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Review

Lifespan development: The effects of typical aging on theory of mind

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HIGHLIGHTS

- ► I review the extant literature on aging and social cognition.
- ► I cover studies investigating theory of mind and moral judgments.
- ► Theory of mind deficits are partially dependent on deficits in general cognition.
- ► The brain regions linked to theory of mind show task-specific deficits in aging.
- ► Aging is a unique method to study whether theory of mind is a specialized module.

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ABSTRACT

Whether typical aging is associated with impairments in social understanding is a topic of critical importance in characterizing the changes that occur in older adulthood. Theory of mind (ToM) refers to the ability to represent other's mental states, and has been tested in a variety of different paradigms in older adults. The overarching research question has been whether ToM abilities may rely on other cognitive abilities, such as processing speed or executive functioning, and as such declines in ToM may reflect a decline in general meta-representational abilities. Alternatively, ToM abilities may be relatively spared, suggesting the acquisition of a sort of social wisdom with advancing age. The preponderance of the evidence is in line with the first possibility: namely, ToM, as measured by paradigms involving faces, cartoons, stories, and videos is typically impaired in social aging, and these impairments are at least partly mediated by impairments in executive functions and fluid intelligence (but not typically by crystallized intelligence). Neuroimaging investigations suggest that older adults who perform as well as younger adults may activate compensatory mechanisms, but are impaired in the brain mechanisms most closely associated with ToM ability when their task performance is impaired. Recent methodological advances allowing continuous rather than categorical assessment of ToM show that ToM may be observed to function independently from general cognition in aging, but further investigation is needed to confirm this point. Implications of these findings for the longstanding discussion regarding Theory of Mind's endangered status as a special cognitive module are discussed.

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1. Introduction

Social cognition, or how humans understand and interact with other humans, comprises a set of skills whose successful application is critical for the cohesion of individual and societal relationships. For humans, the development of social interaction may represent the pinnacle of evolution of our cognitive architectures. According to Dunbar [1], the relative explosion of neocortex size in humans compared with other primates and with non-primates is tightly associated with the larger social groups in which we embed ourselves. And indeed, understanding our social partners who in turn are attempting to predict our actions is a difficult computational task that may be unparalleled by other evolutionary pressures (such as the use of tools [2]), and thus may have provided selection pressures for larger neocortices. Theory of mind (ToM) is a hallmark ability underlying social interaction, which allows representation of the mental states of others. Evidence from the evolutionary perspective hence suggests that social cognition may comprise a set of abilities (including ToM) that are independent from general cognition, and theorists in cognitive development have separately posited the existence of a Theory of Mind Module [3]: a domain-specific cognitive device that is specialized for the understanding of mental states. An alternative hypothesis, supported by lesion work and by some work in autism, is that Theory of Mind is predicated on meta-representation, which is the domain-general ability to think about and manipulate other representations (such as a mental image of a drawing of a pencil) [4].

Another perspective that could inform this debate is investigating how ToM fares in later lifespan development. If ToM is impaired in aging, does it decline in ways that tie it to more basic cognitive operations? If so, would we be able to conclude that ToM is, in general, predicated on more domain-general cognitive abilities? Reflection on the possible trajectories for ToM in typical aging suggests two hypotheses. First, since ToM is tied to the functioning of a specific cognitive architecture, declines in that cognitive architecture (e.g., [5]) may also be associated with declines in social functioning. The weight of the evidence suggests that older adults do show marked declines in aspects of 'fluid' intelligence [5]; those aspects include skills such as working memory, processing speed, and numerical ability. If older adults perform worse at ToM, one explanation is that low fluid ability simply makes the task more difficult for them, independent of any domain-specific difficulties in ToM. Therefore, it is important to note whether effects are independent of differences in these crucial domains of cognition. Executive functioning (e.g., inhibiting prepotent responses, choosing among alternatives) also declines with age [6]. Presumably, such declines might also be associated with difficulties in some of the nuances of social cognition.

Alternatively, a lifetime of accumulation of knowledge about the social world may lead to us becoming much more efficient in our social interactions, and as a result, certain aspects of social cognition may comprise a domain in which experience trumps youth. This view sits well with the evidence from general cognition [5], which argues that older adults show sparing of 'crystallized' aspects of intelligence, such as verbal memory, general knowledge, and vocabulary. If older adults show preserved ToM ability, this may result from greater knowledge about social relationships that does not decline in aging. It is important to note here that spared ToM could be due either to fluid declines being compensated for by improved crystallized intelligence, or to a true lack of decline in a specialized ToM module. Initial evidence favored the general hypothesis that ToM is unimpaired with age, but in recent years the preponderance of data has edged toward the alternative that there are specific measurable deficits in ToM with increasing age. This review will first describe the early developmental trajectories of aspects of social cognition such as theory of mind and moral judgments. In doing so, the gradual development of ToM will be revealed, whereby more complex aspects of ToM emerge only once simpler aspects are mastered. Any differences in ToM due to age can thus be interpreted in light of how those specific aspects of ToM map onto the typical developmental trajectory. I will then discuss behavioral evidence concerning social cognition in typical aging, and finally turn to recent neuroimaging results that provide complementary evidence on the effects of normal aging on social cognition.

