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Theory of Mind and Executive Functions in normal aging: Independent or Related Deficits?

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Abstract

Objective: Higher-order cognitive and affective Theory of Mind (ToM) and simple emotion identification constitute essential prerequisites of social cognition. Recently, literature has begun to be interested in the trajectory of ToM in late adulthood, providing contradictory results as regards age effects in mentalizing and mechanisms that may account for these changes. The present study attempted to address how specific ToM aspects change in normal aging, their intercorrelations and the unique role of executive functions in these relationships.

Method: Fifty healthy old adults were compared against a younger control group on a neuropsychological battery consisted of measures of core executive functions (working memory, inhibition control, and mental flexibility), faux pas test for affective and cognitive ToM and the Reading the Mind in the Eyes test (RMET) for emotional identification. Regression and mediation analyses were conducted to identify the best predictors of every ToM subcomponent and to examine the real effect of age upon mentalizing.

Results: Data yielded robust age differences in all executive tasks, as well as in faux pas stories and RMET scores. The only significant predictor for cognitive ToM was age, whereas neither executive subdomains nor the emotional detection accounted for its variation. Similarly, age explained an important variation of RMET performance among participants, while a trend occurred for inhibition to become a significant regressor too. Age in cooperation with cognitive flexibility and emotional perception capacity were the strongest predictors for affective ToM, but working memory and inhibition remained nonsignificant predictors. Mediation analysis indicated that only emotional identification attenuated the effect of age on affective mentalizing, although age continued to be significantly correlated with emotional faux pas scores.

Discussion: Rather that a selective decline of ToM, older individuals show generalized difficulties on lower and higher order ToM tasks. Decline in cognitive ToM seem to occur independent of executive deterioration. Reduction of emotion perception appears as a sequalae of late adulthood changes, but the likelihood of some executive dysfunction to exacerbate the difficulties should be considered. Diminished affective ToM may happen either directly due to older age or as an indirect outcome of age through the underlying deteriorations on basic emotional skills. Findings highlight the need for further studies regarding ToM in normal aging within a multidimensional context.

Keywords: Theory of Mind; normal aging; affective; cognitive; emotion identification; executive functions

Contents

Introduction	4
The role of executive function in ToM	6
Theory of Mind in normal aging	7
The role of executive dysfunction in ToM during normal aging	9
The present study	12
Purposes of the study	12
Materials and Methods	13
Participants	13
Procedure and materials	14
Higher-order and lower-order ToM tasks	14
Executive function measures	16
Statistical Analysis	18
Results	19
Individual Differences Measures	20
Correlations and Regression Analyses	23
Mediation Analysis	29
Discussion	30
Deterioration of ToM in older age	31
Relationships between age, executive functions and mentalizing	34
Basic emotional recognition and complex ToM ability	36
Strengths and Limitations of the study	38
Conclusions	39
References	41

Introduction

Social cognition constitutes a complex socio-cognitive ability that enables us to make sense of the world and to function harmoniously in complex social settings by effectively regulating and guiding our behavior (Frith, 2008). In order that we do that we need to interpret, process properly and represent mentally social cues (Love, Ruff & Geldmacher, 2015). Social cognition is a multi-dimensional concept. Emotional awareness and understanding and Theory of Mind (ToM) are essential prerequisites of social cognition.

ToM – also referred as mindreading and mentalizing – is the capacity of attributing to and reasoning of other people's mind states, (Premack & Woodruff, 1978; Baron-Cohen, Leslie & Frith, 1985), with the knowledge that often our perspective about the world differs from the others' (Kanske, Böckler, Trautwein & Singer, 2015; Dvash & Shamay-Tsoory, 2014). Researchers have repeatedly demonstrated that putting oneself into someone else's shoes is not a univariate process. It contains two distinct, yet interconnected, dimensions, namely cognitive and affective ToM (Shamay-Tsoory, Tibi-Elhanany, & Aharon-Peretz, 2006).

The cognitive subcomponent of ToM reflects the ability to identify others beliefs, thoughts, intents, and desires; the cognitive states of another person. Affective ToM is the capacity to recognize someone else's feelings and emotions; its emotional condition in a given social circumstance (Henry, Cowan, Lee, & Sachdev, 2015). According to Shamay-Tsoory (2010), these two aspects are counted within the wider, general system of empathetic ability, comprising the cognitive concept of getting inside the mind of another person and adopting its perspective.

Investigations of typically developed children have shown that ToM is developing in a continuum (Ibanez, Huepe, Gempp, Gutiurrez, Rivera-Rei & Toledo, 2013). Normal

9-years-old children can easily succeed in first and second-order mentalizing tasks, such as false belief and strange story tests. They are capable to assume that people happen to carry diverse beliefs about the world, different from their own. Around the age of 11 to 13, children can deal with much more sophisticated social scenarios and they are able to detect intentional and unintentional behaviors, like faux pas and to recognize even more complex emotional conditions (Giovagnoli, 2018; Yeh, 2013; Miller, 2009; Korkmaz, 2011).

In addition, a clear pattern of impaired or preserved ToM is detected in certain clinical populations. Patients with Alzheimer's disease, for instance, show difficulties in tasks that assess complex cognitive mentalizing with a relatively spared emotional ToM at least in the first stages of the disease (Poletti, Enrici & Adenzato, 2012). On the contrary, psychiatric disorders, like schizophrenia, tend to be more impaired in affective aspect of ToM, with a well-preserved cognitive ToM (Kennedy & Adolphs, 2012).

Neuroimaging studies, on the other hand, have demonstrated that ToM is supported by a complex neural network, the "ToM circuit", involving multiple prefrontal, temporal and parietal regions (Schurz, Radua, Aichhorn, Richlan & Perner, 2014). It is supposed that posterior cortical areas are involved in both dimensions of ToM and in lower processes of emotional perception, while anterior regions follow a kind of specialization. That is to say, dorsolateral and dorsomedial prefrontal regions and dorsal anterior cingulate cortex (ACC) play a major role in cognitive mentalizing, while ventromedial prefrontal cortices and ventral ACC serve affective ToM (Kalbe et al., 2010; Abu-Akel & Shamay-Tsoory, 2011). Empirical evidence for this differentiation comes from patients with well-defined focal lesions (e.g. damage to ventromedial PFC) who proved ineffective in the attribution of emotional states, but were capable to discern mistaken perceptions of others (Shamay-Tsoory, Tomer, Berger, Goldsher & Aharon-Peretz, 2005; Shamay-Tsoory, Tibi-Elhanan & Aharon-Peretz, 2006).

The role of executive functions in ToM

Mentalizing is not an isolated process independent from other cognitive functions. Among different cognitive processes, executive functions have been the most studied regarding their possible associations with ToM. It is commonly recognized, that executive function is an umbrella term consisted of a set of abilities with the primary purpose of conscious monitor of behavior and goal-directed action (Wade, Prime, Jenkins, Yeates, Williams & Lee, 2018). Some of the basic processes of executive control are those of inhibition, cognitive flexibility, working memory, planning and problem-solving (Lezak, 1995).

Developmental psychologists have provided empirical evidence, reporting that a mature executive system is the strongest predictor for a subsequent well-developed ToM in childhood (Fisher & Happe´ 2005). Especially inhibition control and flexibility are necessary to firstly suppress our self-viewpoint about the world (Cavallini, Lecce, Bottiroli, Palladino, & Pagnin, 2013; Launay, Pearce, Wlodarski, van Duijnb, Carney, & Dunbar, 2015) and secondly to swift and adopt someone else's perspective (Carlson, Moxes & Claxton, 2004). Neuroanatomical studies propose a common neural basis for executive functions and ToM, with prefrontal cortical regions possessing an important role. As in ToM, dorsolateral prefrontal cortex has been found to be associated with swift set and working memory and the ventromedial prefrontal cortex with the inhibitory control, while orbitofrontal cortex is activated during impulse control and monitoring of social behavior (MacPherson, Philips & Della Sela, 2002).

While there is adequate evidence to justify the interconnection of executive function and ToM, other data come into conflict with this idea (Wade et al., 2018). Although, individuals with high-functioning autism note outstanding performance in executive tasks, they are not as sufficient as the healthy controls in complex metalizing assessment (Giovagnoli, 2018). Some authors, also, contend that while executive mechanism is an essential factor for ToM development during early childhood and until adolescence, once ToM has fully developed, it becomes independent from executive functioning (Apperly, Samson & Humphreys, 2009; Yeh, 2013). Thus, beyond a critical point, the maintenance or impairment of an ability does not necessarily entail the other's conservation or decline.

Theory of Mind in normal aging

As for late adulthood, studies are far from getting a clear conclusion on social cognition's changes occurring with age. ToM has been repeatedly evaluated in old adults over the last twenty years, and despite the fact that there is a trend and a general consensus of decline, results are still contradictory (Henry, Philips, Ruffman & Bailey, 2013; Moran, 2013). The first study that attempted to investigate ToM in normal aging concluded that older people were much more efficient in a ToM task than younger individuals, arguing that as we age, we become wiser and more capable of social interactions (Happé, Winner, & Brownell, 1998).

