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The influence of inhibitory processes on affective theory of mind in young and old adults

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ABSTRACT

The primary aim of this study was to examine the impact of an inhibition manipulation on the effect of age on theory of mind (ToM) in an ecologically valid, affective ToM task. Participants were 30 young and 30 old adults. The Cambridge Mindreading Face-Voice Battery was used to measure ToM; in addition, measures of fluid and crystallized intelligence were taken. Participants were subjected to three levels of inhibitory demand during ToM reasoning: emotional inhibition, non-emotional inhibition, and no inhibition. Old adults performed worse than young adults. The emotional and non-emotional inhibition conditions resulted in worse ToM performance compared to the no inhibition condition. There were no differences in the impact of the inhibition conditions on old and young adults. Regression analyses suggested that old adults' crystallized intelligence was a significant predictor of ToM performance, whereas it did not predict young adults' ToM performance. Results are discussed in terms of verbal ability as a possible compensatory mechanism in coping with verbal inhibitory load in ToM reasoning.

Keywords: Aging; Inhibition; Theory of mind; Crystallized intelligence; Fluid intelligence.

The ability to represent and understand mental states of others', known as theory of mind (ToM), is a critical skill for seamless interpersonal interactions in

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daily life. For example, understanding that one's spouse is upset about a conflict with a colleague allows for avoidance of the topic during dinner, creating a situation less likely to lead to conflict or further increases in negative affect. Therefore, a well-developed ToM allows adults to function more effectively in interpersonal relationships and social interactions (e.g., Hodges, Clark, & Myers, 2011; Vescio, Sechrist, & Paolucci, 2003). In contrast, failure to consider differing mental states, motivations, and expectations between the self and others can lead to miscommunication and conflict (e.g., Pronin, Puccio, & Ross, 2002).

While understanding basic mental states such as desire or belief (*cognitive* ToM) is evident in children around 5 years of age (e.g., Wellman, Cross, & Watson, 2001; Wellman & Liu, 2004), more complex forms of ToM develop later in childhood. For example, second order ToM (i.e., understanding that Mary thinks that John thinks that his cat is hungry) develops in middle childhood (Perner & Wimmer, 1985). Further, understanding more complex emotional states (*affective* ToM) such as embarrassment or pride requires a more sophisticated form of ToM that develops in late childhood and continues to develop into adolescence (e.g., Shamay-Tsoory, Harari, Aharon-Peretz, & Levkovitz, 2010; Vetter, Altgassen, Phillips, Mahy, & Kliegel, 2013; Vetter, Leipold, Kliegel, Phillips, & Altgassen, 2012). Despite the relatively early development of many ToM concepts, individual differences in ToM persist throughout the lifespan. For example, in adulthood better ToM is associated with the presence of fewer autistic traits (Baron-Cohen, Wheelwright, Hill, Raste, & Plumb, 2001), greater cooperative tendencies (Paal & Bereczkei, 2007), and higher levels of emotional intelligence (Ferguson & Austin, 2010).

In recent years, there has been a growing interest in ToM functioning in old age (see Moran, 2013 for a review). So far, the small body of literature on ToM in the elderly has revealed inconsistent findings. Yet, understanding how age affects ToM and what mechanisms cause age-related changes are important as recent research shows that decreases in ToM mediate a decline in social participation in old adults (e.g., Bailey & Henry, 2008; Bailey, Henry, & Von Hippel, 2008) which has been linked to loneliness and poorer health (Henry, Phillips, Ruffman, & Bailey, in press).

