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Cognitive and Affective Theory of Mind in Healthy Aging

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ABSTRACT

Background: Previous studies on the effect of healthy aging on Theory of Mind (ToM) have produced mixed results. A possible explanation may be that different ToM components and types of inference have not systematically been considered. This study examined the effect of aging on ToM by assessing both first and second order cognitive and affective components within a single task.

Methods: We compared performance of young (*M* = 18.3y) and older adults (*M* = 61.0y) on the Yoni task. This task allows for a within-subject assessment of both first and second order cognitive and affective ToM.

Results: We observed that older adults had longer reaction times than young adults across cognitive and affective first order items. For second order items, this age difference was larger for affective than cognitive items. Results showed no indications that these findings could be explained by age differences in speed/accuracy trade-offs.

Conclusion: Our findings suggest that decision processes underlying ToM are slower in older adults on both first and second order inferences, but that age differences in these processes between cognitive and affective ToM are selective to second order inferences. We propose that the observed age differences may be associated with cortical and mental changes that occur with aging.

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Introduction

Theory of mind (ToM) refers to the ability to attribute independent mental states – such as beliefs, emotions, or desires – to oneself and others, and to understand that such states can differ between individuals (Premack & Woodruff, 1978). Typically, two different ToM components are distinguished: The cognitive component involves attributions regarding cognitive mental states such as beliefs and intentions, while the affective component involves attributions regarding emotional mental states. Several neurostimulation (e.g., Kalbe et al., 2010; Krause, Enticott, Zangen, & Fitzgerald, 2012) and clinical studies (e.g., Shamay-Tsoory & Aharon-Peretz, 2007; Shamay-Tsoory et al., 2007) have demonstrated that these components are independent from one another and are associated with different underlying neural networks.

While lifespan research on ToM originally focused on its development in children, the last two decades has seen an increase in studies focusing on changes in ToM associated with healthy

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aging. These studies have robustly and widely reported age-related reductions in ToM performance across different experimental paradigms (for reviews, see Henry, Phillips, Ruffman, & Bailey, 2013; Moran, 2013). However, studies using a within-subject design to distinguish between effects of healthy aging on cognitive versus affective ToM have yielded mixed findings. For example, Duval, Piolino, Bejanin, Eustache, and Desgranges (2011) and Rakoczy, Harder-Kasten, and Sturm (2012) found that aging had similar effects on both components of ToM. In contrast, Li et al. (2013) and Wang and Su (2013) observed that aging negatively affected the cognitive but not the affective ToM component. While these studies provide indications – albeit contradicting – about the effect of aging on the ability to represent one's own and others' cognitive and emotional mental states, an important caveat is that they used separate tasks with different modalities (e.g., verbal vs. non-verbal; static pictures/cartoons vs. dynamic videos) and different levels of difficulty (e.g., first vs. second order inferences; see below) to assess cognitive and affective ToM. These varying methodological aspects and related task-demands may cause performance to differentially rely on other age-sensitive processes (e.g., working memory), which subsequently could contribute to the mixed findings. For instance, the fact that studies reporting similar age effects on both ToM components used non-verbal tasks (i.e., Duval et al., 2011; Rakoczy et al., 2012) whereas studies that found effects on cognitive but not affective ToM used verbal tasks (i.e., Li et al., 2013; Wang & Su, 2013) is in line with prior indications that age effects on ToM may be more pronounced for visual as compared to verbal tasks (Slessor, Philips, & Bull, 2007). To eliminate any influence of such factors on the relationship between age and ToM, it is imperative that both cognitive and affective components are assessed within the same task.

