THE RELATIONSHIP BETWEEN MEMORY AWARENESS AND THEORY OF MIND IN INDIVIDUALS WITH AUTISM

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Autism is a developmental disorder characterized by behavioral, communicative and social impairments. With regard to social deficits, research burgeoned when children with autism were found to have impaired theory of mind (ToM) abilities and difficulty attributing mental states to others. Although ToM has been extensively studied in individuals with autism, little is known regarding this population's understanding of their own mental processes. While researchers have argued that metacognition and ToM are related, few empirical studies have examined these two constructs together. The current study examined memory awareness, a component of metacognition, and its relationship to ToM in individuals with autism. Furthermore, memory awareness was examined within the context of both incidental and explicit facial recognition tasks. Participants consisted of high-functioning children and adults with autism and control children and adults, matched on age, FSIQ, VIQ & PIQ. Memory awareness accuracy was assessed based on the accuracy of certainty judgments for each recognition trial. Overall, individuals with autism had less accurate memory awareness compared to controls. In particular, children with autism appear to have a less accurate understanding of their memory awareness. Furthermore, overall memory awareness was associated with measures of ToM. These results indicate that deficits in memory awareness for faces may contribute to more general social deficits and suggest that further research is needed to better understand metacognitive processes in individuals with autism.

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1.0 INTRODUCTION

Autism, a developmental disorder characterized by behavioral, communicative and social impairments, has gained much attention over the past years as a result of increasing incidence rates and increasing public concern (American Psychiatric Association, 2000). The majority of research on autism has focused on deficits within the social domain, including those relating to nonverbal behaviors (e.g., eye-to-eye gaze, facial expression and body posture), the quality and quantity of social relationships, interpersonal sharing, and social or emotional reciprocity. Research on social deficits in individuals with autism burgeoned when children with autism were found to have impaired theory of mind, or an impaired ability to attribute mental states to others (Baron-Cohen, Leslie, & Frith; 1985). Consequently, theory of mind tasks have become the predominant measure used to assess deficits in social cognition among individuals with autism.

While deficits in theory of mind (ToM) are thought to explain much of the behavioral, communicative and social impairments observed in individuals with autism, deficits in theory of mind are now included more broadly in Baron Cohen's empathizing and systematizing theory of autism (Baron-Cohen, Wheelwright, Lawson & Griffin, Hill; 2002). Although the suggested importance of theory of mind has been reduced, impaired theory of mind remains a common characteristic of individuals who have autism. Moreover, subsequent research has shown that performance on theory of mind tests is associated with measures of social functioning in individuals with autism, suggesting that theory of mind deficits are meaningful for social interactions (Frith, 1994). Thus, competing theories, including the executive function and the weak central coherence accounts of autism, have been modified to explain the observed deficits in theory of mind (Ozonoff, South & Provencal, 2005; Happé, 2005).

While theory of mind continues to be the focus of much research on autism, little research has examined the broader implications of this deficit. In particular, researchers have not explored how deficits in theory of mind are related more generally to cognition. In the early literature on autism, Leslie (1987) proposed that a cognitive deficit, the ability for metarepresentation, could explain the observed social, communication, and imagination impairments. He suggested that while children with autism's ability to create primary representations were intact (e.g., concept development), there was a specific deficit in metarepresentation. Consistent with this, several researchers have argued that metacognition and theory of mind are related and therefore should be studied together, both within typically developing children and within children with autism (Bartsch & Estes, 1996; Flavell, 2000; Kuhn, 1999, 2000; Happé , 2003; Frith & Happé , 1999; Frith, 1989; Farrant, Blades & Boucher, 2004; Farrant, Boucher & Blades, 1999). Nevertheless, the majority of research on metarepresentation in individuals with autism has been limited to studies of theory of mind development, and few studies have examined the relationship between theory of mind and other metacognitive processes.

1.1 DEVELOPMENT OF THEORY OF MIND IN TYPICALLY DEVELOPING CHILDREN

Within typically developing children, false-belief tasks are the primary measure used to assess theory of mind. Although there is some variability depending on the false-belief task used, children around the age of 4 are able to pass these tests of theory of mind (Wimmer & Perner, 1983). Thus, between the ages 3 and 5, typically developing children's performance on theory of mind, false-belief tasks dramatically increases. In a meta-analysis of 178 studies looking at theory of mind, Wellman, Cross and Watson (2001) found a significant developmental trend, with a 2.94 increase in the odds-ratio of a child passing a false-belief task for every 12 months of age. Thus, at 32 months of age, typically developing children were performing below chance (33.6%), and by 68 months of age, children were performing at ceiling. Furthermore, this developmental trend did not differ based on the type of false-belief task used (e.g., change-of-location tasks, unexpected-contents tasks, and unexpected-identity tasks), the type of protagonist (e.g., real person, puppet, doll, pictured character, or videotaped person), or the nature of the target object (e.g., real item, toy, or picture), indicating that this trend is quite robust. In a more recent study, Lockl and Schneider (2007) reported a similar developmental trend.

1.2 DEVELOPMENT OF THEORY OF MIND IN INDIVIDUALS WITH AUTISM

In contrast to typically developing children, children with autism have been shown to be significantly delayed in their understanding of false-belief tasks (Pellicano, 2007). In a review of 28 studies, Happé (1995) compared the performance of individuals with autism on two false-belief tasks to the performance of individuals with mental retardation and to the performance of typically developing individuals. While individuals with autism performed significantly worse on average than individuals without autism, they also required a much higher verbal mental age in order to perform above chance (9 years, 4 years; respectively); thus, the observed deficits in theory of mind cannot simply be attributed to language delays which are also associated with autism. Similar results were obtained in a later meta-analysis by Yirmiya and colleagues (1998).

Researchers previously did not focus on the development of more advanced theory of mind since this ability develops rapidly for typically developing children. However, since theory of mind deficits are thought to be vital to our understanding of autism, researchers have subsequently developed more advanced tests of theory of mind, including the Strange Stories test (Happé, 1994) and the Reading the Mind in the Eyes test (Baron-Cohen, Jolliffe, Mortimore, & Robertson, 1997). High functioning adults with autism performed worse on the Reading the Mind in the Eyes test and on the Strange Stories test compared to both adults without autism and adults with Tourettes Syndrome (Baron-Cohen et al. 1997). Thus, while impairments in theory of mind are evident early in childhood, adults with autism continue to have impaired theory of mind.