Nevertheless, more recent findings confute this statement and support that older population underperform younger adults in many ToM tasks and this decline is much more apparent in demanding tests. Elderlies are shown to be as capable as young and middle-age adults, when they have to consider what a single person might think (Duval et al., 2011; McKinnon & Moscovitch, 2007; Zaitchik, Koff, Brownell, Winner & Albert, 2006), but they demonstrate extreme difficulty in simultaneously detecting thoughts and beliefs of more than one individuals (Lecce, Ceccato & Cavallini, 2019; Cavallini et al., 2013; Fischer, O'Rourke, & Thornton, 2016; Love et al., 2015). Again, other studies failed to confirm this pattern, with old and young participants achieving equal scores in complex ToM tasks (Giovagnoli, 2018; Saltzman., Strauss, Hunter, & Archibald, 2000).

Given that most researchers have focused on cognitive aspect of mentalizing, the mechanism of affective ToM through lifespan is, until now, little understood. Results remain ambivalent, indicating either conservation (Castelli et al., 2010; Bottiroli, Cavallini, Ceccatob, Vecchi, & Lecce, 2016; Yıldırım, Büyükişcan & Gürvit, 2019) or reduction (El Haj, Raffard, & Gély-Nargeot, 2015) of the older people's capacity to decipher and classify socially related emotional states. Some investigators have proposed that the age-related decline is apparent only for complex feelings, not for simple emotions (Ze, Thoma & Suchan, 2014; Duval et al., 2011). Others highlight the possibility of a positive emotional processing bias, an adaptive strategy, through which older adults prefer to *avoid* unpleasant emotions in order to prevent social conflict (Ruffman, Henry, Livingstone & Phillips, 2008; MacPherson, et al. 2002). The inferences of these specific emotional stimuli decrease with aging, however, are still debatable

Under the shadow of uncertainty, it is noteworthy that, until now, almost all studies confronted some methodological shortcomings. Small sample sizes (Castelli et al., 2010. Saltzman et al., 2000) and a trend of female over-representation (Mahy, Vetter, Kühn-Popp, Löcher, Krautschuk, & Kliegel 2014; Bernstein, Thornton, & Sommerville. 2011) may account for differentiating outcomes among studies. Gender is supposed to influence performance in social related tasks, with women outperforming men, especially when emotion detection is involved (Yıldırım, et al., 2019). Moreover, several researches adopted slightly flexible inclusion criteria, namely a relative lower education level for older participants and a cut-off point of score equal to 23 -26/30 in screening tests (Giovagnoli, 2018; Lecce et al., 2019) Furthermore, initial studies examined either the cognitive or the affective ToM, in isolation, (Happe' et al., 1998; MacPherson et al., 2002; Maylor., Moulson, Muncer, & Taylor 2002), making impossible a direct comparison between the two components in the same sample.

The role of executive dysfunction in ToM during normal aging

Even among nondemended older adults a degree of cognitive decline is unpreventable. Executive functions seem to be the most vulnerable cognitive domain after the age of sixty, due to progressive anatomical and functional deterioration of the frontal lobes (Buckner, 2004; Baksh, Bugeja, & MacPherson, 2020; Peters, 2006). A different pattern of alternation might occur within the prefrontal cortex, during late adulthood, with lateral and ventromedial regions exhibiting the most severe levels of volume loss and white matter microstructural damages (Cabeza & Dennis, 2013), thus, inducing several executive difficulties. Bear in mind that these regions are supposed to be involved in ToM processes, as well (Abu-Akel & Shamay-Tsoory, 2011).

Working memory and cognitive inhibition are the functions with the most early age-related changes (Turner & Spreng, 2011; Buckner, 2004). Studies have indicated the negative association between gray matter atrophy of prefrontal cortex and performance in working memory and inhibition tasks (Treiz, Heider & Daum, 2007; Buckner, 2004). Furthermore, older adults recruit compensatory, yet insufficient, mechanisms, during low and high demanding working memory and inhibition tasks (Treiz et al., 2007), activating bilaterally adjacent frontal regions in order to accomplish as good performances as younger groups (Turner & Spreng, 2011; Cabeza & Dennis, 2012).

Assuming that ToM and executive abilities change from younger to older adulthood and that executive functions correlate with mentalizing, as studies in childhood and youth indicate, and because of shared anatomical circuits including prefrontal cortices, an important issue concerns the relationship between ToM difficulties and executive decline in normal older adults. The contribution of cognitive decline in ToM performance in older populations is still a matter of debate.

The *domain-general hypothesis* argues that the observed ToM underperformance is mainly a byproduct of an age-related dysexecutive syndrome, not a social reasoning decline per se (Yeh, 2013; Bottiroli et al., 2016; Phillips, Bull, Allen, Insch, Burr & Ogg, 2011). Making inappropriate comments or even falling victims of frauds is due to the fact that elderlies are unable to suppress their own initial perspective (inhibition), manipulate multiple social cues (working memory) and step into someone else's shoes (cognitive flexibility), so as to appreciate what other people may think and feel. On the other hand, the *domain-specific hypothesis* assumes that ToM is a functionally dissociable mechanism among general cognitive abilities and, although they decrease concurrently as we age, they are fully independent and unrelated (Cavallini et al., 2013; Giovagnoli, 2018; Bernstein et al., 2011). There is evidence for both assumptions, while more attention has been given to cognitive mentalizing and little is known about affective ToM (Moran, 2013; Wade et al., 2018).

Recent studies have mainly focused in deterioration of working memory and inhibition and they have partly affirmed that their decline affects mindreading. Older participants' lower performances in some complex cognitive ToM tasks were mediated by achievements in executive functions scores (Charlton, Barrick, Markus, & Morris, 2009; Bottiroli et al., 2016). Yet literature advocates the opposite assumption too. Age differences in ToM remained, even after controlling for executive function effect, and researchers concluded that mentalizing decline is not attributable to general cognition (Wang & Su, 2013; Baksh et al.,2020; Bernstein et al., 2011).

Data for affective ToM are limited. Evidence suggests some kind of positive association between affective mentalizing and some executive tasks, mainly those assessing inhibition abilities (Li et al., 2013; Racokzy et al., 2013), but relationships with other core executive skills remains unstudied. Again, another option is that emotional decoding and affective understanding in complex social environments does not demand intact executive processes (Mahy et al., 2014; Wang & Su, 2013; Yildirim et al., 2019; Ahmed & Miller, 2011) and that any possible impairment of this process is a direct outcome of age alone.

It is worth noticing, however, that conflicting findings, both for the affective ToM deficiency itself and for its speculated relationship with executive deterioration could be attributed to the false interpretation of some tasks, such as the Reading the Mind in the Eyes Test (RMET). For the most studies, it is a characteristic tool for affective ToM assessment (Henry et al., 2015). Actually, is a simpler task compared to the second-order cognitive ToM tests and reflects a more primitive mentalizing skill, namely emotional recognition (Ahmed & Miller, 2011; Launay et al., 2015). It demands only the attribution of one's mental state, the very first step in ToM, (I only understand that somebody feels that way), independently of any social content (I understand that somebody feels that way because something happened) (Wang & Su, 2013; Bailey, Henry & Von Hippel, 2008; Nazlidou et al., 2015). Thus, the conclusion that older people maintain intact affective ToM abilities by using only this assessment needs additional and more extensive investigation.

The present study

Research has thoroughly investigated the developmental trajectory of mentalizing and the most prominent factors that affect this development throughout childhood. We know quite well how ToM functions among many clinical populations, such as in autism spectrum disorder and in various neurological and psychiatric conditions. However, a framework of mentalizing functioning in normal aging should be better clarified, in order that future studies provide more reliable comparisons between normal and clinical populations.

Given the discrepancies of the literature so far, deriving from various methodological limitations and the restricted empirical data regarding the investigation of social cognition in late adulthood, we conducted a case-control study seeking to examine how mentalizing functions in older population. The study aimed to examine the core components of social cognition – the complex affective and cognitive ToM and the more basic emotional identification – among normal aging, as well as the interaction between lower and higher-order ToM tasks and core executive processes, namely inhibition, working memory and cognitive flexibility. We would like to demonstrate that chronological age affects, alone or in combination with other confounders, mentalizing skills.

The present study was approved in September 2019 by the Ethics Committee of the Postgraduate Program at the National and Kapodistrian University of Athens.

Purposes of the study

In order to reach our goals, the primary and secondary hypotheses were formulated as follows:

1. Although deficits in cognitive ToM have been confirmed by most previous studies, affective ToM has seldom been taken into account and a definite conclusion is not possible. We expected to detect an age-related decline in cognitive ToM, but also a difficulty as regards complex and basic affective ToM (namely emotional recognition) relative to a normal younger group.

2. We explored the possible associations between executive functions, both aspects of sophisticated ToM (cognitive and affective), and the simpler ToM ability of emotional recognition. We speculated a different pattern of associations between every component of mentalizing and executive functioning, since higher and lower-order cognitive and affective ToM are distinct dimensions of social cognition and thus they may demand different executive processes.
3. As emotional recognition is an essential ability for more complex ToM schemas, we aimed also to examine the possible associations between these two processes. Little is known about this relation, as many studies equate emotional identification and complex ToM and they do not consider emotional awareness as a simpler mentalizing aspect and a key requirement for a well-functioning sophisticated mentalizing.

Materials and Methods

Participants

One-hundred participants were recruited for the purposes of the study. The first group consisted of fifty older adults, between 60 and 80 years old (mean age; 69.13±5.76), and the second one was comprised of younger adults with an age range between 20 and 40 years (mean age; 29.70±6.92).

