

Theory of mind and cognitive processes in aging and Alzheimer type dementia: a systematic review

Mélanie Sandoz^{a*}, Jean-François Démonet^b and Marion Fossard^a

^a *Institut des Sciences du Langage et de la Communication, Faculté des Lettres et Sciences Humaines, Université de Neuchâtel, Neuchâtel, Switzerland*

^b *Centre Leenaards de la Mémoire, Département des neurosciences cliniques, Centre hospitalier universitaire vaudois & Université de Lausanne, Lausanne, Switzerland*

Objectives: Theory of mind (ToM) performance in aging and dementia of the Alzheimer type (DAT) has been a growing interest of researchers and recently, theoretical trends in ToM development have led to a focus on determining the cognitive skills involved in ToM performance. The aim of the present review is to answer three main questions: How is ToM assessed in aging and DAT? How does ToM performance evolve in aging and DAT? Do cognitive processes influence ToM performance in aging and DAT?

Method: A systematic review was conducted to provide a targeted overview of recent studies relating ToM performance with cognitive processes in aging and DAT.

Results: Results suggest a decrease in ToM performance, more pronounced in complex ToM tasks. Moreover, the review points up the strong involvement of executive functions, especially inhibition, and reasoning skills in ToM task achievement.

Conclusion: Current data suggest that the structure of ToM tasks itself could lead to poor performance, especially in populations with reduced cognitive abilities.

Keywords: Theory of mind; aging; Alzheimer's dementia; cognitive processes; systematic review

1. Introduction

Theory of mind (ToM) refers to the ability to attribute mental states such as belief, desires and knowledge to oneself and others (Premack & Woodruff, 1978). This competence is considered essential for social functioning because it enables individuals to understand and predict others' behavior. Literature investigating ToM has a long tradition of research, especially in children, and many tasks have been constructed to try to understand how people attribute mental states to others.

Developmental literature currently agrees about the progressive acquisition of two different levels of representation when reasoning about others' mental states: we can distinguish between tasks assessing abilities to construct 'simple' representations of another person's mental states (as beliefs or thoughts, i.e. 'What does Paul think') and tasks assessing more complex attributions. The latter assess the ability to build the representation of one person's mental state about a second person's mental state (i.e. 'What Paul thinks that Mary thinks'). Learned in late childhood, these attributions are considered to require more cognitive resources (for a review, see Miller, 2009). Although there has been some recent interest in the literature in identifying more general cognitive resources involved in attributing mental states to others, two diverging theoretical aims are currently discussed in the research on ToM abilities. Studies on the early development of ToM abilities focus either on determining the existence

of a ToM component with the independent functioning of other cognitive processes (see Baron-Cohen, 1995 for a review) or on specifying the existence of a more shared network of competences, interacting in attributing mental states, such as with language skills (de Villiers & Pyers, 2002; Lohmann & Tomasello, 2003) or executive function development (Carlson, Moses, & Claxton, 2004). More recently, researchers have focused on a more 'integrated' approach, attempting to match these two conflicting theoretical trends. It is suggested that there may be a specific ToM component but its interaction with more general resources, such as executive functions, is necessary for optimal ToM competences in children (Stone & Gerrans, 2006; for experimental studies, see also Leslie, German, & Polizzi, 2005; Leslie & Polizzi, 1998). To illustrate this approach, it is proposed that an innate 'module' of ToM is active in early childhood, manifesting for instance through a detecting gaze direction task (Onishi & Baillargeon, 2005; Surian, Caldi, & Sperber, 2007) but in middle childhood, performance on ToM tasks such as first-order false beliefs (Wimmer & Perner, 1983) and second-order false beliefs (Perner & Wimmer, 1985) may depend on more non-specific cognitive abilities, such as executive competence, to successfully attribute the character's belief (Gerrans, 2003; Stone & Gerrans, 2006). Although these data point to a direct interdependence between ToM task performance and cognitive/executive resources, it is still not clear if cognitive/executive functions are needed for

*Corresponding author. Email: melanie.sandoz@unine.ch

the development of ToM abilities (Carlson & Moses, 2001) or only for the expression of innate ToM abilities (Leslie, Friedman, & German, 2004).

Over the past two decades, ToM performance in healthy aging has been a growing interest of researchers. Traditionally investigated in children with the aim of outlining a developmental pattern of acquisition, more recently ToM has been studied in the opposite developmental continuum with the principal purpose to understand how ToM abilities evolve in healthy aging. For example, to our knowledge the princeps study of Happé, Winner, and Brownell (1998) was one of the first to assess ToM performance in healthy aged participants, compared to young adults. With an assessment based on short stories, they found that their elderly group of participants was better at attributing mental states than young adults. The authors suggested that this result may be due to the particular cognitive profile of their elderly group, who presented better verbal abilities than the young adults. However, this result is quite isolated and contrary to later studies assessing ToM in healthy aging, which report a mostly significant inferior performance of healthy aged participants compared to young adults (Castelli et al., 2010; McKinnon & Moscovitch, 2007; Pardini & Nichelli, 2009), with variable cognitive measures performed in order to control for cognitive efficiency in doing ToM tasks. Since the initial studies on ToM in aging, research has evolved in line with recent studies on the probable interaction of ToM performance with cognitive processes (for a review, see Apperly, Samson, & Humphreys, 2005). The expansion of research on the decrease of particular cognitive processes in healthy aging, such as executive abilities (Belleville, Rouleau, & Van der Linden, 2006; Fisk & Sharp, 2004), has also helped to increase interest in the cognitive basis of ToM difficulties in aging. As suggested by Happé's princeps study and given the diversity of the ensuing literature on ToM in aging, it would be interesting to look at studies that explicitly account for the cognitive profile of their elderly participants in order to better understand the contributions of cognitive processes in ToM performance.

In parallel with the research on healthy aging, studies on ToM abilities in pathological aging have increased due to the improvement in knowledge emphasizing cognitive/emotional profiles in different neurodegenerative pathologies. The growing interest in the impacts that these particular profiles may have on social interactions has led to numerous studies, especially on social cognition in the behavioral variant of fronto-temporal dementia (for a review, see Kipps & Hodges, 2006). Concerning dementia of the Alzheimer type (DAT), patterns of ToM performance that have been found are less clear. Although a decrease in empathy and emotional difficulties are identified in the literature (Henry, Rendell, Scicluna, Jackson, & Phillips, 2009; Phillips, Scott, Henry, Mowat, & Bell, 2010), studies on social cognitive skills, such as attributing mental states to others, have shown less agreement. Participants with probable Alzheimer's dementia seem to be impaired in complex ToM tasks with a high demand on reasoning skills and executive functions, but those studies

do not account for such substantial difficulties in tasks with less demand on cognitive resources (Fernandez-Duque, Baird, & Black, 2009; Zaitchik, Koff, Brownell, Winner, & Albert, 2006).

To summarize, current research indicates that ToM abilities may be understood within an integrated conception as relying on both a specific ToM component and general cognitive resources. As studies on aging and DAT show a decrease in ToM performance, it would be relevant to investigate specifically how cognitive competences may interact with ToM performance, compared to young and middle adulthood. Recently, some literature reviews attempted to identify general trends in ToM abilities, both in healthy aging (Moran, 2013) and neurodegenerative diseases (Kemp, Després, Sellal, & Dufour, 2012; Poletti, Enrici, & Adenzato, 2012). Although these reviews also address the contribution of general cognitive processes in ToM abilities, they do not focus selectively on their relationships to ToM performance. Moreover, the variability of cognitive difficulties in aging and DAT (for a recent account concerning DAT, see Weintraub, Wicklund, & Salmon, 2012) could be especially informative in pointing to the most predictive cognitive dimensions involved in attributing mental states.

This review provides an overview of the literature on ToM performance in aging and DAT and its relationship with more general cognitive resources. The aim, for theoretical purposes and considering the experimental data outlined above, is to answer three main questions:

1.1. How is ToM assessed in aging and DAT?

The interest in ToM performance in aging is quite recent compared to developmental studies in children. As the majority of ToM tasks were initially created to explore acquisition patterns of ToM competences, we wanted to get an overview of ToM tasks in adult assessment. The review also aims to determine if ToM assessment in adulthood includes tasks with progressive degrees of difficulty.

