Theory of Mind in aging: Comparing cognitive and affective components in the faux pas test

Sara Bottiroli[a]*, PhD; Elena Cavallini[b], PhD; Irene Ceccato[b], Tomaso Vecchi[2 a], PhD, and Serena Lecce[b], PhD

[a]*National Neurological Institute C. Mondino, Pavia, Italy;*

[b]*Department of Brain and Behavioral Sciences, University of Pavia, Italy*

*Corresponding author at: Department of Brain and Behavioral Sciences, University of Pavia, P.zza Botta 6, 27100 Pavia, Italy. Tel.: +390382986273

E-mail address: sara.bottiroli@unipv.it (S. Bottiroli).

This paper is not the copy of record and may not exactly replicate the final, authoritative version of the article. The final article is available at: https://doi.org/10.1016/j.archger.2015.09.009

Abstract

Objectives: Theory of Mind (ToM) is a complex human ability that allows people to make inferences on others' mental states such as beliefs, emotions and desires. Previous studies on ToM in normal aging have provided heterogeneous findings. In the present study we examined whether a mixed calculation of different aspects of ToM may have contributed to these conflicting results. We had two aims. First, we explored the age-related changes in the performance of cognitive vs. affective ToM. Second, we investigated the extent to which the effect of aging on cognitive vs. affective ToM is mediated by age-related differences in executive functions.

Method: To address these issues three age groups (young, young-old, and old-old adults) were compared on cognitive and affective ToM using the faux pas test. In addition, participants were tested using a battery of executive function tasks tapping on inhibition, updating, working memory, and word fluency.

Results: The analyses indicated that young adults outperform both young-old and old-old adults on cognitive ToM but not on affective ToM. Correlations showed that, whereas cognitive ToM was significantly associated with age, working memory, updating, and inhibition, affective ToM was not. Finally, analyses revealed that individual differences in working memory and updating (but not inhibition) mediated the effect of age on cognitive ToM.

Conclusion: Our findings support the view of a selective age-related differences on cognitive, but not affective, ToM in normal aging. The distinction between the two ToM components is further supported by a dissociable pattern of correlations with executive functions.

Keywords: Theory of Mind; Cognitive and affective components; aging; executive functions.

1. Introduction

Theory of Mind (ToM) allows people to explain others' behavior on the basis of their mental states (Premack & Woodruff, 1978) and has significant consequences for social interactions (Paal & Bereczkey, 2007).

Recently, interest in ToM research has shifted towards the analysis of changes associated with normal aging. Existing studies on this topic have provided conflicting results. In the first study on this issue, Happé, Winner, and Brownell (1998) reported an improvement in ToM in older adults that makes them speculating on increasing wisdom in old age. Subsequent research did not support such a view as it showed either age-related differences (e.g., Charlton, Barrick, Markus, & Morris, 2009; Castelli et al., 2010; Cavallini, Lecce, Bottiroli, Palladino, & Pagnin, 2013; Maylor, Moulson, Muncer, and Taylor, 2002) or no age differences (e.g., Keightley, Winocur, Burianova, Hongwanishkul, & Grady, 2006; MacPherson, Phillips, & Dalla Sala, 2002; Saltzman, Strauss, Hunter, & Archibald, 2000) in ToM.

In the present study we address this topic taking as our premise that ToM is a multicomponential ability, made up of several components and processes (Amodio & Frith, 2006) that may be differentiated. We argue that inconsistent findings in existing aging studies can be explained by a mixed calculation of different aspects of ToM.

Following the framework of Shamay-Tsoory, Harari, Aharon-Peretz, and Levkovitz, (2010), we focused on the distinction between cognitive and affective ToM. Cognitive ToM is the ability to make inferences on others' thoughts and beliefs, whereas affective ToM is the individual's ability to make inferences on emotions and feelings (Shamay-Tsoory, Tibi-Elhananyab, & Aharon-Peretz, 2006). Support for a distinction between cognitive and affective ToM comes from developmental and clinical studies. For example, experimental evidence (Repacholi & Gopnik, 1997; Rieffe, Terwogt, Koops, Stegge, & Oomen, 2001;

Wellman, Cross, & Watson, 2001) showed that children succeed on tests of affective ToM prior than on those of cognitive ToM, highlighting a different developmental timing between these two components (e.g., Baron-Cohen, O'Riordan, Stone, Jones, & Plaisted, 1999; Perner & Wimmer, 1985). In addition, observational findings suggest that children's understanding of thoughts and feelings have distinct antecedents, correlates and sequels (Cutting & Dunn, 1999; Dunn, 2005; McElwain & Volling, 2002). Hence, these data suggest that affective and cognitive ToM may well be distinct aspects of ToM. To support such a view, clinical studies on adults reported that the impairment in ToM can be selective (e.g., Shamay-Tsoory, Tomer, Berger, Goldsher, & Aharon-Peretz, 2005; Shamay-Tsoory et al., 2006; Shamay-Tsoory & Aharon- Peretz, 2007; Van Overwalle, 2009). For example, patients with Alzheimer's and Parkinson's disease seem to be able to infer other people's emotions and pass affective ToM tasks (Euteneuer et al., 2009; Fernandez-Duque, Hodges, Baird, & Black, 2010; Gregory et al., 2002; Mimura, Oeda, & Kawamura, 2006; Modinos Obiols, Pousa, & Vicens, 2009; Roca et al., 2010) as accurately as healthy elderly, whereas they show difficulties with 2nd-order-false-beliefs tasks (Fernandez-Duque, Baird, & Black.,2009; Gregory et al., 2002; Monetta , Grindrod, & Pell, 2009). Altogether these considerations make it crucial to adopt a cognitive-affective distinction when studying ToM in aging.

1.1. Effect of aging on the cognitive and affective ToM components

To date, the majority of aging studies on ToM has considered either the cognitive *or* the affective components (e.g., German & Hehman, 2006; Mahy et al., 2014; McKinnon & Moscovitch, 2007; Slessor, Phillips, & Bull, 2007). Except for the pioneering study in this area by Happe et al. (1998), data on cognitive ToM are usually congruent in showing age-related differences. Many authors (Cavallini et al., 2013; Charlton et al., 2009; Maylor et al., 2002; Sullivan & Ruffman, 2004) found evidence for ToM impairment in aging using stories (i.e., Strange Stories task) involving complex psychological affairs such as double bluff, irony, mistakes, etc.. Studies using other 2nd-order false belief tasks (e.g., Bernstein, Thornton, & Sommerville, 2011; Phillips et al., 2011) come to similar conclusions. The only cases attesting no age differences in cognitive ToM are those where participants have to take only one character's perspective (i.e., 1st-order false beliefs) into account (McKinnon & Moscovitch, 2007; Slessor et al., 2007). Overall, then, existing studies entail us to expect a decline in cognitive ToM skills.

Literature examining age-related changes in affective ToM has yielded more mixed findings. Some studies showed a preservation of this ability in aging (Castelli et al., 2010; Fischer, Nyberg, & Backman, 2010; Keightley et al., 2006; MacPherson et al., 2002; Phillips, MacLean, & Allen, 2002). For instance, Phillips et al. (2002) found no age effects in the ability of decoding emotions from narratives. More recently, Keightley et al. (2006) showed that older adults were as accurate as younger adults in identifying the emotional valence (i.e., positive, negative, or neutral) of words and facial expressions. However, other studies (for a review Henry, Phillips, Ruffman, & Bailey, 2013) reported that older adults were impaired in inferring others' emotions (Mahy et al., 2014; McKinnon & Moscovitch, 2007; Pardini & Nichelli, 2009; Slessor et al., 2007; Sullivan & Ruffman, 2004), especially when they were asked to decode complex emotions (for a review see Ruffman, Henry, Livingstone, & Phillips, 2008).

A clearer pattern of the effects of aging on cognitive vs. affective ToM may be derived from those studies – which were, to our knowledge, only four (Duval, Piolino, Bejanin, Eustache, & Desgranges, 2011; Li et al., 2013; Rakoczy, Harder-Kasten, & Sturm, 2012; Wang & Su, 2013) – that considered both ToM components. Unfortunately, this is not the case, given they provided inconsistent findings. Duval et al. (2011) and Rakoczy et al. (2012) found that both cognitive and affective ToM (especially when complex emotions were concerned) were equally affected by aging. Instead, Wang and Su (2013) and Li et al. (2013) reported that older adults performed worse than younger people in the cognitive but not in the affective component. Li et al. also found age-related differences in the faux pas test, which were limited to those low-educated older adults. Albeit these studies are interesting as they allow us to make a comparison between older adults' ability to reason about cognitions vs. emotions, they all measured cognitive and affective ToM by using different tasks, with different types of stimuli and modality. In particular, they mostly differed in the way they assessed the affective ToM component. Duval et al. and Li et al. used the same visual ToM task, the Reading the Mind in the Eyes Test. However, many differences could be identified between these two studies: (a) the former distinguished between basic and complex emotions, whereas the latter considered a global affective performance; (b) the former compared three age groups (young, middle-aged and older adults), whereas the latter only two (young and older adults, distinguishing between low or high education levels). Also Rakoczy et al. used a visual task – i.e., the Video task – with young and older adults. By contrast, Wang and Su preferred verbal materials, comparing the ability of young, young-old and old-old adults in making inferences on characters' feelings by using a series of verbal stories. As cognitive ToM, these four studies resulted more similar, given they all used verbal false-belief stories, except for Duval and colleagues that used a visual-and-verbal version of this task. Finally, only Li et al. included a mixed cognitive and affective ToM task, which was the faux pas test. As evident, it is possible that the discrepancy between age-related changes in affective and cognitive ToM were due to methodological artifacts rather than to a selective impairment. In order to disentangle this issue, in the present study we adopted a rigorous approach and assessed cognitive and affective ToM using the same task (see section 2.2.4 below).