All subjects were community residents and Greek native speakers, who participated voluntarily in the study. Inclusion criteria for all participants were the absence of a) history of cognitive complaints, b) neurological or psychiatric disorder, c) substance abuse, d) stroke and e) severe brain injury. They had to have normal or corrected-to-normal vision and hearing and no achromatopsia or dyschromatopsia. We briefly evaluated their general cognitive function with the Greek version of Montreal Cognitive

Assessment (MoCA) (Konstantopoulos, Vogazianos, & Doskas 2016). and we sat the cut-off score on 26 points. All subjects had completed at least twelve years of schooling. We were aware of the fact that numerous Greek elderlies have received only an elementary education (9 years or less), while the younger people usually receive a higher level of education (16 years or more). We tried to minimize this difference by selecting participants with almost equal educational level. We excluded every participant with an aberration from the pattern mentioned above.

Procedure and Materials

A 1-hour neuropsychological assessment was conducted consisted of ToM and neurocognitive tests. A consent form- in accordance with the principles laid down by the Helsinki Declaration - was obtained by all participants.

During the first session, subjects were interviewed about their demographic and medical features and they were assessed with MoCA. In the second session, the tests' presentation order was counterbalanced across participants. Some administrations begun with the ToM assessment followed by the executive function evaluation and vice versa.

<u>Higher-order and lower-order ToM tasks</u>

Faux pas test: The Greek, brief version of the faux pas test was administered (adapted from Stone et al., 1998 by Patrikelis & Angelakis, n.d.), with five faux pas stories and five control stories. It has been utilized as a sensitive tool in clinical and research practice to detect subtle social reasoning difficulties. It this study, it was used to assess both complex cognitive and affective ToM, thereby allowing direct comparisons between the groups. It is considered a complex second-order ToM test (Thiebaut et al., 2015).

Test included little written scenarios, where two protagonists interacted each time. Owing to different circumstances, the one character committed a faux pas, making a comment unintentionally without considering whether it was something that the other would not wish to hear or know, and this typically had a negative emotional impact on the listener. Participants had to recognize whether someone acted inappropriately, which one (detection questions), why the person said something that should not have been said (cognitive ToM questions) and how the person who received the faux pas felt (affective ToM questions). If someone responded correctly in the first section, the examiner continued by asking the other questions; otherwise the story was skipped. For each correct answer one point was given. Control stories were given in order to avoid the response yes-bias and measured just the subject's comprehension ability.

Every participant read each vignette aloud. There was no time limit to answer each question and the texts remained in front of the subjects all over the examination. A total score of 30 points was given for all faux pas stories (10 points for the faux pas identification, 10 for cognitive ToM and 10 for affective ToM) and 10 points for all control scenarios.

Reading the Mind in the Eyes Test (RMET): We used the Greek version of the Revised RMET (Baron-Cohen, Wheelwright, Hill, Raste, & Plumb, 2001), that has better psychometric qualities, as it is free of ceiling effects, compared to the original one (Bailey, Henry & Von Hippel, 2008). Thirty-six black-and-white photographs involving only the eyes area of human faces were showed on A4 sheets of paper. Images contained basic as well as complex emotions, such as indecisive, embarrassed and suspicious. Each picture was accompanied by four semantic adjectives that described different emotional mental states. The four descriptors were not only adverse words (one negative vs three positive feelings), as it would be too easy for someone to detect the correct answer; instead they had some common characteristics.

Participants were asked to look each photograph carefully and choose among the adjectives, the one, that they believed, fitted better to the feeling of the person in the image. There was no time boundary for the response and each correct answer was graded with 1 point, thus the total score ranged between 0 and 36 points.

Executive function measures

Stroop Neuropsychological Screening Test (SNST): Inhibition ability was evaluated using the Greek version of SNST (Zalonis et al., 2009; Stroop, 1935). Stroop like tests require high cognitive control, as someone has to consciously restrain an automatic reaction for a non-dominant response. It has been found that this type of inhibition – rather than simpler types like motor inhibition – is associated with mentalizing (Rakoczy et al., 2012).

The test consisted of two conditions, each with one card of three columns of 120 words. A time limit of 120 seconds established for each trial. In the first condition, which served as a control trial, participants had to read color words as soon as possible. In the second and most complicated condition (interference condition), the subjects were asked to name the color of the inks that, however, did not correspond with the written color words. This trial was the main measure and reflects the inhibition ability, as someone must ignore and suppress the automatic process of read the word and instead identify the color of the word.

The time required for completion of the first condition was registered. The number of items mentioned in the given time accounted for the total score in the second condition. The inhibition ability (i.e. interference score) was calculated as the number of correct responses minus the number of errors (e.g. name the written word instead of the color of the word). Higher score meant better performances.

Digit span: This task is considered a classic measure of short term and working memory capacity (forward and backward condition, respectively) (WAIS-R, Wechsler, 1981). Backward digit span involves not just the storage of information in short-term memory, but also the active manipulation of this information. Following the Baddeley's theory, it assesses the central executive mechanism of working memory, e.g. the management of verbal (or spatial) inputs and the direction of attention according their priority (Canchez-Cubillo et al., 2009).

The examiner read aloud sequences of numbers, in a stable rhythm (one digit per second), that progressively became longer. Each sequence consisted of two trials with the same number of items. Once each sequence was presented, participants had to immediately repeat the numbers in the same (forward digit span) or reversed order (backward digit span). The administration terminated when the subject failed to recall both numerical trails of the same sequence.

All responses were recorder and two points were given for every correct recall. The total score ranged from 0 to 24 for the backward condition (eight sequences with two trials each) and from 0 to 25 for the forward condition, as the first sequence was too easy and scored with one point. Higher scores entailed better performances.

Trail Making Test, parts A-B (TMT): Cognitive flexibility were assessed by the Greek version of TMT (Zalonis et al., 2008; Reitan, 1958). The successful completion of the test requires good coordination, sustained and divided attention and motor speed. Additionally, part B demands the flexibility to disengage from a previous response in favor of an alternative one (Wecker et al., 2005).

Part A of TMT is considered a classic baseline measure of processing-speed capacity (Racokzy et al., 2013). It requires the quick, serial connection of the numbers in ascending order. The most challenging Part B, however, commands to draw a line through repeated alternations between number in ascending order and letters in alphabetic order (e.g. 1-A-2-B-3-C, etc). There was an exercise condition before the main assessment, so as participants familiarized with the test's requirements.

We measured performance by timing the subjects until completion of each part. The briefer the time it took to fulfill each condition, the better TMT performance. For Part A this meant faster processing-speed abilities, while for Part B this counted for more successful mental flexibility.

Statistical Analysis

All statistical analyses were performed using IBM SPSS Statistics 21 software. The level of significance was set at $\alpha = .05$. By virtue of large number of comparisons, p value was adjusted, via Bonferroni corrections, to avoid false positive results, so significance was reestablished at $\alpha \leq .005$.

A series of independent samples t-tests was conducted to detect age-related differences in executive functions, emotional detection, control stories and identification of faux pas. Where the assumption of normal distribution was violated, Mann Whitney U tests were performed. Furthermore, a 2 (age groups) x 2 (affective and cognitive ToM) mixed ANOVA was conducted with age group as a between-participants factor and faux pas components as a within-participants factor.

The second step of our statistical analysis contained the investigation of mechanisms, namely age and executive measures, were associated with the performance on the three measures of mentalizing. We examined the correlations between age (modeled as a categorical variable), executive functions, emotional identification, higher-order cognitive and affective ToM. Next, we run three separate hierarchical lineal multiple regression analyses (enter method) to investigate the best predictors on each mentalizing test. Assuming that cognitive and affective faux pas detection is more complex socio-cognitive process than the simple identification of emotions, we entered in their regression models RMET as predictor variable as well. Lastly, we performed mediation analysis to test whether the association between age and sophisticated ToM was mediated by executive functions or lower-order mentalizing abilities, using SPSS PROCESS macro program (Preacher & Hayes's, 2004), following the logic of Baron & Kenny, 1986.

Results

Table 1 demonstrates the comparisons between the two groups on age, gender, education, and general cognitive ability, as measured with MoCA. As shown, the two groups did not differ significantly with regard to gender, education level [t (98) =1.141, *p*=.257], and MoCA scores [t (98) = 1,770, *p*=.080], although there was a trend towards better performances on control group.

Table 1

Sample demographic characteristics and general cognitive ability scores

Background Information	Younger Group (n=50)	Older Group (n=50)	*p*
Age	29.90 (6.719)	69.13 (5.758)	<.001***
Years of Education	15.04 (1.948)	14.58 (2.081)	.257
Male (%)[a]	50	50	1.000
MoCA	28.18 (1.335)	27.72.(1.262)	.080

Notes: We present means and standard deviations as *M* (*SD*).
MoCA=Montreal Cognitive Assessment
[a] *p* value derived from chi-square test
****p* < .001

Individual Differences Measures

Table 2 presents the results of groups' performances on all executive function measures, RMET, control stories and identification of faux pas. Means (or medians), Standard Deviations, t values (or U values) and statistical significance are illustrated. For all variables, effect sizes were calculated.