1.3 THEORY OF MIND AND METACOGNTION

1.3.1 Theoretical relationship

Metacognition can broadly be defined as one's general knowledge regarding any aspect of cognitive activity, either within oneself or within others (Lockl & Schneider, 2007). Under this definition, metacognition includes the knowledge typically described as theory of mind. However, more specifically, metacognition can be divided into two types, metacognitive knowledge of cognition and metacognitive regulation of cognition (Shraw & Moshman, 1995). Metacognitive knowledge refers to what an individual knows generally about cognition, including declarative knowledge (e.g., knowledge about oneself as a learner and about factors that influence performance), procedural knowledge (e.g., knowledge about the execution of strategies or procedural skills), and conditional knowledge (e.g., knowledge concerning when and why to apply various cognitive processes). In contrast, metacognitive regulation refers to how one actively uses metacognitive knowledge to influence cognition. Metacognitive regulation includes planning (e.g., the selection of appropriate strategies and allocation of resources), monitoring, (e.g., one's online awareness of comprehension and task performance), and evaluation (e.g., one's assessment of what one knows). Nevertheless, theory of mind is still included in this more precise definition of metacognition, along with a variety of other metacognitive skills.

While few studies have looked at these to concepts together, researchers have suggested that theory of mind research be viewed within the theoretical framework of metacognition (Bartsch et al, 1996; Flavell, 2000; Kuhn, 1999, 2000). Although theorists differ in their conceptualization of the relationship between theory of mind and metacognition, there is agreement on the idea that, "children's developing understanding of mental states is a foundation achievement necessary for later metacognition and social cognition," (Bartsch et al., 1996).

Similar views have been espoused by autism researchers (Happé , 2003; Frith et al., 1999; Frith, 1989; Farrant et al., 2004; Farrant et al., 1999). Frith acknowledged that within the theory of mind literature, little attention has been given to a child's awareness of self, noting that "there is no reason to distinguish the ability to reflect on other people's mental states and on our own. This reflective ability is self-awareness in the case when we consider our own states of mind. To know that we know and to think about our own thinking are accomplishments that presuppose higher order processing ability," (Frith, 1989). Thus, theorists have argued that theory of mind and metacognition should be studied together in order to improve our understanding of both typical and atypical cognitive development.

1.3.2 Empirical evidence

While the relationship between theory of mind and metacognition is largely conceptually based, there is some empirical support for this relationship in individuals without autism. Research on typically developing children has shown that reasoning about oneself is similar to reasoning about others on false-belief tasks, as performance on self questions is highly correlated with performance on other questions (Wellman et al. 2001; Gopnik & Astington, 1998). More direct evidence is provided by a longitudinal study by Lockl and Schneider (2007). Children's theory of mind was evaluated annually from age 3 to age 5. In addition, their metamemory, specifically, their understanding of factors that influence memory performance (i.e., declarative knowledge), was assessed at age 5. At each age, performance on theory of mind was significantly associated with performance on metamemory questions, even after controlling for language. Moreover, a child's theory of mind performance at 3 years of age accounted for 13% of the variance in later metamemory performance and 27% of the variance at 4 years of age. While this study found a relationship between theory of mind and declarative knowledge about memory, it is unclear whether other metacognitive processes are also associated with theory of mind.

Research on the relationship between metacognition and theory of mind is similarly scarce with regard to individuals with autism (Farrant et al., 2004; Farrant et al., 1999). In one study, Farrant, Blades and Boucher (1999) examined recall readiness in children with autism. Recall readiness refers to the ability to monitor learning and judge when information has been sufficiently learned so that it can be later recalled. Children with autism performed worse on the recall readiness task, indicating that they have trouble monitoring and evaluating their own memory. Although this study did not assess theory of mind, it does provide evidence that metacognition is more generally impaired in individuals with autism. In contrast, a later study by Farrant and colleagues (2004) examined theory of mind and metamemory, including knowledge about variables which influence memory, knowledge about memory strategies, and knowledge about another person's memory. They also studied the influence of categories on memory recall. Contrary to their hypotheses, children with autism did not differ from controls in their knowledge about memory, although there were qualitative differences in the types of memory strategies they reported. In addition, no relationship was found between performance on false-belief tasks and performance on metamemory measures.

Thus, while research on typically developing children offers some support for a relationship between theory of mind and metacognition, the limited research on individuals with autism is more ambiguous. Although the results of the two studies on children with autism are inconsistent, the two studies also examined different components of metacognition. As a result, these conflicting findings may simply reflect the diversity within metacognition. In the earlier study, recall readiness, which requires monitoring and evaluating, components of metacognitive regulation, was measured (Farrant et al., 1999). In contrast, the second study primarily assessed declarative knowledge (e.g., factors which affect memory) and procedural knowledge (e.g. identification of strategies), aspects of metacognitive knowledge (Farrant et al., 2004).

In addition to differences among the specific components of metacognition assessed, there are also more general differences between metacognitive knowledge and metacognitive regulation which could have contributed to these inconsistent results. While nonspecific rules and accumulated knowledge can be used on tests of metacognitive knowledge, these types of information are substantially less useful on tests of metacognitive regulation. For example, when enumerating strategies to improve memory, one can use general rules which have been learned or explicitly taught regarding what do when you forget. In contrast, when evaluating the extent to which information has been memorized, one must actively track one's memory since the evaluation is unique to the situation. Thus, specific differences in the metacognitive process assessed and more general differences between metacognitive knowledge and metacognitive regulation may help explain why conflicting results were found for individuals with autism.

Given the variability within metacognition, it is likely that not all metacognitive processes are related to theory of mind. Therefore, it is important to consider specific metacognitive processes, which at least conceptually, are most closely related to ToM: metacognitive monitoring and evaluating. These two components of metacognitive regulation parallel the on-line monitoring of another person's mental state and the subsequent evaluation of that person's mental state which are necessary to pass tests of ToM. Thus, within the domain of metamemory, memory awareness or the online monitoring and evaluating of memory may be more strongly associated with theory of mind attributions.

1.4 MEMORY AWARENSS IN TYPICALLY DEVELOPING INDIVIDUALS

Within typically developing children, memory awareness is usually deduced by comparing confidence judgments to actual performance. The accuracy of the confidence judgment, or the accuracy of the memory awareness, is indicated by the degree to which reported confidence corresponds with actual performance. In one of the earliest studies to look at memory awareness in children, Berch and Evans (1973) examined the accuracy of confidence judgments in both kindergarten and third grade children. Children as young as 5 1/2 were able to use the 4 level confidence rating scale, and more importantly, confidence ratings of children in both grades reflected the accuracy of their memory recall. However, confidence judgments were significantly more accurate for children in third grade. Research has shown that memory awareness accuracy continues to improve with development (Allwood, Granhag & Jonsson, 2006; Pressley, Ghatala & Ahmad, 1987; Roebers, Gelhaar & Schneider, 2004; Roebers & Howie, 2003; Roebers, 2002). In a study of 11 to 12 year old children and adults, Allwood and colleagues (2006) found further evidence that memory awareness accuracy improves with age. On average, children's reported feelings of confidence on the memory test were 22% higher than their actual accuracy; in contrast, adults' reported feelings of confidence were only 12% higher than their actual accuracy. Thus by adulthood, typically developing individuals have developed highly accurate memory awareness.