1.2. How does ToM performance evolve in aging and DAT?

Studies on ToM in aging and DAT have found interesting evidence of a probable decline in ToM performance. Nevertheless, given the various existing ToM tasks, we wanted to determine if performances are equally affected in the differing degrees of task complexity. A systematic review of recent work on both 'normal' and pathological aging could provide a more continuous overview of the development of ToM performance, from young adulthood to aging and from healthy aging to pathological conditions.

1.3. Do cognitive processes influence ToM performance in aging and DAT?

The major aim of the review was to outline the specific involvement of cognitive processes in ToM performance. Particularly, this review aimed to determine which cognitive processes are more related to ToM performance and

to what extent these processes account for the variability in ToM performance.

2. Methodology

2.1. Article selection

2.1.1. Data sources and keywords

In July 2013, we searched the Web of Science (Web of Knowledge), Psyc'INFO, Medline (EBSCOhost) and PubMed databases. We limited our selection to publications in English language scientific journals with a peer review process. The core subject 'theory of mind' was systematically paired with each of the following keywords: 'aging' and 'elderly' for normal aging, and 'Alzheimer' and 'dementia' for the pathological dimension of aging.

2.1.2. Exclusion/inclusion criteria

Following current guidelines on systematic reviews (Petticrew & Roberts, 2006), criteria for exclusion/inclusion of publications were selected to address the research questions (see Section 1). As the review focuses on ToM performance in healthy aging and DAT, publications that assessed target groups with genetic disease, mental retardation, psychopathology, traumatic brain injury, semantic dementia and frontotemporal dementia only were excluded. Studies that assessed ToM performance in participants with frontotemporal dementia and DAT compared to a control group were included but only the performance of participants with DAT was taken into account (Gregory et al., 2002; Le Bouc et al., 2012). Forty-seven publications were preliminary retained. Then, according to our research objectives, other specific exclusion/inclusion criteria were applied. More specifically, we excluded the following:

- Publications before 1995 and those belonging to a category other than an experimental study in order to get an overview of recent research on ToM performance and related cognitive processes. According to this criterion, four reviews were excluded.
- Given the increasing interest in the literature in comparing cognitive components of ToM performance with affective components, five publications exclusively studying empathy abilities and/or the emotional component of ToM (e.g. emotion recognition) were excluded. When studies assessed both the cognitive and emotional components of ToM performance, they were included in the review (Laisney et al., 2013; Wang & Su, 2013). However, results on affective ToM performance were not discussed as the review focused only on cognitive components of ToM.

Concerning inclusion criteria:

- In order to have reliable data on ToM performance in aging and DAT, only publications with a target group (probable Alzheimer disease or healthy aged adults) and a control group (healthy aged adults or

healthy young/middle-aged adults) containing 10 or more subjects were included. Four publications did not reach this criterion and were excluded. One study retained (Charlton, Barrick, Markus, & Morris, 2009) did not a priori define a target group as the authors aimed to assess ToM performance over a wide age span in healthy aging. However, since they split the population into four age groups and given the objectives of the review, the two oldest groups of participants in the Charlton et al. (2009) study were selected as the two target groups in the review.

- Finally, to identify which cognitive processes are related to ToM performance, only publications relating statistically cognitive performance and ToM abilities in the target groups were included. Twelve other publications did not reach this last criterion and therefore were excluded.

Finally, a total of 22 studies reviewed met the exclusion/inclusion criteria. Fourteen assessed healthy aged adults as the target group, five assessed probable Alzheimer participants as the target group, two assessed both frontotemporal dementia and probable Alzheimer participants as target groups (Gregory et al., 2002; Le Bouc et al., 2012), and one assessed probable mild cognitive impairment (MCI) as the target group (Baglio et al., 2012). This study was retained because of the relevance of data on ToM performance in a population with probable MCI to understand potential differences between healthy and pathological aging.

3. Results

3.1. 'Theory of mind' assessment

Given the diversity of experimental tasks used in the publications reviewed, for clarification purposes ToM tasks were classified according to two dimensions: their assessment modality (verbal or visual) and their demand on reasoning skills. Concerning the level of reasoning complexity and on the basis of the literature on progressive achievement of ToM tasks, tasks with no reasoning about mental states were classified as low level, such as the Eye Direction Detection task (Baron-Cohen, Campbell, Karmiloff-Smith, Grant, & Walker, 1995) or the Revised Eyes test (Baron-Cohen, Wheelwright, Hill, Raste, & Plumb, 2001). Tasks assessing a 'simple' mental state attribution (i.e. 'What does Paul think?') were classified as requiring medium-level reasoning skills and tasks assessing complex mental states attribution (i.e. 'What Paul thinks that Mary thinks?') as the highest level. Some ToM tasks were already classified by level of cognitive complexity in the studies reviewed (e.g. the Tom's taste task as requiring high-level reasoning skills in the Duval, Piolino, Bejanin, Eustache, & Desgranges (2011) study).

The complete distribution of the different ToM tasks used in the 22 studies reviewed is presented in Table 1. Depending on the population assessed (healthy aged, probable Alzheimer and MCI participants), tasks do not

Table 1. Publications retained after selection by exclusion/inclusion criteria and target groups' performance according to assessment modality and level of reasoning complexity.

Study	Target group	Verbal tasks				Visual tasks			
		Mid level	High level	Control	Low level	Mid level	High level	Control	
		ToM performance							
Baglio et al. (2012)	16 MCI participants ($M = 71$)	S-Stories	S-Stories	S-Stories	EDD/DB	2 nd FB*	2 nd FB*	EDD/ 2 nd FB	
Bailey and Henry (2008)	33 aged adults ($M = 72.2$)				R-ET*	1 st FB*	1 st FB*	1 st FB	
Bernstein et al. (2011)	37 aged adults ($M = 67.6$)					SB*	SB	SB	
Castelli et al. (2011)	16 DAT participants ($M = 70.5$)	S-Stories*			EDD*/R-ET*/DB/	2 nd FB*	2 nd FB*	EDD*/R-ET/2 nd FB	
Cavallini et al. (2013)	27 middle-aged adults ($M = 64.93$)	S-Stories*		S-Stories					
	29 aged adults ($M = 74.99$)	S-Stories*		S-Stories					
Charlton et al. (2009)	21 aged adults ($M = 83.86$)	S-Stories*		S-Stories					
	31 aged adults ($M = 75.03$)	S-Stories		S-Stories					
Duval et al. (2011)	25 aged adults ($M = 70.14$)				ET	1 st FB*/Cartoons task*	2 nd FB*/Tom's taste task*	ET/1 st FB*/Cartoons task*/Tom's taste task	
German and Hehman (2006)	20 aged adults ($R = 62-90$)	ToM stories* FP		ToM stories* FP*					
Gregory et al. (2002)	12 DAT participants ($M = 66.5$)	ToM stories*		ToM stories*	ET	1 st FB	2 nd FB*	1 st FB/2 nd FB	
Keightley et al. (2006)	30 aged adults ($M = 72.5$)	ToM stories*		ToM stories*		1 st FB*		1 st FB*	
Laisney et al. (2013)	16 DAT participants ($M = 78.1$)				EDD*/ET*	1 st FB*	2 nd FB	1 st FB/2 nd FB	
Le Bouc et al. (2012)	12 DAT participants ($M = 61.9$)					1 st FB*		1 st FB*	
Li et al. (2013)	24 aged adults with high educational level ($M = 76.29$)	1 st FB/FP		1 st FB/FP	R-ET			R-ET	
	28 aged adults with low educational level ($M = 73.52$)	1 st FB*/FP*		1 st FB/FP	R-ET			R-ET	
Maylor et al. (2002)	Exp. 1: 25 aged adults ($M = 81$)	S-Stories*		S-Stories					
	Exp. 2: 30 aged adults ($M = 80.6$)	S-Stories*		S-Stories					
Phillips et al. (2011)	36 aged adults ($M = 73.6$)	ToM stories*		ToM stories		1 st FB*		1 st FB	
Rakoczy et al. (2012)	20 aged adults ($M = 73.3$)	S-Stories*		S-Stories		ToM stories*		ToM stories*/R-ET*	
Slessor et al. (2007)	40 aged adults ($M = 66.95$)	S-Stories*		S-Stories	R-ET*	ToM stories*		ToM stories	
Sullivan and Ruffman (2004)	24 aged adults ($M = 73$)	S-Stories*		S-Stories		ToM stories		ToM stories	
Verdon et al. (2007)	20 DAT participants ($M = 82$)	S-Stories*		S-Stories		Cartoons task*		Cartoons task*	
Wang and Su (2013)	42 aged adults ($M = 69.21$)	S-Stories*		S-Stories					
	32 aged adults ($M = 78.75$)	S-Stories*		S-Stories					
Youmans and Bourgeois (2010)	10 DAT participants ($M = 82$)				AR/DB	1 st and 2 nd FB*		FB tasks	
Zaitchik et al. (2004)	25 DAT participants ($M = 88.96$)					1 st FB*		1 st FB*	