Table 2

Differences between the groups in terms of neuropsychological performance

Task	Cognitive function	YG (n=50)	OG (n=50)			
		M (SD)/Median	*M (SD)/Median*	*T/U*	*p*	*d/r*[a]
Digit Span Forward	Short-term memory	19.66 (2.18)	14.96 (2.21)	10.70	<.001***	2.14
Digit Span Backward	Working Memory	18.62 (2.14)	12.38 (1.90)	15.45	<.001***	3.09
TMT-A	Processing speed	22.58 (6.43)	46.12 (12.77)	-11.65	<.001***	2.34
TMT-B	Cognitive flexibility	55.14 (16.93)	109.58 (24.24)	-13.02	<.001***	2.60
SNST-A	Reading speed	48.99 (5.15)	63.41 (10.85)	-8.49	<.001***	1.69
SNST-Interference Score[b]	Inhibition	110.00	86.00	113.50	<.001***	-.78
RMET	Emotional recognition	28.24 (2.17)	20.78 (2.63)	15.47	<.001***	3.09
FP-Identification[b]	Complex Theory of Mind	10.00	10.00	785.00	<.001***	-.40
FP-Control Stories[b]	Comprehension ability	10.00	10.00	896.00	.01**	-.34

Notes: We present means and standard deviations as *M* (*SD*).
YG = Younger Group; OG = Older Group; TMT-A = Trail Making Test- part A; TMT-B = Trail Making Test-part B; SNST-A = Stroop Neuropsychological Screening Test- part A; RMET = Reading the Mind in the Eyes test; FP = Faux Pas
[a]*d* represents Cohen's d effect size calculation; small ES ≤ .20; medium ES ≥ .50; large ES = .80; very large ES ≥ 1.30
r represents the effect size of Mann – Whitney U test; small ES ≤ .10; medium ES ≥ .30; large ES ≥ .50
[b]values derived from Mann-Whitney U test
$^{**}p \leq .01$. $^{***}p < .001$. Bonferroni correction was used to adjust for multiple comparisons; $\alpha \leq .005$

Analyses indicated that older participants achieved overall worse scores compared to younger individuals in all tests. These differences maintained significant after Bonferroni corrections, with the exception of performance in control stories of faux pas test (p =.01) Younger group outperformed older group across all cognitive tests, specifically in Digit Span, Forward and Backward [t (98) = 10.70, $p < .001$, $d = 2.14$ and t (98) = 18.62, $p < .00$, $d = 3.09$ respectively], in TMT part A and B subtests [t (98) = -11.65, $p < .001$, $d = 2.34$ and t (98) = -13.02, $p < .001$, $d = 2.60$ respectively], in SNST part A, t (98)= -8.49, p <0.001, $d = 1.69$, and in interference score of SNST (*Mdn* = 110.00 versus *Mdn* = 86.00), U (98) = 113.50, p <0.001, $r = -0.78$. As expected, older group achieved lower performances in mentalizing tasks, as well. As shown, old adults displayed prominent difficulties in detecting complex face emotions [t (98) = 15.47, p <0.001, $d = 3.09$], as well as, in discriminating faux pas commitment [U (98) = 785.00, p <0.001, $r = -0.40$]. Effect sizes for the majority of measures demonstrated that all age differences were robust, highlighting the magnitude of the results.

A repeated measures ANOVA was conducted as described earlier. Means and standard deviations for groups' performances in ToM subcomponents are summarized in Table 3.

The analysis revealed significant main effects for both the ToM conditions [F (1, 98) = 51.78, $p < .001$, $\eta^2 p = .346$] and the age groups [F (1,98) = 154.98, $p < .001$, $\eta^2 p$=.613]. Participants performed better in affective than in cognitive mentalizing and younger group achieved higher scores in ToM subscales compared to older group. There was also a significant interaction between age of participants and faux pas sub scores [F (1,98) = 24.07, $p < .001$, $\eta^2 p = .197$) (Table 4).

Table 3

Means and Standard Deviations for the components of the Faux Pas for the two age groups

Task	Cognitive function	Age group	M (SD)	N
FP-Cognitive	Cognitive ToM	YG	9.16 (0.93)	50
		OG	6.32 (1.24)	50
		Total	7.74 (1.80)	100
FP-Affective	Affective ToM	YG	9.44 (0.84)	50
		OG	7.80 (1.28)	50
		Total	8.63 (1.35)	100

Notes: We present means and standard deviations as *M* (*SD*)
YG = Younger Group; OG = Older Group; FP = Faux Pas

Table 4

Repeated measures Analysis of Variance in components of Faux Pas by age group

	df	*SS*	*MS*	*F*	*p*	$\eta^2 p$
Between groups						
Age group	1	250.88	250.88	154.98	<.001***	.613
Error	98	158.64	1.62			
Within groups						
Faux Pas	1	38.72	38.72	51.78	<.001***	.346
Faux Pas x Age group	1	18.00	18.00	24.07	<.001***	.197
Error	98	73.28				

***$p < .001$

Further analysis of the simple effects revealed that older adults performed significantly lower across cognitive, F (1,98) = 168.03, $p < .001$, and affective ToM, F (1,98) = 67.24, $p < .001$. They also exhibited worse scores for cognitive ToM compared to affective ToM, F (1,98) = 73.23, $p < .001$, while this pattern was not observed in control group of younger individuals, F (1,98) = 2.62, $p = .109$. Figure 1 illustrates graphically the ANOVA's observations.

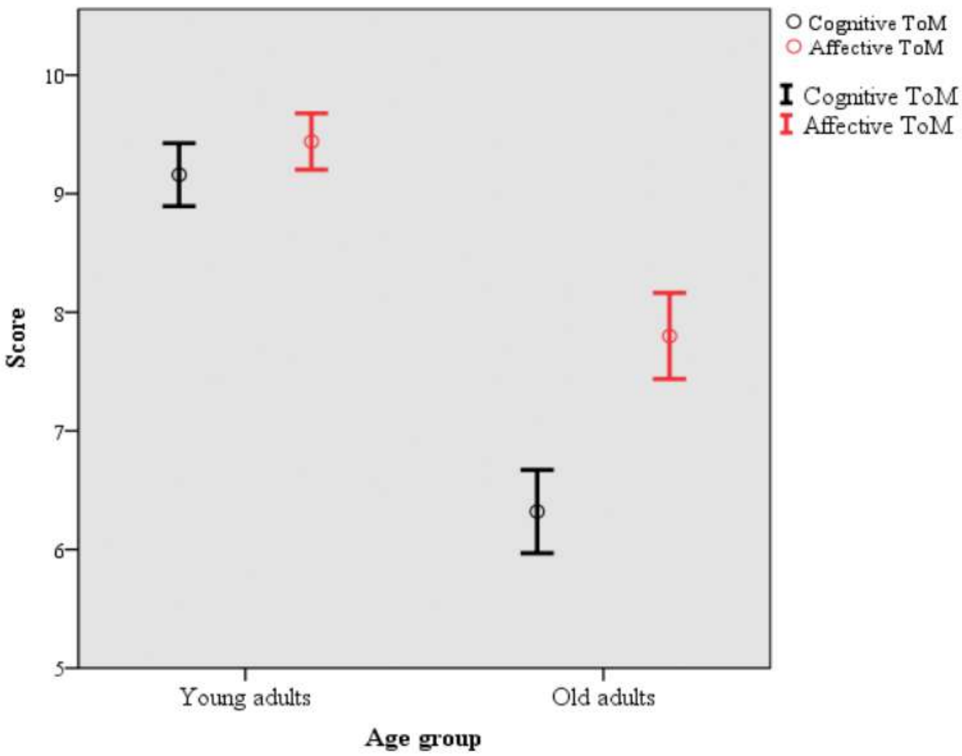

Figure 1: Error bar chart for two groups across the two conditions of ToM

Correlations and Regression Analyses

Correlation coefficients between age, measures of executive functions and ToM tests were investigated. Results are presented in Table 5. Age was negatively and strongly correlated with working memory capacity, inhibition, detection of emotions, cognitive and affective ToM, whereas there was a positive relation between age and scores in TMT-B, indicating diminished cognitive flexibility. Additionally, all executive functions were exhibited significant correlations with every measure of ToM. Relationship between simple ToM capacity (emotional identification), and complex cognitive and affective mentalizing was significant, as well. All the above correlations were significant at the $p < .001$ level.

Given that age and executive functions correlated with all ToM tests, we conducted a series of three independent hierarchical multiple regression analyses to identify the most robust predictors of simple emotional recognition and complex ToM subcomponents. The outcomes of each regression are reported in Tables 6,7 and 8.

Table 5

Correlation coefficients between age, executive functions and ToM

	Age	DS-Backward	TMT-B	SNST-Interference Score	RMET	FP-Cognitive	FP-Affective
Age	-	-.842***	.796***	-.805***	-.842***	-.795***	-.609***
DS-Backward	-	-	-.790***	.719***	.774***	.698***	491***
TMT-B	-	-	-	-.827***	-.778***	-.662***	-.422***
SNST-Interference Score	-	-	-	-	.778***	.691***	.503***
RMET	-	-	-	-	-	.754***	.607***
FP-Cognitive	-	-	-	-	-	-	.661***
FP- Affective	-	-	-	-	-	-	-

Notes: DS = Digit Span; TMT-B = Trail Making Test-part B; SNST= Stroop Neuropsychological Screening Test; RMET = Reading the Mind in the Eyes test; FP = Faux Pas

$^{**}p < .001$.