An early study suggested that old adults performed significantly *better* than young adults on ToM stories (Happé, Winner, & Brownell, 1998) with the authors concluding that social wisdom and intelligence potentially increase with age leading to better ToM performance. However, later analyses suggested that higher verbal intelligence of the old adults compared to young adults may have accounted for ToM performance differences in this study (Slessor, Phillips, & Bull, 2007). In contrast to this finding, other studies have failed to find age differences between young and old adult's ToM using a wide variety of tasks (e.g., Duval, Piolino, Bejanin, Eustache, & Desgranges, 2011; Keightley, Winocur, Burianova, Hongwanishkul, & Grady, 2006; MacPherson, Phillips, & Della Sala, 2002; Saltzman, Strauss, Hunter, & Archibald, 2000). An increasing body of evidence, however, has revealed that old adults have *deficits* in ToM compared to young adults (Henry et al., in press; Moran, 2013). Studies that have documented age-related declines in ToM have used a wide variety of tasks such as non-verbal, visual-static, and dynamic visual ToM tasks (Henry et al., in press) suggesting that age-related decreases are not stimulus- or task-specific. Although the current literature clearly suggests that there are declines in ToM during aging, little work to date has attempted to test the underlying mechanisms of this decline.

One possible mechanism that might contribute to declines in ToM during aging is executive function as these abilities rapidly decline in old age (e.g., Salthouse, Atkinson, & Berish, 2003; Zelazo, Craik, & Booth, 2004). A handful of correlational studies have explored the role of executive function in ToM performance in old age. For example, executive function (working memory, inhibition, set shifting), information processing speed, and performance intelligence fully mediated the relation between age and ToM (Charlton, Barrick, Markus, & Morris, 2009) and difficulties in updating information in working memory (but not inhibition) partially mediated the age differences in false belief reasoning (Phillips et al., 2011). Similarly, German and Hehman (2006) suggested that compromised belief-desire reasoning in old age is likely the result of age-related decline in executive selection skills that supplement core mental state representational abilities, rather than as a result of failures in the representational system itself. Further, Duval et al. (2011) found a direct aging effect on second-order cognitive ToM and an indirect effect on first-order cognitive ToM, mediated mainly by age-related declines in working memory updating, inhibition, and set shifting. In contrast, performance on these executive tasks did not mediate the relation between age and *affective* ToM performance suggesting that executive ability may not play as important a role in the age effect on affective ToM tasks. Taken together, these studies suggest that executive abilities may contribute to age effects at least in *cognitive* ToM performance.

In contrast, other research suggests that the age effect in ToM is unrelated to executive performance. For example, Maylor, Moulson, Muncer, and Taylor (2002) found that the effect of age on ToM could not be accounted for by processing speed or executive function (measures of reactive and spontaneous flexibility). Further, Bernstein, Thorton, and Sommerville (2011) showed that middle-age and old adults exhibited more false belief bias compared to young adults independent of language ability, executive function (set shifting, inhibition, and response monitoring), processing speed, and memory. Importantly, only one study has manipulated executive function experimentally by imposing a secondary working memory task (McKinnon & Moscovitch, 2007) while young and old adults had to simultaneously complete a ToM task. Both young and old adults' ToM performance was negatively affected by the addition of the secondary task that required divided attention. Therefore, there are mixed findings regarding the role of executive processes in the age effect on ToM. A further concern is that the majority of the research has relied on correlational designs in order to control for executive abilities in ToM performance. Finally, a majority of the studies cited have examined the impact of executive function on *cognitive* ToM that focuses on understanding beliefs and knowledge whereas much less work has investigated age-related changes in understanding emotions (i.e., *affective* ToM) in old age (although see Duval et al., 2011; Keightley et al., 2006).

Given the scarcity of experimental manipulations of executive control in ToM performance of old adults, evidence from the young adult literature is worth considering as it provides evidence that divided attention has a negative impact on young adults' ToM performance (e.g., Bull, Phillips, & Conway, 2008; Lin et al., 2010; Maehara & Saito, 2011; McKinnon & Moscovitch, 2007; Qureshi, Apperly, & Samson, 2010; Schneider, Lam, Bayliss, & Dux, 2012). One such study showed that verbal distraction in particular had a harmful effect on ToM performance compared to a secondary motor task (Newton & De Villiers, 2007). Interestingly, Maehara and Saito (2011) noted that all published studies on cognitive load and ToM performance have manipulated load at the time of response, but have failed to control for interference at encoding.