1.5 THE CURRENT STUDY

Although the development of theory of mind has been extensively studied within individuals with autism, little is known regarding this population's understanding of their own mental processes (Happé, 1995; Yirmiya et al., 1998). While there are similarities between theory of mind and metacognition, few studies have examined whether broader deficits in metacognition exist in individuals with autism. Moreover, because there is substantial variability within metacognition, research on memory awareness may be especially informative since memory awareness requires metacognitive processes which appear similar to those required in tests of theory of mind. Currently, it is not known whether metacognitive monitoring and evaluating, as measured by memory awareness, must develop with regard to one's own mental states before these processes can be applied to the mental states of others as in theory of mind judgments. Thus, research on memory awareness in individuals with autism is needed to better understand metacognition within this population and to clarify the nature of deficits in theory of mind.

An important application of memory awareness is in the domain of face recognition. While there is ample research suggesting that individuals with autism have difficulty processing faces (Hauck, Fein, Maltby, Waterhouse, & Feinstein,1998; Rouse, Donnelly & Hadwin, 2004) and that this difficulty continues into adulthood (Blair, Frith & Smith, 2002; Molesworth, Bowler, & Hampton, 2005; Williams, Goldstein & Minshew, 2005), it is unknown whether individuals with autism are aware of this deficit. A benefit of studying memory awareness within face recognition is that it is a task which has real life analogs, as one is frequently expected to remember what acquaintances look like. In addition, it is a skill which individuals regularly receive feedback on, as others provide either validation or invalidation through the way they respond. Furthermore, metacognitive impairments within this domain would have substantial repercussions for social interactions. Without accurate memory awareness for faces, one might falsely identify strangers as friends, or friends as strangers, causing confusing and potentially negative social experiences. Alternatively, accurate memory awareness of one's impaired ability to recognize faces would allow for compensatory strategies. Thus, while memory awareness is generally important for learning, it has additional implications within the domain of face recognition.

For these reasons, the current study examined memory awareness accuracy and its relationship to theory of mind in children and adults with autism on a face recognition task. Consistent with prior research, memory awareness was assessed using confidence judgments, which accurately reflect one's memory in typically developing children as young as 5 1/2 (Berch et al., 1973). Memory awareness accuracy was evaluated separately for each certainty level within the confidence judgments. An overall measure of memory awareness was also used to describe how memory awareness accuracy varies with certainty. In addition, memory awareness accuracy was assessed for both an explicit memory test, in which participants were aware of the pending memory assessment, and an incidental memory test, in which participants were surprised with a memory assessment. These two conditions were included to provide a multifaceted assessment of memory awareness since the degree to which memory awareness is impaired may very depending on type of memory assessed. Though speculative, it was purposed that the explicit condition would indicate optimal memory awareness since participants were purposefully trying to remember the faces and that the incidental condition would indicate basal memory awareness since participants were not actively trying to remember the faces.

Thus, the primary goal of the current study was to examine memory awareness accuracy in children and adults with autism and more specifically, to describe how the accuracy of confidence judgments differs compared to children and adults in the control condition. Substantial evidence indicates that theory of mind is impaired in individuals with autism; however, impairments in theory of mind may reflect more general impairments in metacognitive monitoring and evaluating. Additionally, this study explored how memory awareness accuracy varies between children and adults. Prior research indicates that memory awareness in individuals without autism improves with age, thus the degree to which memory awareness is impaired in individuals with autism may also vary for children and adults. Furthermore, this study was designed to examine how the type of recognition test affects memory awareness and to describe the relationship between theory of mind and memory awareness in individuals with autism. While the experimental condition (i.e., recognition test type) provides a multidimensional assessment of memory awareness in individuals with autism, the association between theory of mind and overall memory awareness clarifies the nature of deficits in metacognitive monitoring and evaluating.

Based on the literature reviewed above, it was predicted that individuals with autism would have impaired memory awareness, as indicated by reduced memory awareness accuracy, compared to individuals without autism. More specifically, it was expected that individuals with autism would report less accurate confidence judgments compared to individuals without autism. It was also hypothesized that individuals with autism would have more accurate memory awareness for the explicit compared to the incidental condition. However, for individuals without autism, the accuracy of confidence judgments would not vary depending on the type of facial recognition test. Lastly, it was hypothesized that overall memory awareness would be positively associated with theory of mind in individuals with autism. Thus, changes in memory awareness accuracy across certainty levels would be associated with one's performance on measures of theory of mind.

2.0 METHOD

2.1 PARTICIPANTS

Participants included both children and adults. Child participants consisted of 47 high-functioning children with autism and 37 typically developing, control children who ranged in age from 9 to 17 years old. For children, both the autism group and the control group included 5 female participants. Adult participants included 31 high-functioning adults with autism and 28 control adults who ranged in age from 18 to 45 years old. For adults, the autism group included 2 female participants, whereas the control group included 4 female participants. Within the entire sample, 96.5% of participants were Caucasian, 2.8% were African American, and .7% were Asian Americans. Control participants in each age group were matched with participants in the autism group on age, full scale IQ, verbal IQ, and performance IQ (see Table 1). For both children and adults, no significant differences existed between the autism group and the control group for any demographic variable.

Table 1. Demographic characteristics of autism and control groups

	Child		Adults	
	Controls (*n*=37)	Autism (*n*=47	Controls (*n*=28)	Autism (*n*=31)
Age	13.11 (2.32)	12.10(2.67)	25.01(7.23)	25.81(7.85)
VIQ	106.60(8.40)	103.75(10.65)	108.01(8.94)	103.39(13.23)
PIQ	107.22(8.05)	110.43(10.72)	112.11(13.8)	109.20(10.52)
FSIQ	108.01(8.22)	107.92(9.77)	111.29(8.29)	107.30(10.94)

Note. Values enclosed in parentheses represent standard deviations.
VIQ=Verbal IQ; PIQ=Performance IQ; FSIQ=Full-Scale IQ.
Age is indicated in years.