A two-step regression was conducted with RMET as the dependent variable. For step 1, age was entered as the only predictor. DS backward, TMT B, and interference score of SNST were added as predictor variables at step 2 (Table 6). Both F-tests for steps 1 and 2 were significant (p < .001). The first model indicated that age alone significantly predicted RMET ($Fchange$ [1, 98] = 239,33, $p < .001$, $R^2 = .709$, $Adj\ R^2$ = .707) explaining an 70.9% (R^2 *change* = .709) of the variation. At the second model, measures of working memory, $\beta = .130$, t (95) = 1.28, p =.204, cognitive flexibility, β = -.157, t (95) = -1.49, p =.140, and inhibition, β = 185, t (95) = 1.84, p =.069, did not significantly accounted for the performance on RMET, adding only an additional 4.4% in the variation (R^2 *change* = .044), whereas age remained the only significant predictor (β = .458, t (95) = -4.08, p <.001). However, there was an obvious trend (p = .069) toward interference score of SNST to be a significant predictor too, supporting partly our primary hypothesis that age-related difficulties in emotional identification could be affected by some aspects of executive functioning.

Table 6

Summary of Hierarchical Regression Analysis for Variables Predicting RMET

	Model 1			Model 2		
	b	SEB	β	b	SEB	β
RMET	28.240	.341		19.878	4.877	
Age group	-7.460	.482	$-.842^{***}$	-4.058	.995	$-.458^{***}$
DS-Backward				.195	.122	.130
TMT-B				-.020	.014	-.157

SNST-Interference Score		.060	.033	.185
R^2	.709		.753	
$Adj\ R^2$	.707		.743	
$F\ change\ in\ R^2$	**.709*****		**.044****	

Note. Each step was compared to the previous model in the hierarchical regression analysis.

DS = Digit Span; TMT-B = Trail Making Test-part B; SNST= Stroop Neuropsychological Screening Test; RMET = Reading the Mind in the Eyes test; FP = Faux Pas
$^{**}p < .01$. $^{***}p < .001$

A second multiple hierarchical regression was performed to determine the best subgroup of predictors of the variance in higher-order cognitive ToM (Table 7). Again, the input order was the same as in first regression. RMET score was entered as an additional predictor, along with executive functions, at step 2. The first step indicated that adding age as the first predictor explained an 63.2% of the variation in cognitive ToM [*Fchange* (1, 98) = 168,03, $p < .001$, $R^2 = .632$, $Adj\ R^2 = .628$]. In the following step, although, DS Backward, $\beta = .052$, t (94) = .46, $p = .672$, TMT B, $\beta = .064$, t (94) = .51, $p = .611$, interference score, $\beta = .097$, t (94) = .80, $p = .425$, and RMET, $\beta = .269$, t (94) = 2.21, $p = .029$, did not account for the variation of cognitive ToM, while they changed the whole model as non-significant [*Fchange* (4, 94) = 1.87, $p = .122$, $R^2 = .659$, $Adj\ R^2 = .641$]. Overall, older age was the only significant variable that affected cognitive ToM and this relation was independent of other cognitive abilities or more basic socio-cognitive skills.

Table 7

Summary of Hierarchical Regression Analysis for Variables Predicting Cognitive ToM

	Model 1			Model 2		
	b	SEB	β	b	SEB	β
FP-Cognitive	9.160	.155		4.060	2.522	
Age group	-2.840	.219	-.795***	-1.779	.514	-.498**
DS-Backward				.025	.059	.052
TMT-B				.003	.007	.064
SNST-Interference Score				.013	.016	.097
RMET				.108	.049	.269*
R^2		.632			.659	
$Adj\ R^2$		.628			.641	
$F\ change\ in\ R^2$		**.632***			**.027**	

Note. Each step was compared to the previous model in the hierarchical regression analysis.
DS = Digit Span; TMT-B = Trail Making Test-part B; SNST= Stroop Neuropsychological Screening Test; RMET = Reading the Mind in the Eyes test; FP = Faux Pas
*$p < .05$. **$p < .01$. ***$p < .001$

A last lineal hierarchical regression was applied to identify the significant regressors as regards affective ToM. The procedure followed was that described in the previous analysis for cognitive ToM. Results are reported in Table 8. The final step was statistically significant, so as the first one ($p < .001$). In the initial model, age was a strong predictor [$\beta = -.609$, t (98) = -7.59, $p <.001$] accounting for 37% of the variation [*Fchange* (1, 98) = 157,64, $p < .001$, $R^2 = .370$, $Adj\ R^2 = .364$]. With respect to the second step, the entrance of all executive measurements and RMET did not affect the significance of age, that remained the most powerful predictor, [$\beta = -.474$, t (94) = -

2.56, p =.012], but they decreased its statistical power. RMET appeared to be the second strongest predictor [β = .425, t (94) = 2.72, p =.008], and TMT-B the third one [β = -.327, t (94) = -2.07, p =.047]. The final model accounted for 43.3% of the variation [*Fchange* (4, 94) = 2.61, p = .041, R^2= .433, R^2 *Adjusted*= .403]. Thus, older age, reduced cognitive flexibility and diminished emotional detection significantly predicted the decreased scores in complex affective ToM.

Table 8

Summary of Hierarchical Regression Analysis for Variables Predicting Affective ToM

	Model 1			Model 2		
	b	SEB	β	b	SEB	β
FP-Affective	9.440	.153		4.370	2.471	
Age group	-1.640	.216	-.609***	-1.278	.500	-.474*
DS-Backward				-.017	.057	-.047
TMT-B				-.013	.006	-.327*
SNST-Interference Score				.009	.015	.095
RMET				.129	.048	.425**
R^2		.370			.433	
$Adj\ R^2$		.364			.303	
$F\ change\ in\ R^2$		**.370***			**.063***	

Note. Each step was compared to the previous model in the hierarchical regression analysis.
DS = Digit Span; TMT-B = Trail Making Test-part B; SNST= Stroop Neuropsychological Screening Test; RMET = Reading the Mind in the Eyes test; FP = Faux Pas
*p < .05. **p < .01. ***p < .001

Mediation analysis

To determine better how the relationships between age, cognitive flexibility, basic and sophisticated affective mentalizing were formed, a mediation analysis was performed. According to Preacher & Hayes (2004, 2008), for a mediation to exist a) the independent variable (age for our study) has to significantly predict the dependent variable (affective ToM), path *c,* and has to affect mediators as well, path *a,* b) mediators (emotion identification and flexibility) have to be significantly correlated with the dependent variable, when the independent variable is also a predictor in regression (path *b*). A mediation exists when the independent variable shrinks (partial mediation) or zeroes (complete mediation) its effect upon the dependent variable with the addition of the mediator to the model (path *c'*)

Age was a significant predictor for TMT-B (β = .796, p < .001), RMET (β = -.842, p < .001) and faux pas affective scores (β =.-.609, p < .001), so paths *c* and *a* were confirmed. However, TMT-B alone did not reach statistical significance (β = .170, p =.201), when age was added in the second regression, thus we excluded this variable from the mediation analysis. By contrast, RMET maintained a significant predictor for affective ToM, after age was included as a co-predictor (β = -.326, p = .028); so, it met the criteria for a probable mediator variable. Mediation results showed a significant association between age and affective ToM (β = -1.211, p < .001), that was partially mediated by RMET performance [(β = -.664, p = .024, Effect = -.740, 95% C.I (-1.440, -.068)]. The 95% confidence intervals excluded zero from values and the significant mediation effect was supported. Sobel test verified the above outcome (z = -2.23, p = .026). Taken together, even so cognitive flexibility predicts affective ToM, does not seem to mediate the relationship between age and complex affective mentalizing. Age, on the other hand, acts upon affective ToM, directly and indirectly, through the ability of correct estimation of complex emotions (Figure 2).

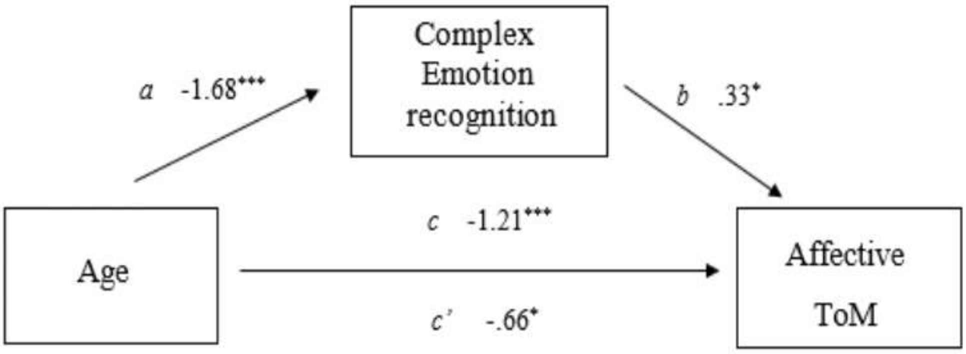

Figure2. Regression model predicting the mediation of age-related change in affective ToM by complex emotion recognition.

Note: the figure illustrates the standardized beta coefficients as calculated by mediation analysis, using SPSS PROCESS macro program. Path *a* = the effect of age group on emotion recognition. Path *b* = the effect of emotion recognition upon affective ToM once age included as a co-predictor in the regression model. Path *c* = total coefficient between age and affective ToM without controlling for emotional perception. Path *c'* = the real effect of age on affective ToM, once emotion recognition was controlled.
$^{*}p < .05$. $^{***}p < .001$

Discussion

The present study tried to investigate relationships in normal aging between difficulties in executive functions, deterioration of emotional accuracy skills and affective and cognitive ToM impairments. We set three main goals for this attempt. The first was to examine the possible age-related differences in sophisticated cognitive and affective mentalizing abilities, as well as the aging effect on the perception of facial emotional expressions. The second objective was to evaluate the role of core executive processes, namely working memory, inhibition, and mental flexibility, in the relationship between age and ToM. The third purpose was to look for the impact of emotional identification capacity on the relationship between normal aging and performances on higher order ToM test.