1.2. Cognitive correlates of cognitive and affective ToM components

A deep understanding on age-related changes in cognitive vs. affective ToM depends on having an insight into the explanatory mechanisms that may account for the age effect on ToM. One of such mechanisms concerns executive functions (EFs). EFs are cognitive processes playing a role in the conscious control of thoughts and actions (e.g., Zelazo, Carter, Reznick, & Frye, 1997). Considering EFs when examining age-related changes in ToM is crucial because EFs: a) are good predictors of ToM across the life span (Apperly, Samson, & Humphreys, 2009), and b) decline with aging (Salthouse, Atkinson, & Berish, 2003). Therefore, it is possible that the age-related changes in ToM reflect a decline in executive abilities underling ToM performance, rather than in mentalizing per se.

Here it is important to note that EF is a construct that encompasses several components, in particular, inhibitory control, updating of working memory, cognitive set shifting, and word fluency (Fisk & Sharp, 2004) and that these components are differently affected by the aging effects. For instance, Crawford, Luszcz, Obonsawin, & Stewart (2000) found age-related decline in inhibition, but not in verbal fluency, suggesting that control of interference was particularly vulnerable to increasing age. Others (e.g., Plumet, Gil, & Gaonac'h, 2005; Wecker, Kramer, Wisniewski, & Delis, 2000) found an age-related decline in inhibition and updating, but not in switching tasks that seem to be more resistant to the aging effect. Hence, these studies suggest that there are changes in executive function that may be selective for some and not other components and that the fractionation of executive function is necessary when studying aging effect on cognitive and socio-cognitive skills.

The great majority of studies focusing on cognitive ToM reported significant associations with executive functions, especially inhibition, working memory, and updating (Bailey & Henry, 2008; Bernstein et al., 2011; Cavallini et al., 2013; Charlton et al., 2009; German & Hehman, 2006; McKinnon & Moscovitch, 2007; Phillips et al., 2011; Uekermann, Channon, & Daum, 2006). As far as the associations between EFs and affective ToM are concerned, in contrast, the majority of studies found no significant correlations (Duval et al., 2011; Mahy et al., 2014; Keightley et al., 2006; Sullivan & Ruffman, 2004; Wang & Su, 2013), with only few exceptions (Bailey & Henry, 2008; Li et al., 2013; Rakoczy et al., 2012).

Said that, very few studies went beyond examining simple correlations between ToM and EFs components in order to explore the *role* of executive functioning in explaining age-related decline in ToM. In the present study, we addressed this issue using mediation analyses that allow us to establish "how" one variable (age) predicts an outcome variable (ToM) (see Baron & Kenny, 1986). In particular, we aimed at gauging the extent to which the effects of aging on different aspects of ToM were mediated by the effects of aging on executive functions. Overall, existing data on this issue showed that EFs accounted for the relation between age and ToM (Charlton et al., 2009; Duval et al., 2011; McKinnon & Moscovitch, 2007; Rakoczy et al., 2012). However, all these studies considered a global index of executive functioning obtained by summing scores on each individual EF task. Interestingly, when single EF components were considered, their specific involvement changed according to the ToM component considered. In particular, updating (Li et al., 2013; Phillips et al., 2011) and inhibition (Bailey & Henry, 2008; Li et al., 2013) resulted as those variables more able to mediate the relation between age and cognitive ToM. For instance, Li et al. (2013) found that the age differences in inhibition partially mediated the effects of age on the false belief stories, whereas other EFs – such as updating and shifting – did not. On the other hand, these same authors highlighted that the age-related differences in the faux pas test were fully mediated by both updating and inhibition. This suggests that the impairment in inferring mental states associated with aging could depend on changes in executive functioning and could vary according to ToM components. However, more research is needed to disentangle the role of executive functions on the age related changes of cognitive vs. affective ToM.

1.3. The present study

The present study was designed to investigate age-related changes in cognitive vs. affective ToM. In addressing this issue, we adopted a rigorous methodological approach and used a single task for assessing both ToM components: the faux pas test (Stone, Baron-Cohen, & Knight, 1998). The term *faux pas* describes a range of social gaffes. A faux pas occurs when someone says something that should not have been said (Gregory et al., 2002). We selected this task because it is an advanced ToM task that taps the understanding of multiple mental states (e.g., intentions, emotions, beliefs) in everyday social situations. More precisely, according to the framework of Shamay-Tsoory et al. (2010) and to previous research (Li et al., 2013), at least two mental-state representations are required for understanding a faux pas: a representation of cognitive states (*cognitive* ToM) of the character making the faux pas because he/she does not know that he/she should not have said it; and a representation of emotional states (*affective* ToM) of the character receiving the faux pas that will feel insulted or hurt (Stone, Baron-Cohen, Calder, Keane, & Young, 2003). Existing data collected using this task are promising as they showed that the faux pas was sensitive to individual differences and to age-related changes in aging (Halberstadt, Ruffman, Murray, Taumoepeau, & Ryan, 2011; Li et al., 2013; Wang & Su, 2006). However, none of these studies distinguished these two ToM components.

The second main aim of the present study was to explore the role of EFs in the association between ToM components and age. We focused on updating and inhibition, which were those EFs mostly involved in ToM functioning, as resulted from the previously reported literature (e.g., Bailey & Henry, 2008; Li et al., 2013; Phillips et al., 2011). It is plausible that the faux pas test is sensitive to individual differences in these two EFs because in order to understand a faux pas it is necessary to inhibit one's own dominant perspective or reality and update relevant information in working memory for each new scenario (Li et al., 2013).

Updating is the ability to flexibly and continuously monitor and modify the content of the working memory store with regard to current task requests (Carretti, Belacchi, & Cornoldi, 2010; Morris & Jones, 1990). To assess this ability, we used the Working Memory Updating task (Palladino, Cornoldi, De Beni, & Pazzaglia, 2001) for two reasons. First, this task requires selecting items on the basis of a criterion which was based on a relevance principle (i.e., item sizes), instead of on item recency (i.e., remember the last items). Thus, it represents a clear measure of the process of updating information in working memory, rather than the simple recall of the last information presented (e.g. Conway et al., 2005). Second, this task allows us to estimate the specific impact of working memory – varying the number of items to-be-remembered – and inhibition – varying the number of updates required – involved in updating information. This is very important, considering that updating is not a unitary process and that the mechanisms involved depend on the kind of task used.

Inhibition is the ability to deliberately suppress pre-potent, but currently irrelevant responses (Friedman & Miyake, 2004). We used the Hayling Sentence Completation task (Borella, Carretti, Cornoldi, & De Beni, 2007), which is a verbal test measuring the ability to inhibit predominant and automatic responses yielded by the high-cloze sentences in order to produce a word that gives no sense to the sentence. This task is sensitive to differences between young and older adults (e.g., Belleville, Rouleau, & van der Linden, 2006), as well as between control and Alzheimer disease patients (Belleville et al., 2006; Collette, Van der Linden, & Salmon, 1999). Moreover, the ability to inhibit predominant responses in the

Hayling task has been shown to be related to frontal lobe integrity (Burgess & Shallice, 1997).

We predicted that the cognitive and the affective ToM components were differently affected by aging, with a more pronounced decline in the former than in the latter. Furthermore, we also expected a different pattern of relation between EFs and cognitive vs. affective ToM. Specifically, we hypothesized that EFs might be involved in explaining age-related decrease in cognitive, but not in affective, ToM.

2. Methods

2.1. Participants

The recruited sample was composed of 20 young adults (age range = 19 to 27), 22 young-old adults (age range = 60 to 70) and 20 old-old adults (age range = 71 to 82). Young adults were undergraduates who completed the study in exchange for course credits. The young-old and old-old participants were volunteers. They all lived independently, were reasonably fit and healthy, and had active social and cognitive lives. They were members of the University of the Third Age of Pavia (located in northern Italy) where they took part in several cultural activities (i.e., classes, conferences, etc.). Italian was the first language of all participants in the study. For both groups of older adults, a first screening was made using the Mini-Mental State Examination (MMSE; Folstein, Folstein, & McHugh, 1975). Furthermore, participants were screened via a demographic questionnaire to ensure that there was no history of psychiatric and neurological illness or substance abuse. None of the older participants exhibited signs of dementia or had such problems. The participants' demographic characteristics are reported in Table 1.

2.2. Materials and procedure

Participants were tested individually during a 2-hrs session in which they completed a demographic questionnaire, the Mini Mental State Examination (Folstein et al., 1975), and a battery of tests assessing inhibition, working memory updating, and verbal ability, and the faux pas test. Except for the MMSE, being administered at the beginning of each evaluation, the presentation order of the other tests was counterbalanced across participants.