It is possible that the mixed findings surrounding the role of executive abilities in old adults' ToM are due to the diversity of tasks that are considered measures of executive function and/or ToM (see Moran, 2013). Certain executive abilities perhaps play a more significant role in the age effect on ToM than others. For example, Duval et al. (2011) suggested that composite cognitive scores might mask the significant involvement of specific executive processes. Four types of evidence suggest that *inhibitory control* may play an especially critical role in ToM reasoning: (1) studies with children that show inhibitory control and ToM are related, (2) experimental studies with young and old adults that show inhibitory control impacts ToM performance, (3) an analysis of the inhibitory demand of basic ToM tasks, and (4) brain regions that support both inhibitory abilities and social reasoning.

Based on the child development literature, inhibitory control plays a particularly important role in children's ToM reasoning during the preschool period (e.g., Carlson & Moses, 2001; Carlson, Moses, & Claxton, 2004; Hughes, 2011). In adolescents and young adults inhibitory control accounts for a significant amount of age-related variance in affective ToM (Vetter et al., 2013). Similarly, Bull et al. (2008) found that young adult's affective ToM showed specific dual-task costs when performed concurrently with a secondary inhibition task. Further, Bailey and Henry (2008) found that old adults' performance suffered in a false belief task that required inhibition of their own perspective but not in a false belief task without an inhibition requirement. Additionally, a task analysis supports the relation between ToM and inhibitory control as many ToM tasks require holding two conflicting mental states in mind (e.g., one's accurate state of knowledge and another's false belief) and in order to select the correct response, one must inhibit their own current perspective. Finally, neuroimaging studies have shown a substantial functional overlap in areas associated with ToM reasoning and with inhibition, particularly in areas of the prefrontal cortex (e.g., Moran, Jolly, & Mitchell, 2012; Rothmayr et al., 2011). Given that the frontal cortex undergoes major structural changes in old age (e.g., Coxon, Van Impe, Wenderoth, & Swinnen, 2012; Sowell et al., 2003), a key question is how such structural changes affect the relation between ToM and inhibition in old age.

Theoretically important to cognitive aging research, an inhibition deficit hypothesis (Hasher & Zacks, 1988) has been proposed to explain the negative impact of age on cognitive performance, especially working memory. According to this hypothesis, the consequence of inefficient inhibitory processes is the infiltration of irrelevant information into working memory that leads to active interference. Empirical support for this hypothesis is provided, for example, by Zeintl and Kliegel (2007) who manipulated inhibitory demand in an operation span task in young and old adults. There was a significant interaction between age and inhibitory requirement such that old adults performed worse in the versions with increased inhibitory demand compared to young adults, indicating age-related deficits in inhibitory control (see also Nieuwenhuis, Ridderinkhof, De Jong, Kok, & van der Molen, 2000; West & Alain, 2000 for other examples).

Given established age-related declines in inhibitory control as well as the critical role that inhibitory control plays in many ToM tasks, the present study will experimentally manipulate levels of inhibition in an *affective* ToM task with young and old adults. Based on the review of the relevant literature several predictions were possible. Due to old adults' declining attentional abilities (e.g., Milham et al., 2002; Pratt & Bellomo, 1999) and greater distractibility (e.g., Fabiani, Low, Wee, Sable, & Gratton, 2006; Hamm & Hasher, 1992), especially by irrelevant material compared to young adults (e.g., Andrés, Parmentier, & Escera, 2006), any type of interference from inhibitory demands may be sufficient to harm old adults' performance (e.g., Connelly, Hasher, & Zacks, 1991; Hartman & Hasher, 1991). It follows that old adults might perform poorly in *any* task that includes an inhibitory demand regardless of its relevance to the task at hand. In contrast, young adults may be more disrupted by material relevant to the current task compared to more generally distracting, task-irrelevant material compared to old adults, perhaps due to superior abilities in filtering irrelevant information (e.g., Alain & Woods, 1999). Therefore, the current study will attempt to examine this hypothesis by directly testing the impact of three inhibition conditions during encoding on young and old adults' affective

ToM performance: emotional inhibition, non-emotional inhibition, and no inhibition.