Deterioration of ToM in older age

Through the data examination, we affirmed that complex cognitive ToM was highly deficient in older population, a finding that has replicated by previous studies (Rakoczy et al., 2012; Charlton et al., 2009; MacPherson et al., 2002; Bernstein et al., 2011; Sullivan & Ruffman, 2004; Duval et al., 2011; Bottiroli et al., 2016). As regards complex affective ToM, efficiency drops as people mature, as well. In general, this decline is in line with some prior studies (McKinnon & Moscovitch, 2007; Bailey, Henry & Von Hippel, 2008; Phillips et al., 2002; Fischer et al., 2016; Rakoczy et al., 2012; Mahy et al., 2014), but in contrast with others (Wang & Su, 2013; Bottiroli et al., 2016; Castelli et al., 2010).

Noteworthy was the comparison between the detection of motives and intentions in faux pas stories and the understanding the characters' emotional states. Although, the younger group yielded similar performances in both ToM measurements, the older group exhibited a distinct pattern. That is, old adults were apparently more accurate in recognizing people's feelings (affective ToM), than in defining their thoughts (cognitive ToM). The fact that the control group did not displayed better scores in affective mentalizing compared to cognitive mentalizing, indicates that all questions were of equal difficulty and manifests that older population, indeed, show greater impairments in cognitive social understanding than in affective one.

Adversely, elderly people showed similar performance in answering the control stories of faux pas with younger participants. This finding is in contrast with some researches that displayed a generalized deterioration on control and ToM stories (Slessor, Phillips, & Bull, 2007; Keightley, Winocur, Burianova, Hongwanishkul & Grady, 2006). This disparity possibly occurred due to the fact that when cognitive demands of the ToM task are increased (e.g when participants are expected to recall the stories in order to answer), older people experience an increased challenge (Cavallini et al., 2013). This was not the case in our study, since participants had no time limit to respond and the stimuli were kept in front of them during the whole examination; thus, the tasks' cognitive load was minimized.

In addition to faux pas assessment, which was used as a second-stage mentalizing test, participants were measured in RMET, a more basic mentalizing test. Elderly individuals displayed severe difficulties in properly attributing the affective mind-state as it was received from the eyes area only. This outcome is compatible with some earlier work (Duval et al., 2011. El Haj et al., 2015; Phillips, et al., 2002; Bailey & Henry, 2008), but inconsistent with other studies (Castelli et al., 2010; Yildirim et al., 2019).

Several reasons may account for the above results and the discrepancies between our finding and other studies' outcomes. Firstly, until recently, the majority of studies treated ToM as a unitary construct, assessing only cognitive ToM, or did not manage to compare both dimensions of ToM within the same task (Henry et al., 2013). It is now accepted that each ToM test assesses different aspects of mentalizing and every mentalizing process declines at different age points (Cavallini et al., 2013; Saltzman et al., 2000). It is essential therefore, affective and cognitive ToM to be measured with a single task, with the same requirements and the same complexity, in order that we better determine if and in which domain there is a decline. Our research, as far as we know, is the second one which extracted two scores from the faux pas test, one for cognitive and one for affective ToM. In the first study (Bottiroli et al., 2016), authors did not find lower performances in affective ToM for older group. On second thoughts, the usage of only one question, which tested the identification of protagonist's emotion, raises some concerns regarding the reliability of their findings.

Secondly, theoretical models have proposed that the reported age-related decline in ToM is more evident in complex tasks, while first order ToM abilities is comparatively spared (Moran, 2013). Empirical data have echoed this notion (McKinnon & Moscovitsh, 2007). Since the faux pas test is known to be one of the most sensitive tools for evaluation of the most complex mind-reading aspects, it is not surprising that a significant deterioration regarding affective and cognitive ToM was found in our elderly group.

The reason why investigation regarding affective ToM in normal aging cannot derive as a definite conclusion as with cognitive ToM, is not fully understood yet. The fact that the available tasks, that evaluate the capacity of assignment feelings to others, are limited and involve simpler mentalizing processes may account for this discrepancy. As mentioned above, RMET is considered a classic affective ToM task. However, it only requires the understanding of a single person's emotion, without involving a meta-representation process of the social content of this emotion; a process that is actually the core of the second order ToM ability (Baron-Cohen et al., 2001; Ahmed & Miller, 2011). Instead, it is a measurement, of a more automated visuo-perceptional ability (Wang & Su, 2013). According to this notion, emotional identification, as measured with RMET, is simpler than other ToM tasks, such as faux pas test or second order false belief tasks, that reflect more socio-cognitive processes. Thus, the need for more sophisticated affective ToM tasks is emerged; tasks that will be closely matched to cognitive ToM tasks in order that more appropriate comparisons can be made in the future.

The poor performance in RMET among older individuals can be attributed to the fact that judgements for negative facial expressions appear to be more affected than positive ones by normal aging (Ruffman et al., 2008; Duval et al., 2011). RMET requires a disproportionally larger number of negative emotion recognitions. (Moran, 2013). The same issue can be mentioned for the faux pas task. Participants are asked to understand that one of the persons felt offended, uncomfortable or irritated because of the other's unintentional gaff; this possibly enlarges the age-related impairments. Although, such an age-related decline may also be attributed to fundamental socio-cognitive alternations, such that older adults fall back on simplified emotional representations (O'Brien, Konrath, Gruhn & Hagen, 2012), where the process of basic emotions is spared, while the perception of complex emotional states is impaired.

Relationships between age, executive functions and mentalizing

In respect of the second aim of this study, we found that all executive measures were associated with faux pas performances (cognitive and emotional subcomponents) and RMET scores.

Despite the correlations, none of the executive functions managed to significantly predict RMET; age was the only significant factor that accounted for the variation of affective recognition performance. Nonetheless, an interesting observation was that inhibition (interference score of SNST) tended (p = .069) to become a significant predictor, along with age, indicating that better regulation of inhibition among older adults affects their emotional detection accuracy. Several other studies similarly noted that emotional state decoding was independent of other cognitive aspects (El Haj et al., 2016; Duval et al., 2011), while others were in line with our tendency, suggesting a correlation between complex inhibition abilities and RMET performances (Fischer et al., 2016). The trend in our study may not be validated because of the relatively small sample size. Literature regarding the interaction between working memory, cognitive flexibility and emotion identification in normal aging is limited. However, RMET is not a task of increased manipulation of information demands nor does it require alternation from one perspective to another (mental flexibility). Provided that, RMET's independency of these certain neurocognitive mechanisms is not irrational.

Likewise, complex cognitive ToM performances found to be non-significantly predicted by cognitive abilities, except for age. Similar results have been reported by previous studies (Bernstein et al., 2011; Cavallini et al., 2013; Giovagnoli, 2018). There are other reports, however, indicating the predictive role of working memory and inhibition in tests, like faux pas and false belief (Wang & Su, 2013; Bottiroli et al., 2016. Charlton et al., 2009. Rakoczy et al., 2012). Duval and colleagues (2011), on the other hand, showed that only first-order ToM abilities were related to executive deficiencies while the performance in second-order ToM tests were independent of all executive measures. In addition, some theories advocate that only basic mentalizing processes may be attributed, at least partly, to executive function changes in normal aging. On the other hand, advanced mental-state decoding decline, such as persuasion, metaphors and faux pas, is more likely to reflect the sequalae of an underlying fundamental mentalizing difficulty, essential to solve second order ToM tasks (Moran, 2013). Although, we cannot confirm these hypotheses, as we did not assess first order cognitive ToM in the current study, we believe that this may partly fit with the current results.

Difficulties in sophisticated affective ToM were founded to be explained by older age, as well as by performances in TMT-B and RMET, to a lower, but substantial, extent. This finding suggests that the understanding of emotional intentions, when socially inappropriate situations occur, is especially challenging for older people with impaired cognitive flexibility and emotional recognition capacity. Affective faux pas discrimination develops during adolescence and early adulthood and executive control is prerequisite for this development (Sebastian et al., 2012). Thus, it is proposed that the reduced cognitive flexibility in late adulthood substantially affects the complex affective decoding; executive functioning and higher-order affective mentalizing seem to be related throughout the human lifespan. However, direct comparisons with other studies cannot performed, because previous work has been mainly concentrated in working memory and inhibition (Fischer et al., 2016; Li et al., 2013; Bailey & Henry 2008), which tend to be involved in successful completion of other ToM tasks and especially cognitive mentalizing (Carlson, Moses & Breton, 2002).

It is important to be mentioned, that we used only simple tasks of working memory and inhibition. More complex tasks (such as Hayling Sentence Completion test), as opposed to simple ones, increase the executive requirements. These tasks seem to be involved and predict better complex ToM tests, such as faux pas. It may be that reason why we and other relevant studies (German and Hehman, 2006) could not find that working memory or inhibition capacity significantly predict any mentalizing ability.