Participants were recruited through posters, newspaper, radio, and television advertisements. For the autism group, participants' diagnoses were confirmed using the Autism Diagnostic Observation Schedule-General (ADOS-G; Lord et al., 1989), the Autism Diagnostic Interview-Revised (ADI-R; Lord, Rutter, & LeCouteur, 1994) and clinical opinion. Participants with Asperger's disorder or PDD-NOS were excluded. Control participants were volunteers recruited from the community. Parents of potential control participants completed questionnaires with demographic and family information to determine eligibility. Control participants were required to have a negative family history of first degree relatives with major psychiatric disorders and of first and second degree relatives with autism spectrum disorder. Control participants were also excluded if they had a history of poor school attendance or evidence of a disparity between general level of ability and academic achievement suggesting a learning disability. The Wide Range Achievement Test-IV was administered to all participants to exclude participants with a diagnosable learning disability. All participants were also required to be in good medical health, free of seizures, have a negative history of traumatic brain injury, and have an IQ greater than 80 as determined by the Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler, 1999).

2.2 APPARATUS

Testing occurred in a quiet room. Each participant sat in front of a 43-cm. monitor controlled by a computer and responded using a modified keyboard with large keys (approximately 2.54 cm. squares) that is commercially available for young children. During the recognition test, all keys were covered with black felt except for the two response keys labeled “old” and “new”. The position (left/right) of the “old” and “new” labels was counterbalanced.

2.3 STIMULI

Stimuli during the learning phase consisted of 24 color photographs of adult female faces. During the memory test, stimuli consisted of 48 color photographs of adult female faces, 24 which were included during the learning phase (old), and 24 which were not included during the learning phase (new). For all stimuli, non-facial cues, (i.e.; as an individual’s hair style and clothing) were occluded. In both the explicit condition and the incidental condition, each stimulus during the learning phase was presented for 5 seconds, and was then followed by a black screen for 4 seconds. For both the learning phase and the memory test, stimuli order was randomized.

2.4 STANDARDIZED MEASURES OF THEORY OF MIND

Theory of mind was measured using false-belief tasks and the Strange Stories test.

2.4.1 False-belief tasks (1st and 2nd order beliefs)

For this study, three standard false-belief tests were used: the Sally-Ann task (with props) (Baron-Cohen, Leslie & Frith, 1985), the John-Mary task (with props) (Baron-Cohen et al., 1985; Bowler, 1992) and the Peter-Jane task (without props) (Bowler, 1992). The Sally-Ann task involved a change of location format and evaluates the participant’s ability to make first-order belief attributions (e.g., Where will Sally look to find x?). In contrast, both the John-Mary and the Peter-Jane tasks used a change of location format to evaluate the participant’s ability to make both first-order and second-order belief attributions, in which the participant must understand one person's belief about what another person believes about reality (e.g., What does John think Mary thinks?).

2.4.2 Strange Stories test

This test provided an assessment of more advanced theory of mind abilities (Happé, 1994). During the test, participants were asked to read short stories about everyday situations which are followed by written questions about the story characters' motivation.

2.5 PROCEDURE

At the initial visit, all participants were administered the three false-belief tasks and the Strange Stories test. At this time, participants were randomly assigned to either the explicit memory condition or the incidental memory condition. At a second visit, participants were tested on their facial recognition and their memory awareness. Procedures varied based on the experimental condition to which participants were assigned.

2.5.1 Explicit memory condition

Prior to the learning phase, participants in the explicit condition were told that they were going to view a presentation of faces. Participants were told to pay attention because immediately following the presentation their memory for the faces would be tested. Following the learning phase, participants were then tested on their recognition of the faces they had just seen. Participants were asked to push the key labeled "old" if they remembered seeing the face in the previous presentation and to push the key labeled "new" if they did not remember seeing the face in the previous presentation. For each test trial, participants were also asked to make a confidence judgment by indicating their certainty for their response using a 3 point Likert scale consisting of “certain” “somewhat certain” and “guessing.”

2.5.2 Incidental memory condition

Prior to the learning phase, participants in the incidental condition were told that they were going to view a presentation of faces. Participants were told to pay attention because they would need to say whether they thought each face was “attractive”, “average”, or “unattractive”. Following the learning phase, participants were immediately given a surprise memory test. The procedures for the memory test and confidence judgments were identical to that in the explicit condition.

3.0 RESULTS

The primary data analyses were designed to assess specific hypotheses regarding: 1) how memory awareness accuracy in individuals with autism differs from that in individuals without autism, 2) how memory awareness accuracy changes with age group, 3) how memory awareness accuracy differs on tests of explicit memory compared to tests of incidental memory, and 4) how memory awareness relates to theory of mind. In the following sections, we first examine the impact of diagnosis, age group, and experimental condition on memory awareness accuracy. We then explore the relationship between overall memory awareness and theory of mind in individuals with autism.

3.1 MEMORY AWARENESS ACCURACY

For each participant, memory awareness accuracy was calculated for each certainty rating (sure, somewhat sure, and guessing) by dividing the number of correct trials for a given certainty level by the overall number of trials a participant reported a given certainty level. Thus, accuracy percentages reflect the percentage of correct recognition trials when the participant said they were a particular certainty level.

A four-way ANOVA was conducted with diagnosis (control vs. autism), age group (child vs. adult) and experimental condition (explicit vs. incidental) as between-subjects variables, certainty (certain vs. somewhat certain vs. guessing) as a repeated, within-subjects variable, and memory awareness accuracy as the dependent measure. Preliminary analysis indicated that there was a violation of the assumption of sphericity. As a result, a Huynh-Feldt correction was employed in subsequent analyses.

Results indicated a significant main effect of diagnosis, $F(1, 127)=15.49$, $p<.001$, with individuals with autism reporting less accurate memory awareness overall compared to controls (see Figure 1). There was also a significant main effect of certainty, $F(1.65, 127)=79.06$, $p<.001$. This suggests that in general, memory awareness accuracy varied depending on one's certainty level, with increased accuracy reflecting greater certainty. Results did not indicate a significant main effect of age group, $F(1, 127)=1.76$, $p>.05$ or a significant main effect of experimental condition, $F(1, 125)=1.03$, $p>.05$. Most importantly, there was a significant Diagnosis x Age Group X Certainty interaction, $F(1.65, 127)=4.67$, $p=.015$ and a marginally significant Diagnosis x Experimental Condition X Certainty interaction, $F(1.65, 125)=3.19$, $p=.053$.

