their gaze was averted. To compensate for this, these participants then allowed their own face to be looked at more directly by the approaching participant by averting their own gaze during the close greeting. The resource allocation problem of gaze during greetings central to this study is therefore solved collaboratively, as with many other aspects of conversation coordination (Bavelas & Coates, 1992; Clark, 1996).

In terms of greeting vocalisations, our results provide evidence of close timing, showing that the no-gap-no-overlap principle (De Ruiter et al., 2006) also applies to greeting contexts. This varied as a function of interpersonal distance, as distant salutations had larger

gaps while close salutations involved more overlap, displaying the temporal progression of coordination. Notably, people did not initiate repair following overlapping talk during close greetings, which was often people's names. It thus appears that participants were aiming to understand well-enough to maintain pleasant social relations (Galantucci et al., 2020) rather than to actually learn their partner's name, in line with the concept of vocal grooming (Dunbar, 2017). The lack of reciprocity observed in adjacency pairs reflects that found in other greetings (Collett, 1983; Duranti, 1997; Goffman, 1963; Youssouf et al., 1976), as these apparently incomplete variants actually appeared functionally equivalent to the complete form. When the second pair withheld a return-greeting they were not perceived as snubbing their conversational partner (Williams et al., 1998). This is likely because the adjacency pair format is a basic model of greeting organisation that people use as a guideline to hold others normatively accountable, rather than a prescriptive rule.

Our results also advance understanding of laughter as a coordinational tool in social interaction. Like other studies that observe laughter as a greeting component (Béal & Traverso, 2010), it helps build an idea of how it is used to coordinate social situations and carry out strategies of coalition formation and maintenance (Bryant, 2020; Platow et al., 2005). Participants may have used laughter to mark the non-routineness of greeting in a lab-based situation, as has been observed in negotiation of greeting behaviour following the COVID-19 pandemic (Mondada et al., 2020). More specifically, laughter related to both temporal distribution, with peaks early on in the approach and during the close greeting, and physical position, as the stationary person being approached laughed more. The coordination functions of laughter during greetings, such as encouraging rapport (Glenn, 2003) and reducing embarrassment (Mazzocconi et al., 2020) thus appear most important at the start and end of a greeting interaction. A conversational lapse is created during the time that the stationary participant waits for the other participant to approach (Hoey, 2017) that the

stationary participant fills with laughter (Haugh & Musgrave, 2019). These asymmetries thus shed light on the nuanced way that laughter helps us to coordinate the start of social interactions.

Gender effects were also observed, but they were not any stronger than the effects of physical position. In terms of non-verbal behaviour, men gazed more at the faces of the other participant throughout the greeting interaction, but gender did not affect any other looking category. This goes against observations that women make more eye contact during handshakes (Åström, 1994). In terms of vocalisations, women laughed more, especially during the close greetings, supporting the literature (Glenn, 2003; Jefferson, 2004).

A major limitation of this research is that the data was collected with an experimental manipulation that is not the object of the current study. Eye visibility was manipulated using shaded ETG inserts, meaning that in some cases mutual gaze was not possible. This manipulation is excluded from our analysis but may have affected the results in an unforeseen way. For example, inability to establish eye contact may have impacted face gazing behaviour, or participants may have compensated for lack of mutual gaze with another greeting behaviour, such as vocalisations.

Timing of greeting components is analysed in detail for this study. This analysis could be usefully extended by further investigating other features of greeting components, such as prosody (Pillet-Shore, 2012) and whether laughter is voiced or not (Bachorowski & Owren, 2001). The stage of the entry phase analysed for this study, from the moment we catch sight of the other person to the end of handshake retraction, allows observation of how we initiate interactions. However, it is not informative regarding how we transition from the greeting into the main body of interaction (Bangerter & Clark, 2003). In other words, once hands have been

retracted, more interactional work is required to terminate the greeting, but this is beyond the scope of the current study.

Further research could use the methodology developed by this study in a wide range of contexts. By combining naturalistic observation with lab-based precision of eye tracking technology, other types of close greetings, and even closings could usefully be studied. A scenario particularly pertinent to better understand coordination processes would be to investigate these same greeting components in multi-party interaction, i.e., interaction between more than two people. Greeting more than one person at the same time is a common everyday occurrence, yet involves sophisticated multimodal coordination. Analysing this in the lab will help build a more representative picture of how greeting behaviour works. The coordination of triadic conversational interaction has already been explored experimentally using eye trackers (Holler & Kendrick, 2015a, 2015b; Zima, 2020; Zima et al., 2019), but not yet in the context of greeting behaviour.

To conclude, this study incorporates eye tracking technology to comprehensively document the coordination of verbal and non-verbal behaviour during handshake greetings. The approach period is included in analysis, allowing us to empirically support observations from early research that there are two distinct salutations, and to reveal their exact composition. Eye tracking data revealed how participants collaboratively averted their gaze over the course of the greeting to regulate intimacy. Vocalisations were carried out according to key principles of conversational coordination, but also violated them in some respects. Laughter was used as a coordinational tool to fill conversational lapses, and facilitate the start and end of greeting interactions. This study therefore builds a nuanced picture of how verbal and non-verbal behaviours are methodically tied together to coordinate handshake greetings.

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Study 2

Gaze in Handshakes: An Eye Tracking Study

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Abstract

Social interactions do not begin by people simply starting to speak. Rather, participants negotiate the start of social interactions using verbal and non-verbal cues that constitute greeting behaviour. Handshakes are a common component of greeting behaviour. Like many other physical-contact greetings, handshakes involve gaze to coordinate movement. But gaze is also an important social signal. So how do humans deal with this dual use of gaze? This can be described as a resource allocation problem: we must look at the other person's hand to ensure we do not miss it while also managing our gaze in a socially appropriate way. This study uses mobile eye tracking technology to shed light on the ways people use gaze behaviour to coordinate handshake greetings, teasing apart the effects of these two forces. Pairs of participants were fitted separately with eye tracking glasses (ETGs) before being introduced under the premise that they would then play a game. Eye visibility, and therefore the possibility of direct mutual gaze, was manipulated using shaded lens inserts for the ETGs. Participants wearing shades had their faces looked at proportionally longer than participants who had their eyes visible. Participants gazed at their partner's hand in the second prior to the handshake grasp, specifically in the first half of that second. Wearing shades did not reduce reported liking and rapport among participants as expected. Several gender effects on face looking time are also analysed

Introduction

Handshaking is a widespread component of greeting behaviour in many cultures and situations (Hall & Hall, 1983). Gaze is usually necessary to signal communicative intent and thus to allow the social interaction to begin (Argyle, 1975). There exists a conflict between forces to look into the eyes of others and forces to look away from their eyes (Argyle & Dean, 1965). This is because people both desire to be looked at, as it signals social inclusion and satisfies our affiliative needs (Wirth et al., 2010), and desire to *not* be looked at, as eye contact causes physiological arousal and is associated with threat (Hall et al., 2005; Pönkänen, Alhoniemi, et al., 2011). However, the interplay between these two forces is highly dependent on context and is the result of many complex and conflicting mechanisms.

Handshakes in greetings

Any joint activity has three phases: an entry, a main body, and an exit phase (Clark, 1996). Greetings are a component of the entry phase, when people are about to experience heightened access to, i.e., interaction with, each other (Goffman, 1963). Greeting behaviour has several important functions, such as coordinating the possibility and purpose of the interaction, defining identities, and re-establishing continuities in order for the interaction proper (main body) to begin (Clark, 1996). In other words, people tend to agree on fundamental points (e.g. “who are you to me?”, “what are we doing here?”) before they start conversations. Handshaking is a frequent component of greeting behaviour in many cultures, during which people make bodily contact, which can convey warmth and closeness in social interaction (Edinger & Patterson, 1983). The strokes of the handshaking motion, lasting approximately three seconds (Nagy et al., 2020) add synchronous movement. The coordinated movement of people in time produces positive emotions, enhancing group solidarities (Ehrenreich, 2007) and cooperation (Wiltermuth & Heath, 2009). Aside from greeting,

handshakes have other functions, such as expressing congratulations (Müller et al., 2013), consolation (Melnyk & Hénaff, 2019), gratitude (Hertenstein et al., 2006) or satisfaction (Jenkins, 2007). They may have originated as a signal of interpersonal trust (Burgoon, 1991), as the shaking motion would purportedly dislodge any hidden weapons and thus show peaceful intent (Hall & Hall, 1983). There is some evidence that handshaking style relates to personality traits (Bernieri & Petty, 2011; Chaplin et al., 2000; Stewart et al., 2008), signals cooperative intent (Schroeder et al., 2019), and may lead to increased risk-taking (Levav & Argo, 2010). Merely observing a handshake improves an observer's evaluation of an interaction (Dolcos et al., 2012). The impact that handshakes have on social interactions may be due to physical touch and synchrony. Handshaking is therefore a prevalent behaviour that can have a positive impact on social interaction.

Gaze in communication

Face-to-face conversation is multimodal, combining speech, gesture, posture, facial expression, gaze and other cues. Gaze is a crucial coordinational tool with many functions in face-to-face social interaction. The pronounced white sclera of the human eye facilitates the recognition of gaze direction (Kobayashi & Kohshima, 1997, 2001), suggesting an evolutionary adaptation to the importance of gaze in social interaction. Whenever we look at faces, the eyes are the primary and most consistent target of our visual attention from early infancy on (Haith et al., 1977; Walker-Smith et al., 1977; Yarbus, 1967). Gaze remains a crucial social cue system throughout adulthood and serves a variety of social-cognitive functions beyond visual detection (Frischen et al., 2007). The eyes are unique to the multimodal system as they represent a simultaneous "input-output device", obtaining information about others (e.g. feelings, thoughts and intentions) whilst also providing this information about ourselves (Jording et al., 2018). People look primarily to see, rather than to send signals (Argyle, 1975), which makes the use of gaze in social interaction particularly

nuanced. Despite us often being unaware of non-verbal cues, we use them highly systematically, tying them together with very tight timing (Clark, 1996). Coordinative functions of gaze in the context of conversation include eliciting responses (Bavelas et al., 2002; Vranjes et al., 2018), providing feedback (Hömke et al., 2017), signalling attention and interest (Bishop et al., 2019), negotiation of speakership (Mondada & Oloff, 2011), and leadership (Vandemoortele et al., July 2017). Gaze is therefore a powerful and versatile cue in the coordination of conversation.

Gaze is particularly important at the start of social interactions as it is the first way we signal communicative intent and open a channel for social interaction (Cary, 1978; Csibra & Gergely, 2009). Despite the many multimodal resources required for face-to face-greetings, much early research was based on transcribed telephone conversations (Hopper & Doany, 1989; Schegloff, 1968, 1979). Much therefore remains to be understood about how gaze ties into the verbal coordination of greetings. There are two crucial periods of mutual gaze during greetings, first the initial sighting, a vital pre-interactional step that gives clearance for further interaction and establishes joint agreement to begin the encounter (Goffman, 1963). This is often immediately followed by a distant salutation (e.g. hand waving, head tossing or eyebrow flashing) (Kendon & Ferber, 1973), and then an approach where people move towards each other in order to perform a close salutation (e.g. smiles, nods, vocalisations and bodily contact) (Kendon & Ferber, 1973). This close salutation is the second crucial period of mutual gaze. People do not usually look at each other continuously as they approach one another in the interim period between the distant and close salutation, but instead avert their gaze. One early observational study of greetings with extended approaches suggested that individuals systematically perform a sharp gaze aversion at roughly ten feet away, about the same distance at which it is possible to talk to someone (Kendon & Ferber, 1973). This pattern of gaze aversion during the approach phase of greetings has also been observed in more recent

studies (De Stefani & Mondada, 2018). Gaze behaviour during greetings therefore appears to combine both direct gaze and gaze aversion in systematic ways as a function of interpersonal distance.

Motor and social functions of gaze

During social interaction, we must balance the motor and social functions of gaze. This is less than straightforward, as the social functions of gaze themselves constitute conflicting approach and avoidance forces. Examples of the motor functions of gaze include locating objects and directing gaze towards them prior to manipulation (Land & Hayhoe, 2001). The relevant eye movements usually precede the motor acts they mediate by less than a second, although the grasp itself is often not executed under visual feedback (Land & Hayhoe, 2001). This has been shown in eye tracking studies of basic manual tasks such as making a sandwich (Hayhoe, 2000) and making tea (Land et al., 1999). Evidence supporting this 'eye-hand' span of under one second has also been found in the contexts of piano playing (Furneaux & Land, 1999), typing (Butsch, 1932) and bead threading (Niechwiej-Szwedo et al., 2021). When in the company of others, we must not only use our eyes to manage these motor functions appropriately (Becchio et al., 2012; Becchio et al., 2010; Sacheli et al., 2012), but also make sure that we are looking at the other person in an appropriate way(Rossano, 2012). Adequate performance of the social functions of gaze depends on the balance between approach and avoidance forces. During social interaction, there exists a conflict between the forces to look into the eyes of the other person and the forces to avoid looking into the eyes of the other person. According to affiliative conflict theory (Argyle & Dean, 1965), gaze plays a key role in developing an equilibrium for intimacy, conceptualised as a joint function of eye contact, physical proximity, intimacy of topic and other factors. Approach and avoidance forces operate to determine how much eye contact will occur, and this in turn regulates intimacy.

The approach forces of gaze in social interaction stem from affiliative need. We take other people's gaze as evidence of what they are attending to. Being looked at indicates that we are the object of another person's attention (Conty et al., 2016). Humans have a fundamental need to belong (Baumeister & Leary, 1995) and gaze signals attentional and social inclusion (Wirth et al., 2010). Direct gaze perception has also been reported to increase self-esteem in the beholder (Wirth et al., 2010). People look more at those they like, and gaze is perceived as a signal for liking (Mehrabian, 1972), with gaze being a better predictor of liking than bodily orientation (Argyle, 1975). Direct eye contact makes people rate others as more likeable, competent, attractive, intelligent credible and potent (Abele, 1981; Hall et al., 2005; Kleinke, 1986; Shrout & Fiske, 1981). Direct gaze is associated with positive affect when compared with averted gaze for various stimuli, such as photographs (Mason et al., 2005; Uono & Hietanen, 2015), filmed actors (Wirth et al., 2010) and avatars (Chen et al., 2017; Kuzmanovic et al., 2009). Gaze promotes affiliative behaviour, also known as the watching eyes effect (Nettle et al., 2013). The mere presence of a photograph of eyes makes people less likely to hoard resources (Baillon et al., 2013; Oda et al., 2011) and reduces the likelihood that they will steal or litter (Francey & Bergmüller, 2012; Nettle et al., 2012), perhaps as a result of heightened self-awareness. It is worth noting that these studies indicating the affiliative effects of gaze were predominantly carried out using static images, or even non-realistic images of eyes (Burnham & Hare, 2007; Powell et al., 2012; Rigdon et al., 2009). Paradigms involving passive observation may not be sufficient to fully understand social gaze behaviour, which typically involves active engagement.

The avoidance forces of gaze in social interaction may be due to arousal that stems from threat perception. When facing the direct gaze of a real person, we experience more arousal than when they have averted or closed eyes (Pönkänen, Peltola, et al., 2011). Too much gaze in terms of duration or frequency may create too much intimacy, which is

uncomfortable (Argyle et al., 1974). Direct gaze increases long-lasting heart rate response (Kleinke & Pohlen, 1971), skin conductance (Hietanen et al., 2008; Nichols & Champness, 1971; Pönkänen, Peltola, et al., 2011), blood pressure (Williams & Kleinke, 1993), EEG alpha asymmetry (Hietanen et al., 2008; Pönkänen, Peltola, et al., 2011) and fMRI responses indicating increased involvement of the amygdala, which has a central role in emotion regulation (George et al., 2001). People also report more arousal as a result of live direct gaze as opposed to diverted gaze (Hietanen et al., 2008) as well as higher public self-awareness (Pönkänen, Peltola, et al., 2011). It would seem, then, that in the context of real social interaction, direct gaze can be perturbing. In many species, direct gaze often signals threat and its opposite, aversion of gaze, signals appeasement (Ellyson et al., 1981; Emery, 2000) . Direct gaze has been linked to dominance in human interaction: Long glances are seen as more dominant than short glances (Thayer, 1969), and dominant people break mutual gaze last (Strongman & Champness, 1968). Direct gaze between humans has also been linked to potency, dominance and power (Argyle et al., 1974; Hall et al., 2005). It also signals threat as being stared at causes individuals to move off more quickly (Ellsworth et al., 1972). Gaze aversion is a powerful interpersonal regulatory behaviour (Ellsworth & Carlsmith, 1973) that can reduce arousal (Field, 1981). In the context of greeting behaviour, temporal violation of the close salutation during a handshake, by making it last more than three seconds, increases anxious behaviour and reduces laughter (Nagy et al., 2020). This may be a result of the prolonged mutual gaze, which usually occurs simultaneously to the grasp (Bangerter et al., 2017). To summarise, the avoidance forces of gaze also stem from the realisation that we are the focus of another person's attention, as this causes physiological arousal and prolonged direct gaze is a signal of dominance and threat.

This study

This study aims to shed light on how people allocate the resource of gaze between affiliative and motor functions during handshake greetings. Gaze is a scarce and valuable resource that we must use to perform many functions during social interaction (Jording et al., 2018). We have seen how these functions relate to both motor actions and the prosocial balancing of approach and avoidance forces of direct gaze (Argyle & Dean, 1965; Argyle & Graham, 1976). Motor functions play an important role in greetings generally, as they often involve navigating a physical space in order to move towards another person, and in handshakes particularly in order to make contact with the other person's hand. Greetings are crucial to regulate interactions and to form and maintain relationships, so the social functions of gaze are undoubtedly also important in this context. We therefore experience a resource allocation problem during greetings as we only have one pair of eyes to perform both motor and social functions.

In this study, we use mobile eye tracking technology to enable the measurement of gaze direction on a millisecond-by-millisecond basis. Eye tracking glasses (ETGs) fit to a participant's face and allow for normal movement of the body and head, enabling the collection of data in naturalistic face-to-face situations (Foulsham et al., 2011). They not only track the participant's focal vision but also record a video of surroundings from their perspective, revealing their peripheral field of vision. This study therefore brings the precision of eye tracking methods to the novel context of greetings. Research on greetings has advanced considerably from early analyses of telephone call transcriptions (Hopper & Doany, 1989; Schegloff, 1968, 1979). Multimodal greeting components have since been incorporated in naturalistic observation studies, which estimate gaze direction based on video recordings (De Stefani & Mondada, 2018; Harjunpää et al., 2018; Mortensen & Hazel, 2014; Nilsson et al., 2018; Pillet-Shore, 2018). Use of ETGs in the current study will take this one step further by

enabling accurate measurement, rather than estimation, of gaze direction. This study also builds on research on direct gaze effects, much of which typically relies on static images or computer-generated avatars as stimuli (Conty et al., 2012; Dolcos et al., 2012; George & Conty, 2008), without any actual social interaction. There is now a growing body of research where experimenters simultaneously fit two (Broz et al., 2012; Rogers et al., 2018) or more (Hessels, 2020; Holler & Kendrick, 2015; Zima, 2020) participants with ETGs to analyse eye movements during real face-to-face conversation. This study applies these methods to the opening phase of conversation rather than the main body.

In order to investigate gaze allocation during handshake greetings, we manipulate the visibility of the eyes, and therefore the possibility of discernible direct gaze, with shaded lens inserts for the ETGs. Observing a person wearing sunglasses can have similar arousal effects to observing a person without sunglasses (Myllyneva & Hietanen, 2015; Nuku & Bekkering, 2008; Teufel et al., 2009), perhaps because we assume we are being looked at even in the absence of evidence of the actual orientation of the wearer's eyes (Mareschal et al., 2013). Despite this, there is considerable evidence that sunglasses reduce the arousal effects of direct gaze (Hazem et al., 2017) and can impair processing, such as accurate identification of facial expressions (Roberson et al., 2012). We expect that blocking the visibility of the eyes with shaded lens inserts will reduce the intensity of direct gaze.

The study has three main hypotheses: firstly, that participants will gaze to their partner's face more when their partner is wearing shades (Hypothesis 1, H1). The rationale behind this is that we expect direct gaze with exposed eyes will create arousal and avoidance forces as participants approach each other, and participants will avert their gaze in order to break the intensity of mutual gaze. Those participants who are not exposed to direct gaze due to their partner wearing shades, however, will not experience these forces and so will gaze at their partners face more. The second hypothesis is that participants will look at their partners

hand or arm in the second preceding the handshake grasp for a longer duration than in the second preceding that (Hypothesis 2, H2). The rationale behind this is that motor functions of gaze will predominate less than one second before the handshake grasp, as in other look-to-grasp contexts (Niechwiej-Szwedo et al., 2021). The third hypothesis is that participants wearing shaded ETG inserts will receive lower ratings for likeability (Hypothesis 3, part 1, H3p1) and rapport (Hypothesis 3, past 2, H3p2) than participants wearing transparent ETG lenses. The rationale behind this is that direct gaze has been shown to have a positive effect on our judgement of other persons (Mason et al., 2005), and so we expect participants to like partners more when they are able to achieve eye contact with them.

Methods

Participants

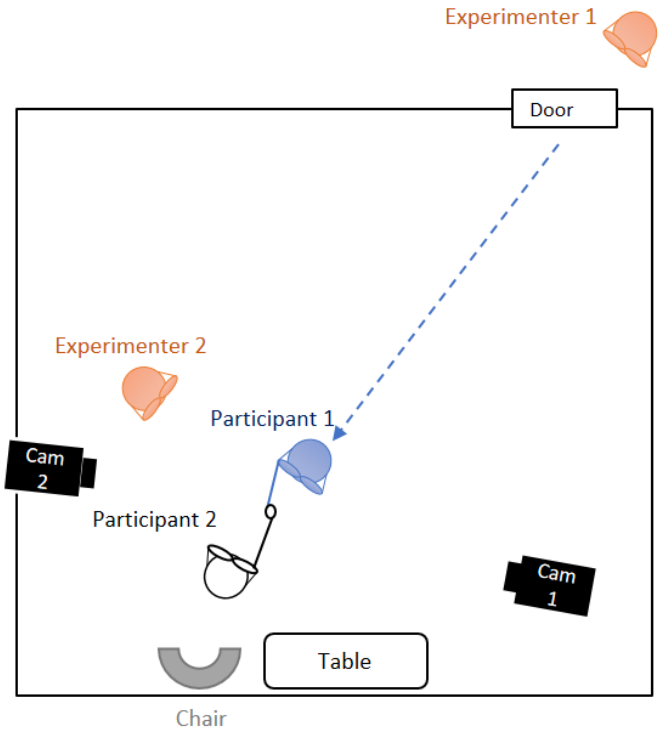
168 native French speakers (59% female, 89% right-handed, *M* = 24 years, *SD* = 4.72) were recruited on campus at the University of Neuchâtel. All participants had normal to corrected vision (contact lenses permitted). Data of 21 pairs could not be used because they did not shake hands when introduced. Eye tracker data of a further 26 participants could not be used due to equipment malfunctions, such as the eye tracker losing calibration. This resulted in a final sample of 100 participants, comprising 40 complete pairs, and 20 individuals without a pair. Each participant was paid 6 CHF and the whole session lasted for around half an hour.

Apparatus and materials

The recordings were made in a room with layout depicted in Figure 1. Each participant wore SMI ETGs to measure their eye movements (sampling rate 60 Hz) and were additionally recorded by two video cameras positioned to capture a close-up and full-body view of the handshake greeting.

Figure 1

Experimental set up



Design

This study has a between-subjects design with three different conditions: 1) both participants wearing clear lenses, 2) both participants wearing shaded lenses and 3) one participant wears clear lenses and the other wears shades. In condition 3, the position of the participants was counterbalanced: half of the time Participant 1 had shades and half of the time Participant 2 had the shades, in a randomised order.

Procedure

Participants simultaneously arrived in separate rooms in different floors of the building under the guise of a study on visual scene perception that involved playing a game of Jenga- a board game where participants aim to move wooden blocks arranged in a tower without causing it to topple over. They were each greeted by an experimenter who introduced themselves and explained they would be fitted with an eye tracker to then play Jenga with another participant who was being prepared in a different location. Participants gave their informed consent and then experimenters fitted them with the ETGs, performed three-point calibration and started the recording. Experimenter 1 brought Participant 1 to the experimental room pictured in Figure 1, and knocked on the door before opening it. Experimenter 1 gestured for the Participant 1 to enter and then closed the door behind them. Experimenter 2 then beckoned in Participant 1 and asked the participants to introduce themselves to each other. Participants were then directed to sit down at the table and told they could begin playing Jenga. After two minutes had elapsed on a stopwatch, participants were told they could stop playing. Their ETGs were removed, they were placed at separate ends of the room to complete the questionnaire and then were debriefed, paid and allowed to leave.