2. Development of social cognition

2.1. Theory of mind

ToM is variously referred to as mental state understanding, social understanding, or mentalizing. It is present in typically developing children by approximately age five [7], may be present in adult chimpanzees [8], and is developmentally delayed in individuals with autism spectrum disorders [9]. The typical developmental course of ToM abilities proceeds along roughly the following 'stages'. Children initially develop shared attention mechanisms that allow them to direct others' attention by pointing around 12 months of age [10]. Children then begin to understand pretense and mental states such as desires around age two [11,12]. Understanding that our beliefs may differ from those of other people appears to be at ceiling by roughly age five [7,13], and comprises the cognitive skill that underlies successful performance on the false belief task [7,14].

The false belief task tests what is known as "first order" ToM, as it requires the ability to represent the mental state of a single third party and contrast it with our own. During the course of the task, participants learn that an actor (Sally) has placed a marble in a basket. Sally leaves the room, and Anne then enters and moves the marble from the basket to a box. Participants are then asked where Sally will look for the marble when she returns. To answer correctly, children must understand that others have beliefs that are (a) different from their own, and (b) different from the veridical state of the world. Once children understand that Sally will look where she has left the marble, and not where the child knows it to be, further development of social reasoning abilities concerning more complex situations can occur. These situations may require perceivers to represent the mental states of multiple agents: For example, "I know that John thinks that Jenny likes ice cream" is a statement that requires second order ToM, as it necessitates representing two agents' mental states. This form of ToM develops roughly between the ages of five and seven [15].

2.2. Moral judgments

While general ToM is necessary for basic social interactions, exercising ToM to make moral judgments is both more complex and has greater consequences for social interactions. There is much work suggesting that being able to judge someone's culpability for a criminal act requires a clear understanding of that person's intention when committing the act [16] and that basic ToM tasks and moral judgments activate very similar neural networks [17]. The developmental trajectory of moral judgments bears out this general idea. Whereas first order mental state understanding is adult-like by ages four or five, typical children at this age are likely to assign more moral weight to outcomes versus intentions when evaluating actions [18]. In so doing, they reveal hidden immaturities in understanding others' intentions. For instance, four-year-old children will judge a person who helpfully attempts to direct a lost traveler to his destination but accidentally misdirects him as more naughty than a person who attempts to misdirect a lost traveler but does not succeed in their mischief [19]. These findings indicate that younger children cannot, in the service of moral judgments, successfully use the mental state information they are known to be able to represent. Using belief information to exculpate people for accidental harms increases in typical children from ages 5 to 11 [20]. Other sophisticated moral judgments (e.g., judgments about actions that knowingly or unknowingly interfere with someone else's plans) also show developmental change through late childhood [21]. It is tempting to suggest that moral judgments may be predicated on the effective functioning of the cognitive processes responsible for ToM, and recent work in autism bears this assumption out [22,23]. Adults with autism spectrum disorders (ASD) who 'passed' the false belief task nevertheless gave moral judgments that focused on outcomes rather than intentions as do younger children [22]. Similarly, patients with damage to the ventromedial prefrontal cortex deliver moral judgments that are more utilitarian (i.e., focus on the action's outcome, [24]), and do not punish individuals who attempt to harm but fail to do so (e.g., attempted murder, [25]). In summary, ToM and moral judgment emerge in a well-delineated developmental trajectory, are ordered in terms of their complexity (moral judgments being predicated on intact ToM), and may be impaired by neurological disorders or insults.

3. ToM in later life and its relation to general cognitive ability

The preceding section suggested a clear developmental path for ToM and more complex ToM-based abilities like moral judgments. Thus, one might expect that any declines in ToM due to age might first be observed in more complex tasks (e.g., second order ToM), and ultimately in more basic tasks (e.g., first order ToM). Because the literature and stimuli used to test ToM in aging are varied, this section begins with a brief historical summary of early findings in the field—which hinted that older adults were unimpaired at ToM. The story has become more complex since, and so the ensuing sections are organized by the kind of task used to assay ToM. The resulting data can be broadly summarized as indicating that ToM is impaired in normal aging, when measured using visual tasks is mostly independent from general cognition, but is at least partially dependent on changes in other cognitive abilities (such as executive functioning) when researchers use verbal story tasks. Further, social-cognitive difficulties due to age have been most consistently observed in more complex (moral judgments, second order) ToM tasks than in simpler (first order) ToM tasks, as predicted by the developmental trajectory just outlined.