We predict that old adults will perform worse on a ToM task than young adults overall, that conditions with higher inhibitory demand will result in worse ToM performance for both young and old adults, and that the effect of inhibition will be different in young and old adults such that old adults will be negatively affected by any type of inhibitory demand, whereas young adults will be more affected by emotional than non-emotional inhibitory demand. Further, we explored the influence of both fluid and crystallized intelligence on inhibition and affective ToM performance in young and old adults given that past work has documented age differences in crystallized intelligence that accounted for ToM performance (see Happé et al., 1998) and established age differences in fluid and crystallized intelligence (e.g., Salthouse, 1993).

METHOD

Participants

Two groups of participants were recruited: 30 young adults (20 men) aged 18–35 years ($M = 22.53$, $SD = 4.59$) and 30 old adults (8 men) aged 60–83 years ($M = 72.13$, $SD = 4.61$).[1] The group of young adults consisted mostly of undergraduate students and the old adults were recruited through a university database. All participants were native German speakers. None of the participants had acute or chronic neurological or psychiatric disorders, uncorrected visual impairment, or severe color blindness.

Old adults ($M = 13.70$, $SD = 3.04$) had more years of education than young adults ($M = 12.42$, $SD = 1.69$), $t(45.36) = 2.02$, $p = .05$. All old participants were screened for the presence of Dementia using the Mini Mental Status Test (MMST; Folstein, Folstein, & McHugh, 1975) and scored above the cut-off of 26. All participants were administered the Digit Symbol Test (ZST; Aster, Neubauer, & Horn, 2006) to assess whether the age groups differed in fluid intelligence. There was no significant difference between the age-standardized mean values of the young ($M = 12.53$, $SD = 2.33$) and old adults ($M = 12.37$, $SD = 1.87$) on the ZST, $t(58) = .31$, $p > .75$. To measure crystallized intelligence, the Mehrfachwahl-Wortschatz-Test (MWT-B; Lehrl, 1995) was administered. The MWT is a vocabulary test with 37 multiple choice items of increasing difficulty. Old adults ($M = 32.47$, $SD = 3.19$) had higher scores on crystallized intelligence than young adults ($M = 30.83$, $SD = 2.74$), $t(58) = 2.13$, $p = .04$.

[1] Given the unequal gender distribution in the young and old adults, we first analyzed the effect of gender. As it was not significant, it was not included in any of the following analyses.

Materials

The Cambridge Mindreading Face-Voice Battery

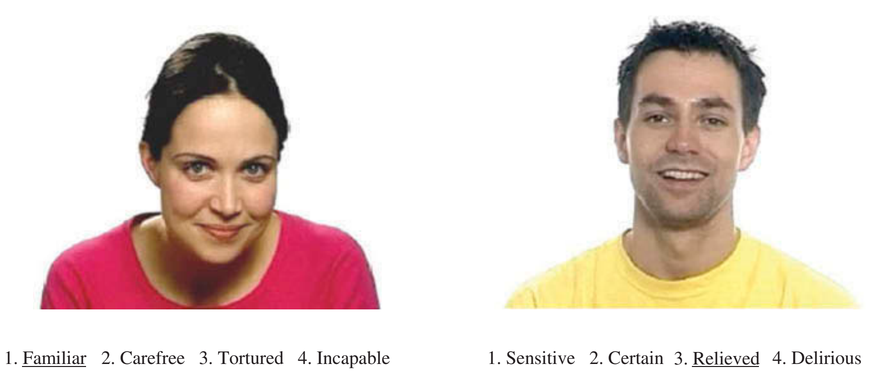
The Cambridge Mindreading Face-Voice Battery (CAM) measures affective ToM in adults using visually dynamic stimuli (adapted from Golan, Baron-Cohen, & Hill, 2006; Vetter et al., 2013). Only the visual component (facial scale but not the vocal scale) of the battery was used in this study. Thirty-nine silent clips of male and female adult actors of different age groups (young, middle-aged, and old adults) that express complex emotions in the face and torso (from the shoulders upward) were presented on a LCD computer screen (Figure 1). Film clips varied from 3 to 8 seconds and faded after presentation. Afterwards, participants selected one of four adjectives presented (different adjectives for each film clip) that best described the emotion of the person in the video by pressing a button. Examples of correct adjectives are resentful, subdued, empathic, and vibrant. A handout containing definitions of all adjectives was provided at the beginning of the task to minimize mistakes due to misunderstanding word meaning. Participants were told to answer as accurately as possible and adjectives stayed on the screen until participants made a response (i.e., response time was unrestricted). A professional translator translated the CAM into German.

