NONVERBAL MEASUREMENT OF METAMEMORY AND ITS RELATION TO AUTISM-LIKE TRAITS

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Abstract

Metamemory develops early in childhood with language, but may be impaired in disorders like autism spectrum disorders. Because of its strong links to language, most attempts to measure metamemory have relied strongly on communicative ability. This study reports on a task that nonverbally assesses metamemory. This novel task modified the delayed-match-to-sample paradigm where the participant chooses a matching response to an initial stimulus. The modification lets the participant review the original stimulus if they are unsure of their answer, allowing for a nonverbal assessment of metamemory. The task is correlated with a current measure of verbal metamemory. Also given strong face validity, the task is an appropriate alternative for the measurement of metamemory. The task was not correlated with a measure of autism-like traits, while a more verbal measure of verbal metamemory was negatively correlated with autism-like traits, suggesting those with these traits may show deficits on verbal measures only.

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Nonverbal Measurement of Metamemory and its Relation to Autism Traits

Metacognition is the understanding and awareness of one's own cognition**.** One aspect of metacognitive ability is the knowledge of one's own memory capabilities; this awareness is called metamemory (Bordignon, Endres, Trentini & Bosa, 2015)**.** Metamemory emerges in early childhood in typically developing (TD) children, but may be delayed in certain developmental disorders such as autism spectrum disorders (ASD). Metamemory is crucial in daily living, in that we often assess our capability to remember how to carry out tasks, and make judgements as to whether we need memory aides or not. We may also need to review or revisit information often in order to bolster our memory. However, our current understanding of metamemory is drastically limited by its dependence on language (Ebert, 2015). All measures assessing human metamemory known to the author use verbal or written approaches. It may be the case in ASD, or other disorders affecting language, that observed deficits in metamemory are due partially, or in whole to issues with language expression (i.e. these participants may find it difficult to put into words the complex task of expressing self-awareness). For this reason, the development of a measure assessing metamemory through nonverbal means will deepen our understanding of this process and its connection to language.

Language, Theory of Mind and Metamemory

Theory of mind (TOM) is the knowledge and understanding of the mental states of others (Baron-Cohen, 1991). Language development, TOM, and metacognitive abilities are known to be correlated from a very young age (Fritz, Howie, & Kleitman, 2010). The development of language may also signal, or otherwise influence, the development of a wide range of mental abstraction abilities, including metacognition and TOM (Borkowski, Ryan, Kurtz & Reid, 1983). Lockl and Schneider (2007) found that language abilities at ages typically before the development of metamemory (3 - 5 years old) were able to predict metamemory abilities at a later age. Similarly, early language abilities predict TOM later in development, but early TOM did not predict language ability (Astington & Jenkins, 1999). It is difficult to know whether this pattern would also hold for metacognitive abilities but the link between theory of mind and metacognition is well supported in literature (Flavell, 2000; Misailidi, 2010) and some advocate that the two should be subsumed into a larger category called meta-knowing (Kuhn, 2000). However, since both of these abilities are measured almost entirely with verbal measures, it is likely that a certain amount of verbal ability is required to demonstrate "meta-knowing".

Meta-knowing and language are both implicated as areas of potential deficit in ASD; however, the relationship between language and metacognition, specifically metamemory, is not well established since most measures of metamemory rely heavily on participants being able to express complex and abstract ideas about the inner states. I will turn to the literature looking at ASD, metamemory, and language and highlight conceptual gaps. Then based on comparative cognition research, I propose a new experimental task that allows for the study of metamemory without requiring expressive language.

Research conducted in the area of metamemory and language in ASD is equivocal. Some researchers limit the sample of ASD participants in their studies to only those without a language delay. Other groups typically study high-functioning children on the spectrum; however, children with ASD who are high-functioning may be able to compensate for language deficits. Because of this, some studies that have matched for language abilities detect no deficits in the verbal measurement of metamemory (e.g. Farrant, 1999).

Some research groups have found inconsistent results when testing different samples of children with ASD. Wojcik, Allen, Brown and Souchay (2011) used confidence judgements (participants must indicate how confident they are in their memory) and the accuracy of these judgements to assess metamemory. After being asked to sort items in a memory task, participants were asked to rate how well they thought they did on a task on a 10-point scale. However, the ASD sample for this study (16 children) consisted of seven children diagnosed with Asperger's syndrome and nine with high-functioning autism. Before the incorporation of Asperger's syndrome inside of autism spectrum disorders in the current edition of the DSM, it was regarded as distinct in terms of more preserved language abilities while sharing similarities in social skill abilities and stereotyped behaviors (Glennon, 2001). The mean IQ of the children in sample used by Wojcik and colleagues (2011) was 112.19. While the typically developing controls used in this study were IQ matched (118.50), issues might arise from only looking at the high-IQ end of the ASD spectrum or a sample consisting of children with Asperger's syndrome. That is, well-developed language in these children may mask metamemory deficits if they exist in the high-functioning end of the autism spectrum. Indeed, in this study, they did not find differences from TD groups in metamemory ability.