To the best of our knowledge, only a few studies to date have examined the effect of healthy aging on both cognitive and affective ToM within the same task. For instance, Fischer, O'Rourke, and Loken Thornton (2017) and Walzak and Loken Thornton (2018) used three tasks to assess ToM in a group of young adults and a group of older adults: the strange stories task to assess cognitive ToM, the "reading the mind in the eyes" test (RMET) to assess affective ToM, and the Yoni task to evaluate *both* cognitive and affective ToM. In the strange stories task, participants are presented a story and are then asked why the main character acted as they did. In the RMET, participants are asked to infer emotional mental states from pictures of the eye region of human faces. In the Yoni task, that we will also use here, participants are asked to identify to which of four items a cartoon character ("Yoni") is referring, based on verbal and facial cues. Fischer et al. (2017) found that older adults performed worse than younger adults on all four ToM indices, suggesting that these age differences were robust across tasks and components. Similarly, within a group of older adults aged 65–89 years, Walzak and Loken Thornton (2018) found that increasing age was associated with poorer cognitive and affective ToM performance. In another study, Bottiroli, Cavallini, Ceccato, Vecchi, and Lecce (2016) used the faux pas test to assess both cognitive and affective ToM in three groups of young adults (19–27y), young-old adults (60–70y), and old-old adults (71–82y). In this test, participants read a series of short stories and have to indicate whether a story contains a social gaffe (i.e., a faux pas). Bottiroli et al. (2016) found that the young adult group outperformed the other two groups on cognitive ToM, but found no effects of aging on affective ToM. Furthermore, they found that age was significantly correlated with cognitive but not affective ToM. Finally, Baksh, Abrahams, Auyeung, and MacPherson (2018) examined the effect of age on both cognitive and affective ToM using a newly developed paradigm they termed the Edinburgh Social Cognition Test (ESCoT) as well as more traditional measures of ToM (i.e., RMET, "reading the mind in films" test, judgment of preference test). While results showed that increasing age was associated with poorer performance on both ToM components in the novel ESCoT paradigm, age did not significantly correlate with performance on the traditional measures of affective ToM.

While these within-subject, within-task investigations thus consistently observed age-related performance reductions for the cognitive component of ToM, results for the effect of aging on the affective component were inconsistent and prompt further investigation. We propose that these inconsistent findings may relate to the lack of a distinction between first versus second order inferences: first order inferences require an individual to have the ability to represent another individual's mental state and compare it with their own, whereas second order inferences require an individual to represent two other individuals' mental states. This distinction is relevant given indications from previous work that aging mainly affects the latter type of inferences (Duval et al., 2011; Moran, 2013). The observation that the studies reporting age effects on both cognitive and affective ToM (i.e., Baskh et al., 2018, ESCoT paradigm; Fischer et al. 2017; Walzak & Loken Thornton, 2018) included both inference types – yet did not analyze these separately – while the studies reporting age effects on cognitive but not affective ToM only assessed first order inferences (Baksh et al., 2018, traditional measures; Bottiroli et al., 2016) further advocates for such a distinction.

The literature discussed above shows that the effects of aging on ToM thus have been studied in relation to either the component type (cognitive vs. affective) or the inference type (first vs. second order), yet these factors have not systematically been evaluated in relationship to aging within a single experimental task. The present study therefore aimed to 1) replicate previous findings that aging is associated with reductions in ToM by assessing both cognitive and affective components, and moreover 2) extend prior work by investigating whether the effect of aging on these components is robust across first and second order inferences, by combining both the component and order factors within a single task. We had a group of young adults and a group of older adults perform the Yoni task (Shamay-Tsoory & Aharon-Peretz, 2007), which is a ToM task evaluating both first and second order cognitive and affective mental states. We hypothesized that aging would be associated with a reduction in cognitive ToM (cf. Bottiroli et al., 2016; Fischer et al., 2017) and potentially affective ToM performance (cf. Fischer et al., 2017). As age-related reductions in ToM performance have been more consistently observed for second order than for first order tasks (Duval et al., 2011; Moran, 2013), we additionally expected that age differences would be particularly evident in second order inferences. Importantly, whereas prior studies on aging and ToM using the Yoni task only included the cognitive and affective conditions, we also included a physical condition to control for inter-individual differences in processing speed (cf. Adjeroud et al., 2016; Shamay-Tsoory, 2008; Shamay-Tsoory et al., 2007). The physical condition has similar attentional and working memory demands to the other conditions, but no mentalizing component, and therefore is well-suited as a baseline condition to control for age-related declines in processing speed (Salthouse, 1996).