3.1. Initial investigation of ToM in aging

An initial wave of studies indicated that older adults tend to do quite well at tasks tapping ToM. Investigation in this domain began with work by Happé et al. in 1998 [26]. In that study, older (*M* age = 73 years) and younger (*M* age = 21) participants read stories taken from the "Strange Stories" battery [27] that were originally designed to investigate enduring ToM deficits in participants with ASD who had succeeded at other first order ToM tasks (such as false belief). Accordingly, these stories contained everyday situations in which people say things that are not intended literally. To understand the speakers' intention participants must represent the speaker's mental state and may not simply use cognitive shortcuts gained from a general understanding of language. Happé and colleagues found that older participants performed significantly better than younger participants at this set of stories, but the two groups were equal on the control (non-ToM) stories. The evidence seemed clear; advancing age was associated with improved ToM abilities on a task testing mental state understanding. These findings suggested that social cognition is a domain in which experience counts. Perhaps developing strong cognitive schemata about the way people do and ought to act over a lifetime provides one with a perspective unequaled by quicker yet less experienced younger adults. Further evidence suggesting that ToM is not impaired in aging came from an older control group in a study investigating the effects of Parkinson's disease on ToM [28]. The authors found equal performance for healthy older (*M* age = 72) and younger participants on several different ToM paradigms, which measured ToM via cartoons [29], and first and second order false belief stories. However, the small sample sizes (9 younger, 8 older participants) preclude drawing strong conclusions from these findings. MacPherson et al. [6] also found that older adults (*M* age = 70) were unimpaired on a ToM task (detecting faux pas; similar to Happé's Strange Stories). Keightley et al. [30] also demonstrated no exclusive impairments for older (*M* age = 72) adults on two different ToM tasks that used stories [31] and cartoons [32] as stimuli. Instead, older participants were impaired at both mental state and control (non-ToM) stories and cartoons relative to younger participants. Zaitchik et al. [33,34] demonstrated ceiling performance levels in a first-order false belief task (presented in cartoon form and narrated by the experimenter) for both healthy older adults (*M* age = 88) and those with Alzheimer's disease. Pezzuti et al. [35] had older participants tell stories about cartoons that implied either mental, behavioral (non-mental), or physical explanations for the actions in the story. Although they did not include a younger control group, they did find that older adults with mild cognitive impairment (as assessed by the Mini-Mental State Examination [36]) provided descriptions of the stories that contained fewer cause-and-effect descriptors but not fewer mental state descriptors, suggesting impairments in general but not social cognition. Later investigations have however tended not to uphold the early conclusion that older adults are not specifically impaired at ToM.

Investigations seeking to replicate and extend Happé et al.'s findings discovered several confounding variables that mitigate the conclusions drawn from the initial studies. In their seminal first study on ToM, Happé and colleagues did not control for differences in general cognitive abilities such as crystallized and fluid intelligence and working memory. In a study building on Happé's findings [37], three groups (young *M* age = 19, young–old *M* age = 67, and old–old *M* age = 81 years) were compared on ToM stories in conditions that varied in the requirement to remember key information from the stories. Both groups of older participants performed worse under a memory load, while the young–old (but not old–old) participants saw their performance ameliorated when the memory load was removed, suggesting a direct effect for working memory in ToM performance. The authors [37] also performed a second experiment closely replicating Happé et al.'s method. Older adults were impaired relative to younger adults on the Strange Stories battery. In both experiments, measured age group differences in crystallized and fluid intelligence and executive functioning did not account for age differences in ToM task performance. Conversely, Sullivan and Ruffman [38] found that age differences between older (*M* age = 73) and younger participants on the Strange Stories task were mitigated by declines in fluid intelligence.

Ligneau-Hervé and Mullet [39] had participants determine whether another person would adopt a medication when given information about that person's preferences (e.g., someone who prefers fewer side effects versus cheaper medication costs). Older adults (*M* age = 81) used information about the person's relative importance of different aspects of the drug less than younger participants in predicting whether the person would adopt the drug, suggesting impairments in perspective taking ability. Other measures of cognitive ability (fluid and crystallized intelligence and executive functioning) were not employed in this study, so it is unclear whether deficits arising in perspective taking were in fact predicated on deficits in other cognitive abilities.

Thus, the early evidence, at least for verbal tasks investigating ToM, was quite mixed. In some investigations, older and younger adults performed equally on verbal ToM tasks, whereas in others older adults were specifically impaired. However, these impairments appear to be at least partially dependent on group differences in crystallized and fluid intelligence.

Later investigations have used many different kinds of ToM tasks in aiming to clarify whether older adults are impaired at understanding others' mental states. Each of these paradigmatic approaches is now discussed in turn in an attempt to organize the literature.

3.2. *ToM in aging measured in multiple ways*

Since ToM is dependent upon on the functioning of multiple basic cognitive processes (e.g., shared attention [40], understanding emotions [41]), accordingly tasks that emphasize different aspects of ToM might prove fruitful in understanding the nature of age-related changes in ToM. This section reviews data from studies investigating mental state decoding from (1) pictures of the eyes, (2) from video stimuli, and then (3) first, and (4) second order ToM. The evidence suggests that older adults are impaired at ToM tasks using visual (eyes and video) stimuli and that these impairments are, more or less, independent from general cognitive deficits. Tasks using more traditional story stimuli, whether tapping first or second order ToM reveal deficits due to age that are likely to be partially or fully dependent on general abilities such as working memory, processing speed, and executive function.