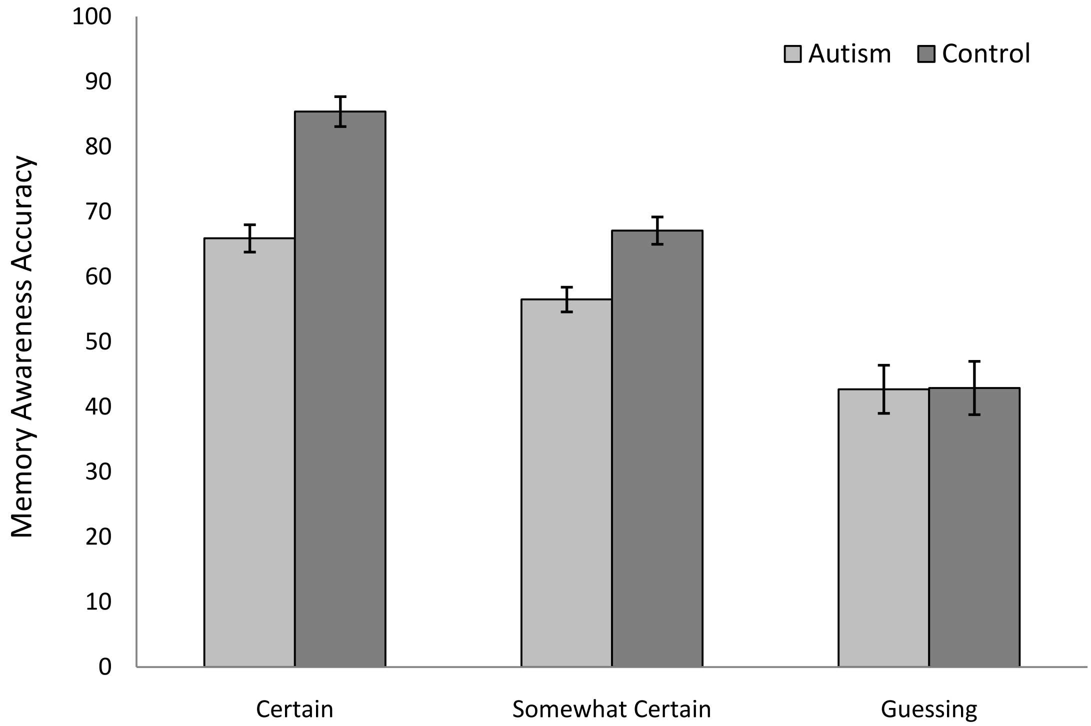

Figure 1. Effects of certainty level and diagnosis on memory awareness accuracy

3.1.1 Effect of age group on certainty and diagnosis

In order to explore the 3-way interaction between diagnosis, age group, and certainty with regard to memory awareness accuracy, 2-way ANOVAs were performed separately for children and adults. For both analyses, diagnosis was included as a within-subjects variable, and certainty was included as a repeated, between-subjects measure.

For child participants, there was significant main effect of diagnosis, $F(1, 76)=11.80$, $p=.001$ and a significant main effect of certainty $F(1.67, 76)= 27.65$, $p<.001$. More importantly, there was a significant Diagnosis X Certainty interaction, $F(1.67, 76)=12.85$, $p<.001$. Thus, while children with autism demonstrated less accurate memory awareness in general, their accuracy was also differentially affected by their certainty level when compared to typically developing children. The interaction between diagnosis and certainty is shown in Figure 2. Additional analyses were conducted to explore the relationship between diagnosis and certainty. In subsequent analyses, Šidák-Bonferroni corrections were used account for multiple comparisons.

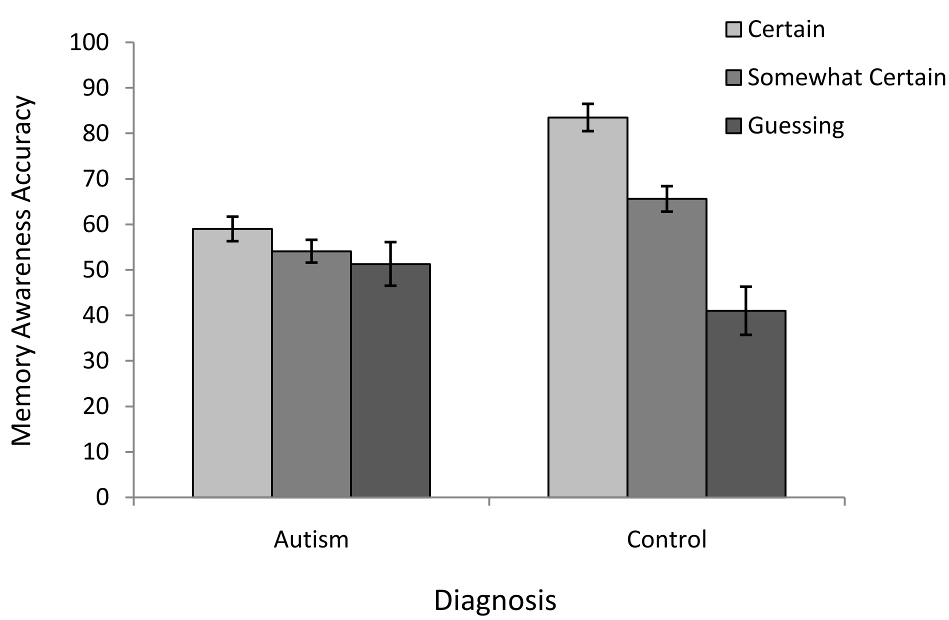

Figure 2. Effects of certainty level and diagnosis on memory awareness accuracy in children

Paired t-tests were conducted to determine if memory awareness accuracy differed significantly between certainty levels. Among typically developing children, memory awareness accuracy when children were certain was significantly different than when they were somewhat certain, and memory awareness accuracy when they were somewhat certain was significantly different than when they were guessing ($t(35)=6.42$, $p<.01$; $t(35)=4.35$, $p<.01$, respectively). In addition, t-tests were used to determine whether memory awareness accuracy levels for certain, somewhat certain, and guessing were significantly better than chance (50%). One would expect that if the relationship between memory awareness accuracy and certainty is meaningful, then accuracy levels both when certain and when somewhat certain would be statistically better than chance, whereas, accuracy when guessing would be random and therefore no different than chance. For children in the control condition, memory awareness accuracy was significantly better than chance both when certain and when somewhat certain (see Table 2). Thus, typically developing children were using all three certainty levels in a meaningful way. These results suggest that each certainty level was both discrete and statistically meaningful for typically developing children. In contrast, for children with autism, differences in accuracy between certainty levels were not significant. Furthermore, children with autism performed better than chance only when they were certain ($t(44)=4.51$, $p<.01$; see Figure 1). Thus, children with autism, unlike typically developing children, appear to have a rudimentary awareness of their memory, as only accuracy when certain was significantly better than chance. Moreover, these results suggest that they are not able to reliably distinguish between certainty levels.