Note: *Performance of target group (aged or DAT participants) significantly lower ($p < .05$) than that of control group (young or healthy aged participants); EDD: Eye Direction Detection task (from Baron-Cohen et al., 1995); ET: Eyes test (from Baron-Cohen, Jolliffe, Mortimore, & Robertson, 1997); R-ET: Revised Eyes test (from Baron-Cohen et al., 2001); DB: Deceptive Box task (from Perner, Leekam, & Wimmer, 1987); AR: Appearance-Reality task (from Flavell, Flavell, & Green, 1983); S-Stories: Strange stories from Happé (1994); SB: Sandbox task (from Somerville et al., 2013); Cartoons task: from Sarfati, Hardy-Baylé, Besche, & Widlöcher (1997); FP: faux pas task (from Stone, Baron-Cohen, Knight, 1998); 1st FB: first-order false belief task (from Wimmer & Perner, 1983); 2nd FB: second-order false belief task (from Perner & Wimmer, 1985); 1st and 2nd FB: combined in the Youmans and Bourgeois (2010) study; Tom's taste task: from Duval et al. (2011).

generally differ. Both target groups are assessed with similar tasks, such as ToM stories and false belief paradigms. Tasks reviewed with mid- and high-level reasoning skills have a control condition which is structured in the same way as experimental tasks, but in which participants have to reason about a physical causality. These control tasks are used to ensure that participants are able to reason about a simple causality effect. In the case of specific deficits in experimental tasks but preserved performance in control tasks, the origin of the difficulties can be inferred in terms of ToM impairment.

For tasks with low-level reasoning skills, studies used mostly the Revised Eyes Test from Baron-Cohen et al. (2001) (for instance, Bailey & Henry, 2008). In most of the studies, tasks that were chosen require mid-level reasoning skills, such as the first-order false belief paradigms (for instance, Duval et al., 2011), the ToM stories (for instance, German & Hehman, 2006) and the Strange stories from Happé (1994) (for instance, Baglio et al., 2012). Finally, for tasks with high-level reasoning skills, only five of the studies reviewed used a second-order false belief paradigm (Baglio et al., 2012; Castelli et al., 2011; Duval et al., 2011; Gregory et al., 2002; Laisney et al., 2013). A last observation emerging from this review is that most of the studies assessed ToM abilities with more than one task (for instance, Gregory et al., 2002), and some of them with the assumption that healthy aged (Duval et al., 2011), probable Alzheimer (Castelli et al., 2011; Laisney et al., 2013) and MCI participants (Baglio et al., 2012) can achieve the rather simple ToM tasks but will have less success in the complex ones, which require greater integrity of ToM abilities and cognitive resources.

3.2. 'Theory of mind' performance

In order to outline ToM abilities in aging, Alzheimer type dementia and MCI, we considered performance to be impaired if the target group scores (healthy aged, probable Alzheimer and MCI participants) were significantly lower ($p < .05$) than their control group scores.

The majority of the studies suggest that the target groups (healthy aged, probable Alzheimer and probable MCI participants) perform generally worse ($p < .05$) than their control groups (Table 1). Specific deficits according to the level of reasoning complexity in the tasks are difficult to identify because both healthy aged and probable Alzheimer participants present variable patterns of difficulties for tasks with low- and mid-level reasoning skills between studies. For instance, healthy aged participants seem to be impaired in resolving ToM stories compared to healthy young control participants, as in the German & Hehman (2006) study, but one study did not find such significant differences (Sullivan & Ruffman, 2004). Likewise, in the Laisney et al. (2013), Le Bouc et al. (2012) and Youmans and Bourgeois (2010) studies, probable Alzheimer participants failed a first-order false belief task paradigm compared to healthy aged participants but similar results were not reported in one study using the same paradigm (Gregory et al., 2002). However, for studies using Happé's Strange stories (1994), the results for both

target groups were very similar. Indeed, only the Baglio et al. (2012) study did not report any significant differences in ToM performance for probable MCI participants compared to healthy aged participants. In the Charlton et al. (2009) study, the oldest group of participants (over 80 years old) had a poorer performance on Happé's (1994) Strange stories than the other three groups, while the youngest group (between 50 and 59 years old) surpassed the three older groups. Thus, the heterogeneity of results for mid-level reasoning tasks may be caused by the diversity of the tasks reviewed, which assessed ToM with various stimuli (verbal, visual static and visual dynamic in the Sullivan and Ruffman (2004) study), but could also be caused by the variability of participant characteristics, such as age (Charlton et al., 2009) and cognitive profiles (Baglio et al., 2012).

For tasks with high-level reasoning skills, the review indicates substantial consensus. Both healthy aged and probable Alzheimer participants present significantly lower scores than their control groups. Surprisingly, the Laisney et al. (2013) study is the only one that did not report a significantly lower performance by probable Alzheimer participants than healthy aged participants on a second-order false belief task. However, this study noted that the performance of the control group on the second-order false belief task was significantly lower than on the first-order false belief task, while any differences between the two tasks were observed for probable Alzheimer participants. These difficulties for control participants in completing complex tasks could explain the lack of significant differences between the two groups. Moreover, questions may be asked regarding the pertinence of using a single control group matched on age when probable Alzheimer participants are assessed. Indeed, if healthy adults present some difficulties in resolving complex tasks and performance within this group is not taken into account, it could mask probable Alzheimer participant deficits. Therefore, some discrepancies between studies could also be explained by the control group performance.

Another interesting result was observed in control tasks: some studies showed that participants demonstrated difficulties in resolving control tasks, in both healthy aged and probable Alzheimer participants (Duval et al., 2011; German & Hehman, 2006; Keightley, Winocur, Burioanova, & Hongwanishkul, 2006; Le Bouc et al., 2012; Slesor, Phillips, & Bull, 2007; Verdon et al., 2007; Zaitchik, Koff, Brownell, Winner, & Albert, 2004), a result which is hardly compatible with a specific ToM deficit. Moreover, even when ToM and control tasks were strictly matched for executive demand, difficulties on control tasks were observed in young healthy subjects (German & Hehman, 2006), tending to suggest that cognitive demand may determine performance, regardless of whether the task includes mental states or not.

To sum up, according to the degree of task complexity, the review shows a general trend in ToM performance, with the simplest reasoning tasks completed better than the most complex tasks for the three target groups, suggesting an involvement of cognitive processes in ToM performance. To explore this hypothesis, the next section

examines more specifically the cognitive processes involved in ToM performance.