However, in a later study that did not match for verbal mental age or restrict the sample to children with high-functioning autism, the researchers found differences in some types of metamemory (Wojcik, Moulin & Sousay, 2013). Similarly, other groups have found deficits when using similar samples (Grainger, Williams & Lind 2014). If language develops alongside metamemory as Lockl and Schneider (2007) suggested, in studies where children with ASD lag behind typically developing peers in terms of language, it is difficult to know whether metamemory is a deficit in ASD independent of language deficits, when metamemory has been evaluated using language-based measures.

Memory strategy use may also be related to the joint development of metamemory and language. Children, when beginning to rehearse items to remember, often repeat words in their mind (Harris, 2000). Cantor, Andreassen and Waters (1985) found that verbal memory strategy use was associated with the development of metamemory abilities in children. Among children in kindergarten, Grade 2 and Grade 5, there was a linear trend in the development of both metamemory and language, as is expected. However, within the groups, the children with the highest metamemory abilities (i.e. knowing when to use a memory strategy) were best able to express themselves. Among the children who were younger (kindergarten and grade 2) but had high metamemory abilities, their language skills still trailed older children with similar metamemory abilities, indicating that language abilities might possibly trail metamemory. Similarly, Bebko, McMorris, Metcalfe, Ricciuti and Goldstein (2014) found that language proficiency mediated metamemory's influence on tasks of recall. Other longitudinal research indicates that language indirectly impacts the development of metamemory (Ebert, 2015). However, since these studies have used measures of metamemory that rely upon children describing their inner states, and require the use of abstract language, it may be that exploration of metamemory has been intertwined with verbal skills. It is important to determine whether metamemory skills can be examined separately from language development.

Nonverbal Metamemory

Assessing metamemory nonverbally in humans has been attempted before, but many of the tests used still had a verbal component. In order to measure metamemory in very young children (aged 4 to 5), Henry and Norman (1996) attempted to convert a metamemory questionnaire (Wellman, 1997) into a set of pictures depicting situations. For example, in one set there would be two pictures: one in which a child has a thought bubble with three items in it and another with a child with a thought bubble that has seven items in it. However, the final part of the questionnaire remained verbal and the experimenter would ask the child in which picture it would be easier for the child to remember the set. To the best of my knowledge, no attempt has been made to attempt to assess metamemory nonverbally in children on the autism spectrum. Researchers examining areas such as Alzheimer's disease and other dementias have tried to develop objective metamemory measures, but these tasks still require participants to verbally explain their memory (e.g. Cosentino, Metcalfe, Butterfield & Stern, 2007; Shaked et al., 2014).

Comparative Cognition

Another approach that has been taken in assessing metamemory is the use of animal models. Since animals cannot speak, the only way they can show metamemory ability is behaviorally. Most animal studies have looked at metamemory either as a part of metacognition, in order to place phylogenetically where metacognition evolved, or in order to assess the animals' own abilities (Smith, Shields & Washburn, 2003). These approaches, if they successfully assess metamemory in animals, may be adapted in order to assess metamemory nonverbally in humans. Bebko and colleagues (2014) suggest that the apparent lack of improvement in metamemory skills in children with ASD (despite training in the use of strategies) may be due to the lack of an appropriate measure for metamemory. They suggest turning to the animal literature, from which I'll briefly review the most promising directions in metamemory research.

Animal research in metamemory has ranged from studies on animals such as pigeons to monkeys and apes. Many of the following animal studies use a delayed matching to sample task (e.g. Inman & Shettleworth, 1999). These studies consist of showing the subjects (in these cases, an animal) a stimulus, followed by a delay. After the delay, the participant has to choose the stimulus seen earlier from among a set of response stimuli (in animals such as birds, they are trained to peck the responses). Pigeons may be a surprising candidate for possessing metamemory abilities, and indeed the results are tenuous at best and highly debated.

Inman and Shettleworth (1999) trained pigeons on a delayed matching to sample task with a 6 pellet food reward for pecking the correct button; for choosing an incorrect option, they would get no pellets. After training the pigeons on these contingencies, the experimenters made available another option that appeared alongside the other possible response buttons – a relatively less risky option (called the "safe option"), where the pigeons could choose another response that would offer a much smaller reward than choosing the correct option. The pigeons chose this option on trials that had lengthy delays or if there were many possible responses in the response set (i.e. on those trials that were the most difficult). This might have indicated metamemory abilities but the authors themselves acknowledged other, more likely explanations.

A follow up study had the same paradigm, but the pellet reward amounts were varied (Sutton & Shettleworth, 2008). For example, in one variation, choosing the third option (that always resulted in a smaller reward than the correct option), the pigeons were rewarded with five pellets compared to six for the correct one. In short, it would almost always have been beneficial to choose the safe option in this scenario, rather than risk choosing an incorrect option since the reward for this option was almost identical to the reward for choosing the correct response. However, like in the first paradigm, the pigeons continued to choose the third option only when delays were long, revealing that associations likely persisted from earlier training, and that various stimulus options were associated with varying delays. In this instance, it was likely that the pigeons were using associative learning to decide when to use the safe option, rather than demonstrating their metamemory.