Inhibition manipulation

The need for inhibitory control processes in the CAM was varied by presenting different auditory stimuli in the three following conditions.

Emotional inhibition: During trials of the CAM, emotion words were presented auditorily while participants were viewing the clip (which lasted from 3 to 8 seconds). The words were relevant to emotional states such as

FIGURE 1. Sample items from the adapted CAM with the four alternative responses. The underlined adjective represents the correct response.



"exonerated" or "unconcerned" and one word was presented every 1.4 seconds on average. Four adjectives were presented for each video clip: a strongly positive, a somewhat positive, a somewhat negative, and a strongly negative word. The words were selected from the Berlin Affective Word List Reloaded (BAWL-R; Vő et al., 2009). The BAWL-R consists of 2900 German words representing positive, neutral, and negative affective valence. The emotional valence of words ranged from +3 (very positive) to –3 (very negative). Importantly, the inhibition manipulation occurred during the viewing of the CAM trials and not during the response selection period.

Non-emotional inhibition: In these trials of the CAM, two neutral nouns and two neutral verbs were presented auditorily while participants viewed the video clips (and again, not during response selection). Examples of words include "justify", "range", or "tie". These words were also from the BAWL-R but only verbs and nouns with a valence in the range of –0.4 to +0.4 were included. The order of word presentation was random. This condition required the inhibition of the irrelevant words, but because they were neither relevant to the judgment nor emotional in valence these trials should require less inhibition than the emotional inhibition trials.

No inhibition: In these trials, participants made judgments about the emotion presented in the video clip without any words presented auditorily. Therefore, no inhibitory process was necessary as no distracting words were presented.

The general instruction for participants was that the auditorily presented words should be ignored and that these words did not include helpful information in selecting the correct response. Participants were given example trials in order to ensure that they understood the task. Thirteen items per inhibition condition were presented, thus, a total of 39 video clips from the CAM were used. Gender and age of the actor in the video were counterbalanced across the three inhibition conditions.

Design

The present study used a 2 (Age: young versus old adults) × 3 (Inhibition condition: emotional versus non-emotional versus no inhibition) factorial design with the second factor manipulated within-subjects. Inhibition conditions were blocked and counterbalanced such that: a third of each age group started with the emotional condition, another third started with the non-emotional condition, and the final third started with the no inhibition condition.

RESULTS

Table 1 shows means and standard deviations of ToM performance by age and inhibition condition. A 2 (Age group) × 3 (Inhibition condition)

TABLE 1. Means and standard deviations for theory of mind task for the inhibition conditions for young and old participants

	Theory of mind performance	
Inhibition condition	*M*	*SD*
Young adults		
Emotional	9.95	1.75
Non-emotional	10.13	1.87
No inhibition	10.80	1.72
Old adults		
Emotional	9.27	1.93
Non-emotional	9.10	1.81
No inhibition	9.87	1.83

Note: Maximum score is 13 per condition.

mixed-factorial ANOVA was performed on judgment accuracy on the CAM. There was a significant effect of age group, $F(1, 58) = 38.14$, $p < .001$, $\eta_p{}^2 = .40$, such that young adults were more accurate on ToM judgments than old adults. There was also a significant main effect of the inhibition condition, $F(2, 57) = 6.85$, $p < .01$, $\eta_p{}^2 = .11$. Planned contrasts revealed that both the emotional and non-emotional inhibition conditions resulted in lower judgment accuracy than the no inhibition condition, $F(1, 58) > 9.06$, $p < .01$, $\eta_p{}^2 > .13$. However, there was no difference in ToM judgment accuracy between the emotional and non-emotional inhibition conditions, $p = .47$, $\eta_p{}^2 = .01$. The interaction between age and inhibition condition was not significant, $p = .39$, $\eta_p{}^2 = .03$, indicating that old adults were not more negatively affected by the inhibition conditions compared to young adults.