Measures

Eye tracker footage from both participants and the side camera that best captured the handshake greeting was synchronised in video editing software Adobe Premiere Pro. Waveform audio files were extracted from the ETG recordings. All of these files were then imported into ELAN (Wittenburg et al., 2006) for analysis. The gaze direction of each participant was analysed manually frame-by-frame in ELAN (the videos recorded by the ETGs mark gaze direction in each frame using a cursor, see Figure 2). The period of time analysed (the approach) was from the moment participants were first revealed to each other by the door opening to the moment that the last handshake retraction ended. To test H1 (the total duration of a participant's gaze to their partner's face will be higher when their partner is wearing shades), the respondent's gaze direction was identified in ELAN for fixation on the face and neck region of the other participant. To test H2 (participants will look at their partners hand or arm in the second preceding the handshake grasp significantly more than the second preceding that) the respondent's gaze direction was identified in ELAN according to fixation on the right arm of the other participant, from shoulder to fingertips. The footage from the close-up side camera was also analysed for the onset and duration of the handshake raise, grasp and retraction, and segments of 1s and 500ms were created for the two seconds prior to the handshake grasp.

For H3, the post-experimental questionnaire included two scales that were translated into French. To test H3p1 (participants wearing shaded ETG inserts will receive lower ratings for likeability than participants wearing transparent ETG lenses), likeability was measured using the 11-item Reysen likeability scale (Reysen, 2005). Example items include: "This person is friendly", "This person is warm" and "This person is similar to me", (1 = *very strongly disagree*, 7 = *very strongly agree*). Five of the items were reverse-scored, and so their scales were inverted for analysis. To test H3p2 (participants wearing shaded ETG inserts

will receive lower ratings for rapport than participants wearing transparent ETG lenses), rapport was measured by the 18-item Rapport questionnaire (Bernieri et al., 1994). Example items include: 'The interaction was involving', 'The interaction was cooperative' and 'The interaction was positive', (0 = *not at all*, 8 = *extremely*). Participant's ratings for each scale were averaged separately to create mean likeability and rapport scores in relation to how they felt towards their pair, with a higher score indicating increased likeability and rapport.

Analysis

All statistical analyses were conducted in R using packages lmerTest (Kuznetsova et al., 2017) and tidyverse (Wickham et al., 2019) for RStudio (2020). The full dataset consisted of 100 participants for which we have useable eye tracker data. Twenty of these were individuals without a pair due to missing data and the remaining 80 participants formed 40 complete pairs. For each participant we calculated Proportion gaze to face (PGF, = total duration gaze to face (msec) / total greeting time (msec)). This variable was transformed using the logit() function in package rgr. Data were fitted with linear mixed-effects models. To account for between-pair variance, the pair identity was included in all models as random intercept. For each analysis, the fixed effects combination accounting for most variance was identified using model comparisons relying on AIC, see Supporting Information.

Table 1

Models created to test research questions and hypotheses

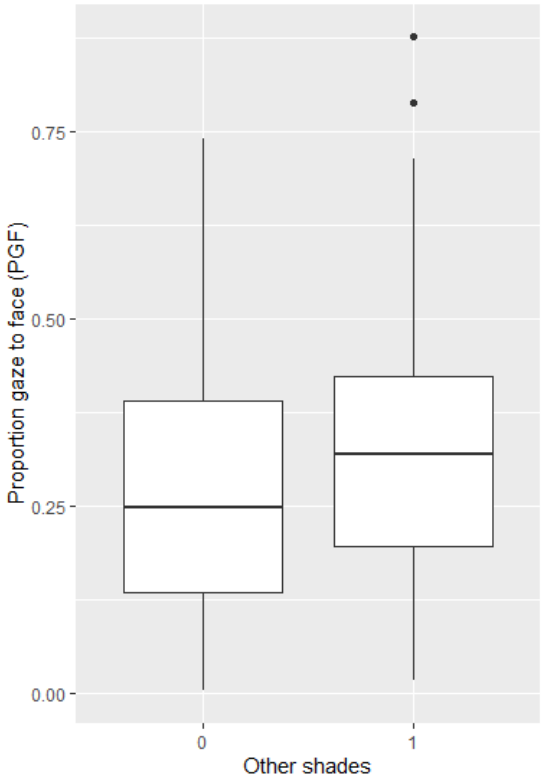
	Outcome variable	Fixed effect(s)	Random effect
H1	Proportion gaze to face (PGF) ~	Other shades + self shades + observer sex * other sex	+ (1|pair)
H2	Duration gaze to hand/arm ~	Seconds prior to grasp + condition	+ (1|pair)
H3p1	Liking ~	Other shades + other sex	+ (1|pair)
H3p2	Rapport ~	Other shades + other sex	+ (1|pair)

Results

Participants gazed more at the face of the other participant (increased proportional face gazing time, PGF) if the other participant was wearing shades, $\beta = 0.48$, $SE = 0.24$, $t = 2.04$, $p = 0.04$ (Hypothesis 1, supported), see Figure 3. If the observer themselves wore shades, they looked at the other person's face less, but not significantly less (decreased PGF) $\beta = -0.43$, $SE = 0.24$, $t = -1.81$, $p = 0.07$. Sex of the observer significantly predicted PGF ($\beta = -1.08$, $SE = 0.33$, $t = -3.29$, $p = 0.001$), the sex of the other pair member (i.e. the person being looked at) had a trending effect ($\beta = -0.57$, $SE = 0.32$, $t = -1.77$, $p = 0.08$) and there was a significant interaction between observer sex and other sex ($\beta = 1.00$, $SE = 0.45$, $t = 2.22$, $p = 0.03$), see Figure 4. In other words, all observers looked at women's faces similarly, but at men's faces very differently depending on their own gender: men looked more while women looked less.

Figure 3

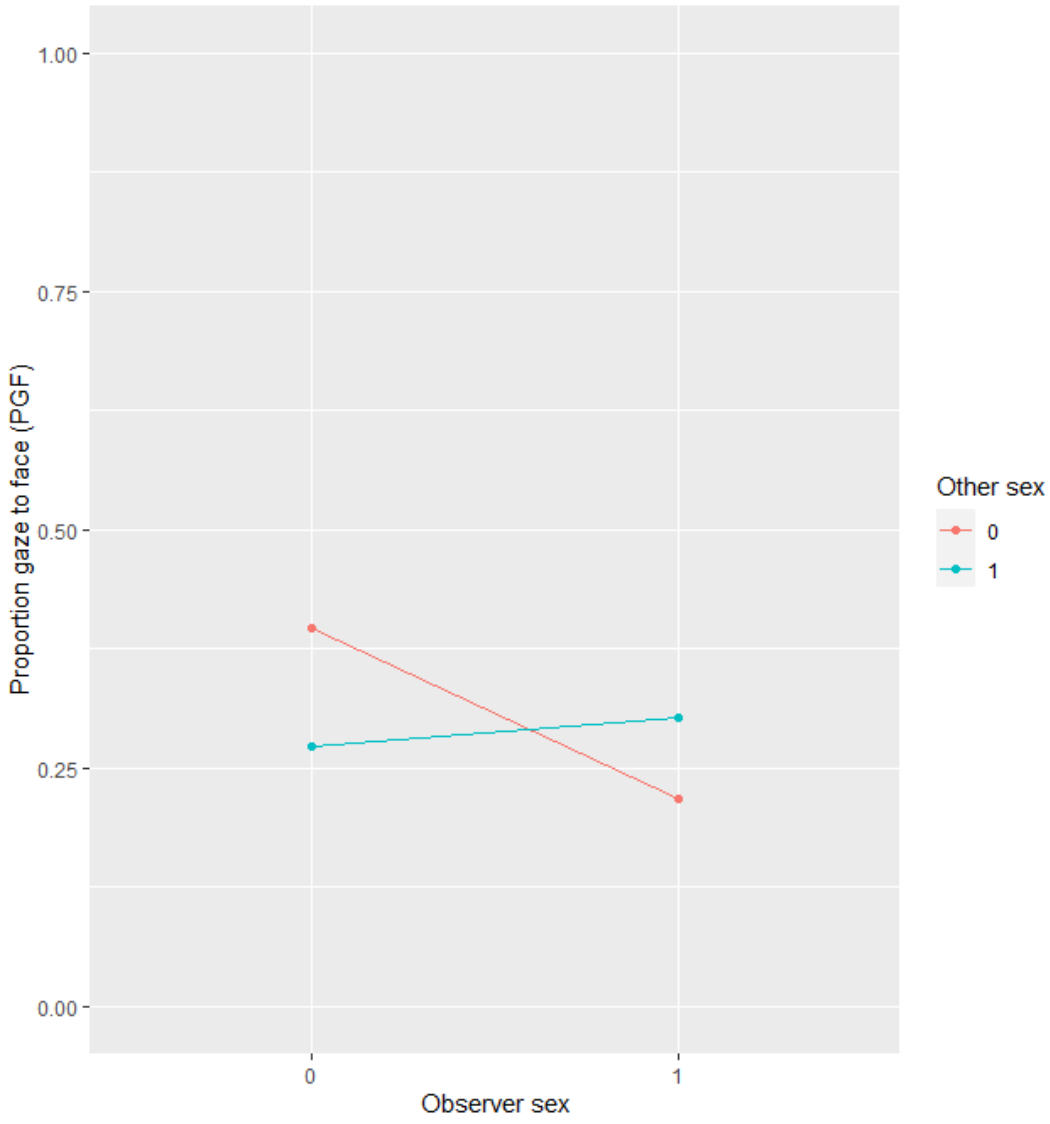
Proportion gaze to face according to whether or not shades are worn



Note. Proportion gaze to face (PGF) measured as total duration gaze to face (msec) / total greeting time (msec). Other shades refers to whether or not the face being looked at is wearing shades (0 = no shades). Whether or not the observer (the person looking) is wearing shades is not taken into account here.

Figure 4

Proportion face looking time shown by sex of both participants

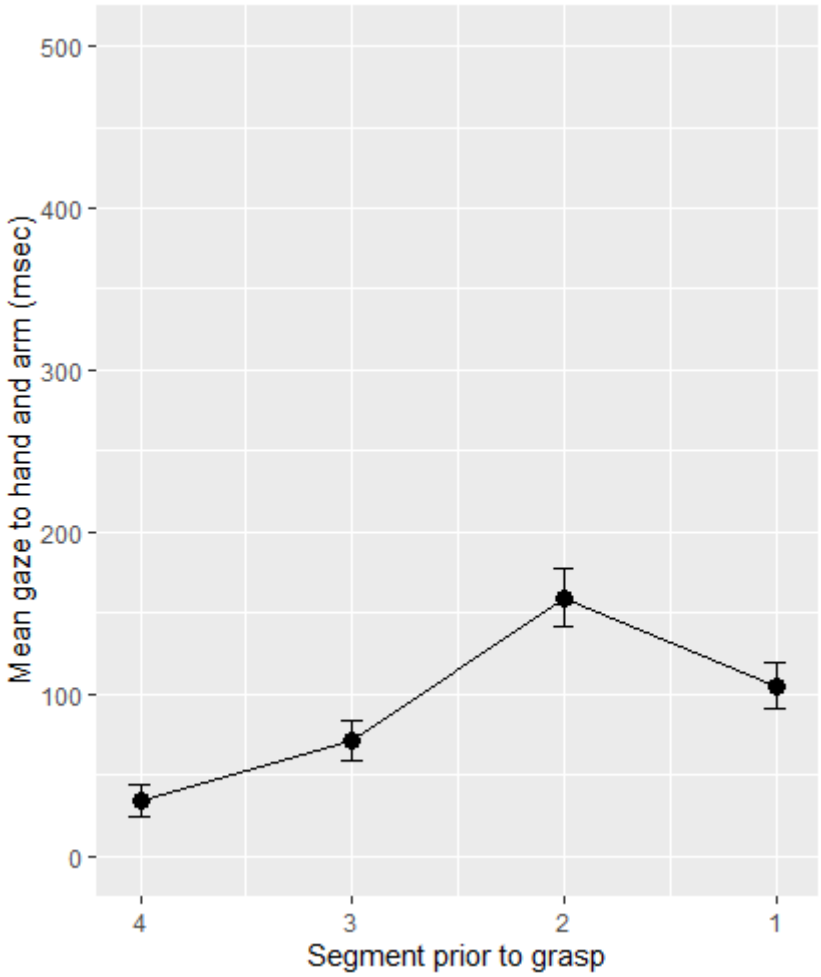


Note. Proportion gaze to face (PGF) is calculated as total duration gaze to face (msec) / total greeting time (msec). Observer sex refers to the sex of the person looking (x axis, 0 = male) and other sex refers to the sex of the person being looked at (legend, 0 = male).

Participants gazed more at hands or arms in the second prior to the grasp (M = 267.76 msec, SD = 231.50) than the second prior to that (M = 107.73 msec, SD = 231.50), β = -164.03, SE = 29.36, t = -5.59, $p < 0.001$, (Hypothesis 2, supported), see Figure 5. There was no effect of condition (β = 5.18, SE = 13.56, t = 0.38, p = 0.70).

Figure 5

Mean gazing time at hand and arm in the two seconds prior to the handshake grasp

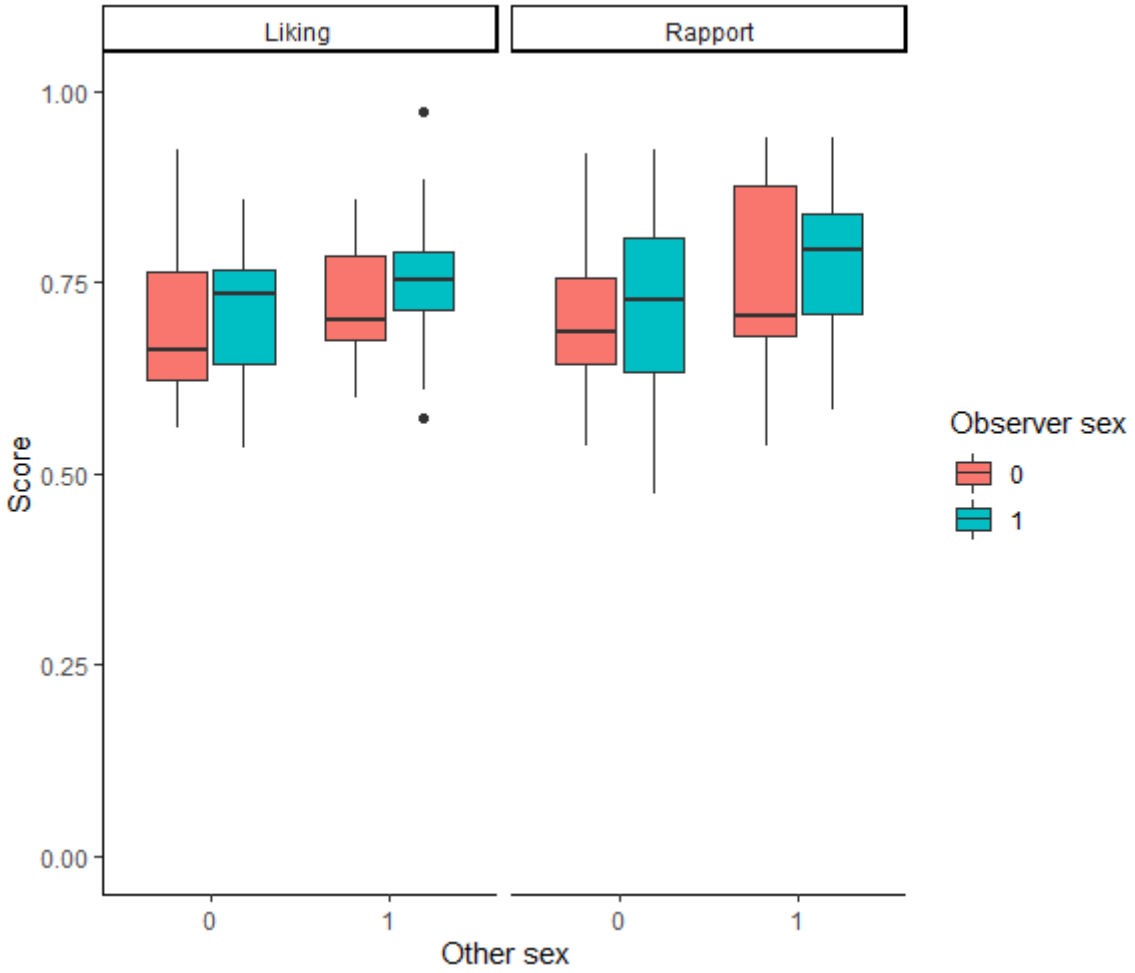


Note. The two seconds prior to the handshake grasp are shown in four 500 msec segments: segment 4 = 2000-1500 msec prior to grasp, segment 3 = 1500-1000 msec prior to grasp, segment 2 = 1000-500 msec prior to grasp, segment 1 = 500-0 msec prior to grasp. Both ID1 & ID2 included. Error bars = *S.E.*

Sex predicted both liking (β = 0.26, *SE* = 0.13, t = 2.06, p = 0.04), and rapport (β = 0.42, *SE* = 0.18, t = 2.33, p = 0.02), as both women and men rated female participants more highly, see Figure 6. However, whether or not the other person wore shades did not predict either liking (β = -0.03, *SE* = 0.13, t = 0.24, p = 0.81) or rapport (β = -0.15, *SE* = 0.18, t = 0.80, p = 0.42), (Hypothesis 3 parts 1 & 2, not supported).

Figure 6

Liking and rapport score allocated according to the sex of both participants



Note. Percentage score has been calculated as liking and rapport were measured on different scales. The sex of other (x axis, 0= male) refers to the person receiving the rating and the sex of the observer (colour, 0= male) refers to the person giving the rating.

Discussion

This study is the first to provide precise evidence of gaze allocation during handshake greetings, including the approach period during which interpersonal distance is reduced. Several observations can be made on the basis of these results that shed light on how people deal with the resource allocation problem of gaze during greetings.

Principally, blocking visibility of a participant's eyes with shaded lenses significantly affected how much that participant's face was looked at: faces with shaded eyes were looked at proportionally more than faces without shades. This supports approach-avoidance theory (Argyle & Dean, 1965) as those who were not exposed to direct gaze looked away less, perhaps as they experienced less arousal, an established direct gaze effect (Pönkänen, Peltola, et al., 2011). Whether or not the person looking was themselves wearing shades did not have a significant effect, supporting the view that eye movements are largely outside of our conscious control (Rogers et al., 2018). Participants knew that their own eyes were not visible to others, but this did not prevent them from managing their gaze behaviour according to social functions. This may also be due to the highly ritualised nature of gaze during greetings (Mondada, 2009), making it a robust to many different conditions.

Participants gazed at their partner's hand in the second before the handshake grasp, specifically in the first half of that second. This supports studies suggesting the eye-hand span is one second or less (Niechwiej-Szwedo et al., 2021) by observing it in the novel context of greeting interactions. This adds to a growing body of research investigating motor functions during social interaction (Becchio et al., 2012; Becchio et al., 2010; Sacheli et al., 2012). This is quite a feat of coordination considering the amount of on-the-fly adjustment required during face-to-face interactions generally and greetings specifically. For example, people must accommodate the body movements of others as well as simultaneously navigating objects in the surrounding environment.

Results revealed unexpected gender effects. For example, the sex of the observer affected face gazing time: there was not much difference in how much both genders looked at women's faces, but there was an immense difference in how men's faces were looked at, as men were looked at by other men a lot while women looked at men's faces very little. This could be related to the fact that handshaking is historically a male behaviour (Hall & Hall,

1983), and handshakes are more frequently observed among men in a wide range of contexts (Åström, 1994; Greenbaum & Rosenfeld, 1980; Kendon, 1990). Men may therefore feel more ease and confidence when performing handshakes, resulting in increased direct gaze. However, our findings go against previous research showing that women's handshakes involve more eye contact (Åström, 1994). Gender effects exist when it comes to regulation of interpersonal distance (Breed, 1972; Petri et al., 1974), and our results suggest that gaze is an important resource used to regulate intimacy when an observer wishes to approach a man in order to greet him. Gender also had a strong effect on participants' reported liking and rapport, as both men and women rated women more highly. This fits with traditional associations between 'femininity' and likeability (Shaffer & Wegley, 1974) and goes against evidence that men are more likely to form positive impressions of others following a handshake than women (Chaplin et al., 2000). Our results also support a mock interview study that found women still received favourable assessments despite lower quality handshakes than their male counterparts (Stewart et al., 2008). To summarise, although it is not possible to identify the definitive cause of these gender effects, our results suggest that people approach men differently than they do women, and also form impressions differentially on the basis of gender.

Two other novel aspects regarding the participants in this study are worth noting. Firstly, both participants in each handshaking pair were naïve in that they did not know that the main focus of the study was the actual handshake greeting. Much experimental work on handshakes uses a confederate who is instructed to act in a certain way when shaking the participant's hand (Åström, 1994; Nagy et al., 2020; Stewart et al., 2008). Given the inherently collaborative nature of social interaction (Bavelas & Coates, 1992; Clark, 1996) and the hazards of using confederates in studies of communication and dialogue (Kuhlen & Brennan, 2013), the use of two naïve individuals is preferable. Secondly, participants in each

handshaking pair were not previously known to each other. There are systematic differences in greeting behaviour as a function of whether or not we know the other person (De Stefani & Mondada, 2018; Pillet-Shore, 2012). Being introduced to a stranger by a mutual acquaintance is a common occurrence in everyday social interactions (Firth, 1972; Goffman, 1963), and one that is recreated in this study. Our selection of naïve, unacquainted participants for this study enhance the validity of our findings by making them more applicable to real-life greeting situations.

Overall, the results of this study suggest that people collaboratively balance motor and affiliative functions of gaze during handshake greetings, and that this balance is affected by the visibility of the eyes and by gender.

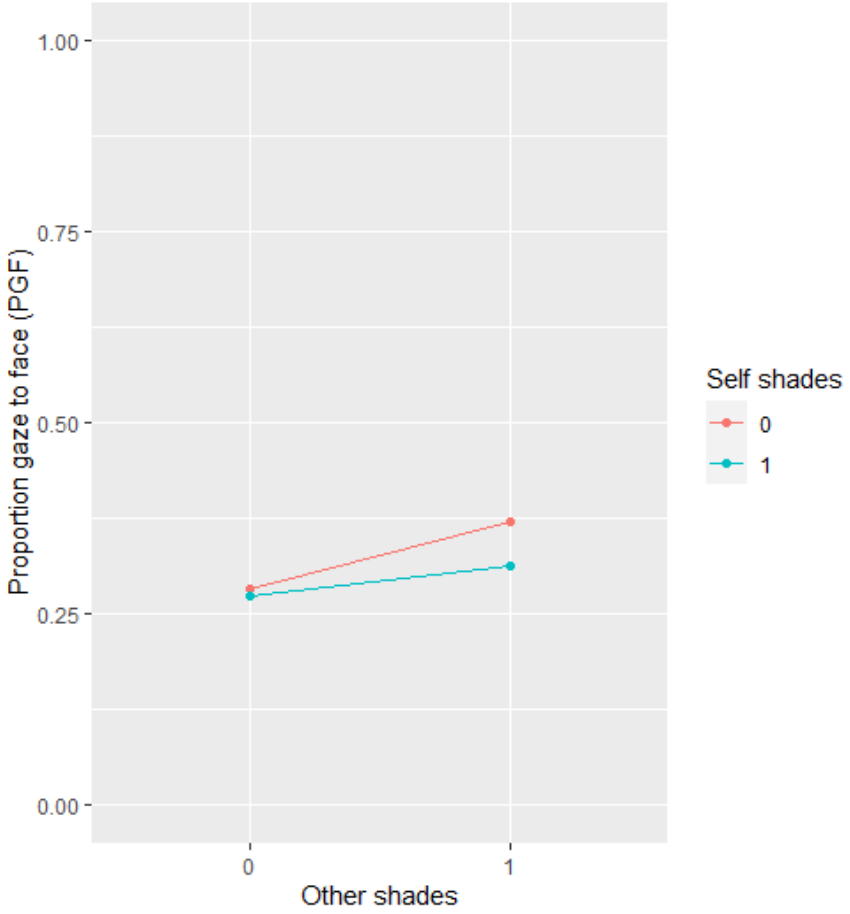
Supporting information

Note on analysis for H1

In accordance with the AIC model selection procedure outlined in the Analysis section, the model used to test H1 was run without an interaction between Other shades and Self shades. This is owing to the interaction model having a higher AIC (316.48) than the model that still included these two terms but without interaction (314.51). The model with no interaction was thus selected as it was the best-fit model. Other shades and self-shades do not interact in terms of Proportion gaze to face (PGF), see Figure 7.