3.2.1. *Decoding mental states from eye information alone*

The "reading the mind in the eyes" task (RME) [42,43] requires participants to decode mental states from photographs displaying only the eye area of the face. On each trial, participants select from one of four options (e.g., "annoyed", "hostile", "horrified", "preoccupied"). Although the task was originally designed to test for ToM deficits in autism, it has since been used by several different groups to investigate the status of ToM in older adults—with the major advantage of mitigating verbal processing requirements. Results from a series of studies using this task indicate that older adults are indeed impaired at decoding mental states from eye information alone and that these impairments are likely independent from declines in general cognition.

In the first investigation of this kind, older adults (*M* age = 69) performed worse on the RME task, and their performance remained significantly different from younger participants when years of education and fluid and crystallized intelligence were included in the analysis [44]. Pardini and Michelli [45] extended these findings to show that impairments on the RME task are evident in both late middle-aged (55–65 years) and elderly (70–75 years) participants relative to young and early middle-aged (45–55 years) participants, although they did not control for differences in intelligence. Bailey and Henry [46] found RME impairments in older adults that were partially mediated by their scores on the Hayling test of controlled inhibition—a test of executive functioning. Bailey et al. [47] found that older adults (*M* age = 70) reported lower levels of cognitive empathy as measured by the Empathy Quotient [48], and performed worse than younger adults on the RME test. Further, reduced cognitive empathy was associated with reduced social engagement in the older participants, as measured by the prosocial subscale of the social functioning scale [49]. The authors argued that older adults' worse performance on the RME may be due to their reduced ability to decode negative emotions (cf. [50]), and report a trend suggesting that older adults' performance was indeed differentially impaired for negative RME items (e.g., "horrified") versus positive RME items (e.g., "interested"). Slessor et al. [51] also had older participants complete the RME and found that they were impaired relative to younger participants, but that this impairment was also evident in the control condition (judging age and gender from the eyes). The authors suggest that the ToM impairments observed could be due to general impairments in social understanding with advancing age. Duval et al. [52] had older participants (*M* age = 70) perform two versions of the RME task, one requiring the decoding of basic emotions, and the other the standard RME task requiring the decoding of complex mental states which is thought to rely more heavily on ToM. They found that older adults were impaired at the ToM version of the task (complex mental states), but not at decoding basic emotions, and that the effect of age on RME task performance was not mediated by processing speed, executive function, or episodic memory differences.

Two studies found evidence for spared performance on the RME task. Forming part of a large battery of ToM tests, older adults (*M* age = 74) answered a reduced set of questions from the RME task (24 versus 36 pictures) and performed as well as younger adults [53]. In a neuroimaging investigation also using a set of 24 RME pictures, older adults (*M* age = 65) were unimpaired relative to younger adults at the RME task [54], although both groups' performance was near to ceiling, unlike in some other investigations (e.g., [46,47]). The lack of difference observed in these two investigations (and not in the others covered here) could have been due to the restricted set of questions (and hence restricted range of scores) observed.

The results from studies using the RME task in aging suggest that this ability is impaired, is more often than not independent from general cognitive declines in fluid or crystallized intelligence or executive functioning, and may be predicated on more fundamental biases in emotion recognition that reduce older adults' ability in identifying negative emotions.

3.2.2. *Decoding mental states from video stimuli*

Using videos as stimuli allows perceivers to use many more cues to infer intentions than just presenting the eyes alone. Thus, one might imagine that decoding mental states from video stimuli might be less complex (and thus easier for older adults) than decoding mental states from impoverished static stimuli. Several aging investigations using video stimuli suggest however, that older adults are significantly impaired at decoding mental state information from videos.

Sullivan and Ruffman [38] had older (*M* age = 73) and younger participants watch silent, brief video clips of actors and decode their mental states. The authors included this task in their study to specifically mitigate working memory demands, similar to previous efforts [37]. Since the task itself more closely resembled real-life interactions and did not confound verbal and working memory abilities with ToM abilities it is arguably a more 'pure' test of ToM. Older participants performed significantly worse than younger participants. Here, as in [37], older participants' worse performance was not accounted for by measured differences in either crystallized or fluid intelligence. Slessor et al. [51] noted that a major problem in interpreting the literature summarized to this point concerns the relatively small number of participants and test items used. Null effects observed in those investigations could simply be a function of low experimental power. In their investigation, a larger sample of older participants (N = 40, M age = 67) completed the videos task from [38], and again were found to be impaired relative to younger adults. However, impairments were also observed in control (non-ToM videos). Again, group differences in crystallized intelligence did not account for differences in ToM performance. In a further replication of this task [55], older adults were impaired at decoding complex mental states from videos, even when they were matched with younger adults on crystallized intelligence. The evidence from this videos task [38] thus argues that the ToM abilities it measures decline in aging, and are independent of at least crystallized intelligence skills.

Bailey and Henry [46] found that older adults (M age = 72) were impaired at a video false belief task that required participants to inhibit their own perspective, but not at a false belief task that did not require inhibition, thus investigating the influence of executive functioning directly. Importantly, older adults' impairments in the high-inhibition false belief videos were mediated by their scores on a general measure of inhibition (the Stroop [56] task), but not by scores on other measures of cognitive functioning such as short-term memory span and Raven's progressive matrices (fluid intelligence).