Exploratory results: The role of fluid and crystallized intelligence

In order to examine the role of fluid and crystallized intelligence in the three inhibition conditions for young and old adults, a series of regression analyses were conducted. In the emotional inhibition condition, young adults' ToM performance was not predicted by their age, fluid, or crystallized intelligence, whereas old adults' ToM performance was significantly predicted by their age ($\beta = -0.12$, $t = 2.10$, $p = .05$), crystallized intelligence ($\beta = 0.27$, $t = 2.98$, $p = .006$), and fluid intelligence at the level of a trend ($\beta = 0.28$, $t = 1.82$, $p = .08$). In the non-emotional inhibition condition, young adults' ToM performance was predicted by fluid intelligence only ($\beta = 0.24$, $t = 2.32$, $p = .03$), whereas crystallized intelligence marginally predicted old adults' ToM performance ($\beta = 0.20$, $t = 1.88$, $p = .07$). Finally, in the no inhibition condition, none of the variables of age, fluid, or crystallized intelligence predicted young adults' ToM performance, however, age ($\beta = 0.16$, $t = 2.53$,

$p = .02$) and crystallized intelligence ($\beta = 0.20$, $t = 2.09$, $p = .05$) predicted old adults' ToM performance.

DISCUSSION

The main goal of this study was to examine how age affects performance on an ecologically valid affective ToM task. In addition, the impact of various levels of inhibitory demand on ToM performance was examined to investigate the effect of emotion-relevant inhibition on the ToM age effect. The results revealed a clear age effect in ToM performance with young adults outperforming old adults. The impact of inhibition was such that all participants were negatively impacted by both the emotional and non-emotional inhibition compared to the no inhibition condition. Age group and inhibition condition did not interact suggesting that the inhibition conditions did not differentially affect young and old adults similar to McKinnon and Moscovitch's (2007) finding. When fluid intelligence and crystallized were used to predict ToM performance for old and young adults in each of the inhibition conditions, crystallized intelligence tended to independently predict ToM performance in old adults but not in young adults.

Several important conceptual conclusions are supported by these findings. First, old adults had significantly poorer achievement on the affective ToM task compared to young adults. This result is consistent with most of the available but still limited literature, especially in the affective domain, that shows an age-deficit in ToM performance (e.g., Charlton et al., 2009; Henry et al., in press; Moran, 2013; Slessor et al., 2007; Sullivan & Ruffman, 2004). In consequence, these findings contradict those of Happé et al. (1998) who found improvement in ToM skills of the elderly and the findings of MacPherson et al. (2002) who found no age differences in ToM skills. Importantly, because young and old adults did *not* differ on fluid intelligence (in contrast to Happé et al., 1998), the age effect on ToM performance cannot be attributed to general cognitive differences in the current sample. Interestingly, old adults performed *better* than young adults on crystallized intelligence on a mean group level, yet this superior performance did not close the age gap in ToM performance.

The manipulation of inhibition showed that emotional and non-emotional inhibition had a negative impact on ToM compared to the no inhibition condition in both age groups. Therefore, the presence of any distracting stimuli (whether emotional or not) had a negative impact on performance compared to when there were no distractions. Verbal distraction might have had a particularly powerful impact on ToM as interference from verbal stimuli has a detrimental impact on ToM reasoning in young adults (Newton & de Villiers, 2007). Perhaps while engaging in complex affective ToM judgments that rely on detecting of both facial and bodily cues, any type of distracting verbal input takes attentional resources away from ToM processing. Further, because our manipulation of inhibition occurred only during the presentation of the trials, at response selection there was no concurrent inhibitory demand suggesting that inhibitory demand at encoding is particularly detrimental to later ToM performance. This novel aspect of our study supports the suggestion that a cognitive load during encoding may be more harmful than a load during response (Maehara & Saito, 2011).