Within adult participants, the 2-way ANOVA indicated a significant main effect for both diagnosis, $F(1, 52)=9.164$, $p<.01$ and certainty $F(1.34, 52)= 54.396$, $p<.01$. The interaction between Diagnosis X Certainty was nonsignificant, $F(1.34, 52)=.171$, $p>.05$. While adults with autism were still less accurate than adults in the control condition, their accuracy was similarly affected by their certainty level (see Figure 3).

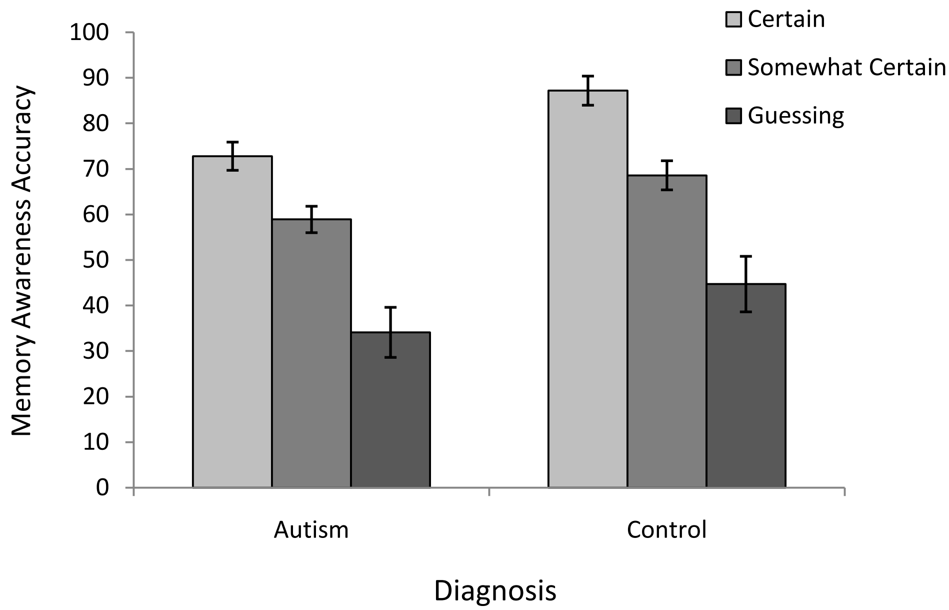

Figure 3. Effects of certainty level and diagnosis on memory awareness accuracy in adults

In order to clarify the effects of certainty, additional analyses which employed Šidák-Bonferroni corrections were conducted. As in previous analyses, paired t-tests indicated that memory awareness accuracy was significantly better when certain compared to somewhat certain and when somewhat certain compared to guessing for both adults with autism ($t(30)=3.60$, $p<.01$; $t(30)= 4.12$, $p<.01$, respectively) and adults without autism ($t(25)=5.23$, $p<.01$; $t(25)= 3.47$, $p<.01$, respectively). These results indicate that when adult participants in both groups were more certain, their memory awareness accuracy for faces improved. In addition, t-tests were used to examine whether memory awareness accuracy levels were significantly different than chance. As shown in Table 2, accuracy when certain and accuracy when somewhat certain were significantly better than chance for both adults with autism and adults in the control condition. Thus, for all adult participants, accuracy was uniquely and meaningfully moderated by certainty level.

Table 2. Significance of mean memory awareness accuracy compared to chance

	Autistic		Control	
Certainty Level	Child (*df*=42)	Adult (*df*=30)	Child (*df*=35)	Adult (*df*=25)
Certain	59.0% (14.4)*	72.8% (22.6)**	83.5% (12.4)**	87.2% (19.3)**
Somewhat	54.1% (18.7)	58.9% (15.6)*	65.6% (13.8)**	68.6% (14.2)**
Guessing	51.3% (27.2)	34.1% (32.2)	41.0% (30.8)	44.7% (37.8)

Note. Values enclosed in parentheses represent standard deviations.
* p <.05. ** p <.01.

In summary, memory awareness for younger participants with autism was significantly less accurate than controls. In addition, children with autism did not distinguish between the three levels of certainty. Thus, when children with autism reported they were certain, their memory awareness accuracy was not significantly different than when they reported they were guessing. In comparison, adults with autism were able to distinguish between each of the three levels of certainty; however, their memory awareness accuracy was still worse than adult controls. In contrast, typically developing children's accuracy varied significantly between each certainty level, suggesting that their accuracy was modulated by their degree of certainty. For control children, their use of the certainty levels was also meaningful, with their accuracy being significantly better than chance for both certain and somewhat certain. Similar results were obtained for control adults, suggesting that typically developing children are performing at adult levels with regard to their memory awareness accuracy.

3.1.2 Effect of diagnosis on experimental condition and certainty

In order to explore the 3-way interaction between diagnosis, experimental condition, and certainty with regard to memory awareness accuracy, 2-way ANOVAs were performed separately for participants with autism and for participants in the control group. In both analyses, experimental condition was included as a within-subjects variable and certainty was included as a repeated, between-subjects measure.

Within control participants, there was significant main effect of experimental condition, $F(1, 60)=9.10$, $p=.004$, and a significant main effect of certainty $F(1.45, 60)= 67.11$, $p<.001$. Thus, control participants on average performed significantly better on the incidental condition (M=70.7%, SD=13.1%) compared the explicit condition (M=59.7%, SD=15.6%). In addition, there was a significant Experimental Condition X Certainty interaction, $F(1.45, 60)=4.94$, $p=.017$. As show in Figure 4, the impact of study condition differed depending on the certainty level for control participants. One-way ANOVAs were conducted for each certainty level to examine the interaction between study and certainty. A significant difference in accuracy between incidental and explicit conditions was found only when control participants were guessing ($F(1, 60)=9.04$, $p=.004$). However, a t-test revealed that accuracy when guessing in the incidental condition was not significantly different than chance, suggesting that this difference is not meaningful ($t(33)=.99$, $p>.05$).