3.3. Cognitive processes and 'theory of mind' performance in aging and Alzheimer type dementia

The different cognitive processes assessed in the studies reviewed cover five major cognitive dimensions: executive functions ($n = 18$), vocabulary level ($n = 11$), processing speed ($n = 8$), logical reasoning ($n = 6$) and episodic memory ($n = 6$). In order to identify particular cognitive processes involved in ToM abilities, the relationships between cognitive processes and ToM abilities for the target groups are listed according to their degree of statistical significance ($p \leq .05$, $p \leq .01$ and $p \leq .001$). With respect to the significant correlations reviewed (Table 2), it can be seen that executive functions have many significant relationships with ToM performance. In all studies performing a correlation analysis, only one did not find any significant results with the target group (Bernstein, Thornton, & Sommerville, 2011). Correlations performed are often quite strong, with significant results at $p < .01$ (for instance, Bailey & Henry, 2008) and $p < .001$ (for instance, Le Bouc et al., 2012) for all target groups assessed (healthy aged, probable Alzheimer and MCI participants) and all levels of reasoning complexity of the tasks. For other cognitive dimensions assessed, studies also found some significant and strong relationships with the different ToM tasks and for all target groups: episodic memory (for instance, Castelli et al., 2011), vocabulary (for instance, Cavallini, Lecce, Bottiroli, Palladino, & Pagnin, 2013), logical reasoning (for instance, Baglio et al., 2012) and processing speed (for instance, Li et al., 2013). The significant correlations observed between vocabulary level and ToM performance might be partly explained by the verbal modality of tasks in Cavallini et al. (2013), Charlton et al. (2009), Maylor, Moulson, Muncer, and Taylor (2002) and Sullivan and Ruffman (2004) studies (ToM stories and Strange stories from Happé (1994)). However, not all statistical analyses present significant correlations between ToM performance and cognitive processes. For executive functions, some measures of flexibility did not demonstrate any relationships to ToM performance (for instance, Bailey & Henry, 2008); the same was true for inhibition (for instance, Laisney et al., 2013) and updating measures (for instance, Le Bouc et al., 2012). For other cognitive competences, episodic memory (for instance, German & Hehman, 2006), processing speed (for instance, Rakoczy, Harden-Kasten, & Sturm, 2012) and vocabulary level (for instance, Keightley et al., 2006) also failed to demonstrate any significant relationships to ToM performance. Finally, concerning correlation analyses, performances on control tasks also present some significant relationships with executive functions (inhibition: Bailey & Henry, 2008; Bernstein et al., 2011; German & Hehman, 2006; flexibility: Bailey & Henry, 2008; Bernstein et al., 2011; Castelli et al., 2011; Maylor et al., 2002; and updating: Cavallini et al., 2013), vocabulary (German & Hehman, 2006; Maylor et al., 2002; Rakoczy et al., 2012), processing speed

(German & Hehman, 2006) and logical reasoning (Castelli et al., 2011; Sullivan & Ruffman, 2004).

To go further than the relationships presented above, significant regression and mediation analyses ($p \leq .05$, $p \leq .01$ and $p \leq .001$) are also presented in Table 2. Studies reviewed found some significant and important involvements of cognitive processes in ToM abilities in healthy aged participants and probable Alzheimer participants. More precisely, performance on executive functions presents an important contribution to ToM task achievement, as suggested by regression analyses: inhibition as in the Bailey & Henry (2008) study, updating as in the Phillips et al. (2011) study and the composite scores as in the Duval et al. (2011) study. Moreover, mediation analyses show that inhibition performance (Bailey & Henry, 2008; Li et al., 2013), updating performance (Li et al., 2013) and executive functions composite score (Charlton et al., 2009; Rakoczy et al., 2012) can totally explain ToM task performance: once the variability in the executive measures is accounted for, the variable age is no longer a significant predictor of ToM performance. Conversely, the Wang and Su (2013) study reports that once age is taken into account, their inhibition measure is no longer a significant predictor of ToM performance. One explanation of this result could be that they split their ToM task according to the cognitive or affective components of stories, reducing the number of items in each category and weakening their cognitive ToM measure. The strong involvement of cognitive dimensions in ToM performance is also shown with processing speed (Charlton et al., 2009; Li et al., 2013; Rakoczy et al., 2012) and with a measure of logical reasoning (Charlton et al., 2009). The review also points to more moderate results with some cognitive processes that account for only part of the variance in ToM performance (executive functions as updating and composite scores (Duval et al., 2011; Phillips et al., 2011), vocabulary (Charlton et al., 2009; Maylor et al., 2002) and processing speed (German & Hehman, 2006; Maylor et al., 2002; Rakoczy et al., 2012)). In the Duval et al. (2011) study, the moderate involvement of their composite score of executive functions is related to second-order false belief performance, contrary to performance on the first-order false belief tasks, which is totally mediated by executive functions. This result tends to demonstrate that for high-level reasoning tasks, more complex interaction between cognitive processes is involved. The involvement of vocabulary level can be explained by the verbal modality of tasks (Strange stories from Happé (1994) in the Charlton et al. (2009) and Maylor et al. (2002) studies). Finally, as for correlation analyses, the Bernstein et al. (2011) study does not report any significant results. One possible explanation for this lack of significant results is that the authors used a score derived from principal component analysis to assess relationships between ToM performance and cognitive processes. It is possible that one target cognitive dimension instead of a global score derived from a component analysis would account better for ToM performance in this particular ToM task (the Sandbox task adapted from Sommerville, Bernstein, & Meltzoff, 2013).

Table 2. Correlations and regression analyses between ToM performance and cognitive processes for the target groups.

Relationships with cognitive processes									
Analyses performed by study	EF	Inhibition	Updating	Flexibility	Episodic memory	Vocabulary	Logical reasoning	Processing speed	Cognitive profile
Baglio et al. (2012): correlation				2 nd FB**	2 nd FB/ S-Stories		2 nd FB*/ S-Stories*		
Bailey and Henry (2008): correlation		R-ET**/ 1 st FB**		R-ET**/ 1 st FB			R-ET**/ 1 st FB**	R-ET**/ 1 st FB**	
Bernstein et al. (2011): correlation	SB	R-ET**/ 1 st FB*							
Castelli et al. (2011): correlations	SB								
Cavallini et al. (2013): correlation			EDD/DB/ R-ET/ S-Stories/2 nd FB	EDD*/DB/R-ET**/ S-Stories/2 nd FB**	EDD/DB/R-ET/S-Stories/2 nd FB*		EDD/DB/R-ET*/ S-Stories*/ 2 nd FB*		
Charlton et al. (2009): correlation	S-Stories**	S-Stories**	S-Stories**	S-Stories**	S-Stories**	S-Stories**	S-Stories**	S-Stories**	
Duval et al. (2011): correlation	S-Stories***	S-Stories**	S-Stories*	S-Stories**	S-Stories**	S-Stories**	S-Stories**	S-Stories***	
	ET/ Cartoons task***/ 1 st FB***/ 2 nd FB*/ Tom's taste task**				ET*/ Cartoons task/ 1 st FB/ 2 nd FB/ Tom's taste task*			Cartoons task*/ 1 st FB***/ 2 nd FB/ Tom's taste task*	
	ET/ Cartoons task**/ 1 st FB**/ 2 nd FB*/ Tom's taste task				ET/ 2 nd FB/ Tom's taste task			ET/ 1 st FB/ 2 nd FB/ Tom's taste task	
German and Hehman (2006): correlation		ToM stories**	ToM stories**	ToM stories**		ToM stories		ToM stories**	
Keightley et al. (2006): correlation		ToM stories ^{ca}	ToM stories	ToM stories		ToM stories		ToM stories ^{ca}	
		ToM stories/ 1 st FB	ToM stories/ 1 st FB	ToM stories/ 1 st FB		ToM stories/ 1 st FB		ToM stories ^{ca}	
Laisney et al. (2013): correlation		ET/ 1 st FB/ 2 nd FB*	ET/ 1 st FB/ 2 nd FB*	ET/ 1 st FB/ 2 nd FB**	ET/ 1 st FB/ 2 nd FB**				ET*/ 1 st FB*/ 2 nd FB
Le Bouc et al. (2012): correlation		1 st FB***	1 st FB	1 st FB	1 st FB				
Li et al. (2013): correlation		R-ET*/ FP*/ 1 st FB*	R-ET*/ FP*/ 1 st FB*	R-ET*/ FP*/ 1 st FB*	R-ET*/ FP*/ 1 st FB*				
	regression	FP*/ 1 st FB*	FP*/ 1 st FB	FP*/ 1 st FB					
Maylor et al. (2002): correlation									
Phillips et al. (2011): correlation		ToM stories/ 1 st FB**	ToM stories**/ 1 st FB***	ToM stories**/ 1 st FB**					
	regression								
Rakoecy et al. (2012): correlation	S-Stories*/ ToM stories**	S-Stories*/ ToM stories**	S-Stories*/ ToM stories**	S-Stories*/ ToM stories**	S-Stories*/ ToM stories**				
	regression	S-Stories*/ ToM stories**	S-Stories*/ ToM stories**	S-Stories*/ ToM stories**					