Materials and Methods

Participants

The older adult (OA) group consisted of 18 participants who volunteered to enroll in the experiment. According to the Montreal Cognitive Assessment (MoCA; Nasreddine et al., 2005) none of the older adults showed signs of cognitive impairment. Their data were compared with those of the young adult (YA) group consisting of 17 first-year psychology students who took part in the study in partial fulfillment of a course requirement. Participant demographic characteristics are listed in Table 1. Prior work showed large effect sizes for age differences in both cognitive and affective ToM (d = 0.75 and d = 0.86, respectively; Fischer et al., 2017). Sample size calculations using G*Power v3.1.9.4 software including these effect sizes with a one-sided alpha level of 0.05 and statistical power of 0.80 indicated we required 18–23 participants per age group. Students and older adults were tested in our laboratory and in their home, respectively. All participants provided written informed consent prior to the study. The study adhered to the general ethical protocol of the ethics committee of the Faculty of Psychology and Educational Sciences of Ghent University.

Experimental Task and Procedure

At the start of the experiment, subjects signed the informed consent form and completed a demographical questionnaire. The OA group also completed the MoCA. All subjects then performed a ToM task called the “Yoni task”, which assesses the ability to infer mental states from verbal and facial cues (Shamay-Tsoory & Aharon-Peretz, 2007). The task has been used in previous investigations on cognitive and affective ToM in both healthy and clinical populations (e.g., Adjeroud et al., 2016; Kalbe et al., 2010; Kim et al., 2016; Krause et al., 2012; Li et al., 2017; Shamay-Tsoory et al., 2007). In this task, subjects are presented a cartoon character named “Yoni” and four colored pictures of faces or objects belonging to a single category (e.g., animals, fruits, flowers), one in each corner of the computer screen. Participants have to evaluate, based on the available cues, to which of these four pictures Yoni is referring. These cues include a sentence that appears at the top of the screen, Yoni’s facial expression or eye gaze, and the response options (Figure 1).

There are three conditions, namely affective ToM, cognitive ToM, and a physical control conditions. Whereas the control condition requires participants to evaluate the cartoon’s physical attributes (e.g., “Yoni is close to … ”), the cognitive and affective ToM items require making mental inferences based on the available cues (e.g., cognitive: “Yoni is thinking of … ”; affective: “Yoni loves … ”). In second order trials the choice for the correct answer additionally requires an understanding of the interaction between Yoni’s and others’ mental states (e.g., cognitive: “Yoni is thinking of the fruit that … wants”; affective “Yoni loves the animal that … does not love”; physical: “Yoni has the same toy as … has”). The cognitive and affective ToM conditions each consisted of 12 first order trials, 6 second order trials with gaze directed toward the correct answer, and 6 second order trials with the gaze

Table 1. Overview of the demographic characteristics of the YA and OA groups and performance on the neuropsychological test by the OA group.

	Young adults		Older adults		
	Mean ± SD	Range	Mean ± SD	Range	Group difference
Age (years)	18.3 ± 0.8	17–21	61.0 ± 3.9	55–69	$t(33) = -43.38$, p <.001
Gender	3 M/14 F	n/a	11 M/7 F	n/a	$\chi^2 = 6.88$, p =.009
Education (years) [a]	12.29 ± 0.8	11–15	12.94 ± 2.8	8–17	$t(33)<1$, p =.37
MoCA	n/a		28.56 ± 1.65	26–30	n/a

[a]Data from two subjects in the OA group were missing.
MoCA = Montreal Cognitive Assessment