Figure 7

Proportion gaze to face shown by whether or not both participants are wearing shades



Note. Proportion gaze to face (PGF, total duration gaze to face (msec) / total greeting time (msec)) is shown by Other shades (x axis, 0 = no shades) and Self shades (legend, 0 = no shades).

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Part Two: Social interaction in cultural transmission

Study 3

Storytelling as adaptive collective sensemaking

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Abstract

Storytelling represents a key element in the creation and propagation of culture. Three main accounts of the adaptive function of storytelling include (1) manipulating the behavior of the audience to enhance the fitness of the narrator, (2) transmitting survival-relevant information while avoiding the costs involved in the first-hand acquisition of that information, and (3) maintaining social bonds or group-level cooperation. We assess the substantial evidence collected in experimental and ethnographic studies for each account. These accounts do not always appeal to the specific features of storytelling above and beyond language use in general. We propose that the specific adaptive value of storytelling lies in making sense of non-routine, uncertain or novel situations, thereby enabling the collaborative development of previously acquired skills and knowledge, but also promoting social cohesion by strengthening intra-group identity and clarifying intergroup relations.

Keywords: storytelling; adaptive function; cultural transmission; sensemaking.

1. Introduction

Storytelling plays a central role in our everyday lives. It is one of the most widespread social activities through which people in different cultures share personal memories (e.g. Fivush, 2011; McBride, 2014) and cultural information (e.g. Boyd, 2009; Currie & Sterelny, 2017; Donald, 1991; Dunbar, 2010; Scalise Sugiyama, 2001). In its canonical form, storytelling is a collaborative conversational activity focused on the production of narrative discourse (Mandelbaum, 2012; Norrick, this issue), whereby a narrator typically recounts a sequence of past events, including protagonists' actions, and how they contribute to changing an initial situation (Bruner, 1990; Labov & Waletzky, 1967). Members of the audience participate in the activity by reacting to the tellings or guiding them (Bavelas, Coates, & Johnson, 2000; Hirst & Manier, 1996). The activity of storytelling can be analytically distinguished from stories or narratives which are cultural products created, transmitted and transformed through the storytelling activity.

The universality of storytelling (Brown, 1991) suggests it may have an adaptive function, that is, it may have evolved because it confers some kind of fitness benefit to individuals or groups in the ancestral environments where it emerged. Various contenders for this function have been suggested, including (1) manipulating the beliefs of the audience to enhance the fitness of the narrator (Scalise Sugiyama, 1996), (2) transmitting survival-relevant information while avoiding the costs involved in the first-hand acquisition of that information (Boyd, 2017; Scalise Sugiyama, 2001) or (3) maintaining social bonds or group-level cooperation (Dunbar, 1996; Smith et al., 2017).

While each of these accounts is supported by substantial evidence, they do not always appeal to the specific features of storytelling above and beyond language use in general. We argue in this paper that the specific adaptive value of storytelling lies in *making sense* of non-routine, uncertain or novel situations, thereby enabling the collaborative development of previously acquired skills and knowledge, but also promoting social cohesion by strengthening intra-group identity and clarifying intergroup relations. In this function, storytelling acts as social glue that brings the community together by enabling the co-construction of social histories (e.g., Dunbar, 2014) the formation of a collective memory (e.g. Coman, Brown, Koppel, & Hirst, 2009) or the preservation of an established group history (e.g. Wertsch,

2002). The adaptivity of sense-making via storytelling is perhaps most evident when fast, and unforeseen, changes in the cultural niche (e.g., natural distasters, sudden disease outbreaks, aggression by outgroups) (Claidière & Sperber, 2010) take place. In such situations, groups need to protect or modify existing worldviews to make sense of out of the ordinary, uncertain or novel situations that otherwise could undermine group cohesion and thus survival. Evidence for the sensemaking function of storytelling comes from a wide range of disciplines, contexts, and historical epochs, but we make the case that it is also plausible in the ancestral environments where storytelling probably evolved. The sensemaking function of storytelling is therefore the means by which the other functions of storytelling are realized.

We proceed by briefly reviewing what should count as acceptable standards of evidence for making adaptive claims about storytelling (Section 2). Then, in Section 3, we review three prominent claims about adaptive functions of storytelling. It is important to note that these claims are not mutually exclusive, nor are they exclusive of a collective sensemaking function of storytelling. In Section 4, we describe collective sensemaking as the specific mechanism by which storytelling serves an adaptive function, over and beyond the advantages afforded by language use more generally. We conclude with implications and avenues for future research in Section 5.

2. Is storytelling an adaptation?

A prima facie line of argument for the adaptive nature of storytelling is its universality. Storytelling has emerged independently across the globe, even among isolated peoples, and develops reliably early in ontogeny (Scalise Sugiyama, 2001). Early humans began to be increasingly involved in cooperative tasks and the transmission of skills from elders to youngsters (Bowles & Gintis, 2011). Thus, cooperative behavior became crucial for human survival (Tomasello et al., 2012) and may have boosted the transition from the use of simple communicative behaviors like gesture, body posture, movement, vocalizations and facial expressions (Donald, 1991, 2007) to more elaborated forms like language, including narrative (Donald, 1991). Narrative itself may have emerged from these prior developments, probably in the Pleistocene epoch, between 30’000 and 100’000 years ago (Scalise Sugiyama, 2001).

But demonstrating the adaptive nature of storytelling beyond "just-so" stories requires evidence that it is more than a by-product of existing mechanisms and capacities (Mellman, 2012). Conclusive evidence may be forever beyond our grasp (Scalise Sugiyama, 1996). However, to be plausible, candidate accounts for the adaptive nature of storytelling should fulfil at least three related criteria. First, storytelling has to provide a reproductive or survival advantage. Typically, these advantages most immediately benefit individuals, so it is not a priori clear how storytelling may be adaptive because it seems costly to the individual to share information with others. But adaptations that increase the chances of survival of the group may also affect individual members of those groups. Second, there should be some evidence of "special design", that is, that storytelling is sufficiently universal or complex to make an "evolutionary byproduct" account improbable (Mellmann, 2012; Sugiyama, 2001, 2005). Third, because storytelling is a linguistic phenomenon, claims that storytelling *per se* is adaptive should show the specific benefits that storytelling brings above and beyond those conferred by the ability to communicate via language (Mellmann, 2012), which can help to solve a number of cooperation dilemmas (E. A. Smith, 2010). Evidence for these criteria is typically drawn from three sources. A first source is the structure and content of narrative, which exploits various aspects of the human cognitive system (e.g., content biases; Stubbersfield, Tehrani, & Flynn, 2017). A second source is the instinctive motivations of participants to engage in storytelling activities (Mellmann, 2012). A third is the existence of neural circuits specialized for story production and comprehension (Mar, 2011). The accounts we describe typically focus on evidence from the first two sources.

Demonstrating that storytelling is an adaptation is complicated by the fact that what counts as a "story" or "storytelling" varies widely. A staggering wealth of human knowledge gets expressed in narrative form, including gossip (Dunbar, 2004), rumors (e.g. Guerin & Miyazaki, 2006), urban legends (Bangerter & Heath, 2004; Stubbersfield, Tehrani & Flynn, 2017; Zipes, 2012), traditional legends (Dégh, 2001), conspiracy theories (Franks, Bangerter & Bauer, 2013), myths (Lévi-Strauss, 1955), personal life events (McAdams & Guo, 2015) and even scientific facts (Dahlstrom, 2014). The functions of these different discursive products may vary; thus claiming a singly overarching function risks being excessively reductive. Moreover, because language use in its modern form has evolved over long time

scales, and co-evolved with cognitive abilities (Oatley & Mar, 2005), functionalities may have shifted over time. Ancestral functions may have been co-opted to serve in new contexts (Buss, Haselton, Shackelford, Bleske, & Wakefield, 1998). Modern functions of storytelling may not correspond to the functions it originally was selected for. For example, modern life is replete with narratives (novels, movies, jokes, conspiracy theories, gossip) that are produced and consumed for their entertainment value. However, this does not necessarily mean that stories evolved as a form of entertainment.

In the next section, we examine three accounts of the adaptive nature of storytelling according to these criteria, detailing the arguments and sources of evidence they provide.

3. Adaptive functions of storytelling

3.1 Enhancing individual fitness

Storytelling may be primarily adaptive for individuals. One account builds on the Machiavellian intelligence hypothesis (Byrne & Whiten, 1988) which proposed that social competition for resources and mates constituted a key selection pressure leading to humans' high cognitive abilities. This pressure selected for socially intelligent strategies like deception, manipulation or coalition formation as a means to beat competing conspecifics. Consistent with this account, the ability to craft narratives may have evolved in order to manipulate the perceptions or beliefs of others. Indeed, storytellers tailor their stories to fit their individual audiences to further their own interests (Scalise Sugiyama, 1996). Distinct from the Machiavellian intelligence hypothesis, Miller (2000) has suggested that verbal abilities more generally may have evolved as an honest signal (Zahavi & Zahavi, 1997) of an individual's reproductive fitness to potential mates. The ability to procure novel information for conspecifics may constitute a reliable indicator of an individual's social status, power, or access to information or allies. Likewise, the ability to entertain others via displays of verbal prowess like poetry or storytelling may signal intelligence and thus quality as a mate (Donahue & Green, 2016). Recent evidence confirms that, in hunter-gatherers, skilled storytellers are indeed more popular and reproduce more than non-skilled storytellers (Smith et al., 2017).

If storytelling were to only benefit tellers, however, listeners would evolve to disregard stories

in order to avoid being manipulated. Clearly, then, storytelling abilities also benefit listeners. Scalise Sugiyama (2001) suggested that such benefits derive from the capacity of storytelling to create representations of the world that can substitute for firsthand experience via trial and error, which is often laborious and dangerous to acquire. Thus, humans acquire survival-relevant information from narratives transmitted by their parents (Hewlett & Cavalli-Sforza, 1986), peers (Zarger & Stepp, 2004) and institutions (Barkow, O' Gorman, & Rendell, 2012), gaining access to a larger body of knowledge than would be feasible to acquire via first-hand experience (see the information transmission account in 3.2). Within the signaling approach, Dessalles (2010) suggested that information communicated must be relevant to audiences, and that it is often so when it is surprising, i.e., when it violates their expectations (Labov, 2010; Labov & Waletzky, 1967). Surprising information enables the generation of inferences (Sperber & Wilson, 1986) to update an individual's assumptions about a situation that may incorrect (e.g., negative gossip about a third party may lead me to revise my previously positive view of that individual). The ability of an individual to provide audiences with unexpected information advertises the individual's ability to detect unexpectedness in the environment, which is a valuable asset. Dessalles (2010) tested this claim in a study where participants chose among possible variations of a detail in a story to make it more interesting. There was a strong tendency to choose the most unexpected variant. He interpreted this finding as suggesting a bias for surprising or unexpected information in narrative that confers adaptive benefits because it helps anticipate sudden lethal aggression by other group members.

Dessalles' (2010, see also Saillenfest & Dessalles, 2013) hypothesis exploits a particular structural feature of narrative, namely surprise (Brewer & Lichtenstein, 1982). This feature makes the adaptive nature of storytelling *per se* more plausible, because the abovementioned accounts did not really analyze storytelling properties: Machiavellian political manipulation or advertising of reproductive quality via language need not necessarily involve storytelling. But storytelling may be particularly useful for manipulating audiences because they have evolved mechanisms for epistemic vigilance (Sperber et al., 2010), that is the ability to assess the quality of the information received and the trustworthiness of the individual who conveys it. Epistemic vigilance makes audiences wary of

attempts at manipulation. The development of reasoning abilities may have been driven by epistemic vigilance. That is, storytelling may have constituted an adaptation to the epistemic vigilance of audiences. For example, storytelling devices like describing the behavior of target individuals or using reported speech that purports to quote them exactly (Holt, 1996) may be useful in suggesting particular interpretations of those individuals' characteristics, but without explicitly stating them. Because of epistemic vigilance, individuals are more readily convinced by conclusions they have drawn themselves. Thus, the apparently objective and contextualized nature of the actions depicted in a story allow the audience to derive their own interpretations of the characters without the narrator explicitly communicating those interpretations to them. Skilled storytellers may use this to their advantage, making storytelling a particularly persuasive means of communication.

3.2 Transmitting survival-relevant information

In forager societies, storytelling may have constituted an effective practice for the transmission of survival-relevant information allowing group members to avoid physical, social and health risks and increase their fitness (Boyd, 2017; Scalise Sugiyama, 2001, 2017). Stories about survival-relevant information reduce the complexity of the natural and social world (e.g., by compressing time relative to the actual experience being transmitted) and reduce the risk involved in acquiring such information. For example, novice hunters may learn about animal behavior from the stories that more expert hunters share in camps during hunting excursions, without actually getting involved in potentially dangerous hunting activities (Scalise Sugiyama, 2001). Thus, the transmission of cultural information via storytelling may constitute a means for peers and younger generations to expand episodic memory via vicarious experiences (Scalise Sugiyama, 2011), which in turn may enhance their ability to imagine or predict future events (Schacter, Addis & Buckner, 2007), potentially enhancing the fitness of the group as a whole.

If storytelling evolved as a means of transmitting survival-related information, the content of stories should reflect that kind of information. In hunter-gatherer societies, many stories do indeed feature such content. For example, trickster stories reflect the problem of free-riding, and tellings involve mimicry of the behavior of animals or describe their habitats (Scalise Sugiyama, 2001, 2017). Similar

content biases are apparent in modern-day stories like urban legends (Stubbersfield, Flynn, & Tehrani, 2017). Urban legends often evoke emotions relevant for survival. For example, disgust is survival-relevant because it motivates avoidance of potential contaminants in food and body products of humans and other animals (Heath, Bell, & Sternberg, 2001). Disgust has evolved to include a broader range of contaminants including disease-causing pathogens (Eriksson & Coultas, 2014; Rozin, Haidt & Fincher, 2009; Schaller & Park, 2011). Eriksson and Coultas (2014) showed that urban legends featuring high disgusting content are more preferentially transmitted than those with low disgusting content. Such an emotional transmission bias in storytelling may be an efficient way to sensitize other group members to health risks.

Another aspect relevant to this account concerns the way the content of stories is adapted to the constraints of human memory. Stories are highly memorable (Scalise Sugiyama, 2001; Sperber, 1985). In oral traditions, storytellers transmit cultural information handed down to them in spoken conversation by authoritative sources (Rubin, 1995). The recurrence of themes in these narratives operates to lighten the memory load of the teller and the audience, imply certain features of the plot and define and stabilize oral traditions. These narratives contain scenes with visual imagery, tend to remain unchanged over time and generations, and are often remembered with a high degree of accuracy (Rubin & Umanath, 2015), even when the events in the narratives transmitted did not happen to either the teller or the listeners. Stories are also adapted to memory via minimally counterintuitive content (Barrett & Nyhoff, 2001; Boyer, 1994; Norenzayan, Atran, Faulkner, & Schaller, 2006). Stories featuring an optimal level of counterintuitive items are more memorable, better transmitted, and ultimately enjoy more cultural success. It is unclear how this bias facilitates the transmission of survival-related information in a narrow sense, because it would seem that such information should retain a minimal degree of accuracy in its representation of reality. However, minimal counterintuitiveness may favor the transmission of ideas fostering social cohesion, like religious ideas (see Section 3.3).

If storytelling confers adaptive benefits related to the transmission of survival-related information, it should feature prominently in teaching (Scalise Sugiyama, 2017). Teaching is "behavior evolved to facilitate learning in others" (Kline, 2015, p. 3). It enables younger or less experienced group members

to become better fitted to their community and thus be more successful in their responses to the ecological demands of their cultural niche throughout their lives. A review of 982 texts from 23 diverse hunter-gatherer societies (Garfield, Garfield & Hewlett, 2016) collected from the Human Relations Area Files (HRAF) showed that teaching in the form of storytelling plays a significant role in the transmission of cultural information about ecology, religious belief and practices and cultural values and kinship (Garfield et al., 2016). However, teaching in the form of storytelling plays a limited role in the transmission of subsistence skills (Garfield et al., 2016). Ethnographic studies in farmer societies have shown that in contexts of informal instruction, learning in children occurs through observation and active participation (Silva, Correa-Chávez, & Rogoff, 2010). In Mayan communities, for example, children "learn through engagement with others (in a system of ongoing guidance and support) in the everyday mature activities of their community" (Rogoff, 1994, p. 216). In these contexts, the transmission of cultural information (e.g. weaving) from adults to children relies on the interplay of imitation, demonstration, trial and error, scaffolding, and storytelling (Greenfield & Lave, 1982).

More recently, experimental studies have begun to use the method of serial reproduction (Wagoner, 2017) to simulate cumulative cultural evolution, or the continuous improvement of cultural artefacts (e.g. woven baskets, knots, paper airplanes, and stone stools) from one generation to the next (Bietti, Bangerter & Mayor, 2017; Caldwell, Atkinson, & Renner, 2016; Mesoudi & Whiten, 2008; Morgan et al. 2015; Zwirner & Thornton, 2015). This research has typically compared the emergence of cumulative culture as a function of various modes of information transmission (Caldwell & Millen, 2008, 2009), including imitation (new generations observed what previous generations did), emulation (new generations observed cultural products and their performance) and teaching (new and old generations interacted about the completed task). Findings coming from experiments using low complexity tasks (e.g. building a paper airplane or building a tower having as tools only spaghetti and modeling clay; see Caldwell & Millen, 2009) tended to show that cumulative cultural evolution can occur in any of these conditions. That is, teaching was not a necessary ingredient for cumulative culture to accrue (Caldwell & Millen, 2009; Zwirner & Thornton, 2015), although it may have been beneficial in some situations, such as for more complex tasks (Caldwell, Renner & Atkinson, 2017; Morgan et al.,

2015). Moreover, these studies did not examine the content of the social interactions involved in the teaching conditions. Thus, they were not informative about whether teaching involves storytelling. A recent study that did so (Bietti et al., 2017) found that storytelling was quite rare in transmitting knowledge of cooking skills to further generations. More frequent kinds of talk included instruction-giving or advice. Thus, while evidence from foraging societies, ethnography and experiments suggests that storytelling may play an important role in transmission of survival-related information, its exact role as a teaching method is unclear. Other forms of communication (e.g. direct instruction) may be more frequent, and possibly more efficient, in teaching than storytelling.

Taken together, there is much evidence that storytelling may play a role in the transmission of survival-related information (Scalise Sugiyama, 2001). There are some open issues with this account of the adaptive nature of storytelling. First, the range of what counts as survival-related information is broad. On the one hand, this could mean information about the physical environment, about food sources, or about animals, that is relevant to physical survival. On the other hand, this could be information about cultural norms or values, which are relevant for the cohesion of the group. Moreover, survival-relevant information of the first type should be accurate to at least some degree in order to be adaptive. However, many stories contain information that can hardly be described as accurate (e.g., myths, religious beliefs, fairy tales, and the like). While this may be detrimental to survival in terms of foraging or avoiding predators, it is not necessarily so for survival in terms of fostering group cohesion. A final issue concerns the added value or special role of storytelling in the transmission of survival-related information relative to language use more generally (Mellmann, 2012). This is an especially important issue for teaching, where storytelling appears to be used infrequently alongside other linguistic behaviors like instruction-giving.

3.3 Facilitating social cohesion

The adaptive value of storytelling may lie in its use for creating and cementing social bonds and thus facilitating social cohesion. This account is very broad and has been put forward in many different forms (Mellmann, 2012). Here, we describe a generic version before motivating its plausibility with reference to hunter-gatherer societies, thereby sharpening the claims and showing their limits.

An initial line of argument for the social-cohesive function of storytelling comes from ontogeny. The emergence of storytelling between the age of three and five years (Haden, Haine, & Fivush, 1997; Salmon & Reese, 2016) occurs in concert with an important development in children's theory of mind (e.g. Doherty, 2008). At this age, children already understand false beliefs (Baillargeon, Scott, & He, 2010), detect pretending (e.g. Doherty, 2009; Onishi, Baillargeon, & Leslie, 2007) and lying (Talwar & Lee, 2008), are able to keep secrets (Peskin & Ardino, 2003), develop peer relationships (e.g. Hay, Payne, & Chadwick, 2004) and understand moral culpability (Killen et al., 2011). Storytelling thus emerges as part of an increasingly sophisticated array of cognitive abilities oriented towards sociality. Early childhood is also when adults start to talk with their children about their memories (Fivush, 2011; Haden, Marcus & Jant, 2018). This affects how children structure their autobiographical memories in the future (Nelson & Fivush, 2004). In turn, these autobiographical memories constitute the foundation for the creation of a life story that is unique to the self (Bruner, 1990; Habermas & Bluck, 2000; McAdams, 2001; Nelson 2003). Reminiscing together about the day's events is also part of everyday interactions in families (Fivush, Zaman & Merrill, 2018). In sum, then, storytelling is a vehicle for fostering the integration of individuals into groups from early childhood onwards.

Storytelling is instrumental in fostering bonds in many other small-scale social units. Romantic partners, friends and colleagues all tell stories to begin new relationships and consolidate social bonds. For example, work groups constitute communities of practice (Wenger, 1998) in which storytelling is constitutive of everyday activities, but also the maintenance and continuity of experience and collective expertise (Orr, 1996; Bangerter, Mayor, & Pekarek Doehler, 2011).

Memory plays an important role in the way storytelling fosters social cohesion. As discussed in the previous section, memory biases make storytelling an inherently constructive activity, where constraints on the accurate transmission of information are often secondary.

Thus, it seems unlikely that storytelling's adaptive value derives solely from the transmission of survival-relevant information in a narrow sense. On the other hand, memory biases allow enhanced memory conformity with other ingroup members than with those outside the group, regardless of the truth-value of the information recalled. Memory conformity refers to cases in "when two people see the

same event and discuss it, one person's memory report can influence what the other person subsequently claims to remember" (Gabbert, Memon, & Wright. 2006, p. 480) and may lead to mixing of individual episodic memories (based on first-hand experience) with vicarious episodic memories (recollections of events that happened to other people; Pillemer, Steiner, Kuwabara, Thomsen & Svob, 2015). Social memory biases in the transmission of information include memory conformity (Gabbert, Memon, & Allan, 2003; Hope & Gabbert, this issue; Jaeger, Lauris, Slemeczy, & Dobbins, 2012; Meade & Roediger, 2002; Roediger & McDermott, 2011), socially shared-induced forgetting - increased forgetting of non-mentioned information related to what is mentioned in conversation relative to unrelated information that is not mentioned in conversation – (Cuc, Koppel, & Hirst, 2007; Stone, Barnier, Sutton, & Hirst, 2010, 2013; Stone & Wang, this issue), or the preferential retention of stereotype-consistent information over repeated transmission (Allport & Postman, 1947; Bangerter, 2000b; Lyons & Kashima, 2003, 2006; Maswood & Rajaram, this issue). Social memory biases may lead to the emergence of collective memories (Hirst, Yamashiro, & Coman, 2018). Thus the operation of memory biases in storytelling may enable the creation of a "shared reality" (Echterhoff, Higgins, & Levine, 2009; Hardin & Higgins, 1996), which can be understood "as the experienced commonality, or alignment, of inner states (attitudes, judgments) about a given target with another person" (Echterhoff, Kopietz & Higgins, 2017, p. 807). Experiencing a shared reality is one way to foster social bonds or feelings of belonging and community between individuals.

This account of storytelling as fostering social cohesion is well-supported by a broad base of research from psychology and other social sciences and is thus relatively unproblematic. It remains to be shown, however, that the account works for the ancestral environments where storytelling emerged (Mellmann, 2012). In other words, how did the social cohesion fostered by storytelling alleviate ancestral selection pressures? One prominent hypothesis in this respect is Dunbar (1996), who proposed that language evolved as an extension of grooming in primates. Language, especially gossip, was instrumental in maintaining social bonds and coalitions between individuals in a more efficient way than physical grooming. Language enables the creation of kin out of non-kin, extending "the common practice in small-scale societies of assigning a non-kin newcomer a status as fictional kin within the

existing kin-group" (David-Barrett & Dunbar, 2017, p. 25). Gossip in particular is a process for managing reputations of individuals within a group by identifying and punishing cheaters, thereby maintaining incentives for cooperation. An ethnography of gossip in Zinacantán, Mexico (Haviland, 1977) found that the most frequent topics were about social deviancy (e.g., illicit sexual relationships, drunkenness). Ju/'hoansi Bushmen spend a third of daytime conversations in criticism related to norm violations (Wiessner, 2014). Experimental game theory research further suggested that gossip fosters cooperation (Feinberg, Willer, & Schultz, 2014) by allowing group members to identify and ostracize cheaters. By strengthening social bonds and allowing the identification of cheaters, gossip represented an important boost to sociality as groups started to become larger and began to include non-kin (Dunbar, 2004). Note that Dunbar's account did not discuss storytelling in particular. But because gossip consists of talk about absent others' actions, it can be considered as a form of storytelling.