Conversely, older adults were tested on a series of cartoon videos designed to test ability to decode true and false beliefs [57]. Older adults (M age = 74) were significantly impaired at understanding false, but not true belief videos relative to both younger and middle-aged control participants. This effect was partially mediated by differences in working memory ability, but this time not by differences in Stroop performance. One possible reason for the discrepancy in the role of inhibition across the two papers is that Bailey and Henry's [46] study directly compared high versus low inhibition videos whereas Phillips et al.'s study did not [57]. Therefore, measured differences between older and younger participants on inhibition might have been more related to the ToM task used in the former study.

Moran et al. [17] used stimuli similar to those introduced by Heider and Simmel [58], which were brief, silent video clips of animated geometric shapes acting in ways that either implied intentions (social condition, e.g., friends sharing ice cream) or implied non-mental, mechanical actions (control condition, e.g., a cannon firing). In contrast to the previous videos studies just described, participants were not required to make a response; instead, neuroimaging measures across multiple ToM paradigms were used to infer participant's engagement of ToM processing. In neuroimaging investigations in younger adults, the social condition activates regions of the brain involved in mental state understanding, such as the temporoparietal junction (TPJ) and medial prefrontal cortex (mPFC) [59]. In [17] there was greater activation in mPFC in younger versus older (M age = 72) participants when viewing social stimuli, suggesting greater mentalizing about those stimuli in the younger participants. The authors however did not covary other cognitive measures.

In an attempt to use much richer video stimuli to investigate ToM ability, Halberstadt et al. [60] used videos taken from the television series "The Office" to determine the effects of age on detecting faux pas from scenarios which included verbal interactions with multiple social partners. They found that older adults (M age = 70) rated faux pas as more socially appropriate than did younger adults, but that these effects were fully mediated by performance on other measures of emotion recognition ability. That is, older adults who were less adept at recognizing basic emotions in an emotion recognition battery were those participants who rated faux pas as more socially appropriate.

In summary, results from tests designed to investigate whether older adults can detect complex mental states from video clips suggest that this ability is impaired in aging and is independent from general cognitive declines in fluid or crystallized intelligence. However, when videos require inhibition directly, executive functioning deficits do predict older adults' performance. Similarly, detecting faux pas from videos—a process downstream from emotion recognition—requires emotion recognition abilities known to be impaired in aging [50]. Evidence from both static and dynamic visual ToM paradigms presented so far thus argues that ToM when measured visually might be predicated on emotion recognition ability more so than general cognitive skills.

3.2.3. First-order mental state understanding: false belief and others

In Section 3.1, I discussed a series of studies that used the Strange Stories battery [27] as stimuli. These stories are examples of first order ToM tasks, as they require participants to understand the mental state of a single third party for successful resolution. In this section, I consider the ensuing literature that used either the Strange Stories set or other first order ToM tasks to assess ToM in typical aging. These tasks most often use verbal stimuli, sometimes in conjunction with cartoon stimuli that provide a visual description of the verbal information being relayed. I will note where each kind of stimulus is used—again in an attempt to clarify exactly which kinds of stimuli are associated with any observed deficits in ToM in aging. Much of the story regarding these deficits is qualified by age-related changes in other cognitive measures, so I will note the effects of mediators where appropriate.

German and Hehman [61] investigated the effects of executive functioning declines on mental state decoding, employing two tasks that (i) varied whether participants had to reason about a mental or physical state, and (ii) varied whether participants had to answer mental state questions based on an actor's true or false belief. In both tasks, older adults (M age = 78) were significantly impaired relative to younger adults. That is, older participants were impaired at all tasks that required reasoning about mental (and physical) states, a finding that the authors interpreted to imply a general impairment in executive selection processes. Accordingly, older adults' difficulties across reasoning tasks were mediated by group differences in processing speed. Phillips et al. [57] replicated this second task [61] and found, in contrast, that older adults were impaired at false but not true belief reasoning. Interestingly, older adults in Phillips et al.'s investigation had improved vocabulary relative to younger adults in contrast to equal between group vocabulary in German and Hehman's dataset, suggesting that improved vocabulary may have helped spare their performance in the true belief condition. In [57], the effects of age on false belief performance were partially mediated by working memory, but not by executive function differences. This suggests that working memory may play a more direct role in ToM, whereas processing speed affects executive selection tasks more generally.