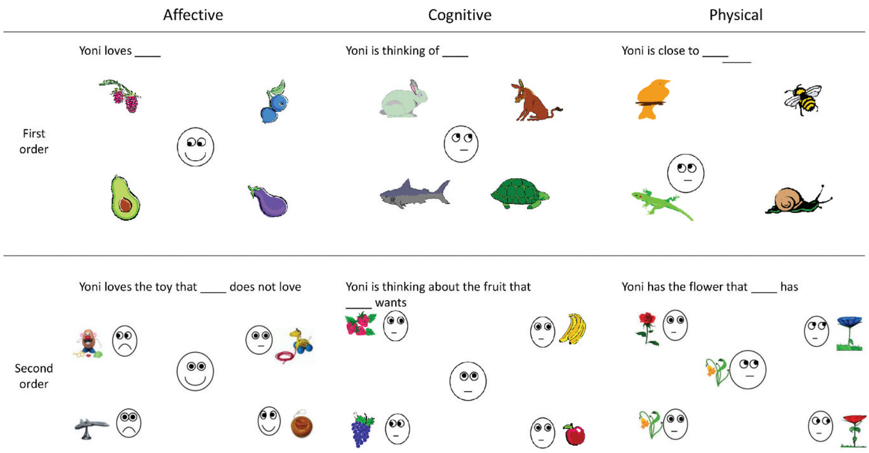

Figure 1. Examples of items in the first and second order affective ToM, cognitive ToM, and physical control conditions (color figure online).

directed straight ahead. The physical condition consisted of 8 first order and 8 second order trials, half of which had directed gaze and half straight gaze. Participants thus completed 64 trials in total. Trials on which the gaze was directed straight ahead were included to prevent subjects from simply responding to the picture that Yoni's gaze was directed to without reading the sentences (cf. Shamay-Tsoory & Aharon-Peretz, 2007).

Participants were instructed to use a computer mouse and click on the correct picture as fast as possible. At the beginning of each trial the mouse cursor was automatically relocated to the center of the screen, such that mouse movements were always initiated from the same central location and movement distance toward each response option was controlled for. We used E-Prime software (version 2.0) for stimulus presentation and data registration. The software registered on each trial whether the response was correct/incorrect and additionally logged the response time. Participants used a standard computer mouse for responding, with the cursor speed set at the 6/11 default mode in Windows 10.

Data Processing and Analysis

As one of the participants in the OA group performed the ToM task at an accuracy of <80% (with only 42% correct responses in the second order affective condition), data from this subject were excluded from further analyses. For the remaining 17 subjects in each age group we determined their median RTs and their proportion of correct responses for each condition. Trials on which an incorrect answer was given were omitted from the RT analyses. In line with previous studies using the Yoni task (e.g., Li et al., 2017; Shamay-Tsoory, 2008; Shamay-Tsoory et al., 2007) we ran mixed analyses of covariance (ANCOVAs) for both the first and second order conditions with Component (2; cognitive vs. affective) as a within-subject variable, Age Group (2; YA vs. OA) as a between-subject variable, and performance in the Physical condition as a covariate to control for group differences in baseline performance. We ran our analyses using both the more traditional null-hypothesis significance testing approach (NHST; via SPSS software, version 25.0; IBM Corp, 2017) and a Bayesian approach with default prior settings (via JASP software, version

0.11.1; JASP Team, 2020). For the mixed ANCOVAs we report the Bayes Inclusion factor based on matched models, which represents the evidence for all models containing a particular effect to equivalent models without that effect (i.e., $BF_{Inlcusion}$, also known as Baws factor). For other analyses presented below, such as t-tests and correlation analyses, we report the Bayes factor reflecting the relative plausibility of the data under H_1 versus H_0 (i.e., BF_{10}).

Results

Response Times

We first performed two independent-samples t-tests on performance in the first and second order Physical condition with Age Group as the independent variable to evaluate whether the performance in these control conditions differed between YA and OA. Results showed that there were differences for both first order (YA = 1356 vs. OA = 2936) and second order control items (YA = 2363 vs. OA = 5749), $ts(32)<-6.64$, $ps<.001$, $ds<-2.27$, $BF_{10}s>100$, justifying the inclusion of performance in the Physical condition as a covariate in our analyses.

Figure 2 shows the RTs of YA and OA in the affective and cognitive trials as a function of order condition.[1] Error bars presented in all figures were calculated via the Cousineau-Morey method for repeated-measures (Cousineau, 2005; Morey, 2008). For the first order condition, results of the ANCOVA showed that YA responded faster than OA (1736 vs. 3050 ms), $F(1,31) = 8.50$, $p = .007$, $\eta_p^2 = .215$, $BF_{Inclusion} = 29.51$. There were no other significant main or interaction effects (main effect of covariate $p = .051$; all effects of Age Group and/or Component $ps>.30$). To verify that the effect of Age Group was significant within both the affective and cognitive components, we performed two univariate ANCOVAs. Results confirmed that YA were faster than OA on both the affective component (1732 vs. 3213 ms), $F(1,31) = 7.78$, $p = .009$, $\eta_p^2 = .201$, $BF_{Inclusion} = 22.45$, and the cognitive component (1740 vs. 2887), $F(1,31) = 7.46$, $p = .010$, $\eta_p^2 = .194$, $BF_{Inclusion} = 15.27$.