2.2.1. Verbal ability

Given that we used a verbal ToM task in which participants have to verbalize an answer, two measures of verbal ability were used, both taken from the Primary Mental Abilities test (PMA) (Thurstone & Thurstone, 1963): the Vocabulary and the Word Fluency subtests. The Vocabulary subtest was a 50-item measure that requires participants to identify the synonym of a target word within a span of eight minutes. The total score ranged between 0 and 50. The Word Fluency subtest requires participants to generate as many words as possible, according to a lexical rule (i.e., words beginning with “s”) during a span of five minutes.

2.2.2. Inhibition

Inhibition was evaluated using the Hayling Sentence Completion Test (Borella et al., 2007; adapted from Burgess & Shallice, 1997). The test comprised two sections (Part A and Part B), in each of which participants were presented with 14 sentences with the last word missing (e.g., The dog sleeps in the...). In Part A they were asked to complete it with an expected word. In Part B they were asked to complete the sentence with a word providing no meaning to the sentence but fitting it grammatically.

According to Borella et al., (2007), an inhibitory index, based on the differences between correct completions in the inhibition and initiation phases, was calculated as follows: correct completions (i.e., expected words) in Part A – correct completions (i.e., unrelated words) in Part B. Thus, a higher score implies a higher difficulty in producing the unexpected word in the inhibition condition. The total score ranged between -14 and 14.

2.2.3. Updating

Updating was measured by the Working Memory Updating task (Palladino, et al., 2001; adapted from Morris & Jones, 1990). Participants were presented with four trials, each consisting of six lists of 12 words, for a total of 24 lists. The lists were divided into four categories (low and high maintenance combined with low and high suppression) according to the number of items to be remembered (high or low maintenance demands in loading) and to the number of relevant items to be updated (high or low suppression demands). In the high maintenance condition (HM), there were five items to be remembered, whereas they were three in the low maintenance (LM) one. In the case of high suppression condition (HS), there were five relevant but not-target items, whereas they were two in the low suppression condition (LS). Abstract words were introduced in order to maintain invariable the list length of 12 words. An example of high maintenance and low suppression (HMLS) list (with 2 abstract entities and 5 items to be remembered) was the following: ascensore (lift), televisione (television), scarpa (shoe), energia (energy), lavastoviglie (dishwasher), telefono (phone), orologio (watch), accordo (agreement), tram (tram), borsetta (handbag), portacenere (ashtray) and stufa (stove). The instructions emphasized that participants were presented with lists including filler abstract items and concrete items, the size of which had to be considered. Participants were requested to remember only the five (for the two high maintenance trials) or the three (for the two low maintenance trials) smallest items among the concrete items comprised in each list. The words were presented orally using a tape recorder, at the rate of one word per second. Each participant was tested individually and gave a verbal response after each list. Participants were assigned a global score reflecting the total number of correctly reproduced words among the four trials (global updating score, ranging from 0 to 96) as well as four sub-components scores reflecting scores in each of the four trials (score range from 0 to 30 for both HMLS and HMHS trials; score range from 0 to 18 for both LMLS and LMHS trials).

Besides considering the global updating score, also the four sub-scores are interesting, given that they reflect the ability of updating information in conditions with different demands in term of working memory (high and low maintenance trials) and inhibition (high and low suppression trials).

2.2.4. Faux pas test

The Italian version of the faux pas test was used (adapted from Stone et al., 1998 by Liverta Sempio, Marchetti, & Lecciso, 2005). Participants were asked to silently read a series of 7 short stories containing a faux pas. In order to avoid a YES-bias response, 7 control stories that did not contain a faux pas were also administered. Faux pas stories and control stories were presented in mixed order. Participants had no time limit and they were allowed to read the stories as many times as necessary in order to fully understand them. An example of faux pas story with corresponding scoring criteria is given in the Appendix.

Each story was followed by a series of questions: (1) detection question, (2) person identification question, (3) false belief question, and (4) affective question, as reported in the Appendix. The cognitive ToM component was assessed via the false belief question (question #3), which tested whether participants understood the false beliefs of who committed the faux pas. The affective ToM component was assessed via the affective question (question #4), which tested the emphatic understanding of how the person in the story would feel. Questions 2 to 4 were asked only if participant detected the faux pas, that is, answered Yes to the first question. If he or she said No, the experimenter skipped to the next story. One point was given for each correct answer, so that scores for each question/component of the faux pas stories ranged from 0 to 7.

The control stories were in the same format as the faux pas stories, but had a different scoring system. Two points were given for the first question; zero points for a wrong response. Thus, the total score for the first question ranged from 0 to 14.

The Faux pas test was given in the Italian version, which has good internal consistency (detection question $\alpha = .53$; person identification question $\alpha = .52$, false belief question $\alpha = .60$; affective question ToM $\alpha = .53$).

2.3. Statistics procedure

First, a preliminary one-way analysis of variance looking at age differences (3 levels: young, young-old, and old-old groups) in years of education, verbal ability, inhibition, and working memory updating measures was carried out.

Second, we explored the age-related differences on the ability to detect that a faux pas occurred; we ran a series of one-way ANOVAs on scores at the first two questions of the faux pas stories (detection and person identification) and on the first one of the control stories (detection).

Third, we looked at age differences in the cognitive and affective ToM as indexed by the answers to the third and fourth questions of the faux pas stories. To this end, we ran a 3 (age groups) X 2 (faux pas components: cognitive ToM and affective ToM) mixed ANOVA, with age group as a between-participants factor and faux pas components as a within-participants factor. Separate one-way ANOVAs were conducted on these two faux pas components in order to examine the significant interaction.

Fourth, in order to investigate the mechanisms associated with the performance on these two faux pas components in aging, we examined the correlations (Pearson correlation coefficient) between age (modeled as a categorical variable), each faux pas component (cognitive ToM and affective ToM), crystallized abilities (education and vocabulary), and EFs.

Fifth, a series of stepwise regressions were conducted to investigate the best predictors (EFs and age) on each ToM component.

Sixth, we performed mediation analyses through a series of statistical regressions, to test whether the relation between age and ToM components was mediated by EFs. This mediation model was tested using the causal steps strategy proposed by Baron and Kenny (1986) involving a series of regressions coupled with the Sobel test, which directly examines the reduction in the effect of the initial variable on the outcome. However, because the Sobel test assumes a normal distribution (Zhao, Lynch, & Chen, 2010), we also used Preacher and Hayes's (2004) SPSS bootstrap macro to assess mediation. This is a nonparametric method of estimating effect size that is preferable for small samples (Preacher & Hayes, 2004; Preacher & Hayes, 2008; Shrout & Bolger, 2002). It uses a random sampling-with-replacement technique to obtain a number of subsamples from the original sample and, hence, generates an empirical sample distribution of indirect effects. Typically, at least 1000 bootstrap samples are selected to compute confidence intervals (derived from the indirect effect estimates and their standard errors); the 95% confidence intervals must exclude zero if a significant mediation effect is to be supported.

All statistical analyses were performed using SPSS. The level of significance was $p <$ .05. All post hoc comparisons were calculated with the Tukey test with .05 level of significance according to Keppel (Keppel, 1991).

3. Results

3.1. Age differences in the background characteristics and in the executive functioning

Descriptive statistics for age, years of education, and scores on executive functions and vocabulary are shown in Table 1.

Table 1.

Means (and Standard Deviations) for the background characteristics and executive functions for the young, young-old and old-old age groups.

	Young adults (n=20)	Young-old adults (n=22)	Old-old adults (n=20)	*p*-value
Age	22.75 (2.55)	65.18 (3.53)	75.50 (3.17)	< .001
Female, n (%)	11 (55.00)	13 (56.50)	14 (70.00)	.56
Years of education	15.90 (1.86)	14.23 (4.33)	13.70 (4.86)	.19
MMSE	-	28.90 (1.69)	28.20 (1.50)	.16
Vocabulary	45.15	47.00	44.95	.072

	(3.07)	(2.67)	(3.66)	
Word fluency	48.70	41.36	32.45	< .001
	(4.66)	(10.19)	(9.24)	
Inhibition	6.40	7.77	9.70	.005
	(2.84)	(3.26)	(3.06)	
Global score of	84.80	77.59	67.35	< .001
updating	(8.12)	(8.42)	(10.08)	
HSHM sub-score	23.85	21.32	18.15	< .001
	(4.60)	(4.37)	(3.91)	
HSLM sub-score	17.15	16.14	14.00	< .001
	(1.23)	(1.52)	(2.53)	
LSHM sub-score	25.95	22.77	19.25	< .001
	(2.63)	(2.43)	(3.68)	
LSLM sub-score	17.85	17.36	15.95	.006
	(0.37)	(1.18)	(3.01)	

Note: HSHM = high suppression and high maintenance trial, HSLM = low suppression and high maintenance trial, LSHM = low suppression and high maintenance trial, LSLM = low suppression and low maintenance trial, Maximum MMSE = 30, Maximum vocabulary score = 50, Maximum Working memory updating score = 96, Maximum HSHM and maximum LSHM score = 30, Maximum HSLM and maximum LSLM score = 16.