Beyond gossip about particular individuals, stories in hunter-gather societies are also concerned with norms and cultural values. Garfield et al.'s (2016) review of social learning in hunter-gatherer societies showed that cultural values and kinship (including social norms, morality, culturally preferred social and emotional behaviors between kin, gender roles, and age-graded social distinctions) and religious beliefs and practices are often transmitted by teaching and sometimes (less frequently) by storytelling. A recent study of the Agta, a Filipino hunter-gatherer population, also found that storytelling often was about norms. Agta narratives feature information about coordinating cooperative behavior (e.g., foraging) and broadcasting social norms (e.g. sex equality). Moreover, the presence of skilled storytellers in a camp is associated with an increase in cooperative behavior in individuals from that camp (Smith et al., 2017). Campfires may have been the place where stories were first told as a regular part of hunter-gatherer life, often at dusk or at night (Dunbar, 2014; Wiessner, 2014). They created opportunities for cooperative work (fire-making and fire-tending) and sharing food in the more relaxed environment granted by extra hours of light after sunset. Among Ju/'hoansi Bushmen, campfire conversations differ from daytime conversations, with storytelling being more frequent in the nighttime and more focused on individuals from larger social networks (geographically dispersed communities) and illustrate the functioning of social institutions, besides provides entertainment, a further mechanism

for reinforcing social bonds (Wiessner, 2014).

4. The collective sensemaking function of storytelling

The arguments proposed to further the previous accounts are not always clear about how storytelling is adaptive above and beyond the ability to communicate via language. In other words, what makes storytelling particularly suited to (1) enhancing individual fitness, (2) transmitting survival-relevant information, or (3) facilitating social cohesion? In this section, we review literature on storytelling as a social activity specialised for collectively making sense of non-routine events, that is, events that violate expectations. We argue that it is sensemaking that constitutes the specific adaptive benefit of storytelling.

Sensemaking is so central in human psychological functioning it has been independently investigated by a host of observers of the human condition, including novelists, philosophers and scientists (Proulx, Inzlicht, & Harmon-Jones, 2012). It is the process by which people give meaning to experience (Weick, 1995). Experiences are organized through knowledge structures (e.g., schemas, scripts, frames, or social representations; Bartlett, 1932; Goffman, 1974; Mandler, 1984; Schank & Abelson, 1977; Moscovici, 1984). Meaning is usually derived from expectations being met, which makes people feel they can predict and control their environments (Harris, 1994). Sensemaking is thus most necessary in out-of-the-ordinary situations that cannot be readily categorized on the basis of what is already known (Kiesler & Sproull, 1982; Proulx et al., 2012). In these situations, the incongruity between pre-existing schemas and events leads to subjective experience of surprise (Reisenzein, Horstmann, & Schützwohl, 2017) and a state of "aversive arousal" (Proulx et al., 2012, p. 317) at the level of very basic physiological parameters (e.g., increased skin conductance and cardiac variability; vascular constriction). These physiological signatures of negative arousal produced by expectancy violations occur irrespective of how momentous or trivial the violation is or of its valence. That is, even minor violations of expectancies and positive violations produce arousal. This state in turn motivates efforts to re-establish meaning via compensatory behaviors (e.g., accommodation, altering a schema to account for the event, or assimilation, reconstructing the event so it matches the schema; Piaget, 1952).

Sensemaking is both an individual and a collective process. Individual sensemaking is constituted by social-cognitive processes (Harris, 1994), while collective sensemaking involves communication (Weick, 1995). The process of collective sensemaking is facilitated by particular group members, like parents in family remembering (Hirst & Manier, 1996) or leaders in organizations (Isabella, 1990, Maitlis, 2005). Indeed, one of the main characteristics of charismatic leaders is their ability to orchestrate dramatic narratives that facilitate followers' identification to a cause, vision or worldview (Gardner & Avolio, 1998; Sharma & Grant, 2011). Storytelling is arguably the primary social activity by which collective sensemaking is accomplished. By its very nature, storytelling is geared towards surprise and unexpectedness. Part of the intuitive concept of what makes a story worth telling is its contrast with the audience's expectations (Polanyi, 1979; Labov, 1972; Bruner, 1991). Routine information does not violate expectations, and so does not meet the minimum requirement of significance for "tellability" (Norrick, 2007). Storytelling entails placing events into a coherent sequence or animating them by invoking protagonists' motives. It can enable the establishment of causal links or the attribution of responsibility for actions and events (Gabriel, 2000). This promotes understanding, enabling groups to build, use and update knowledge structures to respond to unexpected situations. The intrinsically constructive nature of storytelling further enables tellers to tailor stories to audiences' needs or interests (Scalise Sugiyama, 1996), making the story meaningful for them. Such a process may explain how storytelling fosters social cohesion as well as why good storytellers are often valued social partners or charismatic leaders (Gardner & Avolio, 1998; Smith et al., 2017).

A wealth of literature across the social sciences indeed documented the collective sensemaking function of storytelling, in both small and large groups. For example, research on small groups such as families suggested it is possible to re-story problematic life events that may have disrupted shared systems of belief by narrating them together (Koenig Kellas & Trees, 2006; Monk, 1997; Brookfield, Brown & Reavey, 2008). Sensemaking in family remembering is enabled by members adopting different roles. Children might act as narrators, while parents may take on the roles of mentors (who prompt) or monitors (who assess) during collaborative storytelling (Hirst & Manier, 1996). Other small groups confront non-routine events, both on a low-level, everyday basis and in the form of large-scale change.

This is achieved through face-to-face storytelling (Bangerter, Mayor, & Doehler, 2011; Brown & Duguid, 1991; Linde, 2001; Brown, 2006). Stories can provide an interpretative framework and enable participation in a collective reasoning process (Orr, 1996), often being told in series (Norrick, 2007; Ryave, 1978; McBride, 2014). Many organizational groups tell stories as part of their everyday knowledge integration, for example nursing teams (Bangerter et al., 2011), midwives in traditional societies (Jordan, 1987), photocopy repair technicians (Orr, 1996) and car factory workers (Patriotta, 2003). Storytelling is therefore an important way for small groups to make sense of the unexpected events and problems that constitute everyday life, be it in families or at the workplace.

Small group interactions are typically embedded in larger networks (see Maswood & Rajaram, this issue). Storytelling facilitates the creation of an overarching identity and thus the definition of an ingroup and an outgroup. Large groups cohere based on shared norms, beliefs and ideologies (e.g. Bar-Tal, 2000) or collective memories (Halbwachs, 1950). Two prominent forms of such large groupings include nations and religions. For nations, narratives like founding myths establish a sense of nationhood and enable people to imagine themselves as belonging to a community, even when it is comprised of a vast amount of individuals they will never meet (Anderson, 1983). These narratives are an important component of nationalist discourse that link the present to the past and give meaning to current events. They can be told and re-told by both ordinary citizens and leaders (De Cillia, Reisigl, & Wodak, 1999). For religions, storytelling interacts with more formalized aspects of religious discourse like laws, hymns or prophecies (Ricoeur, 1995). Religious storytelling is a vast topic that cannot be treated in detail here. Suffice it to say, however, that many symbolic elements of religion are narrative in nature, and that storytelling can be used to create a sense of religious community. For example, in late nineteenth-century America, religious sermons became progressively infused with storytelling as a means to appeal to a wider and more diverse set of audiences (Reynolds, 1980).

At no time are collective sensemaking processes more evident than in the wake of sudden catastrophic events that threaten existing worldviews (e.g., disease outbreaks, natural disasters, outgroup aggressions) Proulx et al., 2012; Rosnow, 1980; Wagner, Kronberger, & Seifert, 2002) as well as survival. This is when people most need symbolic protection, because several conflicting explanations

coexist to create a climate of fear and uncertainty (Franks et al., 2013). Various forms of storytelling emerge spontaneously in such situations. War and conflict lead to the appearance of rumors (Allport & Postman, 1947), as do changes in organizations like mergers or layoffs (DiFonzo & Bordia, 1998; Smet, Van der Elst, Griep, & De Witte, 2016). Outbreaks of infectious diseases are another example. The mortal risk they pose is often accompanied by a symbolic threat, especially when the mechanisms of infection are not well understood (Joffe, 1999). When the Black Death spread through Europe in the 14th century, many narratives emerged and circulated to explain the outbreak. Some were based on (incorrect) scholarly theories (miasmatic theories of disease propagation), while others appealed to religion (e.g., divine punishment) and still others blamed the outbreak on stigmatized outgroups (e.g., Jews) plotting to undermine society. In modernity, this phenomenon persists, with scientific theories competing with various popular explanations for public attention (Eicher & Bangerter, 2015).

The example of the Black Death illustrates a common pattern of collective sensemaking in crises: the stigmatization of outgroups as being the cause of the crisis. While rumors often scapegoat particular outgroups, this pattern is perhaps most evident in conspiracy theories (Graumann & Moscovici, 1987). Beyond disease outbreaks, conspiracy theories are also associated with traumatic events like terrorist attacks or assassinations of leaders and may serve as a means of system justification by scapegoating particular groups in society (Jolley, Douglas, & Sutton, 2017). Outgroup blame can thus serve to sharpen a sense of ingroup identity (Tajfel & Turner, 1986). Moreover, while xenophobic behaviour seems dysfunctional in the modern world, it may have evolved as an adaptive reaction in ancestral environments, where encounters with outgroups were often dangerous because of the risk of aggression or infection by pathogens against which the ingroup possesses no immunity (Schaller & Park, 2011).

The account of storytelling as collective sensemaking is broadly supported by the literature. How does this account fare when applied to ancestral human environments? In other words, is it plausible that stories evolved to facilitate collective sensemaking in ancestral groups and what selection pressure did they help alleviate? Here is it important to note that a sensemaking account is not an exclusive alternative to the other accounts reviewed above. However, sensemaking accounts for the

specific character of storytelling beyond language use in general. That is, while all three accounts above are well-supported by the available data, the functions they embody can and often are fulfilled by other, non-narrative forms of communication. However, storytelling seems adaptive for sensemaking in ancestral environments because managing unexpectedness is relevant for many aspects of survival, including general threat detection (Proulx et al. 2012), predicting lethal aggression (Dessalles, 2010), avoiding infection risk (Schaller & Murray, 2008), or coordinating collective behaviour in the face of external threat (Joffe, 1999), to name but a few examples. The ubiquity of managing unexpectedness makes a group-level social process for this function plausible, storytelling seems like a prime candidate for that process.

5. Discussion

In this article, we have reviewed three prominent accounts of the adaptive benefits storytelling may have conferred to ancestral human groups. First, storytelling may have benefited individuals by allowing them to manipulate information to affect their audiences' beliefs to the advantage of the tellers. Second, storytelling may have increased group-level fitness by constituting a vehicle for efficiently transmitting survival-relevant information. Third, storytelling may have benefited groups by facilitating social cohesion or the coordination of cooperative action. These accounts are not mutually exclusive and are all plausible and supported by various kinds of evidence. However, they are not always clear on a key criterion for explaining putative adaptive benefits of storytelling, namely the specific benefits storytelling confers relative to other forms of language use or social interaction (Mellmann, 2012). We have proposed that the specific benefit of storytelling is its use as a device for collective sensemaking of non-routine or unexpected events that impinge on everyday group life. Storytelling processes (e.g., putting events in a temporal sequence and linking them by the actions of protagonists) are fundamentally constructive, which makes them well-suited to managing the fit between pre-existing knowledge structures and unexpected events. The open-endedness of repertoires of stories in oral traditions may contribute to their adaptive nature, allowing those repertoires to be flexibly tailored to specific circumstances while illustrating or upholding certain cultural traditions and values (Biesele, 1986). The

sensemaking function of storytelling is therefore the means by which the other functions of storytelling are realized.

This collective sensemaking function is broad enough to account for both the way pedestrian forms of storytelling are used in everyday situations (e.g., two individuals gossiping about deviant behavior by an absent third party) as well as how rumors may emerge and spread to fill an informational gap in a highly ambiguous group-level situation (Allport & Postman, 1947) or even how some narratives may coalesce over long periods of time into myths that are fundamental for constituting the identity of a particular group. Our proposal is similar to other explanations of storytelling that have been advanced (e.g., Boyd, 2009; Saillenfest & Dessalles, 2013). But we emphasize the fundamental importance of collective sensemaking in managing unexpectedness as a function for which storytelling is particularly well-suited.

Our proposal of storytelling as adaptive collective sensemaking can link storytelling more explicitly to other common human activities. As just one example, consider play, which, like storytelling, is a social activity that is culturally universal and develops early in ontogeny (unlike storytelling, however, it is widespread across various species). Like storytelling, the adaptive functions of play are still under discussion. Play fighting (or "rough-and-tumble" play) is an inherently unpredictable activity that involves adapting to a partner's moves in real time, distinguishing pretence from real aggression, self-handicapping and the like. One possible function of these behaviors may be enhancing the development of flexible responses to unexpected physical events entailing a sudden loss of control. Play can thus constitute "training for the unexpected" (Spinka, Newberry, & Bekoff, 2001, p. 141). Similarly, Boyd (2009) has proposed that storytelling, or art more generally, can be viewed as a kind of "cognitive play". Viewing both physical play and cognitive play (e.g., storytelling) as adaptations for unexpectedness highlights the importance of the management of unexpectedness in human social life and further underscores a parallel between play and storytelling.

Our proposal has implications for further research on the role of storytelling in cultural transmission. Perhaps the most prominent issue in this respect concerns the transmission of survival-relevant information via teaching. In many cases, it is unclear what the role of storytelling in teaching

is (although large-scale databases like the HRAF may underestimate the prevalence of storytelling in teaching)[2]. In a broad sense, teaching can include many kinds of behavior (Scalise Sugiyama, 2017; Biesele, 1986). Experimental studies of the role of teaching in transmission of culturally acquired information (e.g., Zwirner & Thornton, 2015) typically did not analyze the content of teaching interactions. We have begun to do so (Bietti et al., 2017; Tilston, Bangerter, & Bietti, 2018). We found that much of teaching in social transmission experiments involved instructional discourse about what to do. It was rare for teachers to produce stories about what they actually did. Initial analyses of the conversational contexts where they do actually produce stories (Bangerter, 2000a) suggested that these narratives reflected non-routine occurrences (e.g., poor performance, mistakes, or insights about how to do something better). This is in line with the sensemaking function we propose in this article. Because of the temporal constraints of experimental interactions, however, spontaneous storytelling may be easier to observe in other situations, for example where there is more time to reflect on experience and on lessons learned. That is why it is important for fieldwork to focus more on in-depth analyses of everyday social interaction (e.g., Bangerter et al. 2011; Orr, 1996) to clarify the role storytelling plays alongside other forms of transmission (e.g., commands or explanations; Greenfield & Lave, 1982).

Storytelling is part of an adaptive functional toolkit for the transmission of cultural information, the specific benefit of which is enabling collective sensemaking. What remains to be systematically studied in the laboratory and in the field is for what specific purposes people prefer to craft stories over other forms of communication (e.g., instructional or argumentative discourse) to transmit information, promote social cohesion and organize cooperation.

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[2] This may be because the original materials constituting the HRAF may have missed opportunities for observing storytelling-as-teaching. We thank an anonymous reviewer for pointing this out.

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Study 4

Teaching, emulation and storytelling in cultural transmission

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Abstract

The role of teaching in cultural transmission is unclear. Despite widespread agreement about the importance of teaching, cultural transmission experiments rarely document or analyse the content of teaching sessions. This study is designed to do so. This study investigates the intergenerational transmission of a complex manual skill (basket weaving). It explores the possible benefits of teaching combined with emulation (reverse engineering) over emulation only. Teaching did not significantly improve task performance, but participants told stories during transmission to pass on information about non-routine events and vicarious memories. Storytelling may be a specialised mechanism for face-to-face cultural transmission.

Introduction

Culture involves the social transmission of information from one generation to another. Teaching is a common way for information to be socially transmitted. Although it is widely argued that teaching has an important role in cultural transmission (Thornton & Raihani, 2008), there is disagreement as to what extent it is necessary and what its specific components and functions are.

On the one hand, social interaction (i.e. teaching) can decrease the loss of transferred information and skills when compared to imitation and emulation alone (i.e. reverse engineering) (Morgan et al., 2015). This is especially the case for more complex or 'opaque' tasks such as knot tying that cannot easily be reverse-engineered (Caldwell et al., 2017; Derex et al., 2013). On the other hand, interaction is not always necessary to improve cultural artefacts over generations (Caldwell & Millen, 2009; Zwirner & Thornton, 2015). Much of this work is drawn from the tradition of experimental cultural transmission research (Mesoudi & Thornton, 2018). Taken together, these studies suggest that despite not being essential, teaching can be useful to transfer complex information.

In light of this, it is surprising that transmission chain experiments typically do not document or analyse the content of teaching sessions, instead focusing on the artefacts produced (Caldwell & Millen, 2009). This means that there has thus far been no way of finding out what it is about teaching that is beneficial. Teaching can be studied under a number of different conditions in these experimental contexts: either simultaneously while the next participant in the chain is engaged in the task or separated from task performance, and either with or without the presence of the artefact that the 'teacher' has just created. Teaching usually occurs simultaneously with task performance, so time pressure and the affordance of component objects may affect what is taught. The specific features of teaching in cultural transmission, and how teaching interacts with context thus remain unclear.

We propose that storytelling is a form of teaching that has several potential functions in cultural transmission. The most contentious of these functions is facilitating accurate information transfer, as storytelling appears to both promote and inhibit the accurate replication of information. This is because storytelling is a highly memorable form of communication, yet it also facilitates the

warping of information through elaboration or reducing to gist – for example in the context of rumour and urban legends (Bartlett, 1932; Sperber, 1985; Xu & Griffiths, 2010). However, this transformative aspect of storytelling enables a second important function: helping us to collectively make sense of confusing events. Lastly, storytelling is a popular way to pass on the experiences of others through the form of vicarious memories. This enables us to learn from the mistakes of others without having to learn from our own trial and error. Storytelling is therefore a likely candidate as a component of teaching in cultural transmission.

The current study is designed to allow a detailed examination of the content of teaching during skill transmission. We propose that storytelling spontaneously occurs during teaching, and thus expect to observe it during our interactional sessions, albeit infrequently. When storytelling does occur, we predict that it tends to reflect non-routine occurrences, such as poor performance or mistakes. Among other possible functions, we propose that the presence of storytelling slows the rate of information loss by preventing the intergenerational transfer of mistakes.

Teaching in cultural transmission

Experimental paradigms investigating cultural transmission have widely examined how cultural products (i.e. information or artefacts) are modified when passed through a succession of individuals (Mesoudi & Whiten, 2004). The path of transmission varies according to experimental design, from linear chains of individuals (Bangerter, 2000b; Morgan et al., 2015; Tamariz et al., 2016; Zwirner & Thornton, 2015) to "microsociety" groups with or without the replacement of their members (Caldwell & Millen, 2008; Fay et al., 2010; Kameda & Nakanishi, 2002; Mesoudi & O'Brien, 2008). Generational change is thus often modelled by each individual representing a different generation (Boyd & Richerson, 2005; Enquist et al., 2010). These studies usually focus on cumulative cultural evolution - often defined as a specific type of cultural evolution whereby behaviours or behavioural artefacts show a directional trend towards improvement over generations (Caldwell et al., 2017). Manipulating the amount of interaction between participants allows us to investigate the social learning mechanisms involved in cultural transmission. Social interaction can take the form of

teaching, and conditions allowing interaction to occur between generations are often named 'Teaching conditions' (Caldwell & Millen, 2008; Caldwell et al., 2017; Zwirner & Thornton, 2015).

One key phenomenon of cultural transmission is high-fidelity information transmission, in other words precise copying. Studies that measure the rate of loss in the transmission of a target skill over generations enable us to make inferences about fidelity in cultural transmission. Precise copying prevents the loss of rare or subtle modifications (Tennie et al., 2009), and as technological advancement often depends more on combination and modification of traits than on "genius"-like novel invention, even slight differences in fidelity can greatly increase both the longevity of cultural traits and the number of cultural traits in a population (Lewis & Laland, 2012). Fidelity can therefore be thought of as a key driver of cumulative cultural evolution, and facilitator of the ratchet effect, i.e.: the prevention of slippage backwards through loss of technological advances(Tomasello, 1999; Tomasello et al., 1993).

High fidelity transfer may be facilitated by teaching over and above other forms of information transmission. The transmission chain method has been employed to generate evidence for this claim (Caldwell & Millen, 2009; Zwirner & Thornton, 2015). In the original 'serial production' studies (Bartlett, 1932), participants individually reproduced a drawing or text, which lost detail and became gist-like as it was assimilated to prior knowledge over generations. However, these studies were carried out in a written format and participants never saw or conversed with others in their chain. When generations are allowed to interact face-to-face, the rate of information loss slows compared to listening to the previous generation audiotaped (Tan & Fay, 2011)[3]. This suggests that information is transmitted more accurately when the incoming participant has an interactive discussion with their outgoing counterparts.

However, many studies using similar methods suggest that teaching is not essential for information transfer. This could be because these studies focus on investigating the necessary

[3] This study does not explicitly investigate "teaching", but social interaction in this context has been labelled teaching in many similar transmission chain experiments. There are clear parallels with the definition of teaching as "a form of cooperative behaviour which functions to promote learning in others" (Thornton & Raihani, 2008)

conditions for *cumulative improvement* of artefacts over generations, rather than rate of information loss (Mesoudi & Thornton, 2018). These experiments enable the effective comparison of different forms of information transmission by separating them into distinct conditions. For example, teaching (i.e. when interaction about the task occurs between generations) is compared to other forms of information transmission, such as imitation (individuals learn by watching the previous generation perform the task), emulation (individuals reverse-engineer by examining the previous generation's completed product) or asocial (one participant performs repeated trials of the task). In the absence of social interaction, emulation is generally more effective than asocial learning (Caldwell & Millen, 2008; Zwirner & Thornton, 2015). Teaching does not appear necessary for cumulative improvement to occur in low complexity tasks, such as building spaghetti towers, paper aeroplanes or baskets to carry rice (Caldwell & Millen, 2008; Zwirner & Thornton, 2015). Yet when the task is opaque, in other words less easy to reverse-engineer, the benefits of teaching become evident. This has been found using tasks such as knot tying (Caldwell et al., 2017; Derex et al., 2013), and flint-knapping of arrowheads (Morgan et al., 2015). These studies measured the rate at which original traits were lost, rather than searching for evidence of improvement, further indicating the link between teaching and high-fidelity information transfer.

Storytelling: Accuracy or sensemaking?

What occurs during teaching that may be beneficial to accurate transmission? Storytelling constitutes a teaching method (Scalise Sugiyama, 2017; Williams et al., 1999), and is defined as a collaborative conversational activity focused on the production of narrative discourse (Mandelbaum, 2013), whereby a narrator typically recounts a sequence of past events, including protagonist's actions, and how they contribute to changing an initial situation (Bruner, 1990; Labov & Waletzky, 1967). Anthropological evidence indicates that storytelling is adaptive (Smith et al., 2017) and may have been used by ancestral humans to transmit survival-related information (Sugiyama, 2001). Storytelling about events is less costly than experiencing them first hand by trial-and-error, as narrative processing requires no physical exertion and enables the compression of time (Sugiyama, 2001). Today, it remains one of the commonest ways of sharing personal experiences (Boyd, 2018; Currie & Sterelny,

2017), and is an activity we engage in spontaneously, effortlessly and pleasurably (Mellmann, 2012). Storytelling is also a popular way to encode and pass on the experiences of others in the form of vicarious memories (McBride, 2014).