For the second order condition, results again showed that YA responded faster than OA (3119 vs. 6341 ms), $F(1,31) = 11.73$, $p = .002$, $\eta_p^2 = .274$, $BF_{Inclusion} = 99.27$. In addition, we

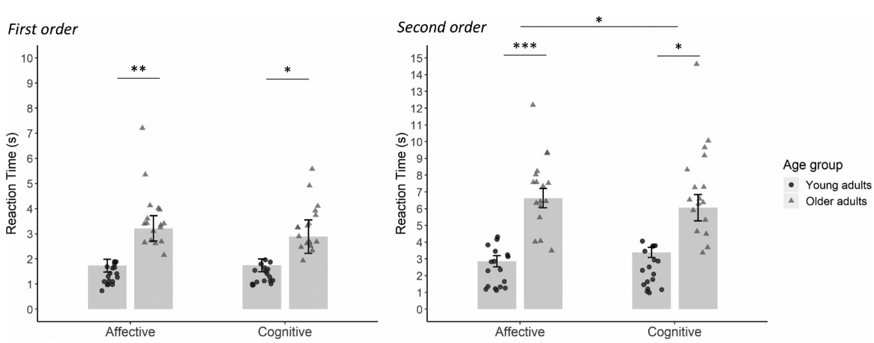

Figure 2. Individual median RTs and mean median RTs (adjusted for performance in the physical control condition) for the affective and cognitive ToM components as a function of age group in the first (left) and second (right) order conditions. Error bars represent within-subject standard errors. * p <.05 ** p <.01 *** p <.001.

observed that across the two age groups participants responded faster to cognitive compared to affective items (4720 vs. 4741 ms), $F(1,31) = 8.89$, $p = .006$, $\eta_p^2 = .223$, $BF_{Inclusion} = 0.21$. There was a significant Component × Physical condition interaction, $F(1,31) = 9.73$, $p = .004$, $\eta_p^2 = .239$, $BF_{Inclusion} = 1.81$, and post-hoc correlation analyses showed that performance on physical trials was positively related to performance on both affective trials, $r(34) = .69$, $p < .001$, $BF_{10} > 100$, and cognitive trials, $r(34) = .75$, $p < .001$, $BF_{10} > 100$. A z-test for evaluating the difference between correlation coefficients (Lee & Preacher, 2013) indicated that the strength of the associations did not significantly differ between the two ToM components ($z = -1.33$, $p = .18$). Most interestingly, results revealed a significant Component × Age Group interaction, $F(1,31) = 5.17$, $p = .030$, $\eta_p^2 = .143$, $BF_{Inclusion} = 0.80$. Follow-up analyses indicated that YA were faster than OA on both the affective component (2855 vs. 6626 ms), $F(1,31) = 17.23$, $p < .001$, $\eta_p^2 = .357$, $BF_{Inclusion}>100$, and the cognitive component (3383 vs. 6057), $F(1,31) = 6.73$, $p = .014$, $\eta_p^2 = .178$, $BF_{Inclusion} = 9.46$. The interaction in combination with the *p*-values, BFs, and effect sizes of the follow-up analyses suggest that age differences in RT in ToM are more pronounced for affective than cognitive mental states.

Accuracy

Figure 3 shows the response accuracy in each age group for the affective and cognitive ToM components in the first- and second-order conditions. For the first-order condition, results showed no significant effects (*ps*>.12, $BF_{Inclusion}$ between 0.33 and 2.67). For the second order condition, results of the NHST approach showed that accuracy was lower for the YA than the OA group (0.75 vs. 0.85), $F(1,31) = 4.65$, $p = .039$, $\eta_p^2 = .13$, $BF_{Inclusion} = 2.15$. There were no other significant effects (*ps*>.37, $BF_{Inclusion}$ between 0.44 and 2.12).