Results showed that the young, young-old and old-old groups differed in all considered variables, except for vocabulary and years of education. In particular, a significant age effect was found for word fluency, $F(2, 59) = 18.54$, $p < .001$, partial $\eta^2 = .39$, and inhibition, $F(2, 59) = 5.85$, $p = .005$, partial $\eta^2 = .17$. A significant age effect was also found for updating, both in the global score, $F(2, 59) = 17.88$, $p < .001$, partial $\eta^2 = .38$, and in the four sub-scores: HMHS, $F(2, 59) = 8.80$, $p < .001$, partial $\eta^2 = .23$, HMLS, $F(2, 59) = 25.86$, $p < .001$, partial $\eta^2 = .47$, LMHS, $F(2, 59) = 15.36$, $p < .001$, partial $\eta^2 = .34$, and LMLS, $F(2, 59) = 5.65$, $p = .006$, partial $\eta^2 = .16$. Post hoc comparisons showed that three age groups differed one from each other in term of word fluency, global score of updating, and HMLS sub-score. In addition, the oldest group also differed from the youngest one (but not from young-old adults) in inhibition and in three updating sub-scores (i.e., HMHS, LMHS, and LMLS); whereas young-old and young adult groups did not differ among them.

No significant differences across groups resulted in term of education, $F(2, 59) = 1.72$, $p = .19$, partial $\eta^2 = .06$, and vocabulary, $F(2, 59) = 2.75$, $p = .08$, partial $\eta^2 = .09$.

3.2. Analysis on faux pas detection

Separate one-way ANOVAs conducted to explore age-related differences on the ability to detect a faux pas showed that the three age groups did not significantly differ in their ability to detect that a faux pas has, $F(2, 59) = 1.97$, $p = .15$, partial $\eta^2 = .06$, or has not, $F(2, 59) = 1.99$, $p = .15$, partial $\eta^2 = .06$, occurred. Age groups did not differ in the ability to identify who committed the faux pas, $F(2, 59) = 2.54$, $p = .09$, partial $\eta^2 = .08$. Means and standard deviations for these components are summarized in Table 2.

Table 2.

Means (and Standard Deviations) for the components of the Faux Pas and the Control stories for the young, young-old and old-old age groups.

	Young adults (n=20)	Young-old adults (n=22)	Old-old adults (n=20)	*p*- value
Faux pas stories				
Detection[a]	6.85	6.68	6.50	.15
	(0.37)	(0.57)	(0.69)	
Person identification[a]	6.85	6.64	6.45	.09
	(0.37)	(0.58)	(0.69)	
Cognitive ToM[a]	6.40	4.86	4.69	<.001
	(0.60)	(1.12)	(1.69)	
Affective ToM[a]	6.00	5.71	5.90	.65
	(0.92)	(0.93)	(1.11)	
Control stories				
Detection[b]	13.80	13.55	13.10	.15
	(0.62)	(1.22)	(1.37)	

Note: [a]Total score range for all components: 0 – 7, [b]Total score range: 0 – 14.

3.3. Age differences in the cognitive and affective faux pas components

From the 3 (age groups) X 2 (faux pas components: cognitive ToM and affective ToM) mixed ANOVA resulted a significant main effect of faux pas components, $F(1, 59) = 10.36$, $p = .002$, partial $\eta^2 = .15$, and of age group, $F(2, 59) = 7.28$, $p = .001$, partial $\eta^2 = .20$, with a significant interaction between these factors, $F(2, 59) = 7.80$, $p = .001$, partial $\eta^2 = .21$. Means and standard deviations also for these components are summarized in Table 2.

Two separate one-way ANOVAs showed a significant effect of age group for cognitive , $F(2, 59) = 12.16$, $p < .001$, partial $\eta^2 = .29$, but not affective ToM, $F(2, 59) = 0.44$, $p = .65$, partial $\eta^2 = .02$. Post-hoc comparisons on cognitive ToM revealed that young adults outperformed the other two groups, which were comparable.

3.4. Relation between age, cognitive and affective faux pas components, crystallized abilities, and executive functioning

3.4.1. Correlation analysis

Results of correlations are reported in Table 3 and Table 4. In line with the results of the ANOVAs, all correlation coefficients between age and executive functions were significant, whereas those between age and crystallized intelligence were not. Perhaps more importantly, Table 3 shows that cognitive ToM significantly correlated with age, inhibition, and updating. On the contrary, individual differences in affective ToM did not significantly correlate neither with age nor with any EFs task or crystallized abilities. In addition, the strength of the association between cognitive ToM and updating (global score) was significantly stronger than the one between affective ToM and updating (Fisher’s r to z transform $z = 3.17$, $p = .002$). Finally, individual differences in cognitive and affective ToM were not significantly associated to one another.

Similar results were obtained when we considered the four updating sub-scores. Each of these sub-scores significantly correlated with cognitive (HMHS trial: $r = .45$ $p < .001$; HMLS trial: $r = .54$ $p < .001$; LMHS trial: $r = .49$ $p < .001$; LMLS trial: $r = .44$ $p < .001$), but not affective ToM (HMHS trial: $r = -.008$ $p = .95$; HMLS trial: $r = .02$ $p = .90$; LMHS trial: $r = -.02$ $p = .86$; LMLS trial: $r = .14$ $p = .26$).

Table 3.

Correlations between Age, Cognitive and Affective Faux Pas components, Crystallized abilities and Executive functions.

	1.	2.	3.	4.	5.	6.	7.	8.
1. Age group	-	-.49**	-.04	-.22	-.03	-.62**	.41**	-.61**
2. Cognitive ToM		-	.19	-.01	-.10	.18	-.26*	.54**
3. Affective ToM			-	-.03	-.11	.14	-.08	.02
4. Education				-	.48**	.44**	-.10	.06
5. Vocabulary					-	.22	-.17	.08
6. Word fluency						-	-.35**	.37**
7. Inhibition							-	-.36**

8. Global score of updating	-

$^{**}p < .01$, .$^{*}p < .05$.

3.4.2. Stepwise regression analysis

Given that cognitive ToM resulted to be affected by aging, we run a series of stepwise regressions to identify the best EFs predictors of the age-related changes. Age group and all the executive functions that correlated with age and cognitive ToM (inhibition and global updating scores) were included as regressors. Results are reported in Table 4 and showed that performance in cognitive ToM was predicted by updating (*ß* = .54, *t*(60) = 5.00, *p* <.001), whereas age group (*ß* = -.25, *t*(60) = 1.86, *p* = .07) and inhibition (*ß* = -.07, *t*(60) = 0.61, *p* =.55) were excluded from the model. We also re-run this analysis, including the four updating sub-scores, as well as age group, in order to evaluate whether the pattern of results changed according to different involvements of working memory or inhibition. The model accounted for a significant percentage of variance, R^2= .29, *F*(1, 60) = 24.19, *p* < .001, and HMLS trial was the only significant predictor of cognitive ToM, *ß* = .54, *t*(60) = 4.92, *p* < .001, whereas age group (*ß* = -.23, *t*(60) = 1.54, *p* = .13), LMLS (*ß* = .17, *t*(60) = 1.24, *p* = .22), HMHS (*ß* = .10, *t*(60) = .60, *p* = .55), and LMHS (*ß* = .19, *t*(60) = 1.08, *p* = .28) trials were excluded from the model.

Table 4.

Stepwise regression analyses with Cognitive ToM, Age group and Executive functions.

Steps and predictors		*Beta*	*t*	*p*	Correlations		
					Zero order	Partial	Part
1	Global score of updating	.54	5.00	< .001	.54	.54	.54

Note: Step 1: R = .54, R^2 = .29, Adjusted R^2 = .28, Standard Error of Estimate = 1.20, F(1, 60) = 24.99, p < .001.

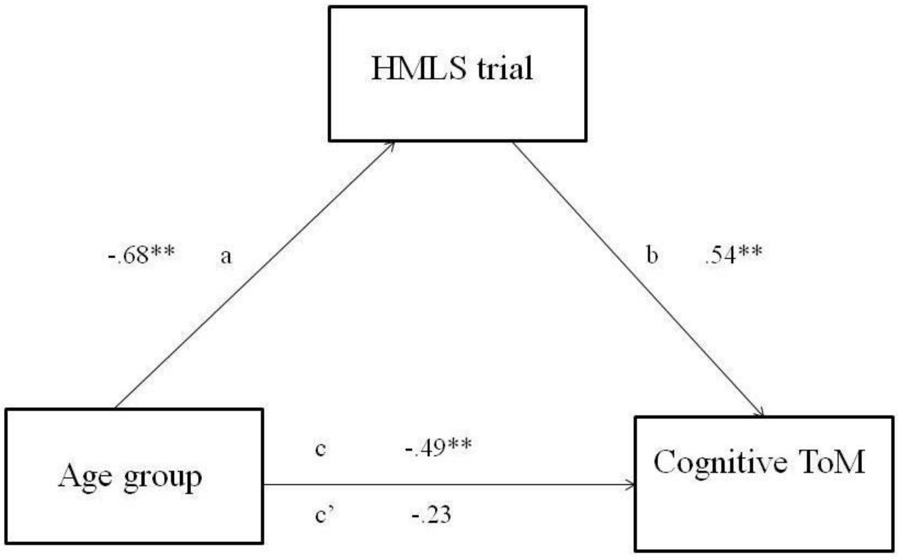
3.4.3. Mediation analyses

As anticipated, one of the aim of the present study was to test the mediating role of EFs in the association between age and ToM. Given the findings reported above, we tested this model for cognitive (and not affective) ToM and the HMLS updating sub-score, given it was the only one updating sub-score able to significantly predict cognitive ToM. First, we regressed cognitive ToM on age group (Figure 1 - Path c). This step established that there was an effect that may be mediated. Second, we regressed HMLS sub-score on age group too (Figure 1 - Path a). Third, a multiple regression was performed for cognitive ToM on both age group (Figure 1 - Path c') and HMLS sub-score (Figure 1 - Path b). If the mediator was significantly associated with the dependent variable in this final step, a Sobel test can be run to determine whether the mediation effect was significant, that is, whether there had been a significant decline in the regression coefficient between the predictor and dependent variable once the mediating variable had been taking into account (Preacher & Hayes, 2004). Preacher and Hayes's (2004) SPSS bootstrap macro to assess mediation were also carried out, given the small size of cases.