A similar task was used to study metamemory in crows (Goto & Watanabe, 2012). The authors used 2 kinds of delayed matching to sample tasks. In the first task, there was a start signal followed by a study phase, where the crow could look at a stimulus to be remembered, followed by a delay (varying between 1 and 32 seconds). After the delay, there was the choice phase where the crow had to indicate (by peck) whether to see the test phase (where the crow would have to select the stimulus that matched the one presented earlier from a set of other stimuli) or to "opt out" and get a smaller reward. They called this the "prospective metamemory task" since the crow had to make a choice before seeing the test phase (i.e before seeing the response stimuli), whether to begin the phase or to opt out and get the smaller reward (making the choice before seeing the response stimuli means the crows would make a prospective "judgement" about their knowledge of their own memory).

Goto and Watanabe (2012) also had another condition where the crows could see the options in the test phase, select an answer, and then indicate whether they would "continue" or "opt out", which was called the retrospective memory task (since the crows had already seen the test stimuli). This almost acted as a confidence judgement (Smith *et al*., 2003). In order to ensure that any results found in this manner would not be due to association, Goto and Watanabe (2012) added a clever twist. On some trials in both the prospective and retrospective and memory tasks, there would be no study phase. This meant the crows would see the start signal, immediately followed by the delay of varying lengths, which they named the "omission trials" since the initial stimulus presentation (the stimulus to be remembered) was omitted. Again in the prospective condition, the crows would have to choose whether or not to see the stimuli for responding. In the retrospective condition, they would choose their answer and then choose whether to opt out or not – a confidence judgement.

Given the complete lack of information in these omission trials, someone monitoring their own memory would decide to opt out every time on an omission trial. The crows showed an interesting pattern. In prospective trials, the crows did not opt out at any different frequency on omission trials compared with regular trials that showed the initial stimulus (Goto & Watanabe, 2012). Presumably, a being with a strong awareness of their memory would always opt out on an omission trial, since there was no initial stimulus presentation and thus it would be impossible to pick an appropriate answer from the response set. However, in the retrospective memory trials, the crows chose to escape significantly more often in the omission trials, regardless of the length of the delay. This indicates they might have had some awareness that they had not seen the stimulus in the test phase and thus were able to choose to escape despite any sort of association with delay length they might have developed.

However, the question remains about why they were unable to monitor their memories in this manner in the prospective phase. The authors suggest that this may be due to the prospective memory task causing "uncertainty" before the opt out/do not opt out choice had been made. It may be a more difficult task to predict what happens next in the experimental task, compared to being aware that you had not seen any of the presented stimuli. It may be quite a while before we definitively decipher the cognitive abilities of animals, especially of those that are so far removed in phylogeny from humans. In contrast, animals such as primates have long been believed to have some metacognitive ability (Metcalfe, 2008). Abstraction abilities such as using symbols to communicate language have been observed occasionally (Lyn, Greenfield, Savage-Rumbaugh, Gillespie-Lynch & Hopkins, 2011). Because primates are more related to humans phylogenetically, research done in this area may be more applicable in developing nonverbal measures of metamemory.

Metamemory in primates. Several studies have looked at the metamemory capabilities of monkeys. Paradigms such as the delayed match to sample tasks with birds, described above, have also been used with monkeys (Tanaka & Funahashi, 2012). The monkeys were also able to complete the tasks successfully; however, as discussed above, this may be due to associative memory abilities. One popular paradigm that does not use the delayed matching to sample task, uses foraging behaviors to assess metamemory. Hampton, Zivin and Murray (2004) had four tubes that were completely opaque. On most trials, an experimenter would bait one tube with food without the monkey observing it. The monkey would then check all four tubes until it found the food. After it had learned this pattern, on some trials the monkey would be able to observe the experimenter bait the tube. The monkeys, on these trials, consistently went to and looked at the tube that they saw being baited first. However, unlike the authors' initial claims, this may be explained as the use of a visual search strategy that incorporates the primates' memory of what they had observed earlier without using any metamemory or metacognition (Hampton, 2009).

A more convincing demonstration of metamemory using monkeys utilized a modified version of the delayed match to sample task (Basile, Schroeder, Browm, Templar & Hampton, 2015). Instead of an escape or opt-out option like the crow experiments had, the monkeys were given a "relearn" option; that is, they were allowed to see the stimulus again (and had to re-experience the delay). There was no consequence for choosing the relearn option, other than having to experience the delay again before receiving their reward.

As was the case with the pigeons, it was still possible that the monkeys were simply associating longer delays with choosing the relearn option. To account for this, the experimenters also used trials where there were more stimuli, thus making the task more difficult, but with a smaller delay. An animal that had simply learned the association with longer delays would have responded based on an association with the delay and not the number of response stimuli. The experimenters were very thorough and manipulated the delay, reward and the number of responses to choose from in order to ascertain whether the monkeys had associated any of these task characteristics (delay, reward, responses) with choosing the "relearn" option. The monkeys only chose to relearn when the task was difficult and not with any particular task characteristic, meaning they most likely had awareness of their memory. The clever ways in which metamemory has been assessed in animals gives us insight into the next steps that might be taken with the assessment of metamemory in populations whose verbal abilities are or may be compromised.