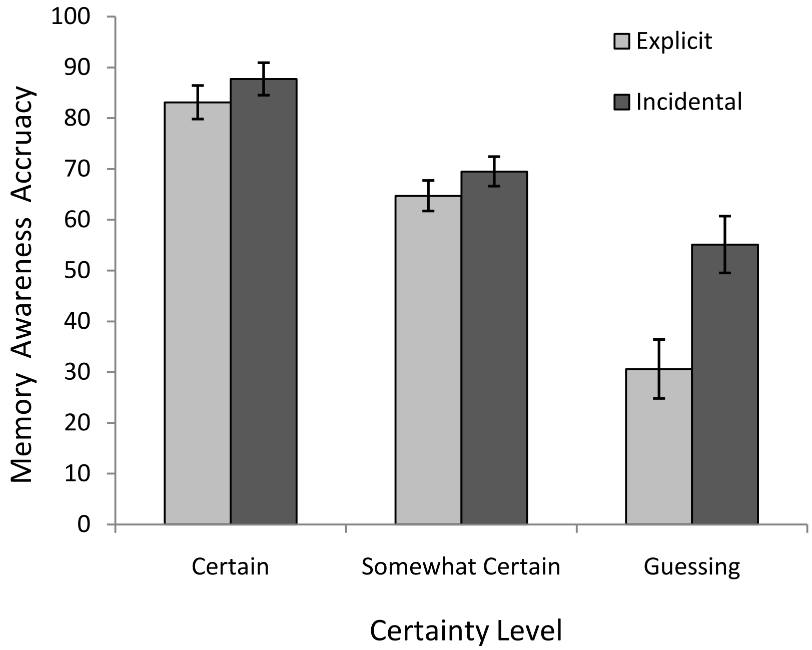

Figure 4. Effects of certainty level and experimental condition on memory awareness accuracy in control participants

Within participants with autism, the 2-way ANOVA yielded a significant main effect of certainty $F(1.65, 71)= 17.58$, $p<.001$. However, the effect of experimental condition was nonsignificant, $F(1, 71)=1.405$, $p>.05$, suggesting that for individuals with autism, memory awareness accuracy was not affected by experimental condition. Unlike control participants, there was not a significant Experimental Condition X Certainty interaction, $F(1.65, 71)=.285$, $p>.05$. As can be seen in Figure 5, individuals with autism performed similarly at each certainty level regardless of study condition.

In summary, memory awareness accuracy varied based on condition in control participants but not in participants with autism. Among control participants, memory awareness was more accurate for the incidental condition compared to the explicit condition. This indicates that they were more aware of their memory when they were surprised with a memory test compared to when they were actively trying to remember the faces. Although this finding was especially pronounced when control participants were guessing, their accuracy was not significantly different than chance which suggests that the interaction between study and certainty was not meaningful.

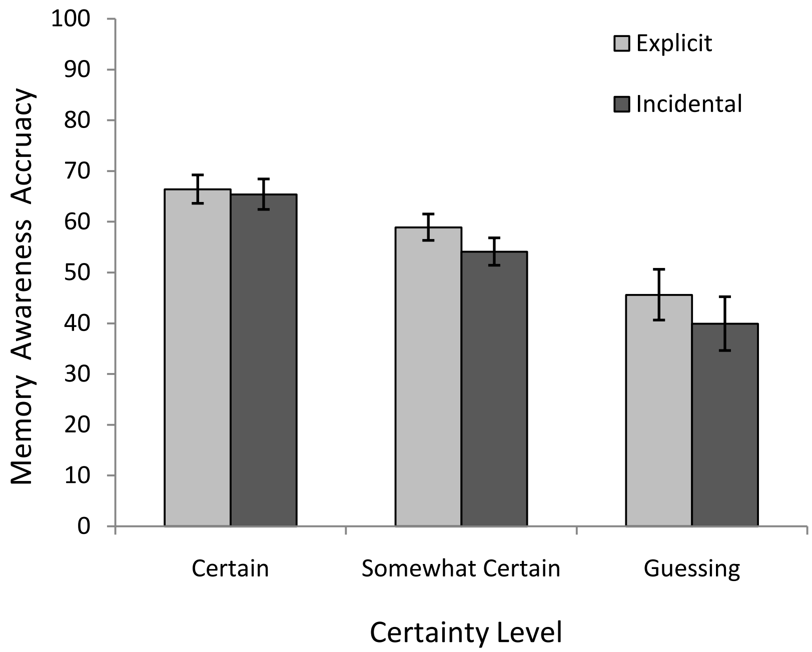

Figure 5. Effects of certainty level and experimental condition on memory awareness accuracy in participants with autism

3.2 OVERALL MEMORY AWARENESS AND THEORY OF MIND

Change in memory awareness accuracy across certainty levels was used to assess overall memory awareness. Difference scores were created by subtracting memory awareness accuracy when guessing from accuracy when certain. As a result, difference scores provide an index of the degree to which accuracy changed depending on one's certainty level. For example, an individual whose accuracy increased with increased certainty would suggest good memory awareness. In contrast, a participant who performed accurately on 80% of the trials both when they were certain and when they were guessing would suggest that the individual was good at recognizing faces but had poor memory awareness. Similarly, a participant who performed accurately on 50% of the trails both when they were certain and when they were guessing would suggest that the individual was poor at recognizing faces and also poor with regard to memory awareness. Thus, difference scores were created for each participant based on the change in accuracy when a participant reported they were certain compared to when they were guessing.

Initially, correlations were calculated to explore the relationship between FSIQ, age, performance on theory of mind false-belief tests, performance on Happé's Strange Stories test and overall memory awareness. Age (r=.335, p=.004) and performance on theory of mind false-belief tests (r=.325, p=.011) were both associated with overall memory awareness among individuals with autism. In contrast, neither FSIQ (r=-.074, p=.532) nor performance on Happé's Strange Stories(r=.099, p=.46) were significantly associated with overall memory awareness. As a result, a regression analysis was run with age and performance on theory of mind false-belief tests as independent variables and overall memory awareness as the dependent measure. Age was entered in Step 1 of the regression and performance on theory of mind false-belief tests was entered in Step 2.

Analysis of Step 1 indicated that age alone accounted for 11.2% of the variance in overall memory awareness for individuals with autism, $F(1,60)=8.70$, $p=.005$. When performance on theory of mind false-belief tests was added, the model explained 16% of the variance in overall memory awareness for individuals with autism, $F(2,59)=6.83$, $p=.002$. Furthermore, the addition of performance on theory of mind false-belief tests significantly improved the predictive value of the model, $\Delta R^2=.06$, $F_{\text{inc}}(1,59)=4.46$, $p=.039$. Among individuals with autism, a one year increase in age was associated with 1.2 % change in overall memory awareness. Furthermore, for every 10% increase in performance on the theory of mind false-belief tests, memory awareness increased 4.8 %. Thus, increases in both age and performance on theory of mind on false-belief tests were found to be associated with increased change in overall memory awareness in individuals with autism. In contrast, FSIQ and performance on Happé's Strange Stories were not associated with memory awareness.