Results showed a significant association between age and cognitive ToM ($ß$ = -.49 p < .001) that was fully mediated by the HMLS sub-score ($ß$ = -.23 p = .13). A Sobel test revealed that updating was a significant mediator (z = -2.41 p = .02). Individual tests for mediation using bootstrap estimation of indirect effects with 1000 replications confirmed the mediation model (95% confidence interval [CI] = [- .91 to - .16]). Together, these results supported that age exerted an indirect effect on cognitive ToM and that updating with high working memory (but not inhibition) demands fully mediated the relation between age and cognitive ToM.

Figure 1.

Path diagrams of mediation analyses examining HMLS (High maintenance and Low suppression) updating trial as possible mediator of age differences in Cognitive ToM.



Note: The figures are standardized beta weights from regression analyses. The coefficients below the pathway between age group and Cognitive ToM (c) are direct effects, whereas below (c') are reported age group effects on Cognitive ToM once HMLS updating trial is included as a mediator in the model. Sobel test indicated that HMLS trial was a significant full mediator of the age group-Cognitive ToM relation.
**p< .001.

4. Discussion

The present study was designed to address two main aims. The first was the analysis of the aging effects on cognitive vs. affective ToM, as assessed using the faux pas test; the second was the examination of the role of EFs in the association between age and ToM.

As far as the first aim is concerned, data revealed that cognitive ToM was impaired in older participants, confirming the results of previous studies that have explored the effects of aging on inferring beliefs (e.g., Bernstein et al., 2011; Cavallini et al., 2013; German & Hehman, 2006; Phillips et al., 2011). As far as affective ToM is concerned, our data showed that performance remained stable across age groups. Notably, and in line with previous findings (Wang & Su, 2006), we also did not find any age-related difference in the ability to detect that a faux pas has been or not committed or not.

Altogether, our findings highlight a divergent trajectory between cognitive and affective components of ToM in aging, with a greater age effect on the cognitive than on the affective component. Two possible explanations may account for such results. The first explanation considers the different neural systems recruited by these two ToM components and their patterns of change in aging. In particular, the dorsolateral prefrontal cortex (PFC) (Kalbe et al., 2010) is supposed to play a role in inferring other's cognitive mental states, whereas the ventromedial PFC is involved in making inferences on other people's feelings and emotions (i.e., affective ToM) (Sebastian et al., 2012; Shamay-Tsoory, Shur et al., 2007). Xi et al. (2011) showed that patients with ventromedial PFC lesions were impaired in the affective components of ToM, whereas those with dorsolateral PFC lesions were impaired in the cognitive ones. Interestingly, existing evidence has demonstrated that aging is associated with a deficit in dorsal but not ventral PFC functioning (e.g., Leclerc & Kensinger, 2010; Moran, Jolly & Mitchell, 2012).

The second possible explanation of our results considers the different trajectories of development characterizing the aging mind. In particular, the self-regulation of emotional functioning seems to be spared – if not enhanced – from age-related changes, as argued by the socioemotional selectivity theory (Charles & Carstensen, 2004). This pattern contrasts with the one of age-related differences characterizing those cognitive abilities and processes that are effortful, deliberative, and resource-intensive, such as executive functions, working memory, and processing speed (e.g., Salthouse, 2009).

Importantly, our results on age-related differences in cognitive vs. affective ToM are in line with those studies, such as Phillips et al. (2002), that used verbal-based tasks, but not with those that used visual stimuli (e.g., Bailey & Henry, 2008; Mahy et al., 2014; Pardini &

Nichelli, 2009; Sullivan & Ruffman, 2004). An interesting possibility is therefore that the difference across studies might depend on the task modality – verbal or visual – used for assessing emotion understanding. It might be that performance on verbal tasks is more preserved in late adulthood, as this modality imposes crystallized-skill demands, which are known to be stable across aging (e.g., Boop & Verhaeghen, 2007; Jenkins et al., 2000; Verhaeghen, 2003). By contrast, visual-based affective tasks, which involve making judgments about people's mental state from their facial expressions, could be more vulnerable to aging. This consideration could explain why Duval et al. (2011) and Rakoczy et al. (2012) – using the Reading the Mind in the Eyes Test and the Video task respectively – reported age differences in the affective ToM component, whereas Wang and Su (2013) – who used verbal affective stories – did not. Thus, age might affect some aspects of affective ToM related to the ability to identify emotions from facial expression rather than to a general age-change in emotion understanding. In the light of these considerations, our results, together with existing data, suggest the importance of distinguishing between cognitive and affective ToM components and between verbal and visual task modalities.

The second goal of this study was to investigate the mechanisms that may account for the effects of aging on ToM, focusing on EFs. In relation to this, our data showed that executive functions, in particular inhibition and updating, were significantly correlated with cognitive but not affective ToM. This is consistent with the view that it is necessary to inhibit one's own perception of reality and to update information about protagonists' mental states in order to perform cognitive – but not affective – ToM tasks. Consequently, these results suggest that cognitive and affective ToM may impose different demands, with the former being more complex and likely to place cognitive demands on individuals in contrast to the latter. This data fit with results of neurological studies showing that cognitive ToM activate the dorsolateral prefrontal region, which is also thought to be important for executive functioning and working memory (Petrides & Milner, 1982). Instead, affective ToM is located in the ventromedial prefrontal region that is involved, for instance, in emotion processing, decision making, and social behavior regulation (e.g., Bechara, Tranel, & Damasio, 2000).

A third important finding of our study was that cognitive ToM was mainly explained by updating in the stepwise regression. Mediational analysis confirmed that the significant age effect we observed on cognitive ToM was indirect and mediated by updating. Indeed, when we controlled for the direct effect of aging on updating, the age effect on cognitive ToM was no longer significant. This pattern was further evident when we used separate updating sub-scores, in favor of the condition with high working memory demands. These findings suggest that having to analyze, maintain, and update information about multiple protagonists' mental states contributes to and accounts for variance in false belief understanding. This may be particularly important for older adults, who have difficulties in updating relevant information (Phillips & Henry, 2008). This finding is consistent with McKinnon and Moscovitch (2007) that, using a dual-task methodology, found that concurrent performance of an updating task impaired answering 2nd-order ToM tasks. To this end, the choice of using the Working Memory Updating task (Palladino et al., 2001) resulted particularly useful in order to detect the impact of different mechanisms involved in the updating process and in determining their role in cognitive ToM.

The present study also showed that inhibition did not mediate the effect of age on cognitive ToM. Two results support this conclusion. First, inhibition as indexed by the Hayling test did not significantly predicted cognitive ToM. Second, updating ability requiring high demands in term of suppression did not predict cognitive ToM. This result contrasts with existing findings (e.g., Bailey & Henry, 2008; Li et al., 2013) and could be related to the tasks used for assessing false belief understanding. A key example here could be Bailey and Henry (2008) that used false-belief video clips manipulated for inhibitory demands and found a full mediation effect of inhibitory control. Hence, it might be that inhibition has less impact on the cognitive ToM component of the faux pas test than updating and working memory do. Our data further highlight the specific and distinct contribution of these components in false belief understanding. We caution, however, that these conclusions are limited to a specific ToM task, the faux pas test. Thus, it could be that the pattern of relation with ToM and EFs changes across other ToM materials. Future studies focusing on mediation analysis (as ours is) should better clarify this issue and should distinguish the cognitive and affective component using different ToM and EF tasks.