Research Goals and Hypotheses

The overall aim of this study was to develop a behavioral measure of nonverbal metamemory. Adapting the delayed match to sample (DMTS) tasks used in animals (Goto & Watanabe, 2012; Basile et al., 2015), the primary goal is to develop a valid measure of metamemory that can be administered without verbal instructions. Convergent validity was assessed based on participant responses on this task with established metamemory questionnaires. If successful, in future studies this measure can be used in populations such as those with ASD, young children with limited language, or elderly populations with metacognitive deficits (such as in Alzheimer's dementia; for a review see Bertrand, Landeira-Fernandez & Mograbi, 2016) to measure metamemory ability or gains in metamemory without relying on language. Since this experimental metamemory task is intended to be a nonverbal analogue of the verbal metamemory tasks, I hypothesized that nonverbal measurements of metamemory will share correlations with verbal measures of metamemory. However, given the separation from language which may contribute to the variance seen in verbal measures, this relationship might be small to moderate.

A secondary aim of the proposed study is to examine the relationship between metamemory measured nonverbally and autism-like traits present in a non-clinical sample. Since the literature on autism and metamemory is inconclusive (possibly because of confounding language ability as mentioned earlier), it is difficult to predict the relation to autism-like traits. However, given the general deficits of theory of mind in autism and how some researchers posit that both metamemory and theory of mind fall under one cognitive category of meta-knowing, I hypothesized there will be a negative correlation of autism-like traits with verbal measures of metamemory. These traits will be measured with a questionnaire designed to assess autism-like traits in a typical adult population.

Finally, because this study will examine typically developing populations, participant responses on the verbal measures may be associated with language abilities. The nonverbal measurements, since they do not depend on language, should not be correlated to measures of language.

Methods

Participants

43 participants were recruited from the undergraduate research participant pool (the URPP) at York University. Participants were between the ages of 17 and 39, and had normal to corrected vision. The mean age was 20.55 years (*SD* = 3.45). There were 24 females and 19 males. All participants reported fluency in English.

Measures

Wechsler Abbreviated Scale of Intelligence – Second Edition (WASI-II; Wechsler, 2011). The WASI is an abbreviated test of intelligence, containing 4 subtests designed to provide an accurate measure of IQ for a typically developing population in between the ages of 6 and 90. This measure provides a verbal reasoning score, a performance score and a full-scale score of IQ and is relatively quick to administer (approximately 30 mins). For this study, I will use the 2-subtest version of the WASI, which includes the Vocabulary and Matrix Reasoning subtests. Both the 2- and 4-subtest version are known to correlate well with other measures of intelligence and in this study the briefer form helped to prevent participant fatigue (McCrimmon & Smith, 2013).

The Autism Spectrum Quotient (AQ; Baron-Cohen, Wheelwright, Skinner, Martin & Clubley, 2001) is a 50-item questionnaire that can be completed in under 20 minutes. For this study, the 10 item short form of the AQ was used (Allison, Auyeung, & Baron-Cohen, 2012). The short form of the AQ has been demonstrated to be effective in screen for autism and in identifying the presence of autism-like traits (Sizoo et al., 2015). The AQ is a measure of autism-like traits and was designed primarily as a screening tool for autism but has also been used by the test developers with non-ASD adult samples, such as university students, to identify the degree to which ASD-like characteristics are present in the general population. Participants were assigned of a score of "1" or "0" on each question (though some items are reverse scored) and a high score reflects the presence of more autism-like traits.

The Expressive One-Word Picture Vocabulary test – Fourth Edition (EOWPVT-IV; Brownell, 2011) is a measure of verbal ability, specifically expressive vocabulary. Participants named pictured items with one word in a series that becomes progressively more difficult. Participants are awarded a point for each word they correctly identify.

The Metamemory Inventory – (MMI; adapted from Flavell & Wellman, 1977; Bebko, Rhee, McMorris & Ncube, 2015) is a series of questions assessing participants' knowledge of his or her own memory and to evaluate the usefulness of strategies such as categorization or rehearsal. Participants were asked whether certain groups of items from a set are easier to remember, how many stimuli they predict they can remember, and how they would remember difficult instructions, with points being awarded for answers that indicate metamemory knowledge. This measure is typically used with children, but since this study tested adults, we used a more difficult version of the MMI (i.e. participants were asked to predict how many words out of a set they will remember; in the child version, there were 8 words in the set, the adult version had 16 words in order to avoid ceiling effects). Participants were given points for their answers if they indicated evidence of metamemory as well as for correctly identifying the number of items they remembered (or for being close). The questionnaire is included in *Appendix A*.

Multifactorial Memory Questionnaire – (MMQ; Troyer & Rich, 2002) was a self-report measure of metamemory. For this study the *How I Feel About my Memory* subscale was used. This subscale consists of 18 items on a 5-point scale from "Strongly Agree" to "Strongly Disagree". The measure is typically used with middle-aged or older adults to assess self-reported confidence in memory. The subscale used in this study is included in *Appendix A*.

Delayed Matching to Sample – (DMTS; adapted from Goto & Watanabe, 2012) was used as the nonverbal behavioral measure of metamemory. In order to differentiate metamemory from language ability, a version of the DMTS task was adapted to assess metamemory nonverbally.