Rakoczy et al. [55] demonstrated age-related differences in ToM performance on the Strange Stories set when older and younger adults were matched on crystallized intelligence. Once again, these differences were partially erased when controlling for age-related differences in speed of processing and executive functioning. Charlton et al. [62] conducted a relatively large-scale investigation into ToM and aging (N = 106) using the Strange Stories battery. Regression analysis revealed significant negative association between age and ToM stories (but not control stories) across a large age range

(50–90, *M* age = 69), which was partially mediated by verbal ability and fully mediated by executive function, processing speed, and performance intelligence. Li et al. [53] found that older adults with fewer years of education (a proxy for crystallized intelligence) performed worse on false belief story and faux pas ToM tests than both age-matched older and younger adults who had more years of education (who did not differ from one another). Again, this difference in ToM task performance was mediated by measures of fluid intelligence and executive functioning, such as inhibition, memory span, and processing speed. Here, it appears that strong crystallized intelligence skills may protect against ToM declines. Duval et al. [52] found that older adults (*M* age = 70) were impaired at three different sets of first order ToM tasks (first order false belief cartoons with verbal descriptions, cartoons where participants had to guess an actor's intentions, and determining a character's preferences), but that these deficits were mostly mediated by executive functioning differences. In concert, these investigations point to the conclusion that in aging, declines in fluid and executive abilities appear to underlie deficits in first order mental state understanding, whereas those older adults with improved crystallized ability show relative sparing of ToM ability.

Supporting these conclusions, Slessor et al. [51] found that older adults were unimpaired at stories taken from Happé's Strange Stories battery, amongst others. However, when controlling for vocabulary (older adults had superior vocabulary), older adults' false belief stories performance was indeed worse than that of younger adults. Importantly, controlling for vocabulary ability did not reveal latent differences on the control (non-ToM) stories. Slessor et al. [51] argued that improved vocabulary skills may have allowed older adults to compensate for general declines in task performance, and noted that earlier investigations that found ToM differences included older adults who were matched on vocabulary scores with younger adults [30,61]. Indeed, later investigations summarized here (e.g., [55]) also reveal ToM deficits in older adults when they are matched with younger adults on crystallized intelligence. Similarly, when older and younger adults were matched on both fluid and crystallized intelligence older adults performed significantly worse on understanding faux pas, but as well as younger adults on the Strange Stories [63]. Since they had neither the benefit of improved vocabulary nor the deficit of impaired fluid intelligence, this pattern of results seems reasonable in the preceding context.

Castelli et al. [54] included two first order false belief tasks. The first, a Deceptive Box Task [64] required participants to encode the contents of a box, and then experience a switch in the contents without their knowledge. Participants had to explain their own false belief about what was in the box, and then answer from the perspective of a hypothetical other that had also not witnessed the box's contents being switched. Older adults were unimpaired at this task, but were impaired on the Strange Stories task. However, the older participants had significantly fewer years of education, which may have contributed to their impairments in the Strange Stories.

The effects of mentalizing on humor comprehension in aging were investigated in an interesting task with a slightly different focus [65]. The authors found that decreases in mental state understanding predicted older adults' (*M* age = 67) inability to understand written jokes relative to younger and middle-aged participants. Differences in working memory also predicted humor comprehension, but did not predict mentalizing scores. While this study did not employ a formal or more widely-used test of ToM, the results nevertheless reveal some downstream consequences of impairments in mental state understanding as we age.

Finally, Bernstein et al. [66] had older (*M* age = 68), middle-aged (*M* age = 56), and younger participants (*M* age = 19) perform a 'continuous false belief' task. The impetus for using this task is that it allows quantification of performance rather than qualification; since preschoolers are at ceiling on the classic (Sally–Anne) false belief test, there is a restricted range in the scores available. Older adults might simply pass or fail at the test. With the continuous false belief task, it is possible to determine the *degree* of difficulty in inhibiting one's own perspective that older individuals might display. In the task, participants watch a protagonist hide a toy inside a rectangular sandbox. The protagonist leaves, and then another actor comes in and moves the toy to a new location. Participants are asked (after a distractor task) to point to a location in the sandbox where the protagonist will dig for the object upon her return. The experimenter can then determine the distance between the object's original location (i.e., the actor's false belief), and where the participant saw the object moved to (i.e., the participant's own true belief) to get a measure of the participant's bias toward his or her own belief. Results revealed that middle-aged and older adults showed larger degrees of false belief bias than did younger participants. On a memory control condition, that did not require representation of another's mental state, only the older participants were impaired. Importantly, a multiple regression analysis revealed that middle-aged and older adults' impairments were predicted only by their age, and not by a series of general cognitive scores, including verbal memory, working memory, executive functioning, and processing speed. It is intriguing that this study appears different to the others summarized in this section such that it did not find any evidence for the influence of fluid or executive abilities on ToM performance. Since the main difference between this task and more traditional false belief tasks is the ability to obtain continuous rather than categorical data, it is possible that more subtle ToM deficits are indeed independent from more general declines in cognitive ability, although this possibility awaits further investigation.

Across this relatively large set of studies, these results converge quite well on the ideas that improved vocabulary may inoculate older adults against declines in ToM, whereas age-related decreases in processing speed and executive functions may precipitate those declines. As such, heterogeneous participant populations that display differing patterns of sparing and deficits in these general cognitive domains may explain the complexity in results observed in first order ToM investigations thus far. An important caveat to the general conclusion just drawn is that continuous rather than discrete measurements of ToM may yet reveal that ToM ability is indeed more independent from general cognition than it at first appeared.