Specific predictions surrounding the relative impact of emotional and non-emotional inhibition on young and old adults were not confirmed: young and old adults were not differentially affected by the emotional and non-emotional inhibition conditions. These findings suggest that although old adults' ToM performance is overall worse than young adults', this might not be due to differences in inhibition costs in ToM performance but may reflect a more general deficit.

Conceptually, the findings surrounding the lack of age differences in inhibition costs do not fit with the inhibition deficit hypothesis (Hasher & Zacks, 1988). Rather, they suggest that inhibitory demands, whether specific or unspecific, do not differentially disrupt affective ToM performance in young and old adults. In other words, these results do not support the assumption that the age effect on affective ToM is due to an inhibitory deficit. This research is in line with other studies that have found that inhibition cannot account for the age effect in *cognitive* ToM performance (Bernstein et al., 2011; Maylor et al., 2002). Moreover, this study corroborates the results of Duval et al. (2011) who found that executive functions did not mediate the relation between age and *affective* ToM performance. It is possible that age-related declines in affective ToM are rather due to more general cognitive or perceptual declines. For example, perhaps processing speed has a greater impact on old adults' affective ToM reasoning than inhibitory demand (e.g., Kail & Salthouse, 1994; Salthouse, 1996; Salthouse, Fristoe, McGuthry, & Hambrick, 1998).

Given that the ToM age effect persisted independently of inhibitory demand, age-related differences may also be attributed to ToM-specific aspects such as differences in the use of mental state strategies. For instance, old adults' judgments may rely more strongly on context-based factors such as the adjectives presented as response alternatives, while young adults more intensively rely on person-based information such as the mental state conveyed by the individual's facial expression. This interpretation is in line with a recent neuroimaging study using a similar ToM-task (reading the mind in the eyes), that showed that old adults recruited neural regions in the mentalizing system differently than young adults (Castelli et al., 2010). Only young participants activated cortical areas associated with mentalizing based on face processing. Therefore, higher error rates in old adults may have resulted from less accurate reading of the specific mental state shown by facial expressions.

Future research needs to specify the strategies used by young and old adults in ToM reasoning, for instance by employing ERP methodology allowing for a detailed analysis of information processing strategies.

An alternate explanation is that executive abilities including inhibitory processes do still at least partly account for this age effect but our study failed to detect them. It is possible that other executive functions such as working memory or set shifting would have had greater explanatory power in accounting for the ToM age effect (see Phillips et al., 2011) and that inhibition specifically does not account for age effects.

Some exploratory results were obtained: crystallized intelligence differed significantly between the two age groups with old adults outperforming young adults, and tended to independently predict ToM performance in old adults but not in young adults. It is likely that old adults with better vocabularies were better able to cope with the ToM task particularly under conditions of verbal interference that was relevant to the ToM task (i.e., emotional inhibition). From an individual difference perspective, this suggests that old adults with superior vocabularies may rely on their crystallized knowledge to compensate for general declines in ToM. In addition to crystallized intelligence, fluid intelligence and age predicted old adults' ToM performance in the emotional inhibition condition suggesting that in the most demanding task higher intelligence and lower age was associated with better performance. Perhaps old adults with better vocabulary knowledge are generally less susceptible to interference from linguistic material and better able to ignore adjectives that are incorrect in describing a person's current psychological state, whereas young adults may be able to rely on their inhibitory abilities so their vocabulary level may matter less.

Alternately, there is a documented relation between ToM and verbal ability in children, adolescents, and young adults (e.g., Happé et al., 1998; Hughes, 2011; Vetter et al., 2012, 2013), so it is possible that old adults with better vocabularies were also better at ToM and therefore less distracted by the verbal material presented. Future research should continue to investigate possible differences in the way which young and old adults deal with relevant and irrelevant distractor information in reasoning in the social domain, how this relates to general executive performance, and possible ways that old adults may compensate for ToM deficits.