Speed/Accuracy Trade-Offs

To examine if a difference in speed/accuracy trade-offs during performance between the two age groups could explain the present findings, we evaluated whether performance as reflected in RTs and the proportion of correct responses were correlated within each age

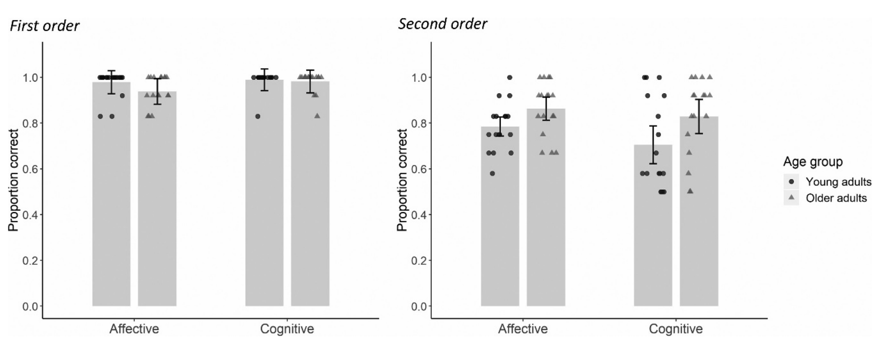

Figure 3. Individual and mean proportion of correct responses (adjusted for performance in the physical control condition) for the affective and cognitive ToM components as a function of age group in the first order (left) and second order (right) conditions. Error bars represent within-subject standard errors.

group. For each condition of our design, we performed separate correlation analyses across participants in the YA and OA groups. The alpha level was adjusted to p < .00625 to Bonferroni correct for the two types of inferences (first vs. second order) multiplied by the two ToM components (cognitive vs. affective). As Table 2 shows, results of the correlation analyses showed no significant correlations in any of the conditions, neither for the YA group (all ps>.083, BF_{10}s between 0.33 and 1.20) nor the OA group (all ps>.047, BF_{10} s between 0.32 and 1.85). The absence of significant negative correlations between RT and the proportion of correct responses argues against the notion of (group differences in) speed/accuracy trade-offs during performance and suggests that the observed effects of aging cannot be explained by age-related differences in such trade-offs.

Discussion

In the present study we examined the effect of aging on ToM using a task that differentiates between cognitive and affective ToM components and between first and second order inferences. We observed that across first order items OA needed more time to make inferences than YA. For the second order items, this age difference was more pronounced for affective than for cognitive ToM. These observations suggest that aging is associated with changes in ToM, but that differences in effects of age between cognitive and affective ToM are selective to second order inferences. However, we also found some evidence supporting age-related improvements on second order inferences when evaluating performance in terms of accuracy. As we found no indications for speed/accuracy trade-offs, it is unlikely that this improved accuracy is due to older participants strategically taking more time. Combining our findings, we propose that aging is associated with slowing of the decision processes underlying ToM inferences, but that the outcome of these processes is unaffected in OA.

The asymmetrical slowing of decision processes underlying cognitive versus affective ToM for second order inferences in older age may be related to the differential neural substrates underlying these components. Research has shown that cognitive ToM engages a network that includes the dorsomedial prefrontal cortex (dmPFC), the dorsal anterior cingulate cortex (ACC), and the dorsal striatum, whereas affective ToM engages a network that includes the ventromedial prefrontal cortex (vmPFC), the ventral ACC, and the ventral striatum (Abu-Akel & Shamay-Tsoory, 2011; Healy & Grossman, 2018). Prior studies have shown that within the prefrontal cortex the vmPFC is more sensitive to age-related structural changes than the dmPFC (see Kemp, Després, Sellal, & Dufour, 2012). This could explain why the OA group in our study showed slower decision making for affective

Table 2. Correlations between performance measures (RT and proportion of correct responses) for each of our experimental conditions as a function of Age group.