(continued)

Table 2. (Continued)

Relationships with cognitive processes									
Analyses performed by study	EF	Inhibition	Updating	Flexibility	Episodic memory	Vocabulary	Logical reasoning	Processing speed	Cognitive profile
Sullivan and Ruffman (2004): correlation						S-Stories*/ ToM stories	S-Stories*/ ToM stories		Cartoons task**
Verdon et al. (2007): regression		S-Stories**		S-Stories**					
Wang and Su (2013): correlation		S-Stories		S-Stories					
Youmans and Bourgeois (2010): correlation				1 st and 2 nd FB**	1 st and 2 nd FB				1 st and 2 nd FB*
Zaitchik et al. (2004): correlation							1 st FB**		

Note: *German and Hehman (2006) did not provided the p -value but the result was significant. Significant correlation or regression at $^*p < .05$, at $^{**}p < .01$ and $^{***}p < .001$; EF: composite score or principal component analyses based on executive measures; cognitive profile: assessed with the MMSE (Folstein et al., 1975) in the Verdon et al. (2007) and Youmans and Bourgeois (2010) studies and assessed with the MDRS (Mattis, 1976) in the Laisney et al. (2013) study; EDD: Eye Direction Detection task (from Baron-Cohen et al., 1995); ET: Eyes test (from Baron-Cohen et al., 1997); R-ET: Revised Eyes test (from Baron-Cohen et al., 2001); DB: Deceptive Box task (from Perner et al., 1987); AR: Appearance-Reality task (from Flavell et al., 1983); S-Stories: Strange stories from Happé (1994); SB: Sandbox task (from Sommerville et al., 2013); Cartoons task: from Sarfati et al. (1997); FP: faux pas task (from Stone et al., 1998); 1st FB: first-order false belief task (from Wimmer & Perner, 1983); 2nd FB: second-order false belief task (from Perner & Wimmer, 1985); 1st and 2nd FB: combined in the Youmans and Bourgeois (2010) study; Tom's taste task: from Duval et al. (2011).

Likewise, although the Cavallini et al. (2013) study reports some strong correlations with inhibition and updating performance, the regression analyses failed to demonstrate any significant contribution of executive competences to ToM performance.

To explain these conflicting findings, it could be argued that the task used in the Cavallini et al. (2013) study (Happé's (1998) Strange stories) does not require particular inhibition and updating competences, contrary to first- and second-order false beliefs, which demonstrated strong involvement of executive competences (Bailey & Henry, 2008; Duval et al., 2011; Li et al., 2013). Indeed, in false belief tasks, one must first inhibit one's own point of view and then switch between one's own knowledge and the protagonist's knowledge in order to attribute the protagonist's false belief, which is not the case in Happé's (1994) Strange stories (for more details, see Leslie et al., 2005; Leslie & Polizzi, 1998). Strengthening this hypothesis, Le Bouc et al. (2012) used a first-order false belief paradigm specifically constructed to tease out inhibitory processes involved in attributing mental states, which distinguishes between two different patterns of errors: belief inference deficits and inhibition of self-perspective deficits. Only the latter error pattern strongly correlated with inhibitory processes. Conversely, for false belief paradigms, the Phillips et al. (2011) study found a strong involvement of updating competences but no effect of inhibitory processes in ToM performance. Albeit surprising, one possible explanation could be that within inhibition competences, different processes might be involved depending on the social nature, or not, of the stimuli used. For instance, Bailey and Henry (2008) found that their two inhibition measures, the Stroop task (Stroop, 1935) and the Hayling task (Burgess & Shallice, 1997), presented different involvement in ToM performance according to the ToM task stimuli. The score in the Stroop task was a better predictor in ToM performance with social stimuli, such as the eyes, and the score in the Hayling task was a better predictor in ToM performance with figurative stimuli, such as pictures in a false belief task (for a more detailed discussion concerning the involvement of different inhibitory processes, see also Phillips et al., 2011). Therefore, there is a need to better understand which particular cognitive processes are related to ToM performance depending on tasks used.

Another interesting statistical analysis worth mentioning is the analysis of covariance (ANCOVA: Cavallini et al., 2013; Maylor et al., 2002; Rakoczy et al., 2012; Slessor et al., 2007; Sullivan & Ruffman, 2004) performed in five of the studies reviewed. Except for the Cavallini et al. (2013) study, they point to a significant involvement of executive competences and processing speed (Rakoczy et al., 2012), vocabulary level (Maylor et al., 2002; Slessor et al., 2007) and reasoning abilities (Sullivan & Ruffman, 2004) in performance on different ToM stories by cancelling the age effect. In the Maylor et al. (2002) and Slessor et al. (2007) studies, the cancelling age effect of vocabulary level might also explain some discrepancies between studies mentioned above. Indeed, these results tend to demonstrate that vocabulary

level might have a ‘protective’ effect on ToM performance in aging when verbal ToM tasks are used. Using visual (static or dynamic) ToM tasks may thus lead to additional difficulties in ToM performance.

4. Discussion

The aim of this review was to examine recent literature focusing on the contribution of cognitive processes to ToM performance in aging and DAT. To answer our research questions, we conducted a systematic review.

4.1. *How is ToM assessed in aging and DAT?*

Concerning ToM assessment in adulthood, this systematic review revealed that ToM is mainly assessed with similar tasks presenting varying degrees of reasoning complexity in both target groups. Experimental paradigms used are generally inspired by those constructed to assess children, such as first- and second-order false beliefs. With the increasing interest in the literature in identifying contributions of particular cognitive processes in ToM performance, some of the studies reviewed used tasks especially constructed to tease out contributions of particular cognitive processes (Bailey & Henry, 2008; Bernstein et al., 2011; German & Hehman, 2006; Le Bouc et al., 2012; Maylor et al., 2002). For instance, in the German and Hehman (2006) study, to assess the effect of executive resources on reasoning about others’ mental states, the authors modified the end of the initial story, with mental state inferences in two different conditions (false or true belief) and with a control (physical) inference. This minimal pair design allows more reliable comparisons between control and experimental stories by reducing other factors that could influence performance in the two conditions. In most studies, control and experimental tasks are not so similar in either content or structure complexity, which could lead to difficulties in drawing conclusions concerning specific ToM deficits rather than broader cognitive deficits when lower performance is observed in ToM tasks.

4.2. *How does ToM performance evolve in aging and DAT?*

All of the studies reviewed pointed to a significant impairment in ToM performance in our three target groups, compared to their respective control groups. However, specific deficits depending on task complexity are difficult to highlight. Although complex tasks like second-order false beliefs seem to be systematically failed by target groups, lower level and mid-level task complexities did not present such an agreement. Most of the studies showed some significant difficulties in medium complex ToM tasks, such as ToM stories and first-order false beliefs, but other studies did not report such findings (Baglio et al., 2012; Gregory et al., 2002; Sullivan & Ruffman, 2004). Different factors could explain these conflicting results, such as the heterogeneity of the experimental paradigms used, the severity of cognitive deficits

in probable Alzheimer participants and the cognitive profile of healthy aged. As Happé’s princeps study mentioned (Happé et al., 1998), the latter must be carefully taken into account. Indeed, one study reviewed (Li et al., 2013) demonstrated that education level has a strong effect on ToM performance, with highly educated old adults performing as well as young subjects in a mid-level reasoning task. Finally, concerning the heterogeneity of the experimental paradigms used, the review found that for the same task (Happé’s Strange stories), similar results for both target groups were observed. The studies reviewed often adapted their tasks in different modality assessments and with different scorings for responses, which could explain the differences observed in the participants’ performance between studies.