Since the task is novel, it will be described in detail here. The task operated like a simple game, where the participant had to choose the correct stimulus from a response set, with a correct choice rewarded with game coins. The task itself began with a fixation cross on a computer screen that depicted a forest environment, followed by a single stimulus to remember. Simultaneous with stimulus presentation, a small figure appeared on the screen carrying five coins in his hand (see Figure 1). After the stimulus disappeared, there were delays of varying length, where the screen would have the small figure running. The purpose was to keep the participant relatively engaged during the delays (compared to a purely black screen). The delay may be 2, 15, or 25 seconds long to vary the difficulty of remembering after the delay.

After the delay, the figure stopped running and was able to "view" the response set which appeared on the screen. The participant was then able to use the mouse to choose the original stimulus out of a picture set of 4 or 8. The stimuli and the responses consist of geometric shapes (such as a pattern of squares or triangles) and other complex images (such as tessellations), and are similar to those used in other DMTS tasks (Goto & Watanabe, 2012; Sutton & Shettleworth, 2008, etc.). The response items within sets had small differences among them, with minor elements changed (e.g. a square has a different size or is in a different location within the item). If the participant chose correctly, s/he was awarded the five game tokens/coins that the character in the game was carrying; an incorrect answer resulted in no coins. On testing trials, another option was present after the participant had made a choice and before feedback about accuracy was given: a small signpost pointing backwards. If participants selected this option, they were taken back to the original stimulus screen but lost two coins (in order to view the stimulus again) and experienced another delay of 5 seconds of the figure running. After this, they were presented with the same response options as before. If they responded correctly after having used the back option, they receive the three remaining coins. If they answered incorrectly they received zero coins. To keep the participants motivated, the coin count was shown at the top of the screen and the entire experimental task was presented in the form of a game.

Three indicators were selected as measures of metamemory ability from the delayed-match-to-sample task. First, drawing from the comparative cognition literature, the overall number of trials when the animals in those studies chose to go back (or have another look, or "escape" and make no decision) has been considered an indicator of metamemory (denoting hesitation, and thus possible awareness of their memory when choosing responses). For this study, the first measure of metamemory from the task was the number of times the participants chose to go back and look at the original stimulus. In line with previous research, this was assumed to be a measure of uncertainty, incorporating hesitation and awareness of memory.

Secondly, the percentage of responses that the participant was able to identify correctly after having gone back was also an indicator of metamemory. For the validation of this new measure, the percentage of correct responses after having gone back was compared to the verbal metamemory inventory. One part of the MMI involves asking participants to estimate how many items (simple words) out of 16 they will remember. This portion of the measure asked participants to make an ease of learning judgement; according to Smith and colleagues (2003), a similar demand was being made of animals during the DMTS task (like the one used in this study) when they choose to go back at a cost (i.e. they are deciding how likely they are to learn the information upon reviewing it). Therefore, the percentage of responses that the participant was able to identify correctly after having gone back allowed for the examination of a type of metamemory that more closely approximates the behavioral aspects of the MMI (NB: the complete MMI used in this analysis also uses other, non-behavioral items).

The final measure of metamemory that was derived from this task is similar to the percentage of correct responses after going back: the improvement in memory due to having looked at the original stimulus again. The percentage of times where the participant went back and chose the correct answer after initially (on the same trial) having chosen an incorrect answer was considered (during the DMTS an answer was chosen before the participant was allowed to choose the option to go back). This allows a functional indicator of the benefit of having gone back to be calculated. This indicator is called *improvement in recall*.

Procedure

Participants were recruited through an undergraduate research pool at York University. Participants received partial course credit for their participation. Consent was obtained from the participant after the general structure of the study was explained to them. Each participant completed the WASI, the EOWPVT, the AQ the MMQ and the MMI in that order. After this, the experimenter informed the participant that the next stage required them to complete a task whose objective will become evident. They were told not to ask any questions regarding the task, and that the task would be completed on a computer.

The participants then began the DMTS task. Initially there were three training trials to acquaint participants with the task. In the first two training trials, participants were free to choose the correct matching response. If they chose an incorrect option, the correct option was highlighted (with a brief flash). For these two initial training trials, the escape option was not present. Then, in the third training trial, regardless of the answer the participant chose, the back option (on a signpost) was highlighted by a brief flash in order to acquaint participants with the function of that option. They were then taken back to the stimulus and experienced another delay, this time for 5 seconds. After these three training trials, they began the testing trials. There