3.2.4. Second order mental state understanding

To recap, second order mental state understanding is the ability to represent the beliefs of multiple others simultaneously, e.g., "I know that John thinks that Jenny likes ice cream". Children develop the ability to understand second order mental states after successful development of first order abilities, between ages five and seven. These skills then are likely to require more executive and fluid intelligence abilities than are first order skills. By that logic, one would expect older adults to show greater impairment at second order ToM tasks, and the literature by and large bears this assumption out.

In several investigations, older adults were impaired on false belief tasks that required second order ToM [52,54,67]. In the two earliest of these experiments [54,67], the authors showed that older adults were unimpaired on first order ToM tasks, but did not determine whether other cognitive abilities mediated their second order ToM deficits. Duval et al. [52], however, showed that older adults were impaired at first order ToM tasks, which *were* mediated by differences in other cognitive abilities (executive functioning), but that the deficits in second order ToM *were not* mediated by any other cognitive measures. They posit, somewhat counter-intuitively, that second order ToM abilities may reflect the use of a specialized ToM module which may be impaired due to aging [68] independent from fluid declines.

While second order ToM abilities in aging appear to be compromised in the brief literature that has investigated them, not enough is yet known about whether these deficits are mediated by other cognitive functions. Duval et al.'s intriguing suggestion that a specific ToM module is both responsible for second order ToM abilities (reasoning about the relations amongst multiple people's mental states) and is specifically affected by aging is an interesting one that awaits further theoretical and empirical development.

3.3. Moral reasoning and moral judgments

There are few investigations to date that have investigated the development of moral reasoning in later life. Moral reasoning is an important topic made distinct from basic ToM by the fact that it requires the use of ToM to make a judgment about someone's behavior. If older individuals are specifically impaired at using intentions in the service of moral judgments, then this may have important ramifications for real-world topics such as jury selection, for example.

Pratt et al. [69], in a four-year longitudinal investigation demonstrated that older adults (*M* age = 69 at time 1) declined in moral perspective taking from time 1 to time 2. This effect was still significant in a hierarchical regression model when participant health and years of education were entered into the model (both of which had a significant positive relationship which moral perspective taking).

Moran et al. [17] included a moral judgment task that requires intact ToM [16,22]. In this task, participants read moral vignettes in which actors either have a negative or neutral intention (i.e., to cause harm or not), and ultimately cause outcomes that are negative or not. Participants then rate how morally permissible the person's actions were. Crucially, when intentions and outcomes do not match (in cases of accidental harms (neutral intention but negative outcome), or attempted (but failed) harms (negative intention but neutral outcome), participants must use intention information either to exonerate (accidental harm) or punish (attempted but failed harm) the actor. These conditions in particular tax ToM ability, and participants with ASDs tend to rely more on outcome information when making their judgments in these conditions (i.e., rating accidental harms as less permissible than controls, and rating attempted harms as more permissible than controls) [22]. In our work on aging [17], we showed a similar pattern of results; older participants tended to rely more on outcome information when judging these crucial ToM conditions than did younger control participants. Again—we did not take measures of fluid or executive abilities, so it is unclear whether these effects might be predicated on impairments in other cognitive abilities.

To summarize, moral judgments appear to be impaired in older adults in much the same way that other ToM tasks are impaired. To the degree that moral judgments require other aspects of ToM which decline in aging, we might expect that future research would demonstrate that moral judgment declines are at least partially mediated by differences in other measures such as inhibition and processing speed.

4. Neuroimaging investigations of ToM in aging

Thus far, the application of neuroimaging to understanding the mechanisms of ToM in aging has been spare. This is unfortunate, as given such conflict in findings in the behavioral literature, neuroimaging may be a particularly useful tool for understanding how, if at all, aging affects ToM processes. Early work focused on gross measures of anatomy, including whole brain volume and white matter integrity. Investigations using functional imaging to this date suggest a pattern of compensatory activations to aid with ToM task performance on the one hand, along with decreases in activations associated with impairments in ToM task performance on the other hand.

4.1. Anatomical imaging

In a pioneering investigation, MRI and Diffusion Tensor Imaging measures were used to correlate participants' ToM abilities with measures of whole brain volume and white matter integrity [62]. White matter integrity is indexed by fractional anisotropy, a metric that is decreased when damage to white matter pathways occurs (and thus decreases in anatomical connectivity). The authors found that ToM ability was correlated significantly with fractional anisotropy, suggesting that older adults with sparing of white matter pathways showed sparing of ToM ability. However, crystallized and fluid intelligence, processing speed, and executive function measures all separately and fully mediated the relationship between white matter integrity and ToM scores, suggesting that the older adults also showed differing rates of decline in abilities such as working memory. Thus, this result argues that changes in anatomical connectivity due to advancing age are associated with changes in general cognition that are themselves associated with decreases in ToM ability.