4.0 DISCUSSION

The primary objective of the current study was to describe memory awareness in individuals with autism compared to that in individuals without autism. Based on the theoretical relationship between ToM and metacognition, it was hypothesized that individuals with autism would also have impaired (i.e. less accurate) memory awareness compared to individuals without autism. Consistent with this hypothesis, both children and adults with autism demonstrated less accurate memory awareness compared to respective control groups. While no hypotheses were made regarding the development of memory awareness with age, age did influence memory awareness accuracy among individuals with autism. The current study suggests that children with autism have poor memory awareness and that their memory awareness is significantly worse than typically developing children. For children with autism, memory awareness accuracy did not consistently vary with their stated certainty levels. Furthermore, on trials in which children with autism were somewhat certain, their accuracy was not significantly different from chance. Thus, children with autism appear to have a very basic awareness of their memory. In contrast, previous research has indicated that typically developing children as young as five and a half can reliably assess whether they are certain, somewhat certain or guessing (Berch et al., 1973). The current study provides additional support, as typically developing children's certainty levels accurately and uniquely reflected their performance on the facial recognition task.

Among adults with autism, increasing certainty was associated with increasing accuracy. Furthermore, memory awareness accuracy for each certainty level was distinct from the accuracies of the other two certainty levels. This indicates that among adults with autism, there were meaningful differences in performance based on their stated certainty. However, while memory awareness improved in adults with autism, their performance remained significantly less accurate than adults without autism. Indeed, memory awareness of adults with autism was even less accurate than that of typically developing children, suggesting that memory awareness in individuals with autism is both delayed, and impaired.

An additional purpose of this study was to examine whether testing participants with an explicit or implicit memory design would influence memory awareness. Specifically it was hypothesized that individual with autism would have more accurate memory awareness for an explicit facial recognition task compared to an incidental facial recognition task. Contrary to this hypothesis, memory awareness in typically developing individuals, but not in individuals with autism, was influenced by the experimental condition. It was also hypothesized that knowing there would be a memory test, as in the explicit condition, would enhance memory awareness during the actually memory test. However, in the present study, memory awareness in typically developing individuals was less accurate in the explicit condition, in which participants were instructed to memorize the faces, compared to the incidental condition, in which participants were instructed to rate the faces on attractiveness. While speculative, this decreased accuracy in the explicit condition may be the result of control participants strategically trying to remember the faces. While knowledge regarding the recognition test may promote metacognitive planning, such as strategies for remembering faces, such knowledge could decrease the accuracy of one's memory awareness. For example, typically developing individuals may have focused more on specific facial features, increasing the amount of attention to the faces or the amount of information memorized, both of which could interfere with one's memory awareness. Alternatively, it is possible that making an attribution about a face, as in the incidental condition, may have increased the saliently of one's memory for the faces by creating an additional dimension by which to gauge memory awareness.

Lastly, the current study explored the relationship between theory of mind and memory awareness in individuals with autism. Theory of mind was found to be related to memory accuracy awareness on the theory of mind false belief task. In contrast this association was not found for the Happé's Strange Stories tests. These discrepant results may reflect differences in the two measures of theory of mind. While both tests are presumed to measure theory of mind, the two tests assess theory of mind at different developmental levels and subsequently, at different difficulty levels. As a result, these differences may moderate the relationship between theory of mind and memory awareness. For example, memory awareness in individuals with autism may be related to a more basic understanding of mental states and therefore independent of more advanced theory of mind knowledge. Indeed, the one study which looked at this relationship in typically developing children focused only on basic tests of theory of mind. Thus, metacognitive knowledge about oneself and about others may initially be very similar. However, as one develops more advanced metacognitive knowledge about oneself and about others, these two types of knowledge may diverge, becoming less and less similar. Unfortunately, very few studies have examined the relationship between theory of mind and metacognition, so any interpretation must be speculative. Furthermore, theory of mind only accounted for a fraction of the variance in memory awareness, suggesting that additional factors are important.

Together, these results have important implications for how we conceptualize specific impairments, as well as our general understanding of autism. Deficits in memory awareness for faces may contribute to more general deficits in social interactions. While there are many barriers that a child with autism must overcome in order to be successful in social interactions, accurately assessing one's recognition of faces is key. In this study, even when children with autism were certain that they remembered a face or didn't remember a face, their accuracy was only 59%, a level which is only marginally better than chance. As a result, children with autism may ignore some acquaintances, and conversely, approach strangers as if they know them. Both of these possibilities would have detrimental implications, either by reducing possible social interactions and slighting peers, or by evoking negative responses from strangers. Furthermore, decreased awareness of this impairment in facial recognition makes it unlikely that individuals with autism will spontaneously employ strategies to compensate for this impairment.

While it is unclear whether impaired memory awareness in individuals with autism reflects a general impairment in metacognitive monitoring, additional research is warranted. Since the current study examined memory awareness within the context of facial recognition, it is possible that the observed impairments in memory awareness are specific to facial recognition. However, the association between performance on theory of mind, false-belief tests and memory awareness suggests that this impairment may apply more broadly to metacognitive monitoring of social information. If this is the case, metacognitive skills may need to be developed before new skills can be incorporated into daily life. For example, even if you develop strategies to increase your memory for faces, you must recognize situations in which you need to use them. While these results are inconclusive regarding the specificity of this deficit in memory awareness, it is important that researchers consider the possibility that individuals with autism may have a general impairment in metacognitive monitoring. While there is a plethora of research on theory of mind development in autism, a general impairment in metacognitive monitoring could underlie these findings. Understanding how deficits in theory of mind relate to metacognitive monitoring is critical since many theorists view deficits in theory of mind as a core feature of autism.

Several limitations are important when considering these results. While this study examined how memory awareness changes with age, only two age groups were tested. Since children were combined with adolescents, it is not clear whether memory awareness accuracy in individuals with autism improves significantly prior to adulthood. Exclusion of children younger than 9 is an additional limitation of this study. Consequently, the age at when typically developing children achieve memory awareness as accurate as adults is not known. Furthermore, the age range studied made it impossible to examine the relationship between theory of mind and memory awareness in typically developing participants since their performance on tests of theory of mind would have been at ceiling. As a result, it is unclear whether a similar relationship between theory of mind and memory awareness exists for typically developing individuals. Another limitation of the current study is that memory awareness was examined only within the context of facial recognition. While it is important to understand memory awareness for faces in individuals with autism, it is unclear whether more general impairments in memory awareness exist. Lastly, the 3 point certainty scale may not have provided sufficient precision in order to detect changes in memory awareness accuracy between children and adults in the control condition. Use of more than three choices might have indicated that control adults, in contrast to children, have an even more finely tuned sense of certainty about their memory performance. Thus, future research on memory awareness in individuals with and without autism is needed to continue to clarify how accuracy changes with development, how the task influences performance, and how memory awareness is related to theory of mind.

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