In contrast to old adults, young adults seemed not to rely on their vocabulary to support their ToM performance but relied perhaps on other cognitive abilities such as fluid intelligence (at least in the non-emotional inhibition condition). It is possible that because young adults have better inhibitory ability than old adults, they may have been able to inhibit the emotional and non-emotional words presented, so their level of vocabulary knowledge was irrelevant to their performance. Young adults' age did not predict their ToM performance suggesting that advancing age is associated with poorer ToM performance only later in life.

From a methodological perspective, the CAM task has previously been used to measure affective ToM development from adolescence to early adulthood and was sensitive in detecting age-related increases in performance in that age range (Vetter et al., 2012, 2013). Taken together with the current study, the CAM seems to have the ability to detect both age-related increases in ToM at the beginning of the lifespan but also age-related declines in old age suggesting an inverted U-shaped pattern of ToM performance across the lifespan. One of the benefits of the CAM is increased ecological validity as participants must detect emotional states based on only a few seconds of exposure to their facial and body movements. This dynamic visual task was fairly realistic in replicating emotion-detection in daily life compared to reading ToM stories which is particularly important for old adults who are less accustomed to responding to verbal material compared to young university students. Moreover, this task allows for a clear distinction between ToM reasoning and inhibition given its low executive demands. That is, in contrast to typical false belief tasks, the CAM task involves little executive effort because of its lack of conflict between reality and the correct response or inhibition of knowledge and different perspectives and thus avoids confounding of mentalizing and inhibition processes. Rather, it requires pure mental state attribution *as such*, i.e., decoding and attribution of emotions.

LIMITATIONS

Although the manipulation of inhibitory control revealed differences between the conditions in which inhibition was present and absent, it may have been that the manipulation of inhibitory demand between the emotional and non-emotional inhibition conditions was still relatively weak. Our manipulation perhaps did not impose enough of an inhibitory demand on old adults to reveal their true inhibitory deficits. It is also possible that our inhibitory manipulation resulted in encoding failures in both young and old adults resulting in poor performance in both the emotional inhibition and non-emotional inhibition condition in young and old adults. A replication of this study with an inhibition manipulation during the response may shed light on the relative impact of inhibition processes at encoding versus response. Further, future work should ensure that the ToM tasks are equally difficult for young and old adults, as the young adults in this study performed relatively well which may have reduced variability and limited our ability to detect differences in performance in the three inhibition conditions. Finally, studies should aim to include a non-mental state control condition in order to make the claim that the effects of inhibition are specific to ToM rather to reasoning more generally.

CONCLUSION

In sum, this was the first study to investigate the impact of inhibition on age effects in an ecologically valid affective ToM task that used visually dynamic stimuli. The level of inhibition was manipulated in a novel way by presenting participants with emotional inhibition, non-emotional inhibition, and no inhibition while carrying out the ToM task. Results confirm prior findings that suggest a negative impact of aging on ToM performance. Emotional and non-emotional inhibition resulted in worse ToM performance compared to the no inhibition condition, although inhibition did not interact with age. Interestingly, our results indicated that young and old adults' ToM performance was not differentially affected by emotional inhibition and non-emotional inhibition conditions. This provides further evidence that inhibitory processes may not play a role in age effects in affective ToM performance as inhibition costs did not differ between young and old adults. Exploratory regression analyses suggested that old adults may have relied on their superior vocabulary ability while performing the ToM task. Taken together with work on children and adolescents, the current study further suggests that ToM may follow an inverted U-shape across the lifespan (see Bernstein et al., 2011). Future work should continue to use ecologically valid ToM tasks instead of relying on stories that lack the dynamic, fast-paced characteristics of real-life interpersonal interactions and further investigate other possible cognitive factors that might be responsible for the age differences in affective ToM performance.

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