There are two sides to the argument about storytelling and accuracy, as it appears to simultaneously promote and inhibit the precise copying of information. On the one hand, accurate copying can be facilitated by storytelling as it is an engaging and highly memorable way of transferring information (Sperber, 1985). Storytelling is a vivid way of relating experiences, often featuring direct reported speech animated by gaze (Holt, 1996; Mandelbaum, 2013), and intensified by facial, gestural or postural mimicry (Sidnell, 2006). Following the step-by-step actions depicted in a first-person perspective allows the listener to relive the experience and learn from it in a convincing way. Narrative oral traditions are often recalled with a high level of accuracy over long periods of time (Rubin & Umanath, 2015), which is also indicated in hunter-gatherer societies (Scalise Sugiyama, 2017; Wiessner, 2014). On the other hand, this can be debated as the process of telling stories also has a transformative component. For example, people commonly recount stories that happened to someone else as if it actually happened to them, thus confusing individual episodic memories (based on first-hand experience) with vicarious memories (events that happened to other people) (Pillemer et al., 2015). When telling stories, narrators often warp information by reducing it for gist (Bartlett, 1932; Xu & Griffiths, 2010), or focusing on or embellishing certain aspects, such as stereotype consistent information (Allport & Postman, 1945; Bangerter, 2000b; Kashima, 2000; Lyons & Kashima, 2006), social information (Dunbar, 1998; Mesoudi et al., 2006), emotional information (Brady et al., 2020; Eriksson et al., 2016; Stubbersfield, Tehrani, et al., 2017) or amusing information (Stubbersfield, Flynn, et al., 2017). These cognitive biases have a cumulative effect, so become particularly evident over increasing generations (Stubbersfield, Tehrani, et al., 2017).

However, even if accurate information transfer is not facilitated, storytelling has other specialised features, one being that it enables us to collaboratively make sense of events. In everyday conversation, stories involve 1) recounting events and 2) inferring what the 'point' is (Labov & Waletzky, 1967). In other words, stories are told for a reason (Norrick, 2007). Sensemaking is defined

as the process by which people give meaning to experience (Weick, 1995), and storytelling is the primary social activity by which this is accomplished (Bietti et al., 2018). We usually arrange our experiences into knowledge structures, such as schemas, scripts or frames (Goffman, 1974; Mandler, 1984), and derive meaning from our expectations being met. Any mismatch between our expectations and an event produces arousal, which will in turn motivate us to reconcile meaning either by changing our expectations to fit the event (accommodation) or re-framing the event to fit our expectations (assimilation) (Müller et al., 2009). Even minor inconsistencies have this effect (Proulx et al., 2012). Surprise enables the generation of inferences (Sperber & Wilson, 1986) as we place disparate events into a coherent sequence, establishing causal links and building or updating our knowledge structures. This could be a key component of how we learn from our mistakes through storytelling in everyday contexts.

This is especially true of events that go wrong, or against our expectations. Intuitively, storytelling is geared towards surprise and unexpectedness, as this is the key component that makes stories "tellable" and interesting to audiences (Dessalles, 2010). When asked to spontaneously recall any salient life event of a close relative or friend, people tend to recount problematic events (Pillemer et al., 2015). Many small work-based communities tell stories as part of their everyday knowledge integration (Bangerter et al., 2011; Jordan, 1989; Orr, 1996; Patriotta, 2003), indicating storytelling may be a mechanism specialised for communicating context-specific problems. This is because the specific adaptive value of storytelling over and above language in general lies in making sense of non-routine, uncertain or novel situations, thereby enabling the collaborative development of previously acquired skills and knowledge (Bietti et al., 2018).

Another specialised feature of storytelling may be the encoding and transmission of vicarious memories (McBride, 2014). Vicarious memories serve many of the same functions as personal memories, although at lower levels of intensity (Bandura, 1971; Larsen, 1988; Pillemer et al., 2015). The ability to learn vicariously through listening to stories may be adaptive, compressing down the time relative to the actual experience being transmitted, and saving costly trial and error (Sugiyama, 2001). Vicarious experiences may also expand episodic memory and enhance the ability to imagine or

predict future events through common brain networks (Schacter et al., 2007). Vicarious memories transmitted through storytelling may therefore inform present and future decision-making behaviours, a function conducive to the intergenerational transfer of experience.

This study

The main aim of this study is to compare the effect of emulation alone (i.e. reverse engineering from end products) to the combined effect of teaching plus emulation. A complex manual skill was transmitted under these two conditions across generations of individuals in transmission chains. The *Emulation only* condition was created to establish the effect of learning from examining the end product alone, without any socially transmitted information from the individual who created it. Teaching was operationalised as participants who had just completed the task interacting with naïve incoming participants about the task, with the artefact they had just created to hand. This exposure to the recently created artefact also enabled emulation, rendering this condition *Teaching plus emulation*. This allowed us to investigate what the specific features of teaching are, in what forms they occur, and how they influence skill transmission over and above emulation.

Two notable modifications were made to the conventional way that teaching is observed in transmission chain / microsociety experiments: teaching was separated from task performance and the time constraint was removed. When teaching occurs simultaneously to task performance, the teacher observes the learner, giving them step-by-step advice and feedback on their task performance as it happens, although teachers are not permitted to construct the object themselves (Caldwell & Millen, 2009; Caldwell et al., 2017; Zwirner & Thornton, 2015). This is likely to stimulate step-by-step instructional speech by the teacher that is continually affected by the changing affordances of the component materials as the learners act upon them. Social learning can take many forms (Heyes, 2012), and this particular context is likely to generate certain types over others. For example, teachers may make gestures for learners to copy, facilitating imitation, i.e. the reproduction of actions that you have seen (Tomasello, 1999; Tomasello et al., 1993). The urgency of time restraints also potentially causes teachers to focus on more immediate aspects of the task, rather than reflect on broader strategies. By creating an opportunity for teaching isolated from these pressures, we may observe

different kinds of teaching content. Dissociating teaching from task performance allows us to more closely examine the value of teaching over and above emulation alone.

The task chosen was a complex manual skill; weaving a basket from strips of card. This task was selected for its high level of complexity and ecological validity. Tasks used in experimental paradigms have so far have varied according to these criteria. In order to model generational change, experiments must 'miniaturise' it to fit laboratory conditions. This often involves using low complexity tasks that can be solved in a limited amount of time, such as making paper aeroplanes (Caldwell & Millen, 2009). However, teaching is most beneficial to the skill transmission process when the task involves producing an object that is high complexity and difficult to reverse-engineer (Caldwell et al., 2017; Derex et al., 2013). Some tasks have high ecological validity, such as making arrowheads and fishing nets, but have been carried out virtually (Derex et al., 2013; Mesoudi & O'Brien, 2008), which arguably reduces the level of manual dexterity required. The task chosen for this study, weaving a basket from strips of card, is a complex manual task that is difficult to reverse engineer. Weaving is an important survival skill socially transmitted among hunter-gatherers (Hewlett et al., 2011), providing the task with ecological validity in an evolutionary sense. This task is therefore well-suited to investigate teaching in a laboratory context.

The yoked chain design (see below) allows a clear, within-subject comparison of the effects of teaching combined with emulation to the effects of emulation alone. Control conditions have been interpreted problematically in many transmission chain experiments (Miton & Charbonneau, 2018). As both conditions in this study share the same first generation, we are able to observe how the same initial artefact develops differentially with and without social interaction over a further two generations. This study measures task performance as the rate at which the skill of weaving is lost over generations, and is therefore not concerned with cumulative improvement. The dependent variable is similarity to the original master basket. The use of the same 'master' basket as the original stimulus for the first participants of all eighteen chains provides a standard from which information loss rate can be calculated. This arrangement also allows us to videotape and transcribe, analyse content and purpose of storytelling. We expect to observe storytelling during teaching interactions, albeit at low

densities, as previous research has indicated that during task-oriented teaching storytelling is actually quite rare, with talk mainly consisting of direct instructions or advice (Bietti et al., 2019). However, when storytelling does occur, we expect it to concern mainly non-routine events, such as poor performance or mistakes.

This study was designed with two goals in mind. Firstly, to test the benefits of teaching plus emulation in cultural transmission over and above emulation alone. Secondly, to investigate the possible roles of storytelling as a teaching method in cultural transmission.

The hypotheses tested were:

H1: There will be higher levels of similarity to the original artefact (the master basket) in the teaching plus emulation condition over emulation alone.

H2: Participants will spontaneously tell stories when teaching occurs in the presence of the object disassociated from task performance.

H3: Storytelling will be proportionally more dedicated to the transmission of non-routine information than non-storytelling talk.

We also used two research questions to guide our analysis:

RQ1: Is the amount of storytelling related to level of similarity to the original artefact (the master basket)?

RQ2: Are vicarious memories transmitted or not?

Methods

Participants

There were 90 French-speaking participants (54 female, $M = 23.3$, $SD = 3.09$), recruited from the student population of the University of Neuchâtel, 13% reported having previous weaving experience. Participants received 6 CHF in exchange for half an hour of their time, along with the incentive of a 30 CHF bonus per person if their group formed part of the 3 best performing groups (out of 18).

Design

Participants were randomly assigned to positions in 18 yoked chains. Five participants (P1-P5) constituted one yoked chain, divided into three generations of basket-making (G1 - G3), of which G2 and G3 were analysed (Fig 1). The teaching condition allowed for both reverse engineering (examination of the previous participant's basket) and social interaction with the previous participant, while the emulation condition allowed for reverse engineering only (for the same duration as the generationally equivalent interaction). Thus, this study had a 2 (condition: teaching and emulation vs. emulation only) x 2 (generation: G2 vs. G3) repeated measures design.

Task

Participants were given 15 minutes to construct a new basket by weaving strips of card, with the basket that their predecessor had made (or the original model basket if generation one) as inspiration. They were told their goal was to make a good basket.

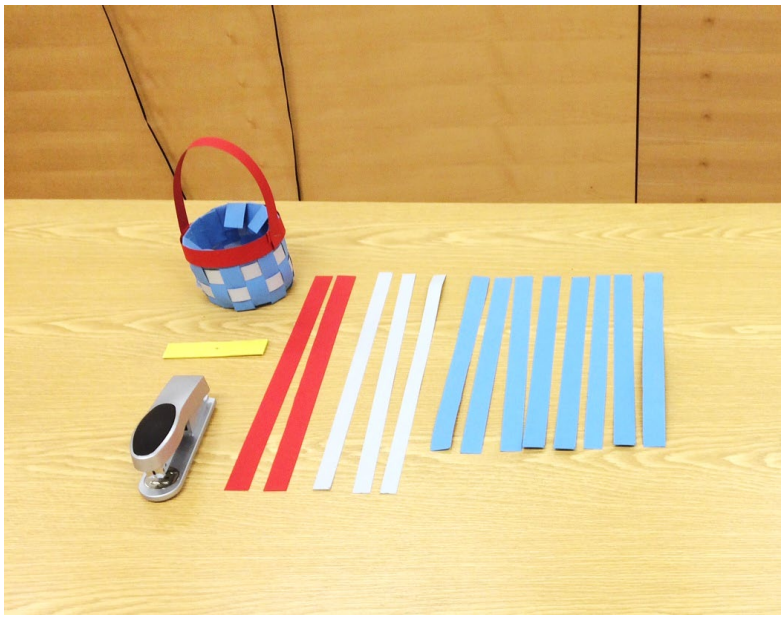
Table 1

List of materials given to each participant

Quantity	Material and dimensions
8	Blue strips of card (2 x 30 cm)
3	Grey strips of card (1.3 x 36 cm)
2	Red strips of card (2 x 35 cm)
1	Measuring stick (2 x 9 cm)
1	Model basket (produced by previous generation)
1	Stapler loaded with 15 staples

Figure 1

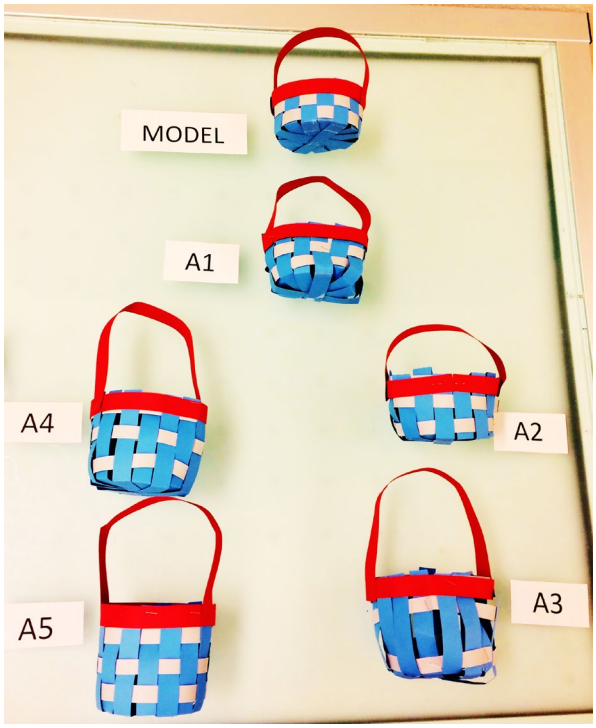
Materials given to each G1 participant



Note: The original master basket is also provided as model. For G2/G3 participants this was replaced by the basket created by the previous generation participant.

Figure 2

One yoked chain of baskets including original model



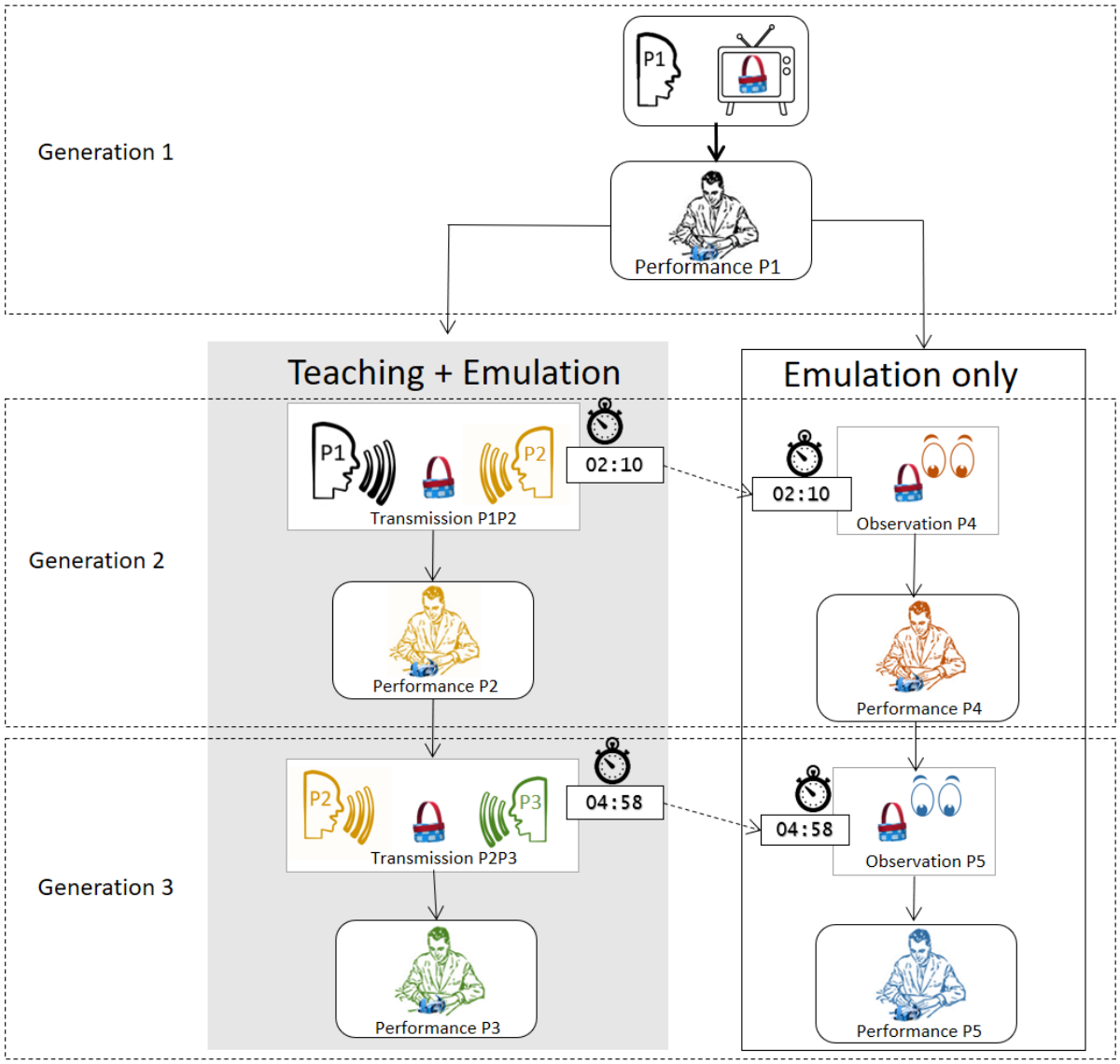
Note. Teaching plus emulation condition = A1, A2, A3, Emulation only condition = A4, A5.

Procedure

Participants signed consent forms on arrival. P1 watched an instructional video and had 15 minutes to construct a basket from available materials, with the master model basket for reference (Performance P1). The master model basket was then removed while P1 instructed P2 how to complete the task, with the basket they had just created to hand (Transmission P1P2). P1 then left the room and P2 had 15 minutes to complete the task with identical materials, and P1's basket as a model (Performance P2). Once completed, the process was repeated with P2 instructing P3 how to complete the task (Transmission P2P3). Once P3 had completed the task (Performance P3), the interactive chain was complete. For the non-interactive half of the yoked chain, P4 was exposed to P1's basket for the same amount of time that P1 and P2 interacted for, and then given 15 minutes to complete the task with P1's basket to hand (Performance P4). P5 was then exposed to P4's basket for as long as P2 and P3 interacted for, and then given 15 minutes to complete the task with P4's basket to hand (Performance P5). Every transmission and performance session was videotaped. Afterwards, all participants were debriefed about the goals of the study and paid.

Figure 3

One yoked transmission chain



Note. An example yoked chain is here depicted by condition (Teaching and emulation or Emulation only), and generation (1, 2 or 3). Each chain began with the first participant (P1) recreating the basket after watching an instructional video. Then they taught the second participant (P2) with the basket to hand, before P2 themselves goes onto perform the task and teach the third participant (P3). This constitutes the Teaching and emulation condition. For the Emulation only condition, P1's basket was observed by a fourth participant (P4).To control for exposure to the basket, this observation period was equal to the amount of time P1 taught P2. Once they had performed the task, the fifth participant (P5) observes P4's basket, for an equal time that P2 taught P3. The total number of yoked chains included in this study was 18.

Coding

Similarity

Task performance was measured as similarity of each basket to the master model basket - which every first generation participant had been exposed to - on a scale from 1 (not at all) to 7

(almost identical) by five different raters. Raters were blind to study aims, and the order of the baskets was randomised as well as the order of presentation. We also measured similarity to the previous basket for G2 and G3 in an identical procedure. An excellent degree of inter-rater reliability was found for both similarity to model ($\alpha = .91$) and similarity to previous ($\alpha = .94$). The average measure ICC was .193, (F (71,284)= 11.502, p <.001) for similarity to model and .943, (F (89, 356)= 17.402, p <.001) for similarity to previous.

Storytelling

Transmission sessions were transcribed and coded for the presence of storytelling in the form of memory utterances (MUs) ($\kappa = .985$), here defined as past-tense utterances produced by the outgoing partner that are thematically related to the task (Bangerter, 2000a). All talk was coded as either MU or non-MU (all other talk), and as either routine (mundane, not describing unexpected events) or non-routine (describing events departing from expectations in either a positive or negative / problematic way). To control for talking time, MU density was calculated by dividing each participant's raw MU count by the total amount of words they spoke.

Excerpt 1

Example of coding for routine and non-routine memory utterances

G1 :	je pense que j'ai mal géré mon temps, j'étais genre ok, je fais ça bien et tout je - *I think I mismanaged my time, I was like ok, I'm doing it well and everything I'm -*
	pense au nombre d'agrafe et du coup j'ai perdu plein de temps je pense *thinking about the number of staples and so I wasted a lot of time I think*
G2 :	Ok *Ok*
G1 :	Je pense que c'est ça aussi, euh, à quoi je peux penser encore, tu vois j'étais - *I think it's that too, uh, what can I still remember, you know I was -*
	tout fier de ma structure genre ah elle est mieux réussie que le modèle - moi j'avais - *all proud of my structure like ah it's better than the model - I had -*
	un modèle - mais en fait [en fait] *a model - but in fact [in fact]*
G2 :	[toi t'avais] le modèle [entire?] *[you had] the whole [model?]*
G1 :	[ouais ouais (inaudible)] que de la merde je suis vraiment désolé mais en plus *[yeah yeah (inaudible)] just shit I'm really sorry but also*
	j'avais pas prévu que ça se passerait comme ça moi *I didn't actually expect it to be like that*
G2 :	(rires) *(laughs)*

Note. Routine memory utterances are marked in yellow and non-routine memory utterances are marked in grey. This is taken from the transcription of the teaching interaction between participants G1 and G2, lines 255 – 264.

Excerpt 2

Example of coding for memory utterances and vicarious memories

G2:	**là il l'avait pas fait avant, il s'était arrêté aux trucs gris** du coup j'étais là [bon alors] ***that he didn't do before, he stopped at the grey stuff*** *so* ***I was like [right then]***
G3 :	[mh (rires) ok] *[mh (laughs) ok]*
G2 :	[donc] là tu poses par-dessus pis après tu dois faire tenir ça donc **lui il me disait -** *[so] you put that over it then after you have to make it hold so* ***he told me -***
	t'es pas obligé de faire tenir une agrafe tu peux genre passer par-dessous et - ***you don't have to staple it, you can like put it through and -***
	encore par-dessous genre un peu comme j'ai fait [(inaudible)] ***back under again*** *like a bit like I've done [(inaudible)]*
G3 :	[ouais ok ouais] *[yeah ok yeah]*
G2 :	Voilà quoi, et pis comme ça ça tient *So there you have it, and then like that it it holds up*

Note. As in Excerpt 1, memory utterances are marked in yellow and non-routine memory utterances are marked in grey. However here additionally, vicarious memories are in bold. This is taken from the transcription of the teaching interaction between participants G2 and G3, lines 97 – 102.

Results

Table 2

Task performance descriptives

		Generation					
		1		2		3	
		Similarity to model	Similarity to previous	Similarity to model	Similarity to previous	Similarity to model	Similarity to previous
		M(*SD*)	*M*(*SD*)	*M*(*SD*)	*M*(*SD*)	*M*(*SD*)	*M*(*SD*)
Condition	Interactive	3.82 (1.97)		4.04 (1.53)	4.39 (1.61)	2.92 (1.16)	4.06 (1.30)
	Emulation			3.03 (1.12)	3.57 (1.30)	2.97 (1.31)	4.27 (1.44)

Table 3

Memory utterance descriptives

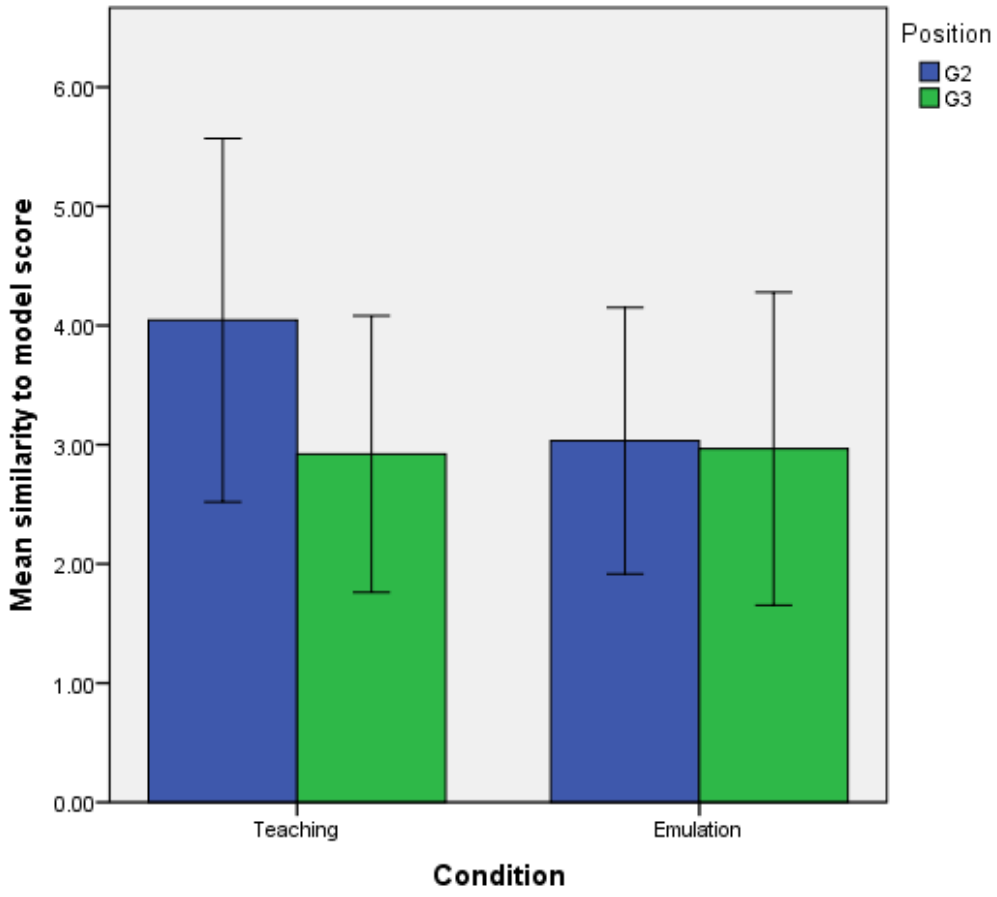
		M	*SD*
Memory utterances	Total density P1	.013	.008
	Total density P2	.023	.013
	Density vicarious P2	.003	.004
	Total % non-routine	57.740	25.058
Non-memory utterances	Total % non-routine	10.260	10.037

Effects of condition and generation on performance

To analyse H1, we used a two-way analysis of variance. There was a significant interaction between condition and generation for difference in similarity to model basket, $F(1,17) = 5.59$, $p = .03$ (Fig. 2), but not for difference in similarity to the previous basket, $F(1,17) = 3.653$, $p = .073$. The ANOVA yielded non-significant main effects of generation ($F(1,17) = .309$, $p = .59$) and condition ($F(1,17) = .019$, $p = .89$) on difference in similarity to model basket, and difference in similarity to previous basket (generation: $F(1,17) = .004$, $p = .95$; condition: $F(1,17) = .236$, $p = .63$). Therefore, teaching did not improve task performance over emulation alone, although second generation participants did perform slightly better in the teaching condition (Table 2, Fig. 2).