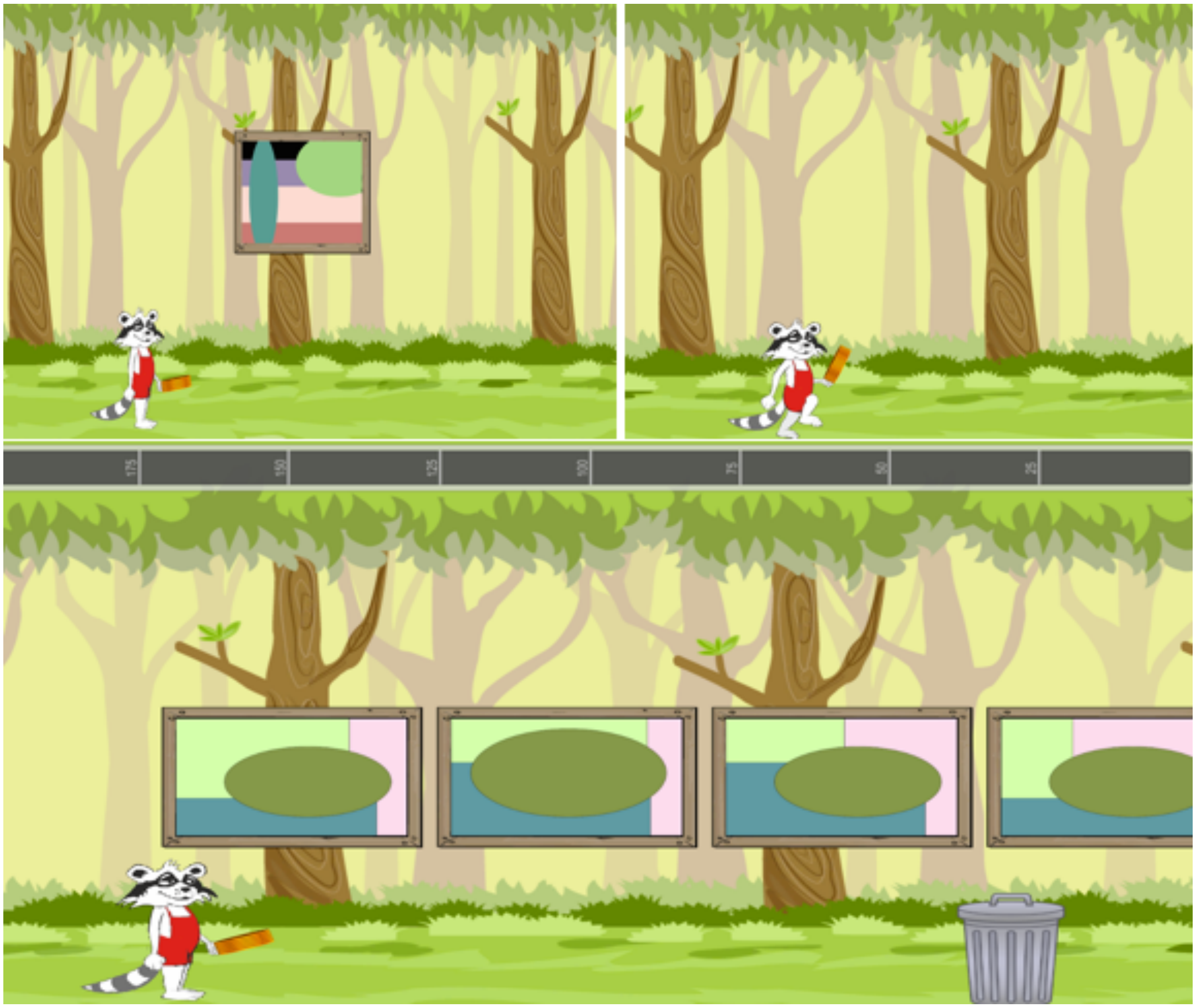

Figure 1: Panels from the DMTS task. Top-left panel depicts the small figure at the original stimulus with coins in hand. Top-right panel shows the figuring running during the delay period. Bottom panel shows the figure “looking” at a different set of response stimuli. At the top of the bottom panel is a counter keeping track of coins. To the right of the image is a garbage can, into which the coins go if an incorrect choice is made.

were 48 testing trails (divided equally among 2, 15 and 25 second delays and sets of 4 and 8 stimuli). Both the variation in time and in the number of stimulus choices affected the difficulty of the task. However, the added benefit of varying the stimulus sets also helped to ensure that associations are not made solely between the length of the delay, and choosing to re-look at the stimulus.

Participants were awarded five coins for a correct reply without going back, three coins for a correct reply after using the back option and zero coins for an incorrect response in either case. As they were received, the coins filled a counter at the top of the screen that kept a count of the coins received up till that point. The counter indicated "x/250 coins", suggesting that the game would be over when they received 250 coins. This was to motivate participants to provide the correct answer. Regardless of their response, however, they finished the task after 48 trials. After the task was completed, participants were debriefed and told the purpose of the study. The procedure lasted between 1.5 and 2 hours in its entirety.

Results

Age was not correlated with any of the main memory or metamemory measures. Similarly, there were no sex differences among any of the memory or metamemory measures. Males were likely to score higher on the Autism Spectrum Quotient than females ($t(41) = 2.11$, $p = 0.04$) as is consistent with other studies (Baron-Cohen *et al*., 2002).

Task characteristics

The average number of matches the participant made correctly to the original stimuli was 32.35 (*SD* = 4.30) out of the 48 total trials. Participants took an average of 8.30 seconds to make a choice (*SD* = 2.65). The preceding means and standard deviations pertain to the time and accuracy of the choice participants made initially, that is before going back and re-looking at the original stimulus. Participants had the option once per trial, after having chosen a response from the response set, to choose to go back and view the original stimulus after which they could then make another (or the same) choice. The average number of times the participants went back was 8.58 (*SD* = 6.40) out of the 48 total trials, representing 17.88% of the trials.

Table 1 and *Table 2* summarize the means and standard deviations of each condition in terms of average time to make the initial response, the number of correct responses the first time on each trial, and the number of times the participants went back to look at the original stimuli.