Basic emotional recognition and complex ToM ability

One of the most important outcomes of this research was that RMET, but not TMT-B, influenced the relationship between age and complex affective ToM. In particular, via RMET mediation, the large age effect, observed in regression analysis, was minimized, even though it remained significant. Older age plays a primitive role, affecting directly complex emotional ToM impairment. Nevertheless, the underlying decrease of basic emotional perception, as we are getting older, mitigates this relationship, so that the differences found in affective faux pas rely not only on age itself but also on other rudimentary basic ToM processes. Older participants who were less effective in accomplishing RMET, were those who were unable to correctly identify the affective state of the social partners. The observation of partial rather than complete mediation accords with the idea that multiple variables may account for decreases of sophisticated ToM in late adulthood.

The model by Shamay-Shoory et al. (2010) suggests that affective ToM is the most complicated process and involves the incorporation of other socio-cognitive functions, such as cognitive ToM and empathetic abilities, part of which is emotional identification. However, the relationships between basic emotional recognition and higher-order mentalizing capacities have been rarely studied in normal aging. The study of Halberstadt and colleagues (2011) highlights the importance of further research in this field. Researchers used faux pas videos to investigate the effects of age on detecting inappropriateness among multiple social characters. They noticed that older adults rated faux pas as more acceptable than younger adults and that those results were completely mediated by success on other emotional recognition measures. Similarly, another study examined the effect of emotional detection, empathy and executive function on complex mentalizing abilities during adulthood, and reported that an intact emotional decoding is a strong predictor for second and higher order ToM abilities, along with inhibition control. (Launay et al., 2015).

However, we cannot preclude the likelihood of these relationships to emerge in an adverse manner. As people age, they tend to minimize their social experiences and this is followed by a reduction in engagement in novel complex situations with new partners (Bottiroli et al., 2016). This may indicate that their ability to infer regarding the mental states of others declines and substantially affects the appreciation of someone else's thought or feeling. In other words, an earliest avoidance of sophisticated mentalizing may later cause a severe deterioration in basic ToM mechanisms, like emotional identification outside from a social context.

From a rational point of view, the stronger relationship between RMET and affective faux pas compared to cognitive faux pas may indicate that higher-order affective ToM is affected only by lower-order affective mentalizing, while higher-order cognitive ToM is solely based on lower-order cognitive mentalizing, elaborating, thus, distinct and clear patterns of intercorrelations; a hypothesis that need further investigation in order to be confirmed.

Strengths and Limitations of the study

One of the benefits of this study is that complex mentalizing ability was assessed with a single task, permitting direct comparisons of affective and cognitive ToM between younger and older groups. Furthermore, our neuropsychological evaluation consisted of both visual and verbal ToM tasks, thus, drawing the conclusion that older people are impaired in verbal, as well as in visual modalities of mentalizing ability. We focused on relationships between executive functioning and mentalizing, using tasks that have been extensively used by other researches, permitting thus direct comparisons with previous, as well as future studies. Moreover, we shed light on the links that are likely to exist between different aspects of sophisticated ToM and primitive mentalizing capacities. However, more research needs to be done to reach a definite conclusion. Last but not least, our study was benefited by the monitoring of possible confounding factors that could impair our results. Namely, we controlled for education level and both groups had equal ratios of females and males participants.

The limitations of our study should also be acknowledged. First of all, our sample was relatively small, and therefore more work is required before the generalization of our findings. The second drawback regards the lack of assessment of individuals' crystallized intelligence, such as vocabulary and comprehension abilities, as literature reports that general cognitive decline may attribute to elderlies' lower performance in complex ToM tasks (Moran, 2013). On the other hand, this does not seem to be the golden rule (Phillips et al., 2002; Duval et al., 2011). Given that we did not add in regression models fundamental cognitive functions, like processing speed or short term-memory capacity, the current results should be interpreted with caution. This thesis constituted a cross-sectional study. Future studies, however will profit from exploring the influence of age and other factors in ToM in a longitudinal context.

Conclusions

The current study supports further the references of age-related deterioration in mentalizing abilities, apparent even from the sixth decade of life. Precisely, our results indicate that both high-level cognitive and affective ToM, as well the lower-level emotional identification, decline. None of the core executive functions seem to account for impairment in cognitive ToM, supporting the idea that this reduction is a domain specific phenomenon, which happens simultaneously but independently of executive deterioration, as people age. On the other hand, it is hypothesized a possible intercorrelation between age, inhibition and performance in emotional decoding; still this relation remained a trend in data analysis and no further examination could be conducted. Notwithstanding that lower scores in affective ToM were significantly predicted by older age, diminished cognitive flexibility and difficulty in emotional perception. Further analysis, however, is in line with the idea that only low-level mentalizing abilities, and not mental flexibility, constitute a substantial part of the scaffolding for sophisticated mentalizing. Thus, the observed difficulties of affective ToM in older age is actually a bottom-up process. Considering the central role of social cognition in daily life, there is need for further studies in order to examine the age-related difficulties in mindreading reasoning. More ecological ToM and cognitive tasks are required so as to offer a more detailed understanding of real-life correlations. (Lecce et al., 2019).

References

Abu-Akel A. & Shamay-Tsoory S.M. (2011). Neuroanatomical and neurochemical bases of theory of mind. *Neuropsychologia,* 49, 2971– 2984.

Ahmed F. S & Miller L. S. (2011). Relationship between theory of mind and functional independence is mediated by executive function. *Psychology and Aging*, 28 (2), 293-303 DOI: 10.1037/a0031365

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.

Bailey P. E., Henry J. D., & Von Hippel W. (2008) Empathy and social functioning in late adulthood. *Aging and Mental Health*, 12 (4), 499-503, https://doi.org/10.1080/13607860802224243

Baksh, R., Bugeja, T., & MacPherson, S. (2020). Executive functions do not underlie performance on the Edinburgh Social Cognition Test (ESCoT) in healthy younger and older adults. *Journal of the International Neuropsychological Society*, 26(5), 527-538. doi:10.1017/S1355617719001450

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*(6), 1173–1182. https://doi.org/10.1037/0022-3514.51.6.1173

Baron-Cohen S., Leslie A. M., & Frith U. (1985). Does the autistic child have a "theory of mind"?. *Cognition,* 21 (1), 37-46. https://doi.org/10.1016/0010-0277(85)90022-8

Baron-Cohen S., Wheelwright S.,Hill J., Raste Y., & Plumb I. (2001). The "reading the mind 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

Beadle J. N. & de la Vega C. E. (2019). Impact of aging on empathy: review of psychological and neural mechanisms. Frontiers in Psychiatry. doi: 10.3389/fpsyt.2019.00331

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(5), 481-502. DOI: 10.1080/0361073X.2011.619466

Bottiroli S., Cavallini E., Ceccatob I., Vecchi T., & Lecce S. (2016). Theory of mind in aging: comparing cognitive and affective components in the faux pas test. *Archives of Gerontology and Geriatrics,* 62,152–162. DOI:10.1016/j.archger.2015.09.009

Buckner R. L. (2004). Memory and executive function in aging and AD: multiple factors that cause decline and reserve factors that compensate. *Neuron,* 44(1), 195-208. DOI: 10.1016/j.neuron.2004.09.006

Cabeza R. & Dennis N. A. (2013). Frontal land aging: deterioration and compensation. Principles of Frontal Lobe Function (5th Edition). *Oxford University Press.* DOI: 10.1093/med/9780199837755.003.0044

Carlson, S. M., Moses, L. J., & Breton, C. (2002). How specific is the relation between executive function and theory of mind? Contributions of inhibitory control and working memory. *Infant and Child Development*, 11, 73-92. doi:10.1002/icd.298

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,* 7(4), 299-319. DOI: 10.1016/j.jecp.2004.01.002

Castelli I., Baglio F., Blasi V., Alberoni M., Falini A., Liverta-Sempio O., Nemni R., & Marchetti A. (2010). Effects of aging on mindreading ability through the eyes: an fMRI study. *Neuropsychologia,* 48, 2586–2594

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. https://doi.org/10.2190/AG.76.3.a

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)

Dvash J. & Shamay-Tsoory S. G. (2014). Theory of Mind and empathy as multidimensional constructs: neurological foundations. T*opics in Language Disorders*, 34(4), 282-295

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. https://doi.org/10.1016/j.concog.2010.10.025

El Haj M., Raffard S., & Gély-Nargeot M.-C. (2015): Destination memory and cognitive theory of mind in normal ageing, *Memory*, DOI: 10.1080/09658211.2015.1021257

Fischer A. L., O'Rourke N.,& Thornton W. L. (2016). Age differences in cognitive and affective Theory of Mind: concurrent contributions of neurocognitive performance, sex, and pulse pressure. Journals of Gerontology: Psychological Sciences, 2 (1),71-81. doi: 10.1093/geronb/gbw088

Fisher, N. & Happe´, F. (2005). A training study of theory of mind and executive function in children with autistic spectrum disorders. *Journal of Autism and Developmental Disorders*, 35, 757–771

Frith C. D. (2008). Social cognition. *Philosophical Transactions of the Royal Society B Biological Sciences*. 363 (1499), 2033–2039. https://doi.org/10.1098/rstb.2008.0005

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

Giovagnoli A. R. (2018). Theory of mind across lifespan from ages 16 to 81 years. *Epilepsy and Behavior*. doi: 10.1016/j.yebeh.2019.05.044.