4.3. *Do cognitive processes influence ToM performance in aging and DAT?*

First, our review offers some interesting data about the cognitive dimensions selected as being related to ToM performance, with a predominance of executive competences. Moreover, some studies hypothesized specific contributions of executive functions to ToM performance. For instance, according to current integrated models of ToM (Leslie et al., 2005; Leslie & Polizzi, 1998), Bailey and Henry (2008) suggested that to attribute others’ mental states, and especially false beliefs, one must first inhibit one’s own point of view. The significant correlations observed between inhibition and ToM performance (for instance, Bailey & Henry, 2008) and the total mediation of inhibition competences in ToM performance (Bailey & Henry, 2008; Li et al., 2013) may support these theoretical propositions. The review also found strong involvement with flexibility (for instance, Li et al., 2013) and updating (for instance, Phillips et al., 2011) in ToM ability, suggesting that the tasks used rely on different executive competences. However, not all studies reviewed reported such strong results (Bernstein et al., 2011; Cavallini et al., 2013). In the Cavallini et al. (2013) study, the authors suggested that these dissimilarities could be due the diversity of tasks used. Indeed, the review showed that depending on the task used (ToM stories or false-belief paradigms), different executive competences are preferentially involved, as inhibition for the false-belief paradigms (for instance, in the Bailey and Henry, 2008 and Le Bouc et al., 2012 studies). Concerning other cognitive dimensions, vocabulary and logical reasoning were also well represented in the studies reviewed. As ToM tasks are often in the verbal modality and as questions used to determine ToM ability require good abstraction skills in order to take the concrete elements of the story further, it would appear important to have good verbal and reasoning skills to complete the task correctly. As for inhibition, the significant correlation analyses (for instance, Charlton et al. 2009), the total mediation of reasoning skills in ToM performance (Charlton et al., 2009) and the strong effect of vocabulary and reasoning skills as a covariate (Maylor et al., 2002; Slessor et al., 2007; Sullivan & Ruffman, 2004) support these assumptions. Moreover, as our review

showed that vocabulary level might improve ToM performance in verbal tasks (Maylor et al., 2002; Slessor et al., 2007), the involvement of cognitive processes should be rigorously evaluated to also ensure that preserved competences are not due to the assessment modality of the task.

Processing speed is a competence which has an impact on numerous cognitive tasks (Salthouse, 1993, 1996) and seems to decrease in aging (Salthouse, 1996). Again, the strong correlation analyses and partial mediation in ToM performance identified by the review are some interesting findings in line with the assumption of a probable contribution of many different cognitive competences to ToM performance. Finally, for episodic memory competence, the review did not find any strong relationships with ToM performance. Memory performance was assessed in six of the studies reviewed but only two found significant correlations with ToM performance (Castelli et al., 2011; Duval et al., 2011). A possible explanation is that ToM tasks rely more on short-term memory and working memory. Indeed, studies that manipulated paradigms with a memory or no-memory load condition found that for healthy aged participants, the task was failed more often when participants did not have any stimuli to refer to during the task (Maylor et al., 2002; Youmans & Bourgeois, 2010). Moreover, studies that assessed the *updating* component, which is the active part of working memory, found some strong relationships to and significant involvement in ToM performance (for instance, Cavallini et al., 2013). Another possible explanation for the lack of significant involvement of episodic memory could be that ToM performance relies on more autobiographical memory, as past experiences could guide inferential processes about others' mental states (for a recent review, see Moreau, Viallet, & Champagne-Lavau, 2013).

A last observation in the studies reviewed concerns performance in control tasks, with difficulties observed for both target groups (Duval et al., 2011; German & Hehman, 2006; Keightley et al., 2006; Le Bouc et al., 2012; Slessor et al., 2007; Verdon et al., 2007; Zaitchik et al., 2004). A recent meta-analysis by Henry, Phillips, Ruffman, and Bailey (2013) on ToM performance in aging nevertheless showed that the effect of aging in ToM tasks is greater than in control tasks. However, this study did not take into account relationships between cognitive processes and ToM performance and did not provide evidence that ToM impairments in aging were not due to primary cognitive deficits. Furthermore, as the present review also found that performance in control tasks correlated with various cognitive processes, determining a specific ToM deficit when comparing performance on ToM and control tasks becomes difficult, as any deficits could be due to the particular demand of cognitive processes rather than a specific deficit in attributing mental states.

To conclude, we used a systematic review method in order to maximize the representativeness of publications on ToM performance in aging and DAT. However, our review has some limitations of. A first limitation concerns the methodology used. Our review was clearly not exhaustive as we predefined some databases, search keywords and exclusion/inclusion criteria for publication

selection (Bambra, 2011). A second limitation concerns the categorization of tasks by degree of complexity in Section 3. In the studies reviewed, the cognitive complexity of ToM tasks is not always clearly presented. Although the categorization was done according to theoretical frameworks or depending on study classification, there is still potential subjectivity bias in categorization decisions. Another limitation in Section 3 concerns the diversity of the methods used in the studies reviewed (such as task properties, variety of scoring system, sample size and characteristics of the population assessed), which could bias our interpretation of the findings. More particularly and as mentioned above, not all studies provided detailed information about their matched control tasks, which is crucial to ensure that the difficulties observed are caused by ToM deficits rather than more cognitive deficits. Taken together, these limitations lead to provisional conclusions concerning the difficulties observed in ToM performance in aging and Alzheimer type dementia.

Nevertheless, on the basis of the publications retained, the present review concludes that healthy aged and probable Alzheimer participants' decline in ToM abilities seems to be preferentially explained by primary cognitive/executive deficits rather than a specific ToM impairment. More precisely, according to current integrated models of ToM (Leslie et al., 2005; Leslie & Polizzi, 1998; Stone & Gerrans, 2006) proposing interactions between a specialized representational module of social actions and more general executive selection processes (such as inhibitory processes), we found no strong evidence for a specific deficit in reasoning about social agents (ToM tasks) more than about physical causality (control tasks), especially on the basis of studies that explicitly assessed contributions of executive selection processes compared to specialized representational resources (Bailey & Henry, 2008; German & Hehman, 2006). There is however a need to further investigate the role of executive selection processes in Alzheimer type dementia. Indeed, the present review contained few studies (only five specifically assessing DAT vs. fourteen for healthy aging) and only one study (Verdon et al., 2007) performed regression analyses to determine the contribution of the global cognitive profile, assessed with the MMSE (Folstein, Folstein, & McHugh, 1975), in ToM performance. Although the latter study found a significant involvement, the Castelli et al. (2011) study did not find any relationship between MMSE scores and ToM performance. The present review clearly does not provide enough data to draw conclusions regarding a specific ToM impairment in Alzheimer type dementia compared to healthy aging. However, it is important to note that in the Le Bouc et al. (2012) study, probable Alzheimer participants showed a different pattern of deficits than participants with frontotemporal dementia in a first-order false belief task, with more reasoning-type than inhibition-type errors in attributing false beliefs. Thus, distinguishing the different processes involved in inferential reasoning about others' mental states could be an interesting approach that would improve our comprehension of the specificity on ToM impairment in Alzheimer type dementia and could

also account for the limited results found with our classification by levels of the task reasoning complexity. To address current theoretical debates and take into account recent data, future research on ToM performance in aging and Alzheimer type dementia should provide tasks that distinguish better between the contributions of both specific and shared competences involved in ToM task achievement with carefully matched control tasks. Furthermore, as our review highlighted the strong involvement of cognitive processes in current ToM tasks, it could be especially interesting to develop more ecological tasks to assess ToM performance in aging and Alzheimer type dementia. Indeed, tasks reviewed assess participants' ToM reception abilities, which are highly dependent on their abstract and reasoning competences, but social interactions take place in a particular context, with many sources of information that could contribute to social inferences about others' intentions or beliefs (for instance, stored information about the other or immediate perceptual information of the interaction context) (Achim, Guitton, Jackson, Boutin, & Monetta, 2013). Taken together, this could also lead to new assessment tools in clinical practice, in designing more ecological tasks, reproducing real constraints in social interaction and thus having more predictive value for everyday living skills.