4.2. Functional Imaging

Castelli et al. [54] imaged older and younger participants while they performed the RME task. They found in the context of matched RME performance that the right inferior frontal gyrus (IFG) was activated by both participant groups. This region has been associated repeatedly with visual memory encoding of faces (e.g., [70]), and thus shows that older adults produced activations in areas expected for this task. However, they also found that older adults activated regions of the left inferior frontal gyrus (lIFG) more than did younger adults. This is interesting as the lIFG is not typically associated with mentalizing tasks [31,71,72]. Instead, it has more typically been associated with verbal memory [70] and selection amongst alternative answers [73]. In this paradigm, older adults activated regions of lIFG presumably to compensate for any difficulties they may have in mentalizing ability, and indeed this interpretation fits well with the preceding behavioral literature on ToM which has shown that improved verbal ability (in those that have it) protects older adults from ToM deficits. Further, younger adults activated the anterior cingulate cortex, a region heavily associated with ToM task performance [74], more than did older adults. Thus, older adults appeared to compensate for impairments in domain-specific ToM performance by using domain general processing skills.

A further investigation of ToM in healthy older adults showed a different pattern of results. Moran et al. [17] scanned older adults while they performed three different ToM paradigms: false belief stories [14,72], moral judgments [16], and animate movement [59]. Prior research has shown the TPJ and mPFC to be critically associated with all three of the mental state conditions of these paradigms in healthy younger controls [16,59,72]. During both false belief and moral judgment tasks, participants read stories and answered questions about those stories via button presses. In the animate movement 'task', participants passively viewed movies of animated shapes with no actual task demands. This highlights one of the benefits of neuroimaging to investigate the topic of ToM in aging. Since we did not require a response, we did not encourage our participants to focus on the mental state information being presented, and hence were able to obtain a more spontaneous measure of their mentalizing ability/tendency. Because we were able to compare activations from the two task-based paradigms to the animate movement paradigm, we were able to infer whether older participants engaged in mentalizing as much as younger participants when viewing the animated shapes. In our work, older adults showed reduced activation of the dorsal mPFC in each of the three paradigms in turn. The anatomical specificity was such that a conjunction analysis (overlaying all activation younger > older maps on top of one another) revealed that a specific region of dorsal mPFC was more active for younger versus older adults across all three tasks together. Interestingly, older adults performed worse at the false belief stories and used mental state information less than younger adults when making moral judgments. Since the area of reduced activation was the same when they viewed animations that implied intentions, we can infer that they were also impaired at extracting intention information from moving shapes as well. This is important as this test of ToM controls directly for the use of verbal materials, working memory demands, and the executive selection demands that are inherent in all false belief, perspective-taking, and moral judgment tasks in which participants read stories, assume the protagonist's perspective, and inhibit their own. Again, an important caveat is that these behavioral and activation differences were not covaried with measures of general cognitive functioning, and so the independence of ToM and general abilities is indeterminate in this dataset.

Neuroimaging work in ToM in aging is in its infancy, but provides promise in interpreting the complex set of findings thus far produced in the field. As fMRI matures, its application to ToM in aging is sure to shed greater light on this curious ability than can behavioral methods alone.

5. Conclusion

Much of the early work in social understanding in aging highlighted the need to obtain multiple measures of cognitive functioning such that we might understand better how ToM relates to general cognitive abilities. This is an important question for aging, as if ToM declines independently from other abilities, it becomes critical to find ways to stem this decline; older adults may need help in relearning the subtleties of social communication, especially with strangers whose intentions are not always obvious. If ToM declines with other abilities, then greater emphasis on preserving those abilities should have payoffs in preserving older adults' social abilities. Beyond the domain of aging, results from this area can have important things to say about the general nature of ToM. Is ToM a specialized module for understanding other people that has spurred the evolution of our species [3], or is it a combination of other cognitive skills that happen to give rise to the emergent property of understanding other minds [4]? Patterns of dependent or independent deficits in ASD, lesion work, and in aging can give us valuable clues. Thus far, the evidence from aging is that traditional ToM tasks that use stories as stimuli are at least partially predicated on our abilities in working memory, executive functioning (mainly inhibition), and processing speed. ToM tasks that use visual stimuli, hence controlling for some of the fluid abilities that are required for interpreting stories, show in aging greater independence of ToM and general cognitive ability. Interestingly, second order ToM task performance might be independent from other cognitive skills, and might reflect an underlying qualitative difference in the kind of ToM ability required to solve second order tasks. New practical developments (e.g., the continuous false belief task) provide a wrinkle to this overall story, and may yet reveal that subtle differences in ToM ability are indeed fully independent of general cognitive skills—a conclusion that would weigh strongly in favor of the idea that there is indeed a Theory of Mind Module [3].

Neuroimaging methods may have much to offer the study of ToM in aging. Now that fMRI research has reached a certain level of maturity and discovered well-specified, well-replicated neural correlates of the different kinds of tasks used to assay ToM, we can be relatively confident about what activation differences (and similarities) between older and younger adults imply. We can further use this information to make more direct inferences about the nature of mechanistic dysfunctions in ToM as we age—evidence for each of the two possibilities discussed has been garnered from theoretical, neuroimaging, lesion, and behavioral work thus far. Neuroimaging work in aging and social cognition, as design, analysis, synthesis, and meta-analysis become ever more sophisticated, may yet provide us with answers that rule definitively on whether the special process of being able to think about what others think about is indeed special in the cognitive-architectural sense.

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