Overall, our data showed that updating is an important mediator of the age-cognitive ToM relation. This does not mean that updating is the *solo* mechanism trough which age affects the ability to infer others' toughs and beliefs. Indeed, it is important to note that a number of extra potential factors may have a role in the relation between age and ToM too. In our view, for instance, social variables, in addition to the cognitive ones, are good candidate. Reasons for such hypothesis can be found in theoretical models and experimental data. Theoretically, several authors have highlighted the social dimension of ToM. For example, Carpendale and Lewis (2004) and Harris (1999) viewed ToM as an ability that is built in the context of social relationships, and Hughes (2011) uses the expression ‘social understanding’ to refer to this construct. Evidence-based genetic studies have stressed the role of environmental factors in ToM performance (Hughes et al., 2005) and direct experimental evidence of the influence of social factors on ToM development is rapidly growing (Lecce, Bianco, Devine, Hughes, & Banerjee, 2014; Ornaghi, Brockmeier, & Grazzani, 2011). For example, Banerjee, Watling and Caputi (2011) found a cyclical relation between faux pas understanding and social relationships (i.e., peer relations) across primary school years. Despite these data mainly referred to children, available evidence leads us to expect a similar pattern of association between ToM and social factors in aging. Indeed, it is reasonable to hypothesize that, growing older, people are less involved in social situations (Wrzus, Hänel, Wagner, & Neyer, 2013), and that this form of isolation, in turn, accelerates the rate of physiological decline (Hawkley & Cacioppo, 2007), negatively affecting ToM performance. In conclusion, we can hypothesize that the relation between age and cognitive ToM might be mediated by social engagement and personal motivation (Zhang, Fung, Stanley, Isaacowitz, & Ho, 2013) as well as by working memory updating. Further studies should shed light on this issue.

The limitations of our study should be acknowledged. First of all, data were collected on a small sample of participants and further research is needed to confirm our findings. Second, in this study affective ToM was not related to any executive task. Again this result needs further support; however it raises the interesting possibility that affective, but not cognitive, ToM is related to other variables such as individuals' emotional state. Third, given that we administered a single verbal task, it would be interesting to investigate whether our findings can be confirmed with ToM measures that use other modalities of stimuli presentation, such as static and dynamic non-verbal tasks. Fourth, we always administered the affective question after the cognitive one. Even if this is the standard procedure (Stone et al., 1998), it could be hypothesized that older adults used their responses to the cognitive question to help them answer the affective question. Future studies should administer questions in counterbalanced order to avoid this issue of non-independence of questions.

Notwithstanding these limitations, this is the first study that compared cognitive and affective ToM using the same task and controlling a number of EFs. This has revealed to be a fruitful approach and an interesting new avenue for future research. Indeed, we think that adopting this broader view may shed light on the links that are likely to exist between distinct aspects of social understanding. This consideration becomes even more crucial and has relevant practical implications considering the different trajectory of impairments across these cognitive and affective ToM components characterizing pathological aging (see Kemp Després, Sellal, & Dufour, 2012; Poletti, Enrici, & Adenzato, 2012).

Conflict of interest statement

No conflict of interest.

References

Amodio, D. M., & Frith, C. D. (2006). Meeting of minds: the medial frontal cortex and social cognition. *Nature Reviews Neuroscience*, *7*, 268-277. doi:10.1016/j.neuron.2006.05.001

Apperly, I. A., Samson, D., & Humphreys, G. W. (2009). Studies of adults can inform accounts of theory of mind development. *Developmental Psychology*, *45*, 190-201. doi:10.1037/a0014098

Bailey, P. E., & Henry, J. D. (2008). Growing less empathic with age: Disinhibition of the self-perspective. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, *63*, 219-226. doi:10.1093/geronb/63.4.P219

Banerjee, R., Watling, D., & Caputi, M. (2011). Peer relations and the understanding of faux pas: Longitudinal evidence for bidirectional associations. *Child Development*, *82*, 1887-1905. doi:10.1111/j.1467-8624.2011.01669.x

Baron, R. M., & Kenny, D. A. (1986). The moderator–mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. *Journal of Personality and Social Psychology*, *51*, 1173-1182. doi:10.1037/0022-3514.51.6.1173

Baron-Cohen, S., O'Riordan, M., Stone, V., Jones, R., & Plaisted, K. (1999). Recognition of faux pas by normally developing children and children with Asperger syndrome or high-functioning autism. *Journal of Autism and Developmental Disorders*, *29*, 407-418. doi:10.1023/A:1023035012436

Bechara, A., Tranel, D., & Damasio, H. (2000). Characterization of the decision-making deficit of patients with ventromedial prefrontal cortex lesions. *Brain*, *123*, 2189-2202. doi:10.1093/brain/123.11.2189

Belleville, S., Rouleau, N., & Van der Linden, M. (2006). Use of the Hayling task to measure inhibition of prepotent responses in normal aging and Alzheimer's disease. *Brain and cognition*, *62*, 113-119. doi:10.1016/j.bandc.2006.04.006

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. doi:10.1080/0361073X.2011.619466

Bopp, K. L., & Verhaeghen, P. (2007). Age-related differences in control processes in verbal and visuospatial working memory: Storage, transformation, supervision, and coordination. *Journal of Gerontology: Psychological Sciences*, *62*, 239– 246. doi: 10.1093/geronb/62.5.P239

Borella, E., Carretti, B., Cornoldi, C., & De Beni, R. (2007). Working memory, control of interference and everyday experience of thought interference: When age makes the difference. *Aging Clinical and Experimental Research*, *19*, 1-7. doi:10.1007/BF03324690

Burgess, P. W., & Shallice, T. (1997). *The Hayling and Brixton Tests*. Thurston, Suffolk: Thames Valley Test Company.

Burgess, P. W., & Shallice, T. (1997). Response suppression, initiation and strategy use following frontal lobe lesions. *Neuropsychologia*, *4*, 263-273. doi:10.1016/0028-3932(95)00104-2

Carpendale, J. I., & Lewis, C. (2004). Constructing an understanding of mind: The development of children's social understanding within social interaction. *Behavioral and Brain Sciences*, *27*, 79-96. doi:10.1017/S0140525X04000032

Carretti, B., Belacchi, C., & Cornoldi, C. (2010). Difficulties in working memory updating in individuals with intellectual disability. *Journal of Intellectual Disability Research*, *54*, 337-345. doi: 10.1111/j.1365-2788.2010.01267.x

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*, 2586-2594. doi:10.1016/j.neuropsychologia.2010.05.005

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. *The International Journal of Aging and Human Development*, *76*(3), 181-198. doi: 10.2190/AG.76.3.a

Charles, S. T., & Carstensen, L. L. (2004). A life-span view of emotional functioning in adulthood and old age. *Recent Advances in Psychology and Aging*, *15*, 133-162.

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*, 338-348. doi:10.1037/a0015225

Collette, F., Van der Linden, M., & Salmon, E. (1999). Executive dysfunction in Alzheimer's disease. *Cortex*, *35,* 57-72. doi:10.1016/S0010-9452(08)70785-8

Conway, A. R., Kane, M. J., Bunting, M. F., Hambrick, D. Z., Wilhelm, O., & Engle, R. W. (2005). Working memory span tasks: A methodological review and user's guide. *Psychonomic bulletin & review*, *12*(5), 769-786. doi: 10.3758/BF03196772

Crawford, J. R., Bryan, J., Luszcz, M. A., Obonsawin, M. C., & Stewart, L. (2000). The executive decline hypothesis of cognitive aging: Do executive deficits qualify as differential deficits and do they mediate age-related memory decline?. *Aging Neuropsychology, and Cognition*, *7,* 9-31. doi: 10.1076/anec.7.1.9.806

Cutting, A. L., & Dunn, J. (1999). Theory of mind, emotion understanding, language, and family background: Individual differences and interrelations. *Child Development, 70*, 853-865. doi:10.1111/1467-8624.00061

Dunn, J., (2005). Individual differences in understanding of mind. In: Astington, J., Baird, J. (Eds.), *Why Language Matters for Theory of Mind*, 50-69. New York: Oxford University Press.

Duval, C., Piolino, P., Bejanin, A., Eustache, F., & Desgranges, B. (2011). Age effects on different components of theory of mind. *Consciousness and Cognition*, *20*, 627-642. doi:10.1016/j.concog.2010.10.025

Euteneuer, F., Schaefer, F., Stuermer, R., Boucsein, W., Timmermann, L., Barbe, M. T., ... & Kalbe, E. (2009). Dissociation of decision-making under ambiguity and decision-making under risk in patients with Parkinson's disease: a neuropsychological and psychophysiological study. *Neuropsychologia*,*47*, 2882-2890. doi:10.1016/j.neuropsychologia.2009.06.014

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*, 489-497. doi**:** 10.1080/13803390802282688

Fernandez-Duque, D., Hodges, S. D., Baird, J. A., & Black, S. E. (2010). Empathy in frontotemporal dementia and Alzheimer's disease. *Journal of clinical and experimental neuropsychology*, *32*, 289-298. doi: 10.1080/13803390903002191

Fischer, H., Nyberg, L., & Bäckman, L. (2010). Age-related differences in brain regions supporting successful encoding of emotional faces. *Cortex*, *46*, 490-497. doi:10.1016/j.cortex.2009.05.011

Fisk, J. E., & Sharp, C. A. (2004). Age-related impairment in executive functioning: Working memory updating, inhibition, shifting, and access. *Journal of Clinical and Experimental Neuropsychology*, *26*, 874-890. doi:10.1080/13803390490510680