Funding

This study was supported by the Swiss National Science Foundation [grant number 140269 to M. Fossard] and by the Faculté des Lettres et Sciences Humaines, Université de Neuchâtel (to M. Sandoz).

References

- Achim, A.M., Guitton, M., Jackson, P.L., Boutin, A., & Monetta, L. (2013). On what ground do we mentalize? Characteristics of current tasks and sources of information that contribute to mentalizing judgments. *Psychological Assessment, 25*(1), 117–126.
- Apperly, I.A., Samson, D., & Humphreys, G.W. (2005). Domain-specificity and theory of mind: Evaluating neuropsychological evidence. *Trends in Cognitive Sciences, 9* (12), 572–577.
- Baglio, F., Castelli, I., Alberoni, M., Blasi, V., Griffanti, L., Falini, A., ... Marchetti, A. (2012). Theory of mind in amnesic mild cognitive impairment: An fMRI study. *Journal of Alzheimer's Disease, 29*, 25–37.
- Bailey, P.E., & Henry, J.D. (2008). Growing less empathic with age: Disinhibition of the self-perspective. *Journal of Gerontology: Psychological Sciences, 63B*(4), 219–226.
- Bambra, C. (2011). Real world reviews: A beginner's guide to understanding systematic reviews of public health policy interventions. *Journal of Epidemiology and Community Health, 65*(1), 14–19.
- Baron-Cohen, S. (1995). *Mindblindness: An essay on autism and theory of mind*. London: MIT Press.
- Baron-Cohen, S., Campbell, R., Karmiloff-Smith, A., Grant, J., & Walker, J. (1995). Are children with autism blind to the mentalistic significance of the eyes? *British Journal of Developmental Psychology, 13*, 379–398.
- Baron-Cohen, S., Jolliffe, T., Mortimore, C., & Robertson, M. (1997). Another advanced test of theory of mind: Evidence from very high functioning adults with autism or Asperger syndrome. *Journal of Child Psychology and Psychiatry, 38*(7), 813–822.
- Baron-Cohen, S., Wheelwright, S., Hill, J., Raste, Y., & Plumb, I. (2001). The 'Reading in the Eyes' test revised version: A study with normal adults, and adults with Asperger syndrome or high-functioning autism. *Journal of Child Psychology and Psychiatry, 42*(2), 241–251.
- Belleville, S., Rouleau, N., & Van der Linden, M. (2006). Use of Hayling task to measure inhibition of prepotent responses in normal aging and Alzheimer's disease. *Brain and Cognition, 62*, 113–119.
- Bernstein, D.M., Thornton, W.L., & Sommerville, J.A. (2011). Theory of mind through the ages: Older and middle-aged adults exhibit more errors than do younger adults on a continuous false belief task. *Experimental Aging Research, 37*, 481–502.
- Burgess, P.W., & Shallice, T. (1997). *The Hayling and Brixton tests*. London: Harcourt Assessment.
- Carlson, S.M., & Moses, L.J. (2001). Individual differences in inhibitory control and children's theory of mind. *Child Development, 72*, 1032–1053.
- Carlson, S.M., Moses, L.J., & Claxton, L.J. (2004). Individual differences in executive functioning and theory of mind: An investigation of inhibitory control and planning ability. *Journal of Experimental Child Psychology, 87*, 299–319.
- Castelli, I., Baglio, F., Blasi, V., Alberoni, M., Falini, A., Liverta-Sempio, O., ... Marchetti, A. (2010). Effects of aging on mindreading ability through the eyes: An fMRI study. *Neuropsychologia, 48*(9), 2586–2594.
- Castelli, I., Pini, A., Alberoni, M., Liverta-Sempio, O., Baglio, F., Massaro, D., ... Nemmi, R. (2011). Mapping levels of theory of mind in Alzheimer's disease: A preliminary study. *Aging & Mental Health, 15*(2), 157–168.
- Cavallini, E., Lecce, S., Bottiroli, S., Palladino, P., & Pagnin, A. (2013). Beyond false belief: Theory of mind in young, young-old, and old-old adults. *International Journal of Aging and Human Development, 76*(3), 181–198.
- Charlton, R.A., Barrick, T.R., Markus, H.S., & Morris, R.G. (2009). Theory of mind associations with other cognitive functions and brain imaging in normal aging. *Psychology and Aging, 24*(2), 338–348.
- de Villiers, J.G., & Pyers, J.E. (2002). Complements to cognition: A longitudinal study of the relationship between complex syntax and false-belief understanding. *Cognitive Development, 17*, 1037–1060.
- Duval, C., Piolino, P., Bejanin, A., Eustache, F., & Desgranges, B. (2011). Age effects on different components of theory of mind. *Consciousness and Cognition, 20*(3), 627–642.
- Fernandez-Duque, D., Baird, J.A., & Black, S.E. (2009). False-belief understanding in frontotemporal dementia and Alzheimer's disease. *Journal of Clinical and Experimental Neuropsychology, 31*(4), 489–497.
- Fisk, J.E., & Sharp, C.A. (2004). Age-related impairment in executive functioning: Updating, inhibition, shifting, and access. *Journal of Clinical and Experimental Neuropsychology, 26*(7), 874–890.
- Flavell, J.H., Flavell, E.R., & Grenn, F.L. (1983). Development of the appearance-reality distinction. *Cognitive Psychology, 15*(1), 95–120.
- Folstein, M.F., Folstein, S.E., & McHugh, P.R. (1975). 'Mini-Mental State': A practical method for grading the cognitive state of patients for the clinician. *Journal of Psychiatric Research, 12*, 189–198.
- German, T.P., & Hehman, J.A. (2006). Representational and executive selection resources in 'theory of mind': Evidence from compromised belief-desire reasoning in old age. *Cognition, 101*, 129–152.
- Gerrans, P. (2003). The theory of mind module in evolutionary psychology. *Biology & Philosophy, 17*, 305–321.
- Gregory, C., Lough, S., Stone, V., Erzinclioglu, S., Martin, L., Baron-Cohen, S., & Hodges, J.R. (2002). Theory of mind in