Figure 4

Mean similarity to model scores by condition and generation



Note. Error bars show means ± 1 SD.

Storytelling

Our results support H2, indicating that people tell stories during the transmission of skills: 97.14% (34 out of 35) teaching interactions contained MUs (Table 3), $t(34) = 9.43$, $p < .001$. Regarding H3, MUs referred more often to non-routine information than non-MUs, (53% vs. 12%), $t(33) = 9.54$, $p < .001$.

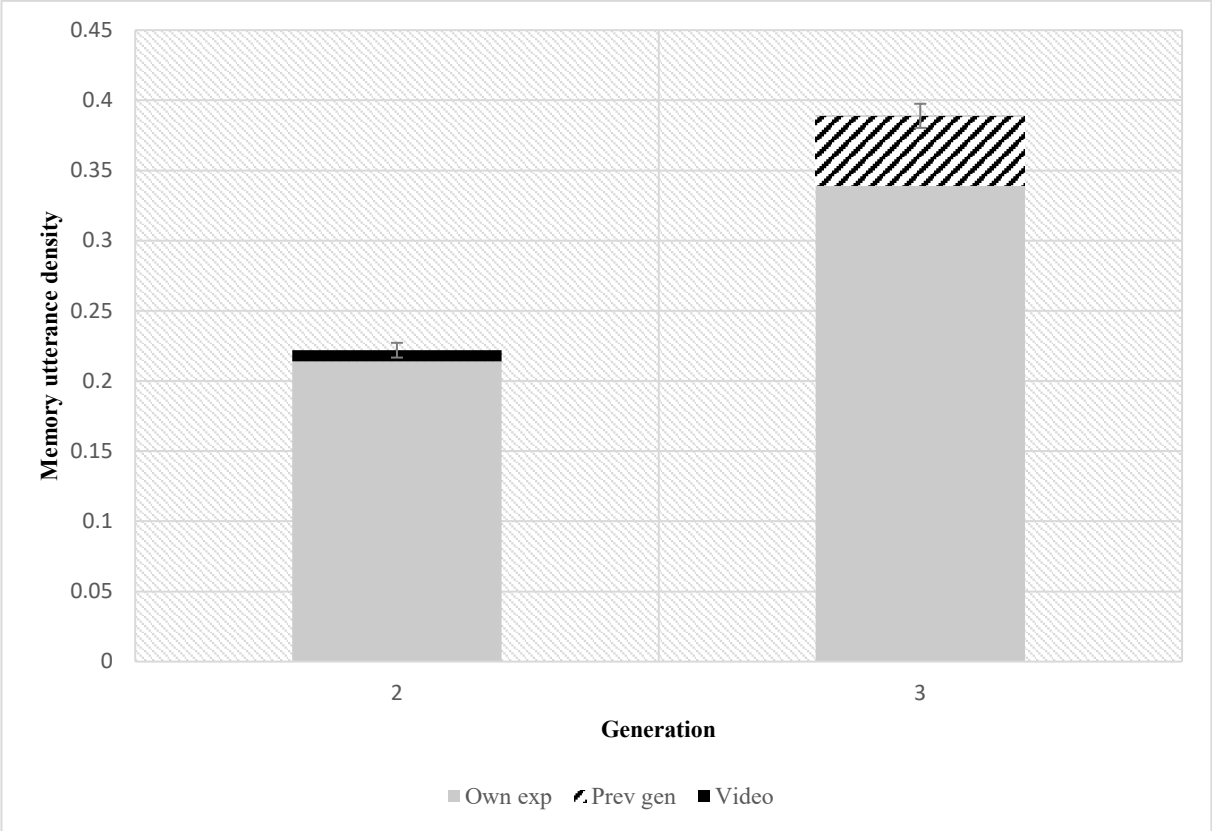
To test Research Question 1, we regressed the density of MUs that a participant was exposed to during teaching to the similarity of their basket to the original master basket (B = -.105, $t(34) = .614$, $p = .543$), and the previous basket (B = .047, $t(34) = .268$, $p = .79$). The amount of storytelling a participant was exposed to during teaching therefore did not significantly predict either measure of

similarity. (We did not predict the performance of G1 as they had no teaching interaction prior to task performance).

To answer Research Question 2, we ran paired samples t-tests comparing the density of MUs in the G1 and G2 (we did not include G3 as they did not fulfil the role of teacher). There is a significantly higher density of MUs in the transmission session P2P3 than transmission session P1P2, $t(16) = 2.47$, $p = .025$ (Fig.3). The density of routine MUs is also significantly higher, $t(16) = 3.19$, $p = .006$. The density of non-routine MUs did slightly increase, but not significantly, $t(16) = .765$, $p = .455$. Of the increase in MU density between P1P2 and P2P3 transmission sessions, 29% consisted of references to the experience of previous generation(s), i.e., vicarious memories.

Figure 5

Total memory utterance density in first and second interactional sessions



Discussion

In this study, we investigated teaching interactions during skill transmission of a complex manual skill. In terms of our primary goal, we observed that teaching did not provide benefits over and above emulation alone, although second-generation participants performed slightly better in the teaching condition. By the third generation this slight benefit had been lost. This provides only partial support of our hypothesis and could be the result of several factors. For example, the procedure that G1 participants underwent differed from that of G2 participants in several ways that may have made their teaching more effective. Firstly, they learnt from an instructional video rather than from interacting with a previous participant, and secondly they were exposed to the original master basket for reference during the task. This may suggest a special benefit of teaching when communicating first-hand rather than vicarious information. This could be related to the credibility of their testimony (Harris et al., 2018), as those who saw the original artefact may be perceived as more believable than those who did not. Cultural transmission does not depend on recall ability alone – people do not always copy everything they remember and may omit aspects from onwards transmission if they doubt their truthfulness (Lyons & Kashima, 2003). There are three distinct phases of cultural transmission: 'choose-to-receive', 'encode-and-retrieve', and 'choose-to-transmit' (Eriksson & Coultas, 2014). Perhaps there are biases in the first stage, making participants more receptive to first-hand experiences of original artefacts, at least in the context of a fidelity-based task. When generation is not taken into account however, teaching combined with emulation does not provide any significant benefit to transmission fidelity when compared to emulation alone. This supports the transmission chain literature suggesting that teaching is not always useful to cultural transmission (Zwirner & Thornton, 2015). This study therefore supports the widely supported view that emulation is a powerful method of cultural transmission that can be as effective as teaching (Whiten et al., 2009).

In terms of our secondary goal, we observed several aspects of storytelling as a teaching method. Our results support the idea that storytelling constitutes a teaching method as participants spontaneously told stories when in a teaching role. Not only this, but participants preferred to use storytelling to communicate non-routine occurrences than non-storytelling speech. This suggests a

tendency to use storytelling to transmit information about mistakes or unexpected events, and provides evidence for our claim that this may be the specific adaptive value of storytelling over and above language in general (Bietti et al., 2018). However, we found no evidence that the following generations actually benefitted from hearing about these mistakes, as there was no relationship between storytelling and task performance. This could be because we measured task performance as fidelity to an original artefact and not functional improvement or innovation. In contexts where there is a complex task with a more 'rugged landscape' of possible solutions to explore (Mason et al., 2008) storytelling may be more beneficial in the intergenerational prevention of mistakes. Furthermore, the effect of storytelling was likely difficult to detect due to its very low density, as teachers mostly used other types of talk such as instructional speech. This resembles a recent ethnographic review indicating storytelling accounts for just 8% of social learning in hunter-gatherers (Garfield et al., 2016). Despite this, the review indicates that storytelling is consistently associated with the transmission of cultural values and religious beliefs, suggesting important symbolic functions. A similar situation may be at hand here, with storytelling's sensemaking function being complimentary to but not the main form of teaching.

Our results indicate that storytelling also plays a role as a specialised way of incrementally storing and then passing on vicarious memories, however the presence of these vicarious memories did not enable more precise copying. This may be because the type of information being transmitted is not optimal to observe this. Other types of content have been associated with high accuracy transmission, for example, third-party social interactions are transmitted with higher fidelity than equivalent non-social information (Mesoudi et al., 2006). This study may have found a link between vicarious memories and fidelity if the information transmitted was itself social in nature rather than about a manual task.

This study shares limitations common to many lab-based cultural transmission experiments, both theoretical and practical. One of the most robust criticisms is that theoretical claims about real generational change spanning multiple lifetimes are operationalised by shrinking them to fit laboratory conditions. This has been referred to as 'miniaturisation', and is problematic in terms of ecological

validity (Miton & Charbonneau, 2018). In our study, participants were given an unlimited amount of time for teaching interactions, but in reality the experimental setting eventually demands a certain temporal constraint. Storytelling among other aspects of teaching may be easier to observe in contexts where there is more time to reflect on experience and lessons learned (Bietti et al., 2018). The chosen yoked chain design also only had three generations, which limits our ability to infer what processes may occur further along the line of transmission. One interesting avenue for further research may be to investigate whether there is an increase in the volume of vicarious memories along a greater number of generations. The choice to represent each generation with a single participant is another limitation, due to high levels of individual variation. Another manual task, knot tying, survived fewer generations of social transmission when there was only one participant generations compared to five participants per generation (Muthukrishna et al., 2014). Higher rates of fidelity have also been indicated when there are multiple cultural parents in the transmission of stories (Eriksson & Coultas, 2012). This horizontal, as opposed to vertical, aspect of social transmission may play an important role, especially in view of the collective reasoning facilitated by sensemaking through storytelling (Bietti et al., 2018). Multiple participants per generation would have better ecological validity, and better still would be the replacement method, which mimics continual population replacement of hunter-gatherer groups via births, deaths and migrations (Mesoudi & Whiten, 2004). Lastly, this study is no exception in its use of a WEIRD, non-representative sample (Henrich et al., 2010). There are few cultural evolution studies conducted with non-Western samples (Efferson et al., 2007; Eriksson et al., 2016; Kameda & Nakanishi, 2002).

To summarise, this study enabled detailed observation of the content and functions of teaching during cultural transmission, thus contributing to the growing body of literature on teaching, not just in humans but also in non-human primates (Whiten et al., 2009; Whiten & van de Waal, 2017), and a range of other species. Results support the argument that teaching does not necessarily benefit cultural transmission over emulation alone, as teaching did not consistently facilitate transmission fidelity. However, storytelling was identified as an aspect of teaching with important functions in cultural transmission. Its presence and intergenerational increase suggests it plays a role in the accumulation of

cultural information, particularly regarding non-routine events and vicarious memories. Human cultural transmission is often vulnerable to distortions rather than constituting high fidelity replication, yet these distortions may themselves have important functions.

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Study 5

Teaching, Storytelling and Innovation in Cultural Transmission

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Abstract

Teaching is widely understood to have an important role in cultural transmission. Despite this, cultural transmission experiments typically do not document or analyse what happens during teaching. We propose that storytelling is a language-based teaching method that facilitates cultural evolution and influences the coordination of learning strategies (i.e. choice to copy or to innovate). Here, we examine the content of teaching during skill transmission under two conditions: in the presence of the artefact (no-displacement condition) and in the absence of the artefact, (displacement condition). Participants built baskets to carry as much rice as possible from various materials before teaching the next participant in line. The efficacy of baskets increased over generations in both conditions, and higher-performing baskets were more frequently copied. Displacement affected strategy use by increasing innovation. Teachers' talk was equally distributed across three categories: instructional, experience-based and storytelling. Teachers used storytelling more to discuss non-routine events (those departing from expectations) than they did other types of teaching, especially without displacement. The sensemaking function of storytelling was supported as exposure to non-routine storytelling during teaching increased subsequent innovation. This study thus provides experimental evidence that storytelling is a useful teaching method in the context of manual skill transmission.

Introduction

Human culture involves the social transmission of information along generations. Teaching is a common way for information to be socially transmitted. Although it is widely argued that teaching has an important role in cultural transmission (Thornton & Raihani, 2008), it is unclear to what extent it is necessary and what its specific components and functions are. While observational learning (such as emulation or imitation) is found in many species, teaching is prominent only in humans and perhaps one of the keys to our particular trajectory of cultural evolution (Burdett et al., 2018; Kline, 2015). In light of this, it is surprising that transmission chain experiments typically do not document or analyse what actually happens during teaching sessions (Caldwell & Millen, 2009; Zwirner & Thornton, 2015). This means that there has thus far been no way of finding out how teaching takes place in this context, or what aspects of it may be beneficial.

The term 'teaching' refers to a range of social learning situations. Some of these, such as observational learning, exist in many species as they can occur by chance observation of an individual using an object (Kline, 2015). However, in other situations, no materials are present and so physical demonstration is not possible. Humans are unique in their ability to teach in these abstract situations (Zlatev et al., 2020). This requires *displacement*, the ability to communicate about things not spatially or temporally present (Hockett, 1960). Teaching under displacement requires the communication of concepts via language (van Schaik et al., 2019). Language is a key factor in cultural transmission (Pinker, 2010) enabling teaching in an almost infinite range of contexts and allowing the scope of human cultural evolution to surpass that of other species (Thornton & Raihani, 2008). The flexible nature of teaching via language means that teachers can influence learners' choices to copy or innovate (Burdett et al., 2018). Here we explore the prevalence and functions of *storytelling* as a language-based teaching method. Anthropological evidence indicates that storytelling is adaptive (Smith et al., 2017) and may have been used by ancestral humans to transmit survival-related information (Sugiyama, 2001). We investigate the content of teaching and the role of storytelling during skill transmission in conditions of displacement and non-displacement and the effects that it has on the balance between precise copying and innovation in cultural evolution.

Teaching in cultural transmission

Teaching is unique to humans and underpins human culture (Galef, 1992) and is a form of cooperative behaviour that has evolved to promote learning in others (Caro & Hauser, 1992). This includes a range of cross-species behaviours differing in their level of intentionality: less intentional forms of teaching are those that can be picked up from chance observation, by teachers merely allowing the learner to observe them using an object. *Direct active teaching* (Kline, 2015), on the contrary, goes beyond the concrete level to a conceptual one, with teachers communicating concepts and explaining the relationships between them (Gärdenfors et al., 2017), mapping onto sequential instructions, or experience-based advice. These forms of teaching are only observed in humans (Kline, 2015).

The role of teaching in the context of cultural transmission has been experimentally investigated using the transmission chain method. These experiments have examined how cultural products (i.e. information or artefacts) are modified when passed through a succession of individuals, often focusing on cumulative cultural evolution - whereby behaviours or artefacts tend to improve over generations (Caldwell et al., 2017). Manipulating the amount of interaction between participants allows investigating the social learning mechanisms involved in cultural transmission. Social interaction can take the form of teaching, and conditions allowing interaction to occur between generations are named 'Teaching conditions' (Caldwell et al., 2017; Zwirner & Thornton, 2015). These studies enable comparisons of different forms of information transmission. For example, teaching (i.e., when interaction about the task occurs between generations) is compared to imitation (watching the previous generation perform the task), emulation (reverse-engineering by examining the previous generation's completed product) or asocial repetition (one participant performs repeated trials of the task). This research has indicated beneficial effects of teaching in cultural transmission (Lombao et al., 2017; Morgan et al., 2015).

Stick-or-switch: Roles of teaching

The dual engines of cumulative cultural evolution are high-fidelity information transfer (precise copying) and innovation (Legare & Nielsen, 2015). Cultural evolution research strives to understand the mechanism behind the decision to stick with a current solution (copy) or switch to a different one (innovate) (Rogers & Fay, 2016). Both sticking and switching are inherently social phenomena (Muthukrishna & Henrich, 2016). They are also interdependent, as both strategies must be employed at some point to enable culture to accrue; precise copying is required to prevent loss of advancements (Tomasello, 1999), but without innovation there would be cultural stasis. This is especially important in technological domains such as the development of functional tools (Acerbi et al., 2016).

Teaching tends to be associated with precise copying (Lewis & Laland, 2012), however it also impacts innovation. The social interaction inherent in teaching may facilitate precise copying over and above other forms of information transmission. We have seen how teaching increases the complexity of information that can be copied by allowing for the communication of concepts. When passing on narrative information, i.e., stories, face-to-face interaction slows the rate of information loss, compared to listening to an audio-recording of the previous generation (Tan & Fay, 2011). Feedback and active participation in the conversation facilitate this. Collaborative accounts of dialogue have shown the importance of feedback to ensure that what is said is mutually agreed, or grounded (Clark, 1996), as active interlocutors comprehend information better than passive overhearers (Schober & Clark, 1989). In experiments with reproduction goals, interactivity slows the rate of information loss over generations for knot-tying (Caldwell et al., 2017) and stone-knapping (Lombao et al., 2017; Morgan et al., 2015), but not for a collaborative cooking task (Bietti et al., 2019). In studies with a performance goal, i.e., to functionally improve rather than copy the predecessor's artefact, teaching interactions support cumulative improvement (Caldwell & Millen, 2009; Zwirner & Thornton, 2015). Thus, teaching not only facilitates precise copying, but also helps balancing it with innovation.

Several aspects of teaching promote innovation in cumulative cultural evolution. Firstly, the flexible and multifaceted nature of teaching in humans means that we can signal whether or not

information can be modified (Burdett et al., 2018). In cumulative cultural evolution, adaptive traits are spread while maladaptive ones are filtered out (Enquist & Ghirlanda, 2007). Teaching provides opportunities to socially appraise solutions and decide whether to spread or filter certain variants, thus enabling coordination of strategies. Content bias (perceived effectiveness of a solution) is instrumental in the decision to transmit one's own solution over someone else's (Tamariz et al., 2014). Access to socially transmitted information during teaching enables better evaluation of one's artefact compared to others, and thus a better-informed decision of which variants to adopt. This could enable group-level coordination and help maintain the optimal balance between innovation and copying.

Displacement

Displacement is the ability to communicate about things that are not spatially or temporally present (Hockett, 1960). It is a universal in human language but rare in non-humans (Lameira & Call, 2018). Displacement may have been a critical evolutionary pressure leading to the emergence and evolution of language (Gärdenfors, 2010). For early humans, the periodic spatial separation of mutually dependent group members created pressure to communicate about things not in the here-and-now (Kendon, 1991), for example, the location of a distant food source (Bickerton, 2009). Teaching under displacement is intentional because it cannot occur through chance observation of the teacher using an artefact. It requires communication about concepts, and explanations of relationships between them (Gärdenfors & Högberg, 2017). There are two forms of enactment in teaching that may be used to accompany verbal communication: demonstration (with the artefact) and pantomime (without the artefact,(Gärdenfors & Högberg, 2017)). The latter is especially supported by multimodality, e.g., gesture, posture and gaze used simultaneously with language. Co-speech gestures have a positive impact on teaching outcomes (Macedonia, 2019). Humans are thus skilled communicators and teachers under displacement as a result of their evolutionary past.

People prefer copying to inventing, especially when they are uncertain (Caldwell & Millen, 2010) or when they lack confidence (Rogers & Fay, 2016; Tamariz et al., 2014). For most everyday problems, we seek to copy solutions that have been transmitted socially (Whiten et al., 2009). This makes sense from an evolutionary perspective, as most species with long life expectancies prefer

social information if available (Forss et al., 2017), avoiding the uncertainty of novelty unless necessary (van Schaik et al., 2019). This copying tendency may be especially strong following exposure to a visual referent. Fixation, a term introduced by Gestalt psychologists (Duncker & Lees, 1945)refers to the default tendency to rely too heavily on familiar or easily accessible information (George & Wiley, 2020). We are constrained by previous examples, particularly when they are visual. When asked to interpret abstract inkblots, we adopt other people's interpretations if available (Rose & Felton, 1955). Even when instructed to be as "wild" as possible, people still tend to preserve the properties of known examples (Goldenberg et al., 2013; Smith et al., 1993). In the context of cultural transmission, 'tweaking', that is, the modest refinement of an existing solution, is a popular and successful strategy (Derex et al., 2019). Tweaks are associated with smaller changes in payoff, while large innovative leaps are either spectacular successes or failures (Miu et al., 2018). People are thus most likely to make small incremental improvements to the best available solution rather than drastic changes, especially when exposed to a visual example. Taken together, then, displacing artefacts may encourage learners to make larger innovative leaps. Lack of a visual referent during teaching may stimulate learners to produce creative and divergent solutions, fostering innovation.

Storytelling: Accuracy versus Sensemaking

Storytelling is a conversational activity focused on the production of narrative discourse (Mandelbaum, 2013). Narrators typically recount a sequence of past events, including protagonist's actions, and how they contribute to changing an initial situation (Bruner, 1990; Labov & Waletzky, 1967). Audience reactions are an important part of the storytelling process, as they can be used to support or even guide narration (Bavelas et al., 2000). Anthropological evidence indicates that storytelling is adaptive (Smith et al., 2017) and may have been used by ancestral humans to transmit survival-related information (Sugiyama, 2001). Telling stories about events can be less costly in terms of resources than experiencing them first hand. For example, knowledge about animals is important in hunter-gatherer societies. One way to gain this knowledge is through hours spent hunting, during which encounters with animals are rare and trial-and-error learning is costly (Sugiyama, 2001). An easier way to gain this knowledge is by listening to other hunter's animal encounters related as stories,

as narrative processing requires no physical exertion while enabling the compression of time (MacDonald, 2007; Sugiyama, 2001). Today, it remains one of the commonest ways of sharing personal experiences (Currie & Sterelny, 2017), and is an activity we engage in spontaneously, effortlessly and pleasurably (Mellmann, 2012).

Storytelling is thus also a teaching method that can enable collaborative coordination of cultural learning strategies. Storytelling both promotes and inhibits accurate copying of information. On the one hand, accurate copying is facilitated by storytelling as it is an engaging and memorable manner of transferring information (Sperber, 1985). Storytelling is vivid, often featuring direct reported speech animated by gaze (Holt, 1996; Mandelbaum, 2013), and intensified by facial, gestural or postural mimicry (Sidnell, 2006). Following the step-by-step actions depicted from a first-person perspective allows the listener to "relive" the experience and learn from it vicariously. Narrative oral traditions are recalled accurately over long timespans (Rubin & Umanath, 2015) (Scalise Sugiyama, 2017; Wiessner, 2014). On the other hand, storytelling also has a transformative component. Narrators often warp information by reducing it to gist (Bartlett, 1932), or embellish certain aspects, such as stereotype-consistent (Lyons & Kashima, 2006), social (Dunbar, 1998), emotional (Brady et al., 2020) or amusing information (Stubbersfield et al., 2017).

However, even if storytelling inhibits precise copying, it can promote innovation. This is because storytelling often arises from people trying to make sense of events. Experiencing mistakes, or productive failure, has educational value (Kapur, 2016). Members of work communities tell stories as part of their everyday knowledge integration (Bangerter et al., 2011), indicating storytelling is specialised for communicating about non-routine, uncertain or novel situations (Bietti et al., 2018). Sensemaking is the process by which people give meaning to experience (Weick, 1995). The human cognitive system usually arranges our experiences into knowledge structures, such as schemas, scripts or frames (Goffman, 1974; Mandler, 1984), that structure perceptual meaning top-down. Mismatches between expectations and an event produce negative arousal (Proulx et al., 2012) which in turn motivates re-conceptualisation of the event. The surprise of incongruence thus enables the generation of inferences (Sperber & Wilson, 1986) as people place events into a coherent sequence, establishing

causal links and updating knowledge structures. Sensemaking is a key component of how people learn through storytelling in everyday contexts. Refinement and recombination of existing variants are sources of innovation (Mesoudi et al., 2013). Sensemaking through storytelling allows individuals to simulate alternative solutions to a problem through "cognitive play" (Boyd, 2009), resulting in more effective innovations.