Friedman, N. P., & Miyake, A. (2004). The relations among inhibition and interference control functions: a latent-variable analysis. *Journal of experimental psychology: General*, *133*, 101-135. doi: 10.1037/0096-3445.133.1.101

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. doi:10.1016/0022-3956(75)90026-6

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. doi:10.1016/j.cognition.2005.05.007

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. doi:10.1093/brain/awf079

Halberstadt, J., Ruffman, T., Murray, J., Taumoepeau, M., & Ryan, M. (2011). Emotion perception explains age-related differences in the perception of social gaffes. *Psychology and Aging*, *26*, 133-136. doi:10.1037/a0021366

Happé, F. G., Winner, E., & Brownell, H. (1998). The getting of wisdom: theory of mind in old age. *Developmental Psychology*, *34*, 358-362. doi:10.1037/0012-1649.34.2.358

Harris, P. L. (1999). Individual differences in understanding emotion: The role of attachment status and psychological discourse. *Attachment & Human Development*, *1*, 307-324. doi:10.1080/14616739900134171

Hawkley, L. C., & Cacioppo, J. T. (2007). Aging and Loneliness Downhill Quickly? *Current Directions in Psychological Science*, *16*, 187-191. doi:10.1111/j.1467-8721.2007.00501.x

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*, 826–839. 10.1037/a0030677

Hughes, C. (2011). Changes and challenges in 20 years of research into the development of executive functions. *Infant and Child Development*, *20*, 251-271. doi:10.1002/icd.736

Hughes, C., Jaffee, S. R., Happé, F., Taylor, A., Caspi, A., & Moffitt, T. E. (2005). Origins of individual differences in theory of mind: From nature to nurture?. *Child Development*, *76*, 356-370. doi:10.1111/j.1467-8624.2005.00850_a.x

Jenkins, L., Myerson, J., Joerding, J. A., & Hale, S. (2000). Converging evidence that visuospatial cognition is more age-sensitive than verbal cognition. *Psychology and aging*, *15*, 157-175. doi: 10.1037/0882-7974.15.1.157

Kalbe, E., Schlegel, M., Sack, A. T., Nowak, D. A., Dafotakis, M., Bangard, C., ... & Kessler, J. (2010). Dissociating cognitive from affective theory of mind: a TMS study. *Cortex*, *46*, 769-780. doi:10.1016/j.cortex.2009.07.010

Keightley, M. L., Winocur, G., Burianova, H., Hongwanishkul, D., & Grady, C. L. (2006). Age effects on social cognition: faces tell a different story. *Psychology and Aging*, *21*, 558-572. doi:10.1037/0882-7974.21.3.558

Kemp, J., Després, O., Sellal, F., & Dufour, A. (2012). Theory of Mind in normal ageing and neurodegenerative pathologies. *Ageing research reviews*, *11*, 199-219. doi:10.1016/j.arr.2011.12.001

Keppel, G. (1991). *Design and analysis: a researcher's handbook*, third ed. NJ: Prentice-Hall.

Lecce, S., Bianco, F., Devine, R., Hughes, C., & Banerjee, R. (2014). Promoting theory of mind in middle childhood: a training study. *Journal of Experimental Child Psychology, 126,* 52-67. doi: 10.1016/j.jecp.2014.03.002

Leclerc, C. M., & Kensinger, E. A. (2010). Age-related valence-based reversal in recruitment of medial prefrontal cortex on a visual search task. *Social Neuroscience*, *5,* 560–576. doi:10.1080/17470910903512296

Li, X., Wang, K., Wang, F., Tao, Q., Xie, Y., & Cheng, Q. (2013). Aging of theory of mind: The influence of educational level and cognitive processing. *International Journal of Psychology*, *48*, 715-727. doi:10.1080/00207594.2012.673724

Liverta Sempio, O., Marchetti, A., Lecciso, F. (2005), Faux Pas: traduzione italiana, Theory of Mind Research Unit, Department of Psychology, Catholic University of the Sacred Heart, Milan.

MacPherson, S. E., Phillips, L. H., & Della Sala, S. (2002). Age, executive function and social decision making: A dorsolateral prefrontal theory of cognitive aging. *Psychology and Aging*, *17*, 598-609. doi:10.1037/0882-7974.17.4.598

Mahy, C. E., Vetter, N., Kühn-Popp, N., Löcher, C., Krautschuk, S., & Kliegel, M. (2014). The influence of inhibitory processes on affective theory of mind in young and old adults. *Aging, Neuropsychology, and Cognition*, *21*, 129-145. doi:10.1080/13825585.2013.789096

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*(4), 465-485. doi: 10.1348/000712602761381358

McElwain, N. L., & Volling, B. L. (2002). Relating individual control, social understanding, and gender to child–friend interaction: A relationships perspective. *Social Development*, *11*, 362-385. doi:10.1111/1467-9507.00205

McKinnon, M. C., & Moscovitch, M. (2007). Domain-general contributions to social reasoning: Theory of mind and deontic reasoning re-explored. *Cognition*, *102*, 179-218. doi:10.1016/j.cognition.2005.12.011

Mimura, M., Oeda, R., & Kawamura, M. (2006). Impaired decision-making in Parkinson's disease. *Parkinsonism & related disorders*, *12*, 169-175. doi:10.1016/j.parkreldis.2005.12.003

Modinos, G., Obiols, J. E., Pousa, E., & Vicens, J. (2009). Theory of Mind in different dementia profiles. *The Journal of neuropsychiatry and clinical neurosciences*, *21*(1), 100-101. doi: 10.1176/appi.neuropsych.21.1.100

Monetta, L., Grindrod, C.M., Pell, M.D., 2009. Irony comprehension and theory of mind deficits in patients with Parkinson's disease. *Cortex*, 45, 972–981. doi: 10.1016/j.cortex.2009.02.021

Moran, J. M., Jolly, E., & Mitchell, J. P. (2012). Social-cognitive deficits in normal aging. *The Journal of Neuroscience*, *32,* 5553–5561. doi:10.1523/JNEUROSCI.5511-11.2012

Morris, N., & Jones, D. M. (1990). Memory updating in working memory: The role of the central executive. *British journal of psychology*, *81*, 111-121. doi: 10.1111/j.2044-8295.1990.tb02349.x

Ornaghi, V., Brockmeier, J., & Gavazzi, I. G. (2011). The role of language games in children's understanding of mental states: A training study. *Journal of Cognition and Development*, *12*, 239-259. doi:10.1080/15248372.2011.563487

Paal, T., & Bereczkei, T. (2007). Adult theory of mind, cooperation, Machiavellianism: The effect of mindreading on social relations. *Personality and Individual Differences*, *43*, 541-551. doi:10.1016/j.paid.2006.12.021

Palladino, P., Cornoldi, C., De Beni, R., & Pazzaglia, F. (2001). Working memory and working memory updating processes in reading comprehension. *Memory and Cognition*, *29*, 344-354. doi:10.3758/BF03194929

Pardini, M., & Nichelli, P. F. (2009). Age-related decline in mentalizing skills across adult life span. *Experimental Aging Research*, *35*, 98-106. doi:10.1080/03610730802545259

Perner, J., & Wimmer, H. (1985). "John thinks that Mary thinks that…" attribution of second-order beliefs by 5-to 10-year-old children. *Journal of Experimental Child Psychology*, *39*, 437-471. doi:10.1016/0022-0965(85)90051-7

Petrides, M., & Milner, B. (1982). Deficits on subject-ordered tasks after frontal-and temporal-lobe lesions in man. *Neuropsychologia*, *20*, 249-262. doi:10.1016/0028-3932(82)90100-2

Phillips, L. H., & Henry, J. D. (2008). Adult aging and executive function. In V. Anderson, P. Anderson, & R. Jacobs (Eds.), *Executive function and the frontal lobes: A life span perspective*. 57-80. Hove: Psychology Press.

Phillips, L. H., Bull, R., Allen, R., Insch, P., Burr, K., & Ogg, W. (2011). Lifespan aging and belief reasoning: Influences of executive function and social cue decoding. *Cognition*, *120*, 236-247. doi:10.1016/j.cognition.2011.05.003

Phillips, L. H., MacLean, R. D., & Allen, R. (2002). Age and the understanding of emotions neuropsychological and sociocognitive perspectives. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences, 57*, 526-530. doi: 10.1093/geronb/57.6.P526

Plumet, J., Gil, R., & Gaonac'h, D. (2005). Neuropsychological assessment of executive functions in women: effects of age and education. *Neuropsychology*,*19*, 566-577. doi: 10.1037/0894-4105.19.5.566

Poletti, M., Enrici, I., & Adenzato, M. (2012). Cognitive and affective Theory of Mind in neurodegenerative diseases: neuropsychological, neuroanatomical and neurochemical levels. *Neuroscience & Biobehavioral Reviews 36*, 2147-2164. doi: 10.1016/j.neubiorev.2012.07.004

Preacher, K. J., & Hayes, A. F. (2004). SPSS and SAS procedures for estimating indirect effects in simple mediation models. *Behavior Research Methods, Instruments, & Computers*, *36*, 717-731. doi:10.3758/BF03206553

Preacher, K. J., & Hayes, A. F. (2008). Asymptotic and resampling strategies for assessing and comparing indirect effects in multiple mediator models.*Behavior research methods, 40*, 879-891. doi: 10.3758/BRM.40.3.879