- patients with frontal variant frontotemporal dementia and Alzheimer's disease: Theoretical and practical implications. *Brain*, *125*, 752–764.
- Happé, F.G.E. (1994). An advanced test of theory of mind: Understanding of story characters' thoughts and feelings by able autistic, mentally handicapped and normal children and adults. *Journal of Autism and Developmental Disorders*, *24*, 129–154.
- Happé, F.G.E., Winner, E., & Brownell, H. (1998). The getting of wisdom: Theory of mind in old age. *Developmental Psychology*, *34*(2), 358–362.
- Henry, J.D., Phillips, L.H., Ruffman, T., & Bailey, P.E. (2013). A meta-analytic review of age differences in theory of mind. *Psychology and Aging*, *28*(3), 826–839.
- Henry, J.D., Rendell, P.G., Scicluna, A., Jackson, M., & Phillips, L.H. (2009). Emotion experience, expression and regulation in Alzheimer's disease. *Psychology and Aging*, *24*(1), 252–257.
- Keightley, M.L., Winocur, G., Burioanova, H., Hongwanishkul, D., & Grady, C.L. (2006). Age effects on social cognition: Faces tell a different story. *Psychology and Aging*, *21*(3), 558–572.
- Kemp, J., Després, O., Sellal, F., & Dufour, A. (2012). Theory of mind in normal ageing and neurodegenerative pathologies. *Ageing Research Reviews*, *11*, 199–219.
- Kipps, C.M., & Hodges, J.R. (2006). Theory of mind in frontotemporal dementia. *Social Neurosciences*, *1*(3–4), 235–244.
- Laisney, M., Bon, L., Guiziou, C., Daluzeau, N., Eustache, F., & Desgranges, B. (2013). Cognitive and affective Theory of Mind in mild to moderate Alzheimer's disease. *Journal of Neuropsychology*, *7*, 107–120.
- Le Bouc, R., Lenfant, P., Delbeuck, X., Ravasi, L., Lebert, F., Semah, F., & Pasquier, F. (2012). My belief or yours? Differential theory of mind deficits in frontotemporal dementia and Alzheimer's disease. *Brain*, *135*, 3026–3038.
- Leslie, A.M., Friedman, O., & German, T.P. (2004). Core mechanisms in 'theory of mind'. *Trends in Cognitive Sciences*, *8*, 528–533.
- Leslie, A.M., German, T.P., & Polizzi, P. (2005). Belief-desire reasoning as a process of selection. *Cognitive Psychology*, *50*(1), 45–85.
- Leslie, A., & Polizzi, P. (1998). Inhibitory processing in the false-belief task: Two conjectures. *Developmental Science*, *1*, 981–991.
- Li, X., Wang, K., Wang, F., Tao, Q., Xie, Y., & Cheng, Q. (2013). Aging and theory of mind: The influence of educational level and cognitive processing. *International Journal of Psychology*, *48*(4), 715–727.
- Lohmann, H., & Tomasello, M. (2003). The role of language in the development of false belief understanding: A training study. *Child Development*, *74*(4), 1130–1144.
- Mattis, S. (1976). Mental status examination for organic mental syndrome in the elderly patient. In L. Bellack & T. Katasu (Eds.), *Geriatric psychiatry: A handbook for psychiatrists and primary care physicians* (pp. 77–120). New York, NY: Grune and Stratton.
- Maylor, E.A., Moulson, J.M., Muncer, A.M., & Taylor, L.A. (2002). Does performance on theory of mind tasks decline in old age? *British Journal of Psychology*, *93*, 465–485.
- McKinnon, M.C., & Moscovitch, M. (2007). Domain-general contributions to social reasoning: Theory of mind and deontic reasoning re-explored. *Cognition*, *102*, 179–218.
- Miller, S.A. (2009). Children's understanding of second-order mental states. *Psychological Bulletin*, *135*(5), 749–773.
- Moran, M. (2013). Lifespan development: The effects of typical aging on theory of mind. *Behavioural Brain Research*, *237*, 32–40.
- Moreau, N., Viallet, F., & Champagne-Lavau, M. (2013). Using memories to understand others: The role of episodic memory in theory of mind impairment in Alzheimer disease. *Ageing Research Reviews*, *12*, 833–839.
- Onishi, K.H., & Baillargeon, R. (2005). Do 15-month-old infants understand false beliefs? *Science*, *308*(8), 255–258.
- Pardini, M., & Nichelli, P.F. (2009). Age-related decline in mentalizing skills across adult life span. *Experimental Aging Research*, *35*, 98–106.
- Perner, J., Leekam, S.R., & Wimmer, H. (1987). Three-year olds' difficulty with false belief: The case for a conceptual deficit. *British Journal of Developmental Psychology*, *5*, 125–137.
- Perner, J., & Wimmer, H. (1985). 'John thinks that Mary thinks that...': Attribution of second-order beliefs by five- to 10-year-old children. *Journal of Experimental Child Psychology*, *39*, 437–471.
- Petticrew, M., & Roberts, H. (2006). *Systematic reviews in the social sciences: A practical guide*. Oxford: Blackwell.
- Phillips, L.H., Bull, R., Allen, R., Inch, P., Burr, K., & Ogg, W. (2011). Lifespan aging and belief reasoning: Influences of executive function and social cue decoding. *Cognition*, *120*, 236–247.
- Phillips, L.H., Scott, C., Henry, J.D., Mowat, D., & Bell, S. (2010). Emotion perception in Alzheimer's disease and mood disorder in old age. *Psychology and Aging*, *25*(1), 38–47.
- Poletti, M., Enrici, I., & Adenzato, M. (2012). Cognitive and affective theory of mind in neurodegenerative diseases: Neuropsychological, neuroanatomical and neurochemical levels. *Neurosciences and Biobehavioral Reviews*, *36*, 2147–2164.
- Premack, D.G., & Woodruff, G. (1978). Does the chimpanzee have a theory of mind? *Behavioral and Brain Sciences*, *1*, 515–526.
- Rakoczy, H., Harder-Kasten, A., & Sturm, L. (2012). The decline in theory of mind in old age is (partly) mediated by developmental changes in domain-general abilities. *British Journal of Psychology*, *103*, 58–72.
- Salthouse, T.A. (1993). Speed and knowledge as determinants of adult age differences in verbal tasks. *Journal of Gerontology: Psychological Sciences*, *48*, 29–36.
- Salthouse, T.A. (1996). The processing-speed theory of adult age differences in cognition. *Psychological Review*, *103*, 403–428.
- Sarfati, Y., Hardy-Baylé, M.C., Besche, C., & Widlöcher, D. (1997). Attribution of intentions to others in people with schizophrenia: A non-verbal exploration with comic strips. *Schizophrenia Research*, *25*(3), 199–209.
- Slessor, G., Phillips, L.H., & Bull, R. (2007). Exploring the specificity of age-related differences in theory of mind tasks. *Psychology and Aging*, *22*(3), 639–643.
- Sommerville, J.A., Bernstein, D.M., & Meltzoff, A.N. (2013). Measuring false belief in centimeters: Private knowledge biases preschoolers' and adults' representation of others' beliefs. *Child Development*, *84*(6), 1846–1854.
- Stone, V.E., & Gerrans, P. (2006). What's domain-specific about theory of mind? *Social Neuroscience*, *1*(3–4), 309–319.
- Stone, V.E., Baron-Cohen, S., & Knight, R.T. (1998). Frontal lobe contributions to theory of mind. *Journal of Cognitive Neuroscience*, *10*, 640–656.
- Stroop, J.R. (1935). Studies on interference in serial verbal reactions. *Journal of Experimental Psychology*, *18*(6), 643–662.
- Sullivan, S., & Ruffman, T. (2004). Social understanding: How does it fare with advancing years? *British Journal of Psychology*, *95*, 1–18.
- Surian, L., Caldi, S., & Sperber, D. (2007). Attribution of beliefs by 13-month-old infants. *Psychological Science*, *18*(7), 580–586.
- Verdon, C.M., Fossati, P., Verny, M., Dieudonné, B., Teillet, L., & Nadel, J. (2007). Social cognition: An early impairment in dementia of the Alzheimer type. *Alzheimer Disease and Associated Disorders*, *21*(1), 25–30.
- Wang, Z., & Su, Y. (2013). Age-related differences in the performance of theory of mind in older adults: A dissociation of

- cognitive and affective components. *Psychology and Aging*, 28(1), 284–291.
- Weintraub, S., Wicklund, A.H., & Salmon, D.P. (2012). The neuropsychology profile of Alzheimer disease. *Cold Spring Harbor Perspectives in Medicine*, 2, a006171.
- Wimmer, H., & Perner, J. (1983). Beliefs about beliefs: Representation and constraining functions of wrong beliefs in young children's understanding of deception. *Cognition*, 13, 103–128.
- Youmans, G., & Bourgeois, M. (2010). Theory of mind in individuals with Alzheimer-type dementia. *Aphasiology*, 24(4), 515–534.
- Zaitchik, D., Koff, E., Brownell, H., Winner, E., & Albert, M. (2004). Inference of mental states in patients with Alzheimer's disease. *Cognitive Neuropsychiatry*, 9(4), 301–313.
- Zaitchik, D., Koff, E., Brownell, H., Winner, E., & Albert, M. (2006). Inference of beliefs and emotions in patients with Alzheimer's disease. *Neuropsychology*, 20(1), 11–20.