Displacement may be the context most conducive to storytelling as a teaching method. Unlike the present moment, which can be shared through copresence, in situations of displacement the past and future must be constructed through mental and linguistic representations (Hockett, 1960). Storytelling is a pervasive way to achieve this (Bruner, 1991) Discussing things that are spatially or temporally absent also unavoidably introduces memory constraints on the part of the speaker (Barrouillet & Camos, 2012). Constraints also exist on the part of the listener, who has a limited sensory memory span for speech signals that are exceedingly short-lived– on average lasting 50 – 100 milliseconds (Isbilen & Christiansen, 2020). This memory bottleneck (Christiansen & Chater, 2016) is a constraining force on cultural evolution that reduces variation (Ferdinand et al., 2013; Tamariz & Kirby, 2015). Memory biases make storytelling an inherently constructive activity (Bietti et al., 2018). Displacement of the artefact during teaching may therefore stimulate use of storytelling as a teaching method.

This study

Existing lab-based transmission chain studies have only allowed for very restricted forms of teaching. For example, participants learn from artefacts without any interaction with the participants who produced them (Derex et al., 2019; Derex et al., 2013; Fay et al., 2019), or observe their actions without being able to talk to them (Wasielewski, 2014). Studies with these observational conditions generally do not specify whether or not the participant is engaged in intentional teaching, such as slowing down their mechanical actions to perform demonstrations, making it difficult to draw conclusions about teaching. When face-to-face, interactive teaching is allowed, it commonly occurs while the teacher (Caldwell & Millen, 2009) and / or the learner (Morgan et al., 2015; Osiurak et al., 2020; Zwirner & Thornton, 2015) is simultaneously engaged in the task, and any analysis focuses on

task performance rather than what is said (Caldwell & Millen, 2009; Zwirner & Thornton, 2015). As such, the presence of component materials stimulates demonstration or monitoring by step-by-step instructional feedback. Time pressure also prevents reflection on broader strategies.

The study thus has three overall goals. First, to investigate teaching content during skill transmission and possible effects on the balance between precise copying and innovation. Teaching is separated from task performance and time constraints are removed to facilitate this. Second, we investigate functions of storytelling as a teaching method. We expect that absence of the referent will increase the use of storytelling during our interactional sessions. Although we expect storytelling to be rare based on prior research findings (Tilston et al., in preparation), we predict it will reflect non-routine events, such as poor performance or mistakes, and stimulate innovation. Third, we investigate the mechanisms balancing innovation and fidelity in cultural transmission.

For this study, chains of adult participants completed a construction task: to make a basket to carry as much rice as possible from various materials (Zwirner & Thornton, 2015). The basket designs were transferred between multiple generations in two conditions: *no-displacement* where participants taught the next-in-line with the basket they had just created to hand, and *displacement* where teaching occurred with the basket absent. Building on existing experimental work on storytelling in teaching during cultural transmission (Bietti et al., 2019), we provide additional analyses of teaching.

The study tests concrete hypotheses concerning the rice-carrying performance of baskets as a function of our experimental manipulations (inter-generational transmission and displacement), and how these effects interact with the content of teaching and storytelling. Our first hypothesis is that the artefacts will become refined and thus more functional over generations as a result of cultural transmission (Hypothesis 1). This motivates the following prediction: The mass of rice transported will increase over generations (Hypothesis 1, prediction 1, H1p1). Our second hypothesis is that the teaching condition (displacement/no-displacement) together with the performance of the last generation predicts the choice of strategy in the current generation (Hypothesis 2). This motivates the following predictions: There will be more innovation in the displacement condition than in the no-displacement condition (Hypothesis 2, prediction 1, H2p1), There will be more low-risk, incremental

improvement in the no-displacement condition than in the displacement condition (Hypothesis 2, prediction 2, H2p2) and participants will innovate more when predecessors produce poor-performing baskets (Hypothesis 2, prediction 3, H2p3). Our third hypothesis is that the teaching condition predicts which strategy will be successful (Hypothesis 3). This motivates the following predictions: Innovation will be a more successful strategy in the displacement condition than in the no-displacement condition (Hypothesis 3, prediction 1, H3p1), and low-risk, incremental improvement will be a more successful strategy in the no-displacement condition than in the displacement condition (Hypothesis 3, prediction 2, H3p2). Our fourth and final hypothesis is that storytelling is a specialised teaching method that differs according to teaching context (Hypothesis 4). This motivates the following predictions: There will be more storytelling in the displacement condition than in the no-displacement condition (Hypothesis 4, prediction 1, H4p1), storytelling will increase task performance (Hypothesis 4, prediction 2, H4p2), storytelling concerns more non-routine events than does non-storytelling talk (Hypothesis 4, prediction 3, H4p3) and non-routine storytelling during teaching increases the likelihood that a learner will subsequently choose to innovate (Hypothesis 4, prediction 4, H4p4).

The hypothesis testing section of this paper will be followed by an exploratory analysis section investigating the content of teaching and how it is affected by displacement. This exploratory analysis will be guided by the following two research questions (RQs): What is the content of teaching interactions? (Research Question 1, RQ1) and how is teaching content affected by displacement? (Research Question 2, RQ2).

Methods

Participants

There were 168 French-speaking participants recruited at *[redacted for peer review]* (88 female, $M = 24.2$ years of age, $SD = 4.53$). Participants received 8 CHF for taking part in the study plus one individual incentive (+2 CHF for every additional 500g of rice transported relative to their predecessor, or to a pilot average if first in the chain) and one group incentive (+20 CHF for the four best groups). Participants were randomly assigned to conditions (displacement vs. no-displacement)

and chains (1 – 28, see Fig.1), however assignment to generation (1 - 6) was non-random as based on availability. During debriefing, participants completed the group cohesion scale (Treadwell et al., 2001) and rated how well they knew others in their chain. Over half (56%) of participants knew at least one other person in their chain, while the rest did not. This did not affect group cohesion ($M_{\text{"Know" group}} = 4.15$, $M_{\text{"Do not know" group}} = 4.25$, $t(166) = 0.85$, $p = 0.40$).

Task

The task involved building a basket in 5 minutes to carry as much rice as possible (Zwirner & Thornton, 2015), measuring performance as the amount of rice in grams successfully transported by each basket. This task mimics challenges faced by early humans and is unlikely to relate to participants' previous experience, while helping build the case for mobile containers as tools in cognitive evolution (Fisher, 1979; Langley & Suddendorf, 2020). Each participant was given an identical set of materials (see Table 1) and a timer.

Table 1
List of task materials

Quantity	Material and dimensions
2	String (40cm)
1	Fabric gauze (25 x 27cm)
1	Newspaper sheet
1	Bubble wrap (40 x 10 cm)
1	Wooden stick (42 x 1.5 x 1.5 cm)
2	Bottle tops
3	Drawing pins
3	Rubber bands
2	Drinking straws (21 cm)
2	Skewers (25 cm)
1	Paper napkin
2	Strips of adhesive tape (42 cm)
1	Stapler with stapes

Design

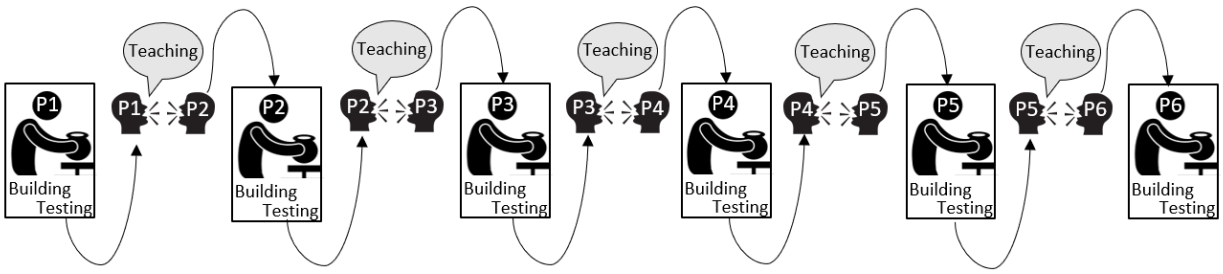
A vertical transmission chain method was adopted, with two conditions: teaching with the basket to hand (*no-displacement*) or removed (*displacement*). Teaching was separated from task performance and there was no time constraint. Building and teaching sessions were video recorded.

Procedure

Participants completed consent forms. The experiment had three phases: building, testing and teaching. During building, participants completed the task. During testing, participants loaded their baskets with as much rice as they dared from the 8kg container, carried it 5m and then poured the rice into a bowl on digital scales. Participants were told the mass of rice they had transported, also noted by the experimenter. During teaching, participants were told to talk with the next participant to help them build their basket. Task materials were replenished and the basket hidden in the storage area if in the *displacement* condition. The next participant entered the room and the two were allowed to talk for an unlimited amount of time (M = 3.58 minutes, SD = 2.21 minutes). Once finished, the initial participant left the room for debriefing, their basket was hidden if in the *no-displacement* condition, and the incoming participant now completed the building, testing and teaching phases as above. This was repeated for the following 5 participants. The last participants in each chain were debriefed and allowed to leave following the testing phase.

Figure 1

One transmission chain



Note. Reads left to right, each participant in the chain noted as "P" followed by a number representing their generational position in that chain (e.g. P1 = Participant 1).

Measures

Task performance

For H1p1 (Mass of rice transported will increase over generations) and H4p2 (Storytelling will increase task performance), task performance was measured as the total weight in grams of rice carried

by each basket for two trials. The first by participants during the testing phase of the experiment, and the second by experimenters aiming to fill each basket with the absolute maximum quantity of rice. The purpose of this second trial was to reduce individual variance in the quantity of rice with which participants dared to charge their baskets.(Zwirner & Thornton, 2015)

Teaching content

Transcripts were created for 140 teaching sessions totalling approximately 8 hours of discussion. All talk was segmented into units of analysis: utterances, corresponding approximately to a sentence in written language. Each utterance was coded for the presence of one of four categories of teaching content (see Table 2). To test H4p1 (There will be more storytelling in the displacement condition than in the no-displacement condition), storytelling was operationalised in the form of *memory utterances*, MUs, defined as past-tense utterances produced by the outgoing partner that are thematically related to the task (Bangerter, 2000b), or *non-storytelling*, non-MU, any present, future or conditional tense utterance relating to the task. Interrater agreement between two coders *[redacted for peer review]* of a randomized subsample (20%) of the dataset revealed almost perfect agreement for the distinction between MUs and non-MUs, $\kappa = .985$. To control for amount of talk, utterance density was calculated by dividing each participant's raw utterance count by word count. Non-MUs and MUs were produced by the outgoing partner (teacher) while Learner responses were produced by the incoming partner (learner).

Routineness was measured for H4p3 (Storytelling concerns more non-routine events than does non-storytelling talk) by coding both MUs and non-MUs as either routine (mundane, not describing unexpected events) or non-routine (describing events departing from expectations in either a positive or negative or problematic way (Bietti et al., 2019)). Interrater agreement between two coders (*[redacted for peer review]* and a naïve coder) for the full dataset revealed sufficient agreement for routineness, $\kappa = .635$.

Table 2

Categories of teaching content used to code all transcriptions

Category of teaching content	Examples
1. Instructional (Non-memory utterances, *Non-MUs*) Utterances produced by the teacher including: - Directive statements - Descriptions of the rules - Description of task materials	- "You have to create a basket to hold rice" - "You have five minutes to build it" - "There's a stapler and two pieces of string"
2. Experienced-based (Non-memory utterances, *Non-MUs*) Utterances produced by the teacher including: - Advice - Hindsight - Encouragement	- "It's better to use the strings than the Sellotape" - "I shouldn't have taken so long on the first part" - "Maybe you've got some better ideas"
3. Storytelling (Memory utterances, *MUs*) Any past-tense utterance relating to the task made by the teacher	- "I reinforced the base with staples" - "The handle snapped off while I was filling the rice"
4. Learner responses Utterances produced by the learner - Questions / clarifications - Suggestions - Backchannels	- "How did the person before you do it?" - "I think it would be better to use the gauze" - "I see"

Innovation

To test H2p1 (There will be more innovation in the displacement condition than in the no-displacement condition) and H4p4 (Non-routine storytelling during teaching increases the likelihood that a learner will subsequently choose to innovate), each basket was classified in one of 8 gestalts (its main structural shape, see Fig.2.) by 3 independent raters, ICC = .896. Innovation was coded as the decision to change gestalt (1) instead of exploiting that of the predecessor (0). Each chain could feature 0 – 5 changes (Fig. 3.). In cases where baskets were 'hybrids' combining features from two different gestalts, the most commonly coded gestalt between the three independent raters was selected.

Figure 2

Coding criteria for eight basket gestalt categories

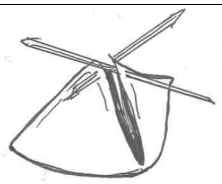
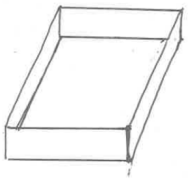
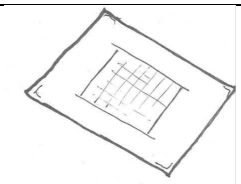
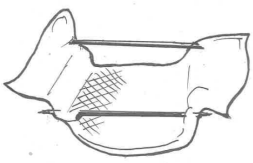
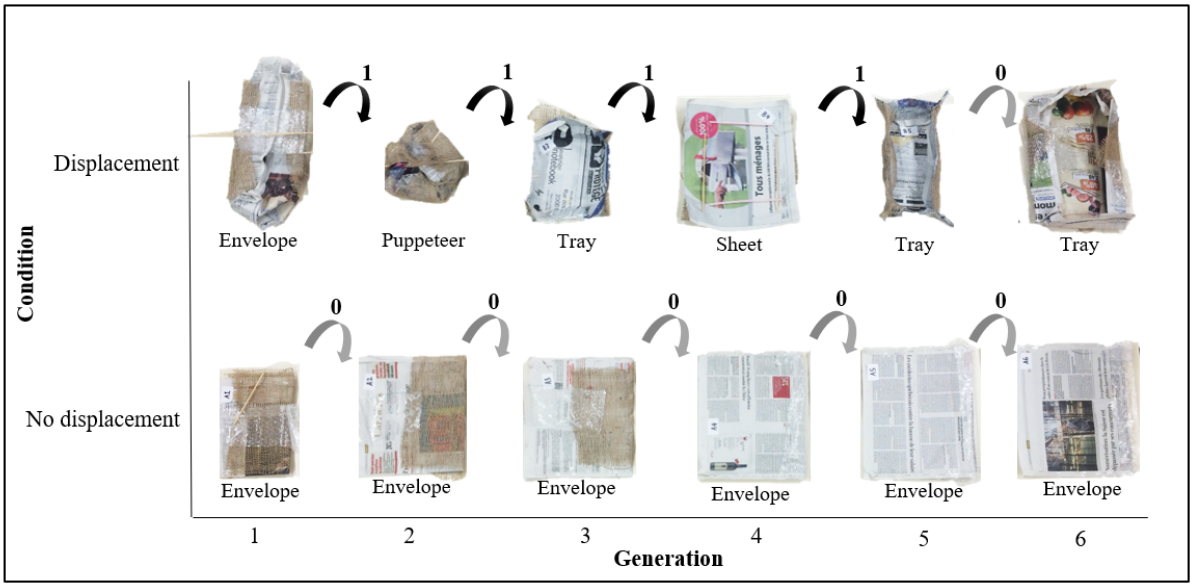
Gestalt	Examples	Definition
Envelope		Newspaper folded in half, in a flat, rectangular shape. Can also be in a canoe shape with lower, more rounded sides
Puppeteer		Four corners folded upwards and each opposing corner brought together with a skewer.
Tray		Low, rectangular shape with pinched sides. A tray always has four corners, folded either inwards or outwards. Corners may be very low, but must be present.
Sheet		A flat sheet with no sides, carried by picking up the edges. It may be reinforced. Some edges may be loosely connected by tape, string or straw.
Sloth		Basket suspended from the large stick, at one, two or several points
Cone		Cornet shape with one end a closed point and the other end open
Stretcher		Carried by two parallel sticks. It often has open sides, which distinguish it from the envelope.
Other		Any basket that doesn't fit into the above categories

Figure 3

Two example chains of baskets from different conditions and their associated gestalts



Note. The chain pictured in the top row had an overall innovation score of 4, while the chain pictured on the bottom row had an overall innovation score of 0.

Low-risk improvement

To test H2p2 (There will be more low-risk, incremental improvement in the no-displacement condition than in the displacement condition), low-risk improvement was measured as baskets that had the same gestalt shape as their predecessors (i.e. innovation = 0) but that also carried more rice than their predecessor. This is a binary variable, 1 meaning a basket has met the criteria, and 0 meaning it has not.

Analysis

The full dataset consisted of variables relating to the features of 168 baskets and 140 transcribed conversations. There was one missing data point: the weight of rice transported by one basket that broke during the testing phase, which was included as a missing value. Data were fitted with linear mixed-effects models (lmer) or generalised linear mixed models (glmer). All statistical analyses were conducted in R using packages lmerTest (Kuznetsova et al., 2017) and tidyverse

(Wickham et al., 2019) for RStudio (2020). For each analysis, the fixed effects combination accounting for most variance was identified using model comparisons relying on AIC. The position of participants within their group (1-6) is referred to as the generation and the serial transmission between 6 participants is referred to as a chain. To account for between-chain variance, the chain identity was included in all models as random intercept. All models also contained condition as a fixed effect, see Table 3. The data associated with this research are available at [link].

Table 3

Models created to test research questions and hypotheses

	Outcome variable	Fixed effect(s)	Random effect
H1p1	Weight of rice ~	condition + generation	+ (1|chain)
H2p1*	Innovation ~	condition	+ (1|chain)
H2p2*	Low risk improvement ~	condition	+ (1|chain)
H2p3*	Innovation ~	condition + previous basket's weight of rice	+ (1|chain)
H3p1+2*	Cases where strategy effective ~	condition	+ (1|chain)
H4p1	Proportion memory utterances (mu)~	condition	+ (1|chain)
H4p2	Weight of rice ~	condition x proportion mu	+ (1|chain)
H4p3	Proportion non-routine ~	condition x storytelling	+ (1|chain)
H4p4*	Innovation ~	condition + proportion of non-routine storytelling	+ (1|chain)
RQ1	Utterances ~	condition + generation	+ (1|chain)
RQ2	Proportion utterances per category ~	condition	+ (1|chain)

Note. Hypotheses marked with * were tested with generalised linear mixed models as they have binary outcome variables, otherwise linear mixed models were used.

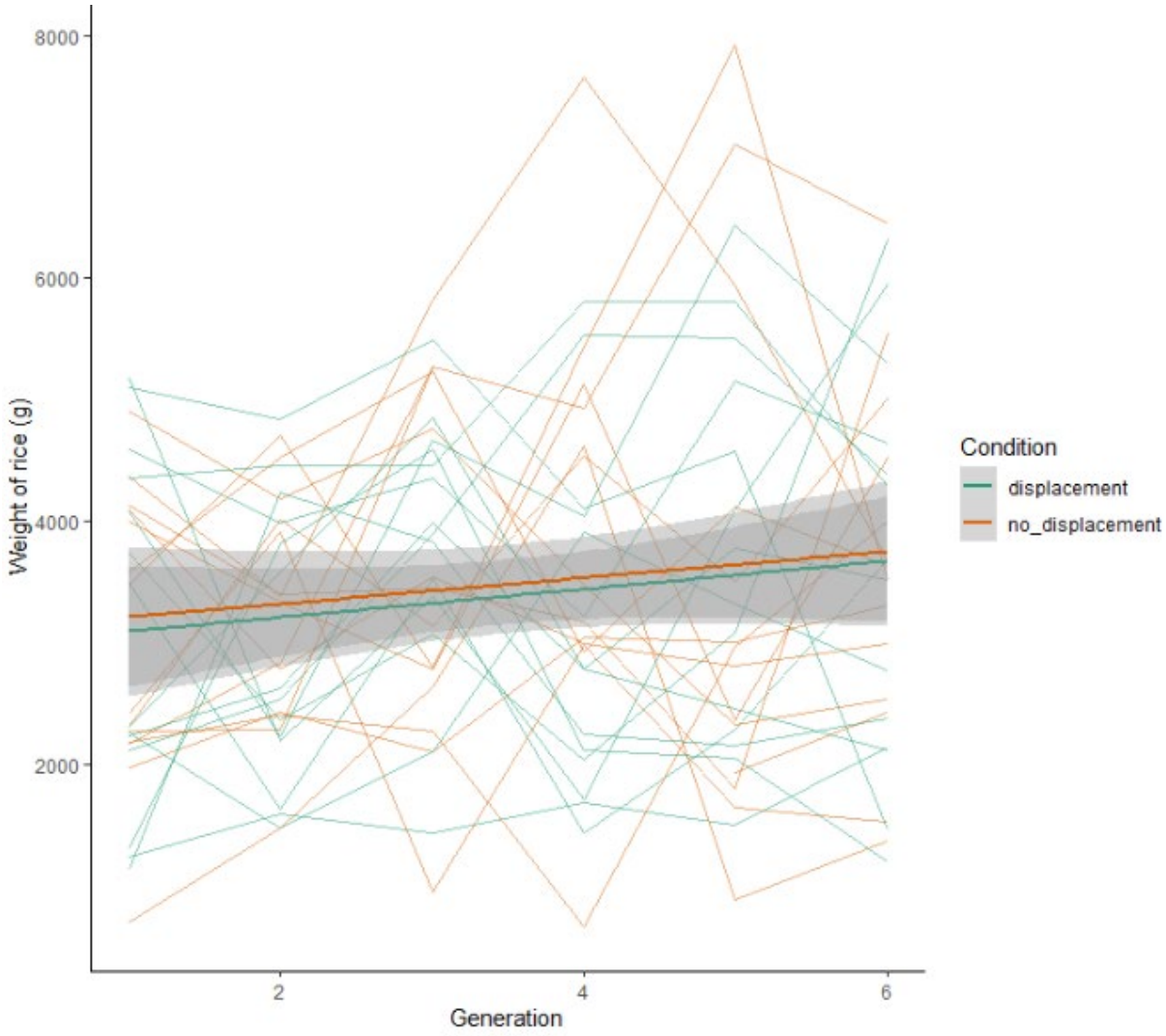
Results

Weight of rice carried

Weight of rice carried significantly increased over generations (H1p1, supported) ($\beta = 117.21$, $SE = 54.26$, $t = 2.16$, $p = 0.03$), but this did not differ between conditions ($\beta = 74.99$, $SE = 351.72$, $t = 0.21$, $p = 0.83$), see Fig. 4.

Figure 4

Weight of rice (g) carried by each basket by generation (1-6) and condition



Note. Weight of rice (g) refers to sum of rice transported by each basket during two transportation trials (one by the participant during the testing phase of the experiment, and one by the experimenters).

Displacement and strategy use

There was more innovation in the displacement condition (M = 0.73, SD = 0.24) than in the no-displacement condition (M = 0.36, SD = 0.24), (β = 1.68, SE = 0.45, z = 3.76, p < .001), (H2p1, supported). There was more low-risk improvement in the no-displacement condition (M = 0.39, SD = 0.49) than in the displacement condition (M = 0.16, SD = 0.37), (β = 1.21, SE = 0.41, z = 2.96, p =

.003), (H2p2, supported). The weight of rice carried by the previous participant's basket predicted propensity to innovate (H2p3, supported) ($\beta < .001$, $SE < .001$, $z = -2.57$, $p = 0.01$), as participants were more likely to copy the shape of high-performing baskets.