Table 1

Means and standard deviations of the average time in seconds to make a response, the number of correct responses, and the number of times participants chose to go back and look at the original stimulus at each level of delay time.

	2 seconds	15 seconds	25 seconds
Average time (seconds)	7.28(2.08)*	8.67(2.54)	8.96(3.00)
# of correct responses	12.44(2.22)*	11.00(2.18)[a]	8.91(1.78)
# of times participants went back	2.56(2.02)*	3.00(2.60)	3.02(2.70)

* = significantly different from the 15 and 25 second conditions
[a] = significantly different from the 25 second condition

Table 2

Means and standard deviations of the average time in seconds to make a response, the number of correct responses, and the number of times participants chose to go back and look at the original stimulus in the 4 and 8 stimuli conditions.

	4 stimuli	8 stimuli
Average time (seconds)	7.56(1.97)*	9.41(2.61)
# of correct responses	17.70(2.72)*	14.67(2.73)
# of times participants went back	4.17(3.17)	4.41(3.34)

* = significantly different from the 8 stimuli condition

An initial MANOVA examined the time conditions and the number of response options as covariates for each of the three of dependent variables (average time to respond, number of correct responses and number of times the participants went back). The MANOVA revealed a non-significant interaction between the time conditions and the number of response set options

($F(5,37) = 1.82$, $p = 0.13$). However, each of the conditions were significant for each dependent variable; follow up univariate tests were conducted.

A series of repeated measures ANOVA tests were conducted to examine differences among the different time conditions (2, 15 or 25 seconds) for average response time for each condition, the number of correct answers, and the number of times the participants chose to go back. A repeated measures ANOVA revealed an effect of time condition for average response time ($F(1,42) = 19.51$, $p < 0.001$). Pairwise t-tests revealed the average response time in the 2s condition was lower than in both the 15s and 25s conditions ($t(42) = 3.65$, $p < 0.001$; $t(42) = 4.42$, $p < 0.001$). No differences were found for average response time between the 15s and 25s group ($p = 0.37$; see *Fig. 2*).

A repeated measures ANOVA revealed an effect of time condition for the number of correct responses ($F(1,42) = 75.05$, $p < 0.001$). Pairwise comparisons revealed that the average numbers of correct responses in the 2s condition were higher than the average number of correct responses in both the 15s and 25s conditions ($t(42) = 3.53$, $p < 0.001$ and $t(42) = 8.66$, $p < 0.001$ respectively). The 15s condition also had more correct responses than the 25s condition ($t(42) = 5.72$, $p < 0.001$; see *Fig. 3*).

Finally, a repeated measures ANOVA also revealed an effect of time condition for the number of times the back option was selected ($F(1,42) = 18.89$, $p < 0.001$). Pairwise comparisons revealed that number of times the participant chose to go back in the 2s condition was lower than the number in the 15s condition ($t(42) = 2.09$, $p = 0.04$) but was not significant compared with the 25s group ($t(42) = 1.75$, $p = 0.09$). There was no difference between the 15s and 25s group ($p = 0.92$; see *Fig 4*).

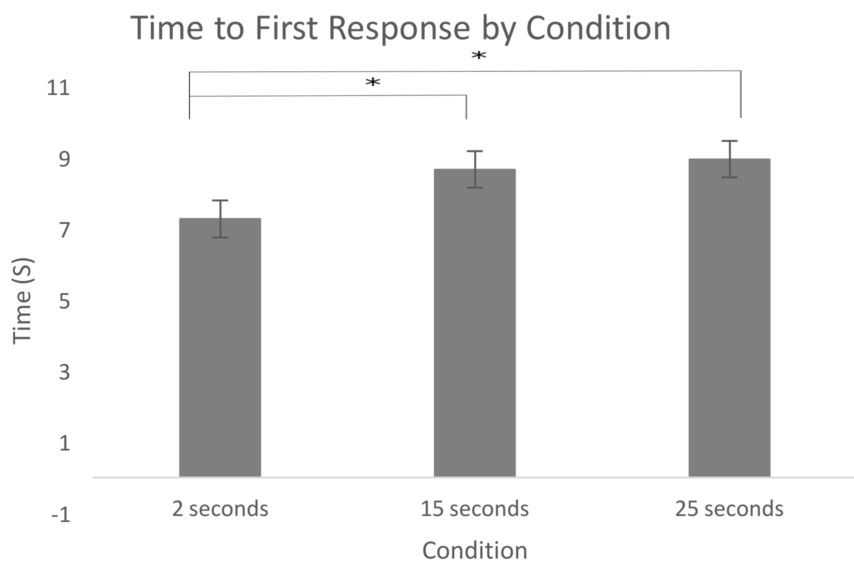

Figure 2: Average time taken for participants to select their response from the response stimuli based on the delay trial condition. Standard error bars are shown.
* denotes significance at p = 0.05 level for all the above graphs