	Young adults			Older adults		
Condition	r	p	BF_{10}	r	p	BF_{10}
First order						
Affective	−.263	.31	0.49	−.487	.047	1.85
Cognitive	−.121	.64	0.33	−.104	.69	0.32
Second order						
Affective	.432	.083	1.20	.206	.43	0.40
Cognitive	.364	.15	0.78	.338	.18	0.67

than cognitive second order items. On the other hand, at the functional level, Moran, Jolly, and Mitchell (2012) found evidence for age-related reductions in dmPFC activation across three social-cognitive paradigms. However, they did not distinguish between cognitive and affective components of social cognition, which may have obscured more specific findings. As prior studies have provided mixed results regarding the patterns of change in the aforementioned ToM networks in healthy aging (for reviews, see Kemp et al., 2012; Moran, 2013), future studies should exploit neuroimaging and – modulation techniques to further address this issue.

While intuitively appealing, such an explanation in terms of cortical changes is admittedly speculative and may be an oversimplification of the mechanism underlying the effects of aging. First, there are also other areas that are typically found to be associated with ToM, in particular the temporo-parietal junction (TPJ; Young, Dodell-Feder, & Saxe, 2010), that do not seem to be differentially recruited during ToM tasks in older compared to young adults (Moran et al., 2012). In addition, one could wonder to what extent the effects of aging rely on structural (degenerative) changes with age, or whether changes in experiences, impulsivity, and hormonal changes, among others, also play a role. For example, the first study on ToM in healthy aging reported that ToM performance remains intact and may even improve with older age, and proposed that this was related to older adults having more wisdom (Happé, Winner, & Brownell, 1998). Our observation of higher accuracy on second order inferences in the OA group is in line with this notion, although literature reviews concluded that most studies subsequent to Happé et al. (1998) in fact showed age-related reductions in ToM performance (Henry et al., 2013; Moran, 2013). As aforementioned, our results suggest that the observed age effect on accuracy was not related to differences in performance trade-offs – however, we acknowledge that this does not conclusively refute the possibility that slowing in OA may have benefited the outcome of the decision process in a more implicit, non-strategic manner. We also note that for first order inferences the absence of a significant age effect on accuracy may reflect a ceiling effect, because over half of the subjects responded correctly on all trials across conditions.[2] This may have obscured age differences in ToM outcomes, and advocates for the inclusion of measures reflecting the decision making process (e.g., RTs or eye-tracking) in addition to mere outcome accuracy. Future studies could investigate which circumstances modulate the outcome of decision making process in OA, such as performing under time pressure. In addition, as recent studies found that ToM in older adults can be improved by training (Cavallini et al., 2015; Lecce et al., 2019) and by enhancing motivation (Zhang et al., 2019), future studies could focus on developing and implementing interventions that can induce compensatory mechanisms and/or plasticity for ToM performance in older age.

Methodological Considerations

A strength of the current study is that the Yoni paradigm allowed us to evaluate both cognitive and affective ToM as well as first and second order inferences within a single task. For cognitive ToM, the present finding that aging was associated with changes in performance is in line with findings from previous studies that have examined the effect of healthy aging on ToM components within the same task (Baksh et al., 2018; Bottiroli et al., 2016; Fischer et al., 2017; Walzak & Loken Thornton, 2018). For affective ToM, our finding that aging adversely impacted performance is in line with results reported by

Fischer et al. (2017) but in contrast with those of Bottiroli et al. (2016). Moreover, we further elucidated the effect of aging on ToM by considering the type of inference, namely first versus second order. Although age differences have been more consistently observed for second order inferences (Duval et al., 2011; Moran, 2013), we here observed that aging slowed decision making on both first and second order inferences. This suggests that the Yoni task provides a sensitive measure to identify changes in ToM processing with older age, even for first order inferences.

Despite the use of sample size calculations to determine the number of required subjects for our study, concerns may arise about whether the small number of subjects per age group yielded sufficient power. To evaluate whether our findings may be subject to unforeseen power limitations, we compared the magnitudes of age effects observed in the present study with those observed by Fischer et al. (2017). As our sample size calculations were based on t-test effect sizes reported in Fischer et al. (2017; cognitive ToM d = 0.75, affective ToM d = 0.86), we converted the effect sizes observed in the present study as reflected in η_p^2 to Cohen's d (cf. Cohen, 1988; DeCoster, 2012). For RTs, converted effect sizes of our age factor in the cognitive and affective conditions were d = 0.91 and d = 0.95, respectively, for first order inferences, and d = 0.85 and d = 1.45, respectively, for second order inferences. For accuracy, the converted age main effect size in the second order condition was d = 0.77 (results showed no significant effects of age for first order inferences). The comparison thus shows similar magnitudes for age effects in the present study and Fischer et al. (2017), arguing against the notion that our findings could be the result of insufficient power.