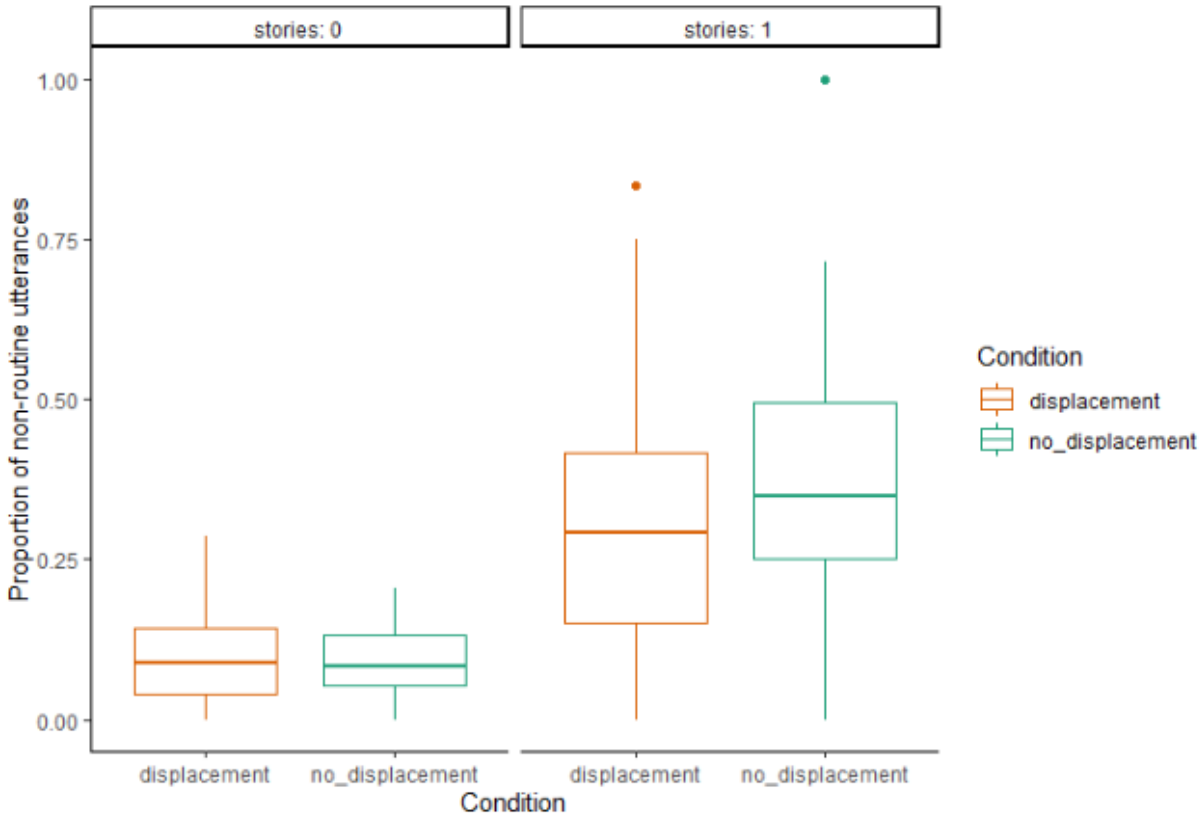
Innovating in the displacement condition was more likely to lead to increased performance (more rice carried) ($\beta = -0.98$, $SE = 0.40$, $z = -2.45$, $p = 0.01$), (H3p1, supported). Copying the previous participant's design was more likely to lead to an increase in performance in the no-displacement condition ($\beta = 1.21$, $SE = 0.41$, $z = 2.96$, $p = 0.003$) (H3p2, supported).

Storytelling

There was no more storytelling in the displacement than in the no-displacement condition ($\beta = 0.01$, $SE = 0.03$, $t = 0.28$, $p = 0.78$), (H4p1, not supported), see Fig 6. Exposure to storytelling during teaching did not increase subsequent task performance (H4p2, not supported): $\beta = 488.27$, $SE = 911.02$, $t = -0.54$, $p = 0.59$). However, storytelling content was proportionally more non-routine than non-storytelling content (H4p3, supported) ($\beta = 1.33$, $SE = 0.08$, $z = 16.42$, $p < .001$), and this significantly interacted with displacement ($\beta = 0.46$, $SE = 0.12$, $z = 3.85$, $p < .001$), with more non-routine utterances in the displacement condition, see Fig. 5. The proportion of non-routine storytelling increased innovation (H4p4, supported) ($\beta = 2.71$, $SE = 1.11$, $z = 2.43$, $p = 0.01$). Non-routine utterances in other forms of teaching (i.e. also including non-storytelling) had no effect on innovation ($\beta = 2.61$, $SE = 2.44$, $z = 1.11$, $p = 0.29$).

Figure 5

Proportion of non-routine utterances by condition and type of talk



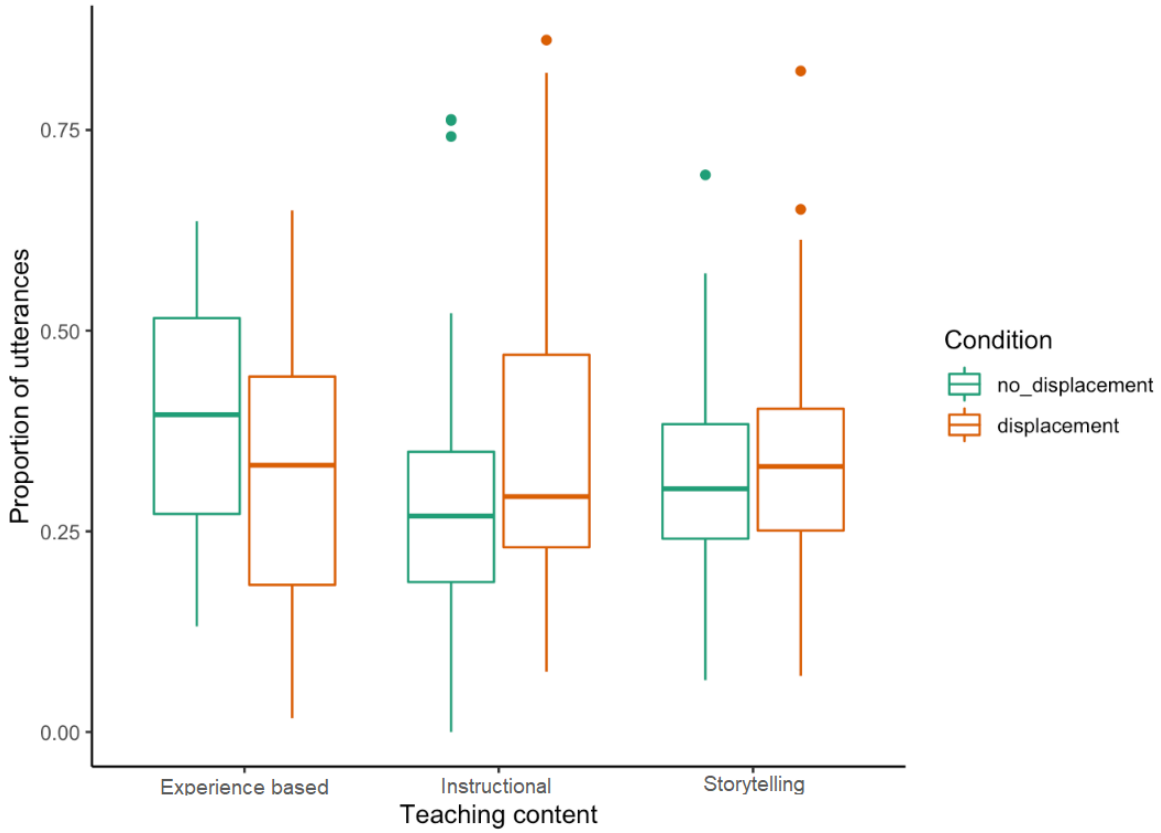
Note. Faceted by storytelling (stories: 1) or non-storytelling (stories: 0).

Explorative analysis of teaching content (RQ1 & RQ2)

Teaching interactions consisted of utterances spoken by the teacher (59%, $M = 64.37$, $SD = 36.21$) and utterances spoken by the learner (41%, $M = 39.52$, $SD = 30.74$). Subsequent analyses focus only on utterances produced by the teacher. The number of teaching utterances was not predicted by either condition ($\beta = -13.98$, $SE = 8.97$, $z = -1.56$, $p = 0.13$) or generation ($\beta = -2.61$, $SE = 1.74$, $t = -1.50$, $p = 0.14$). The three teaching content categories were distributed in approximately equal proportions: instructional ($M = 0.32$, $SD = 0.17$), experience-based ($M = 0.36$, $SD = 0.15$) and storytelling ($M = 0.32$, $SD = 0.13$), see Fig 6. In terms of teaching content, there is a trend that experience–based teaching is lower in the displacement condition (RQ2) ($\beta = 0.07$, $SE = 0.04$, $t = 1.80$, $p = 0.08$), but neither instructional teaching ($\beta = -0.06$, $SE = 0.05$, $t = -1.37$, $p = 0.18$), nor storytelling ($\beta = -0.01$, $SE = 0.03$, $t = -0.28$, $p = 0.78$), is affected by displacement, see Fig 6.

Figure 6

Proportion of utterances by condition and teaching content category



Note. Proportion of utterances refers only to those utterances spoken by the teacher, and is calculated by dividing number of utterances for that category by the total number of utterances for all categories

Discussion

In this study, we investigated the impact of displacement during teaching on the cultural transmission of a complex manual skill. We observed insights in all key areas of the study: teaching content in cultural transmission, the role of displacement, storytelling as a teaching method and mechanisms balancing innovation and fidelity. This study is the first to experimentally investigate storytelling as a teaching method in the context of cumulative improvement of a manual skill.

Our findings contribute to the literature by examining the content of teaching in the context of cultural transmission in an unprecedented level of detail. Two notable modifications were made to the conventional way that teaching is observed in microsociety experiments: teaching was separated from task performance and the time constraint was removed. When teaching occurs simultaneously to task

performance, the teacher observes the learner, giving them step-by-step advice and feedback on their task performance as it happens, although teachers are not permitted to construct the object themselves (Caldwell & Millen, 2009; Caldwell et al., 2017; Osiurak et al., 2020; Zwirner & Thornton, 2015). This corresponds to teaching by evaluative feedback (Kline, 2015). Teaching content is likely to be continually affected by the changing affordances of the component materials as learners act upon them. The urgency of time constraints also causes teachers to focus on immediate aspects of the task, rather than reflect on broader strategies. Moreover, participants may be more focused on creating a shared representation of the task than on the task itself (Osiurak et al., 2020). In contrast, we isolated teaching from task pressures and manipulated access to a visual referent.

The amount of teaching did not decrease over generations. This is likely owing to the improvement incentive of our study, meaning participants aimed to encourage the next-in-line as to how to make a better artefact rather than a faithful reproduction. Our findings support collaborative accounts of dialogue (Clark, 1996) by showing a high level of listener engagement, with over a third of utterances during teaching being produced by the listener. As in (Bietti et al., 2019), learners who had longer teaching interactions performed better on the task. This study advances their approach by determining further categories of teaching content, while exploring the effects they have on the propensity to both copy and innovate. In addition to storytelling, the current study identifies two extra categories of teaching: instructional and experience-based. Teachers used all three categories in equal quantity, suggesting that storytelling is a more prevalent teaching method than expected from the ethnographic record (MacDonald, 2007), in which storytelling accounts for under of 10% of teaching across cultural domains (Garfield et al., 2016).

Another contribution made by this study concerns displacement during teaching. Displacement did not affect cumulative improvement, nor did it affect the content or quantity of teaching. This points to the effectiveness of human teaching under displacement (Gärdenfors et al., 2017), as the learning process is not impaired by absence of a visual example. Displacement in our study prevented fixation on a certain shape, or gestalt, by encouraging innovation. The fact that we observed a wider range of basket designs under displacement is interesting given that other

transmission studies have found memory constraints to reduce variation(Ferdinand et al., 2013; Tamariz & Kirby, 2015). Results of this study are in agreement not only with the argument that people prefer to copy visual referents if available (Henrich & Gil-White, 2001), but also that incremental tweaking is the most successful option (Miu et al., 2018). This may be due to decreased opportunities for simple copying when there is no visual referent, but may also indicate that strategy choice depends on whether or not the referent has been visually accessible. There is a possible explanation for this. It is clear that cultural transmission does not depend on recall ability alone – people do not always copy everything they remember and may omit aspects from onwards transmission (Lyons & Kashima, 2003). Those teachers who had their basket present during teaching may therefore have been perceived as more 'credible' and therefore more frequently copied, demonstrating 'content bias' (Tamariz et al., 2014). Content bias is also indicated by participants' choice to copy better-performing models more often. The presence of the artefact is likely the most common context in which manual skill transmission occurs (Lindwall & Ekström, 2012). Our study suggests that teaching in this context elicits a bias to copy that prevents over-innovating. This is an example of group-level coordination of cultural transmission strategies.

The sensemaking function of storytelling (Bietti et al., 2018) was replicated in our results. Teachers used storytelling more to talk about unexpected, non-routine events than they did non-storytelling. This study is the first to indicate direct effects of non-routine storytelling on cultural transmission strategy. Generally, non-routine content across all teaching (including the present tense) had no effect on strategy choice. However, telling non-routine stories increased learner innovation. Hearing stories about unexpected scenarios therefore encouraged participants to deviate from existing examples by switching designs. This advances the case for storytelling as a functional tool in cultural transmission. The fact that storytelling did not improve the efficacy of artefacts in task performance in our study (as in (Bietti et al., 2019)) is likely because the main function of sensemaking is essentially transformative, and does not promote the precise copying required for the ratchet effect to occur (Tennie et al., 2009). This study provides evidence for our claim that sensemaking constitutes the specific adaptive value of storytelling over and above language use in general.

This study helps broaden the range of manual tasks used to experimentally investigate cultural transmission. The traditional focus on stone tools (Lombao et al., 2017; Morgan et al., 2015) is being expanded to include other varied skills in a large range of domains, such as language (Nölle et al., 2020), food preparation (Bietti et al., 2019) and art (Tamariz et al., 2016). In particular, this study helps build the case for mobile containers in cognitive evolution (Fisher, 1979). Mobile containers such as bags, baskets or slings remain largely unexplored in this context despite the fact they may have been the primary tool of early humans, enabling collection and sharing of food as well as transportation of tools to solve multiple future problems (Langley & Suddendorf, 2020).

Like all lab-based cultural transmission experiments, this study is limited by its 'miniaturisation' of generational change to fit laboratory conditions (Miton & Charbonneau, 2018). As the effects of population size (Fay et al., 2019) and connectivity (Segovia-Martın et al., 2020) are increasingly understood, the representation of each generation with a single participant in our study may affect the ability to generalise findings. Having multiple participants per generation benefits transmission of stories (Eriksson & Coultas, 2012) and manual skills (Muthukrishna et al., 2014). This horizontal, as opposed to vertical, aspect of social transmission may play an important role, especially in view of the collective reasoning facilitated by sensemaking through storytelling (Bietti et al., 2018). Future studies should investigate storytelling in these contexts while continuing to broaden task types.

In this paper, we have provided the first experimental evidence that storytelling is a useful teaching method impacting cultural transmission strategies. This study also provides the most detailed analysis of the content of teaching in the context of cultural transmission experiments to date. Finally, results shed light on the role that displacement of the artefact during teaching plays on choice of cultural transmission strategy.

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Contributions

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General discussion

Face-to-face conversation has been the primary means of communication in everyday life throughout human evolution. The goal of this thesis was to investigate coordination processes in conversation with the general hypothesis that gaze and storytelling are specialised to facilitate different aspects of social interaction. In each case, light was shone on how social interaction has been shaped by evolutionary pressure to solve cooperation problems. In the first part of this thesis, mobile eye tracking technology was used to show precisely how gaze and other multimodal signals are used to facilitate the coordination of greetings (Studies 1 and 2). These studies supported the argument that gaze is used to regulate intimacy during social interaction, especially during the approach phase (Argyle & Dean, 1965). In the second part of this thesis, the transmission chain method was optimised to analyse the content of teaching during intergenerational transfer of basket-making skills (Studies 4 and 5). These studies indicated storytelling is a language-based teaching method that is adapted for the transfer of non-routine information, i.e., information that goes against expectations (Bietti et al., 2019). This argument was further developed in the theoretical review of the role of storytelling in the experimental and ethnographic literature.

Summary of main findings

Study 1 investigated the precise multimodal coordination of handshake greetings. Dual mobile eye tracking was used (Rogers et al., 2018; Stukenbrock, 2018) as two naïve unacquainted participants were introduced in the lab, approached each other and then shook hands. Greetings could be divided into two phases: distant and close, and during the interim approach period participants averted their gaze. There was evidence of close timing in vocalisations, indicating the no-gap-no-overlap principle (De Ruiter et al., 2006) applies in the context of greeting behaviour. When overlap occurred during close greeting vocalisations, participants hardly ever initiated repair. A lack of reciprocity in adjacency pairs was also observed, indicating that one pair-part is sufficient in this context (Duranti, 1997). The coordinational properties of laughter were indicated by its temporal distribution and differential use according to approaching role (Glenn, 2003). Men engaged in more face-gazing and women laughed more than men, suggesting greeting behaviour is to some extent gendered.

Study 2 investigated how people allocate the scarce resource of gaze during handshake greetings in order to balance social and motor functions (Argyle & Dean, 1965). The visibility of direct gaze was manipulated with shaded inserts for the eye tracking glasses. Participants gazed more at the faces of others wearing shades, i.e., with blocked eye visibility than at others not wearing shades, i.e., with visible eyes. This suggests that those not exposed to direct gaze experienced less avoidance forces and so did not have to avert their eyes in order to break intensity. The motor functions of gaze were confirmed as participants gazed at their partner's hand around half a second prior to the grasp, regardless of condition. Gender effects were revealed, as men's faces were looked at very differently according to the gender of the observer: men looked at other men's faces a lot while women looked at men's faces very little. Women were rated more highly than men in terms of liking and rapport.

The theoretical paper (Study 3) investigated the role of storytelling as a key element in the creation and propagation of culture. The experimental and ethnographic literature revealed that storytelling is specialised for making sense of non-routine, uncertain, or novel situations (Proulx et al., 2012). This enables the collaborative development of previously acquired skills and knowledge (Orr, 1996; Wenger, 1999) and promotes social cohesion by strengthening intragroup identity and clarifying intergroup relations (Anderson, 2006). The sensemaking function of storytelling is especially important in times of uncertainty during which groups need to protect or modify existing worldviews to make sense of events around them.

Study 4 investigated teaching in the cultural transmission of basket-weaving skills. Participants were instructed to copy, so the dependent variable was similarity to the original master basket. Use of a yoked chain design allowed us to clearly observe that teaching plus emulation did not benefit task performance over and above emulation alone. Storytelling was used as a teaching method (Scalise Sugiyama, 2017), especially for the transfer of non-routine information. A third of the intergenerational increase in storytelling was comprised of vicarious memories, indicating a role for storytelling in the cultural transmission of second-hand information (Pillemer et al., 2015). Overall,

this study demonstrated the ways in which face-to-face cultural transmission is vulnerable to distortion, but also suggested these distortions themselves may have important functions.

Study 5 investigated teaching in the cultural transmission of basket building skills. Participants were given a performance goal to improve functional efficacy, and the dependent variable was the amount of rice carried in addition to other basket design features. These variables were measured under two conditions: in the presence of the artefact (no-displacement condition) and in the absence of the artefact (displacement condition). Evidence of cumulative improvement was found as the efficacy of baskets increased over generations. Better performing baskets were copied more, suggesting content bias was at play (Tamariz et al., 2014). Teaching content was equally distributed across three categories: instructional, experience-based and storytelling. Storytelling consisted of more non-routine information than any other teaching category, particularly in the presence of the artefact. As in Study 4, this indicated conversational storytelling is specialised for the discussion of unexpected information in order to collaboratively make sense of it. Displacement during teaching increased subsequent innovation, and so did exposure to non-routine storytelling.

Theoretical implications and avenues for future research

Some key theoretical implications can be made based on this thesis. The eye tracking research carried out in Studies 1 and 2 provides insight into greeting behaviour. For example, evidence of close timing indicates that the no-gap-no-overlap principle (De Ruiter et al., 2006) also applies to greeting contexts as well as general conversation. Patterns of gaze aversion were methodically used throughout the approach, supporting the view that gaze is used to regulate intimacy in accordance with the approach-avoidance equilibrium (Argyle & Dean, 1965). In line with this, we did not find a straightforward relationship between mutual gaze and affiliation, as more gaze did not result in higher likeability and rapport ratings. Gaze towards hands prior to handshakes provided supporting evidence that the eye-hand span is one second or less (Land & Hayhoe, 2001) by observing it in the novel context of greeting interactions. We can infer from this that the same motor functions of gaze apply during real social interactions that do for basic manual tasks (Hayhoe, 2000; Land et al., 1999). These findings are especially relevant as the research was based on genuine handshake greetings between

two naïve participants, which is more naturalistic than much existing experimental work on handshakes (Åström, 1994; Melnyk & Hénaff, 2019; Schroeder et al., 2019).

Studies 4 and 5 and the accompanying literature review also have key theoretical implications for cultural transmission research. Taken together, our results primarily suggest that storytelling constitutes a teaching method that is used to transmit information about mistakes or unexpected events. This may be the specific adaptive value of storytelling over and above language in general (Bietti et al., 2018). However, neither experimental study indicated any relationship between storytelling and task performance. It appears that storytelling is not very well suited for precise copying, as emulation was found to be just as useful (Whiten et al., 2009; Zwirner & Thornton, 2015). However, when participants are able to innovate, storytelling reveals its most useful functions. Hearing stories about unexpected scenarios encouraged participants to deviate from existing examples by switching designs. This is because sensemaking is essentially transformative, facilitating group-level coordination of cultural transmission strategies.

Several avenues for future research can be suggested based on this thesis. For instance, the naturalistic eye tracking paradigm developed in Studies 1 and 2 could go beyond pairwise interaction, and be applied to multi-party greetings with more conversational participants. Greeting more than one person at the same time is a common everyday occurrence, and analysing this in the lab will help build a more representative picture of how greeting behaviour works. The coordination of triadic conversational interaction has already been explored experimentally using eye trackers (Holler & Kendrick, 2015; Zima et al., 2019), but not yet in the context of greeting behaviour. Research is also required to advance understanding of laughter as a coordinational tool in greetings specifically (Béal & Traverso, 2010; Mondada et al., 2020) and social interactions more generally (Glenn, 2003). It is clear from our study that gender affects greeting behaviour and formation of first impressions, but further research is required to unpack these effects.

In terms of cultural transmission research, the new method devised in Studies 4 and 5 could be used to analyse teaching in different contexts. This involves two notable modifications to the conventional way that teaching is observed in cultural transmission experiments: separating teaching

from task performance and removing any time constraints. As is commonly suggested regarding lab-based cultural transmission experiments, future research would benefit from using more than one participant per generation (Miton & Charbonneau, 2018). This horizontal, as opposed to vertical, aspect of social transmission may play an important role, especially in view of the collective reasoning facilitated by storytelling (Bietti et al., 2018). Future studies should investigate storytelling in these contexts while continuing to broaden the range of skills explored. Cognitive evolution research has a traditional focus on stone tools (Lombao et al., 2017; Morgan et al., 2015), but research is now starting to include varied skills in other domains, such as symbolic behaviour (Tylén et al., 2020), language (Nölle et al., 2020), food preparation (Bietti et al., 2019) and art (Tamariz et al., 2016). By focusing on basket-making tasks, Studies 4 and 5 help build the case for mobile containers in cognitive evolution (Zwirner & Thornton, 2015). Mobile containers such as bags, baskets or slings were likely crucial tools for early humans, enabling collection and sharing of food as well as transportation of tools to solve multiple future problems (Langley & Suddendorf, 2020). Future research could continue to expand on this.

General conclusion

To conclude, this thesis has made the case for gaze and storytelling as tools specialised to facilitate different aspects of social interaction. In Part One, mobile eye tracking technology was used to capture the approach phase of handshake greetings in unprecedented detail, revealing its multimodal coordination. Individuals collaboratively balanced the motor and social functions of gaze to regulate intimacy, and this balance was affected by eye visibility. In Part Two, the theoretical basis for storytelling as a teaching method and an adaptive tool in cultural transmission was established, and then empirically investigated. Teachers preferentially used storytelling to discuss non-routine, unexpected information. This builds our argument that the specific adaptive advantage of storytelling over and above language use in general is enabling collective sensemaking. These two cases shed light on coordination processes in face-to-face conversational interaction, which even if subject to restriction in recent times, remains the quintessential setting for human communication.

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Publication list

STUDY 1

Tilston, O., Bangerter, A. & Holler, J. (in preparation). Coordination of handshake greetings.

STUDY 2

Tilston, O., Bangerter, A. & Holler, J. (in preparation). Eyegaze in handshakes: An eye tracking study.

STUDY 3

Bietti, L., Tilston, O., & Bangerter, A. (2018). Storytelling as adaptive collective sensemaking. *Topics in Cognitive Science*. https://doi.org/10.1111/tops.12358

STUDY 4

Tilston, O., Bangerter, A. & Bietti, L. (in preparation). Teaching, emulation and storytelling in cultural transmission.

STUDY 5

Tilston, O., Bangerter, A. & Tylén, K. (Under Review at *Evolution and Human Behaviour*). Storytelling, teaching and innovation in cultural transmission.