Premack, D., & Woodruff, G. (1978). Does the chimpanzee have a theory of mind?. *Behavioral and Brain Sciences*, *1*, 515-526. doi:10.1017/S0140525X00076512

Rakoczy, H., Harder-Kasten, A., & Sturm, L. (2012). The decline of theory of mind in old age is (partly) mediated by developmental changes in domain-general abilities. *British Journal of Psychology*, *103,* 58-72. doi:10.1111/j.2044-8295.2011.02040.x

Repacholi, B. M., & Gopnik, A. (1997). Early reasoning about desires: evidence from 14-and 18-month-olds. *Developmental Psychology, 33*, 12-21. doi:10.1037/0012-1649.33.1.12

Rieffe, C., Terwogt, M. M., Koops, W., Stegge, H., & Oomen, A. (2001). Preschoolers' appreciation of uncommon desires and subsequent emotions. *British Journal of Developmental Psychology, 19*, 259-274. doi:10.1348/026151001166065

Roca, M., Torralva, T., Gleichgerrcht, E., Chade, A., Arévalo, G. G., Gershanik, O., & Manes, F. (2010). Impairments in social cognition in early medicated and unmedicated Parkinson disease. *Cognitive and Behavioral Neurology*, *23*, 152-158. doi: 10.1097/WNN.0b013e3181e078de

Ruffman, T., Henry, J. D., Livingstone, V., & Phillips, L. H. (2008). A meta-analytic review of emotion recognition and aging: Implications for neuropsychological models of aging. *Neuroscience & Biobehavioral Reviews*, *32*, 863-881. doi:10.1016/j.neubiorev.2008.01.001

Salthouse, T. A. (2009). When does age-related cognitive decline begin?.*Neurobiology of Aging*, *30*(4), 507-514. doi:10.1016/j.neurobiolaging.2008.09.023

Salthouse, T. A., Atkinson, T. M., & Berish, D. E. (2003). Executive functioning as a potential mediator of age-related cognitive decline in normal adults. *Journal of Experimental Psychology: General*, *132*, 566-594. doi:10.1037/0096-3445.132.4.566

Saltzman, J., Strauss, E., Hunter, M., & Archibald, S. (2000). Theory of mind and executive functions in normal human aging and Parkinson's disease.*Journal of the International Neuropsychological Society*, *6*, 781-788. doi:10.1017/S1355617700677056

Sebastian, C. L., McCrory, E. J., Cecil, C. A., Lockwood, P. L., De Brito, S. A., Fontaine, N. M., & Viding, E. (2012). Neural responses to affective and cognitive theory of mind in children with conduct problems and varying levels of callous-unemotional traits. *Archives of general psychiatry*, *69*, 814-822. doi: doi:10.1001/archgenpsychiatry.2011.2070.

Shamay-Tsoory, S. G., & Aharon-Peretz, J. (2007). Dissociable prefrontal networks for cognitive and affective theory of mind: A lesion study. *Neuropsychologia, 45,* 3054-3067. doi:10.1016/j.neuropsychologia.2007.05.021

Shamay-Tsoory, S. G., Harari, H., Aharon-Peretz, J., & Levkovitz, Y. (2010). The role of the orbitofrontal cortex in affective theory of mind deficits in criminal offenders with psychopathic tendencies. *Cortex*, *46,* 668-677. doi:10.1016/j.cortex.2009.04.008

Shamay-Tsoory, S. G., Shur, S., Barcai-Goodman, S., Medlovich, S., Harari, H., & Levkovitz, Y. (2007). Dissociation of cognitive from affective components of theory of mind in schizophrenia. *Psychiatry Research, 149,* 11–23. doi:10.1016/j.psychres.2005.10.018

Shamay-Tsoory, S. G., Tibi-Elhanany, Y., & Aharon-Peretz, J. (2006). The ventromedial prefrontal cortex is involved in understanding affective but not cognitive theory of mind stories. *Social Neuroscience, 1*, 149-166. doi:10.1080/17470910600985589

Shamay-Tsoory, S. G., Tomer, R., Berger, B. D., Goldsher, D., & Aharon-Peretz, J. (2005). Impaired “affective theory of mind” is associated with right ventromedial prefrontal damage. *Cognitive and Behavioral Neurology*, *18*, 55-67. doi:10.1097/01.wnn.0000152228.90129.99

Shrout, P. E., & Bolger, N. (2002). Mediation in experimental and nonexperimental studies: new procedures and recommendations.*Psychological methods*, *7*, 422-445. doi: 10.1037/1082-989X.7.4.422

Slessor, G., Phillips, L. H., & Bull, R. (2007). Exploring the specificity of age-related differences in theory of mind tasks. *Psychology and Aging*, *22*, 639-643. doi:10.1037/0882-7974.22.3.639

Stone, V. E., Baron-Cohen, S., & Knight, R. T. (1998). Frontal lobe contributions to theory of mind. *Journal of Cognitive Neuroscience*, *10*, 640-656. doi:10.1162/089892998562942

Stone, V. E., Baron-Cohen, S., Calder, A., Keane, J., & Young, A. (2003). Acquired theory of mind impairments in individuals with bilateral amygdala lesions. *Neuropsychologia*, *41*, 209-220. doi:10.1016/S0028-3932(02)00151-3

Sullivan, S., & Ruffman, T. (2004). Social understanding: How does it fare with advancing years?. *British Journal of Psychology*, *95*, 1-18. doi:10.1348/000712604322779424

Thurstone, T. G., & Thurstone, L. L. (1963). *Primary mental ability*. Chicago, IL: Science Research Associates.

Uekermann, J., Channon, S., & Daum, I. (2006). Humor processing, mentalizing, and executive function in normal aging. *Journal of the International Neuropsychological Society*, *12*, 184-191. doi:10.1017/S1355617706060280

Van Overwalle, F. (2009). Social cognition and the brain: a meta-analysis. *Human Brain Mapping*, *30*, 829-858. doi:10.1002/hbm.20547

Verhaeghen, P. (2003). Aging and vocabulary score: A meta-analysis. *Psychology and Aging*, *18*, 332-339. doi:10.1037/0882-7974.18.2.332

Wang, Y., & Su, Y. (2006). Theory of mind in old adults: The performance on Happe's stories and faux pas stories. *Psychologia*, *49*, 228-237. doi:10.2117/psysoc.2006.228

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*, 284-291. doi: 10.1037/a0030876

Wecker, N. S., Kramer, J. H., Wisniewski, A., Delis, D. C., & Kaplan, E. (2000). Age effects on executive ability. *Neuropsychology, 14*, 409-414. doi: 10.1037/0894-4105.14.3.409

Wellman, H. M., Cross, D., & Watson, J. (2001). Meta-analysis of theory-of-mind development: the truth about false belief. *Child Development*, *72*, 655-684. doi:10.1111/1467-8624.00304

Wrzus, C., Hänel, M., Wagner, J., & Neyer, F. J. (2013). Social network changes and life events across the life span: A meta-analysis. *Psychological bulletin*, *139*, 53-80. doi: ì10.1037/a0028601

Xi, C., Zhu, Y., Niu, C., Zhu, C., Lee, T., Tian, Y., & Wang, K. (2011). Contributions of subregions of the prefrontal cortex to the theory of mind and decision making. *Behavioural brain research*, *221*, 587-593. doi:10.1016/j.bbr.2010.09.031

Zhao, X., Lynch, J. G., & Chen, Q. (2010). Reconsidering Baron and Kenny: Myths and truths about mediation analysis. *Journal of consumer research*, *37*, 197-206. doi: 10.1086/651257

Zelazo, P. D., Carter, A., Reznick, J. S., & Frye, D. (1997). Early development of executive function: A problem-solving framework. *Review of General Psychology*, *1*, 198-226. doi:10.1037/1089-2680.1.2.198

Zhang, X., Fung, H. H., Stanley, J. T., Isaacowitz, D. M., & Ho, M. Y. (2013). Perspective taking in older age revisited: A motivational perspective. *Developmental Psychology*, *49*, 1848-1858. doi:10.1037/a0031211

Appendix

Faux Pas story example

Marcella bought her friend Anna a crystal bowl for a wedding gift. Anna had a big wedding and there were a lot of presents to keep track of. About a year later, Marcella was over one night at Anna's for dinner. Marcella dropped a wine bottle by accident on the crystal bowl, and the bowl shattered. "I'm really sorry, I've broken the bowl," said Marcella. "Don't worry," said Anna, "I never liked it anyway. Someone gave it to me for my wedding".

Detection question: *Did someone say something they shouldn't have said*?

Yes (Score: 1)

No (Score: 0)

Person identification question: *Who said something they shouldn't have said*?

Anna. (Score: 1)

Marcella or Others (Score: 0)

False belief question (Cognitive ToM): *Did Anna know who had bought the crystal bowl*?

No (Score: 1)

Yes (Score: 0)

Affective question (Affective ToM): *How do you think Marcella felt*?

Answers reflecting feelings of hurt, anger, embarrassment, or disappointment (Score: 1)

Answers reflecting lack of empathy with the protagonist (Score: 0)