One could argue that the gender difference between the YA and OA groups may compromise the interpretation of our findings in terms of age effects. While there are indications that women have better affective social cognitive abilities than men (e.g., emotion recognition, Hall & Matsumoto, 2004; empathy, Baron-Cohen & Wheelwright, 2004), studies specifically investigating ToM have generally reported no significant gender differences (Frank, Baron-Cohen, & Ganzel, 2015; Pezzuti, Longobardi, Milletti, & Ovidi, 2011; Turkstra, Norman, Mutlu, & Duff, 2018). To evaluate whether the present findings could reflect gender effects, we re-ran our analyses with Gender rather than Age as a grouping variable. We found no evidence that gender affected ToM performance in terms of RTs (first order ps>.29, $BFs_{Inclusion}$ = 0.45–0.66; second order ps>.34, $BFs_{Inclusion}$ = 0.45–0.68) or accuracy (first order ps>.054, $BFs_{Inclusion}$ = 0.81–1.05; second order ps>.048, $BFs_{Inclusion}$ = 0.65–1.60). These results, in combination with the literature, render it unlikely that group differences in gender rather than age underlie the observed effects.

There are some aspects to the present study that limit the generalizability of our findings. First, our OA group comprised community dwelling adults, leaving open the question of how ToM abilities are affected in adults with reduced functional independence. Second, given that we administered a static visual ToM task, an open question remains whether similar findings would be obtained for ToM performance in other modalities, such as verbal tasks (cf. Slessor et al., 2007). Furthermore, it should be evaluated if our findings would be confirmed in more dynamic naturalistic scenarios, as prior studies on the effect of aging on empathic abilities showed that context modulated age differences (e.g., Rauers, Blanke, & Riediger, 2013; Richter & Kunzmann, 2011).

Conclusions

Overall, the current results corroborate that aging is associated with changes in both cognitive and affective ToM (cf. Baksh et al., 2018; Fischer et al., 2017; Walzak & Loken Thornton, 2018) and further refine our understanding of age differences in ToM. Specifically, we demonstrate that decision processes underlying ToM inferences are slower in older adults, but that this slowing does not affect the outcome of the decision (i.e., no ToM deficit). Moreover, we show that differential effects of aging on cognitive versus affective decision processes are selective to second order inferences. As we only compared two age groups, our findings leave open the question of when in the lifespan age-related changes in ToM begin and whether the relationship with age is linear or not. In addition, future studies should take into account individual differences in ToM and how these interact with effects of aging, by for example considering specific dopaminergic gene profiles that are predictive of ToM (Lackner, Sabbagh, Hallinan, Liu, & Holden, 2012; Xia, Wu, & Su, 2012). Longitudinal designs may help to investigate these issues. Finally, while our findings elucidate changes in ToM related to healthy aging, studies should also evaluate the changes that occur with pathological aging. It has been shown that different patterns of change in social cognition (including ToM) are associated with different neurodegenerative diseases, depending on the neuropathological networks and processes that are affected by the disease (Kemp et al., 2012; Poletti, Enrici, & Adenzato, 2012). However, a systematic investigation of the impact of pathological aging on cognitive and affective ToM in first versus second order inferences is currently still lacking.

Notes

1. As visual inspection of the individual data points in Figure 2 suggested that the observed effects could potentially be driven by extreme data points, we tested the data for outliers. Grubbs' test indicated that for the OA group, the data points with the longest RT in the first order affective condition and the second order cognitive condition were outliers. Both data points represented the same subject. There were no outliers in the YA group. When repeating the RT analyses without the data from the OA subject, we observed the same pattern of results as reported for the analyses on all subjects.
2. We thank an anonymous reviewer for this suggestion. For the second order inferences the reasoning of a ceiling affect does not apply, because only two subjects (1 YA and 1 OA) responded correctly on all trials.

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Declaration of Interest

The authors report no conflict of interest.

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