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(1),133-136. DOI: 10,1037/a(K)21366

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

Henry J. D., Cowan D. G., Lee T., & Sachdev, P. S. (2015). Recent trends in testing social cognition, *Current Opinion in Psychiatry,* 28 (2), 133-140 doi: 10.1097/YCO.0000000000000139

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. http://dx.doi.org/10.1037/a0030677

Ibanez A., Huepe D. Gempp R., Gutiurrez V., Rivera-Rei A., & Toledo M. I. (2013). Empathy, sex and fluid intelligence as predictors of theory of mind. *Personality and Individual Differences,* 54 (5), 616–621. https://doi.org/10.1016/j.paid.2012.11.022

Fischer, A. L., O'Rourke N., & Thornton W. L. (2016), Age differences in cognitive and affective theory of mind: concurrent contributions of Neurocognitive performance, sex, and pulse pressure. *Journals of Gerontology: Psychological Sciences,* 00 (0), 1–11. doi:10.1093/geronb/gbw088

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

Kanske P., Böckler A., Trautwein F. M., & Singer T. (2015). Dissecting the social brain: introducing the EmpaToM to reveal distinct neural networks and brain-behavior relations for empathy and Theory of Mind. *NeuroImage,* 15(122), 6-19. DOI:10.1016/j.neuroimage.2015.07.082

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

Kennedy D. P. & Adolphs R. (2012). The social brain in psychiatric and neurological disorders. *Trends in Cognitive Sciences*, 16, 559–572. https://doi.org/10.1016/j.tics.2012.09.006

Konstantopoulos K., Vogazianos P., & Doskas T. (2016). Normative Data of the Montreal Cognitive Assessment in the Greek Population and Parkinsonian Dementia. *Archives of Clinical Neuropsychology*, 31 (3), 246–253, https://doi.org/10.1093/arclin/acw002

Korkmaz, B. (2011). Theory of mind and neurodevelopmental disorders of childhood. *Pediatric Research*, 69 (5), 101–108

Launay J., Pearce E.,Wlodarski R., van Duijnb M., Carney J., & Dunbar R. I. M. (2015). Higher-order mentalising and executive functioning. *Personality and Individual Differences,* 86, 6-14. https://doi.org/10.1016/j.paid.2015.05.021

Lecce S., Ceccato I., & Cavallini E. (2019). Investigating ToM in aging with the MASC: from accuracy to error type. *Aging, Neuropsychology, and Cognition*, 26(4), 541-557, https://doi.org/10.1080/13825585.2018.1500996

Lezak, M. D. (1995). *Neuropsychological assessment* (3rd ed.). New York:Oxford University Press

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(4), 715–727.

Love M. N., Ruff G., & Geldmacher D. (2015). Social cognition in older adults: a review of neuropsychology. Neurobiology, and Functional Connectivity. *Medical and Clinical Reviews*, 1-6. doi: 10.21767/2471-299X.1000006

Nazlidou E. I., Moraitou D., Natsopoulos D., & Papantoniou G. (2015). Social cognition in adults: the role of cognitive control. *Hellenic journal of nuclear medicine.*

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. http://dx.doi.org/ 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, 465–85.

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

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 (4), 598–609. DOI: 10.1037//0882-7974.17.4.598

Miller, S. A. (2009). Children's understanding of second-order mental states. *Psychological Bulletin*, 135 (5), 749–773

Moran J. M. (2013). Lifespan development: the effects of typical aging on theory of mind. *Behavioural Brain Research,* 237, 32– 40

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

O'Brien Ed., Konrath S.H., Gruhn D., & Hagen A.L. (2012). Empathic concern and perspective taking: linear and quadratic effects of age across the adult life span. *The Journals of Gerontology, Series B:Psychological Sciences and Social Sciences,* doi:10.1093/geronb/gbs055

Patrikelis P. & Efthymios Angelakis E. (n.d.) Adaptation of the faux pas test for the Greek language. Retrieved from https://www.autismresearchcentre.com/

Peters P. (2006). Review: Ageing and the brain. *Postgraduate Medical Journal,* 82 (964), 84-88.

Phillips L.H., MacLean R.D., & Allen R. (2002). Age and the understanding of emotions: neuropsychological and sociocognitive perspectives. *Journals of Gerontology Series B, Psychological Sciences and Social Sciences*;57, 526–30.

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(2), 236–247

Poletti M., Enrici I., & Adenzato M. (2012). Cognitive and affective Theory of Mind in neurodegenerative diseases: neuropsychological, neuroanatomical and neurochemical levels

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. http://dx.doi.org/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. http://dx.doi.org/10.3758/brm.40.3.879

Preckel K., Kanske P., & Singe T. (2018). On the interaction of social affect and cognition: empathy, compassion and theory of mind. *Current Opinion in Behavioral Sciences*, 19, 1-6. https://doi.org/10.1016/j.cobeha.2017.07.010

Premack D. & Woodruff G. (1978). Does the chimpanzee have a theory of mind?. *The Behavioral and Brain Sciences*, 49, 515-526. DOI: https://doi.org/10.1017/S0140525X00076512

Rakoczy H., Harder-Kasten A., & Sturm L. (2012). The decline of theory of mindin old age is (partly) mediated by developmental changes in domain-general abilities. *British Journal of Psychology,* 103 (1). 58-72

Reitan, R. M. (1958). Validity of the Trail Making test as an indicator of organic brain damage. *Perceptual and Motor Skills*, 8, 271–276, https://doi.org/10.2466/pms.1958.8.3.271

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 and Biobehavioral Reviews*, 32, 863–881

Sullivan S. & Ruffman T. (2004). Social understanding: how does it fare with advancing years. *British Journal of Psychology*; 95, 1–18.

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 (7), 781-788. DOI:10.1017/S1355617700677056

Schurz M., Radua J., Aichhorn M., Richlan F., & Perner J. (2014). Fractionating theory of mind: a meta-analysis of functional brain imaging studies. *Neuroscience and Behavioral Reviews,* 42, 9-34. https://doi.org/10.1016/j.neubiorev.2014.01.009

Shamay-Tsoory S. G. (2010). The neural bases for Empathy. *Neuroscientist,* 17 (1), 18-24. https://doi.org/10.1177/1073858410379268

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. http://dx.doi.org/10.1016/j. cortex.2009.04.008

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*, 3-4, 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 (1), 55-67.

Sebastian C. L., Fontaine N. M. G., Bird G., Blakemore S.-J., De Brito S. A., McCrory E. J. P., & Viding E. (2011). Neural processing associated with cognitive and affective theory of mind in adolescents and adults.*Social Cognitive and Affective Neuroscience*, 7 (1), 53–63,https://doi.org/10.1093/scan/nsr023

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

Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology,* 18, 643–662.

Treitz F. H., Heyder K., & Daum I. (2007). Differential course of executive control changes during normal aging. *Aging, Neuropsychology, and Cognition,* 14 (4), 370-393. https://doi.org/10.1080/13825580600678442

Thiebaut F. I., White S. J., Walsh A., Klargaard S. K.,Wu H.-C., Rees G., & Burgess P. W. (2015). Does faux pas detection in adult autism reflect differences in social cognition or decision-making abilities? *Journal of Autism Developmental Disorder,* 46, 103–112, DOI 10.1007/s10803-015-2551-1

Yeh Z. T. (2013). Role of theory of mind and executive function in explaining social intelligence: a structural equation modeling approach. *Aging & Mental Health*, 17, 527-534. https://doi.org/10.1080/13607863.2012.758235

Yıldırım E., Büyükişcan E. S., & Gürvit H. (2019). Affective theory of mind in human aging: is there any relation with executive functioning? *Aging, Neuropsychology,and Cognition,* https://doi.org/10.1080/13825585.2019.1602706

Wade M. Prime H., Jenkins J. M., Yeates K. O., Williams T., & Lee K. (2018). On the relation between theory of mind and executive functioning: a developmental cognitive neuroscience perspective. *Psychonomic Bulletin and Review,* 25 (6), 2119-2140. doi: 10.3758/s13423-018-1459-0

Wang, Y. & Su, Y. (2006). Theory of mind in old adults: The performance on Happé's stories and faux pas stories. *Psychologia*, 49, 228–237.

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 & Aging,* 28 (1). 284-291. DOI: 10.1037/a0030876

Wechsler D. (1981). WAIS-R manual: Wechsler adult intelligence scale-revised. New York, NY: Psychological Corporation.

Wecker, N. S., Kramer, J. H., Hallam, B. J., & Delis, D. C. (2005). Mental Flexibility: Age Effects on Switching. *Neuropsychology, 19* (3), 345-352.http://dx.doi.org/10.1037/0894-4105.19.3.345

Zaitchik D., Koff E., Brownell H., Winner E., & Albert M. (2006) Inference of beliefs and emotions in patients with Alzheimer's disease. *Neuropsychology*, 20,11–20.

Zalonis, I., Christidi, F., Bonakis, A., Kararizou, E., Triantafyllou, N. I., Paraskevas, G., & Vasilopoulos, D. (2009). The stroop effect in Greek healthy population: normative data for the Stroop Neuropsychological Screening Test. *Archives of Clinical Neuropsychology, 24*(1), 81-88

Zalonis, I., Kararizou, E., Triantafyllou, N. I., Kapaki, E., Papageorgiou, S., Sgouropoulos, P. E. E. A., & Vassilopoulos, D. (2008). A normative study of the trail making test A and B in Greek adults. *The Clinical Neuropsychologist*, *22*(5), 842-850.

Ze O., Thoma P., & Boris Suchan B. (2014). Cognitive and affective empathy in younger and older individuals. *Aging & Mental Health,* 18 (7), 929-935. DOI: 10.1080/13607863.2014.899973