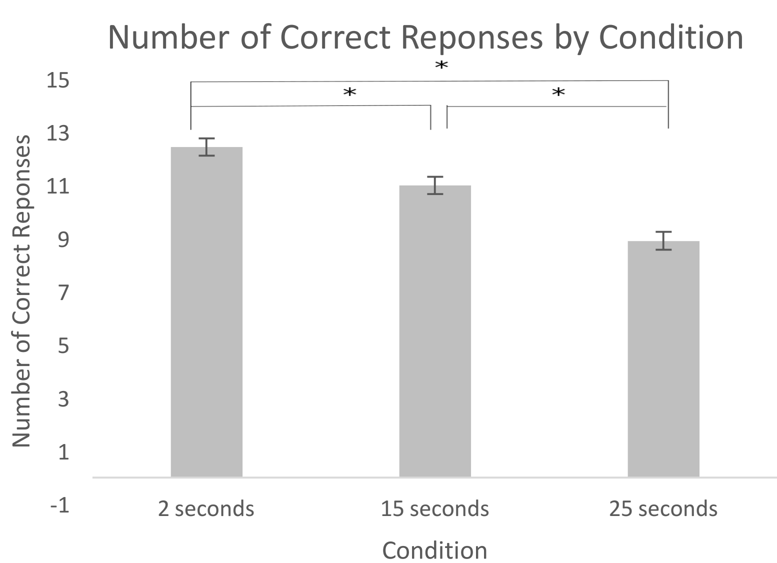

Figure 3: Average number of correct responses selected by the participant in each condition. Standard error bars are shown.
* denotes significance at p = 0.05 level for all the above graphs

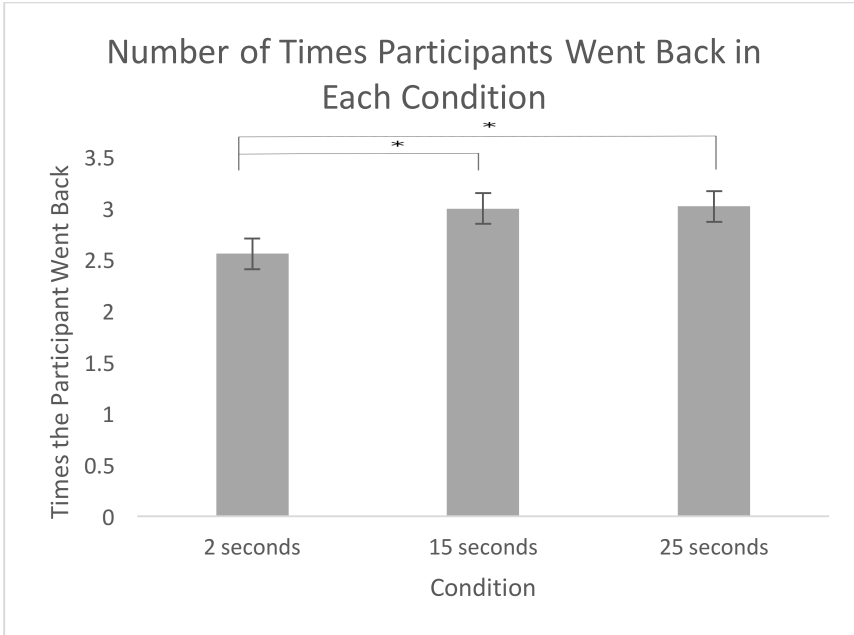

Figure 4: Average number of times the participants chose to go back and look at the original stimulus in each condition. Standard error bars are shown.
* denotes significance at p = 0.05 level for all the above graphs

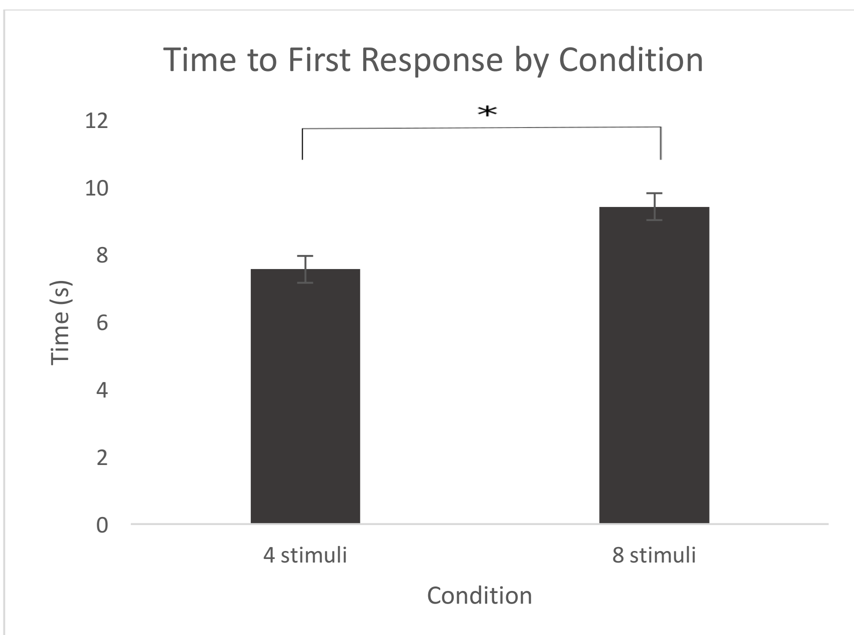

Figure 5: Average time taken for participant to select their response from the response stimuli based on the number of response options. Standard error bars are shown.
* denotes significance at p = 0.05 level

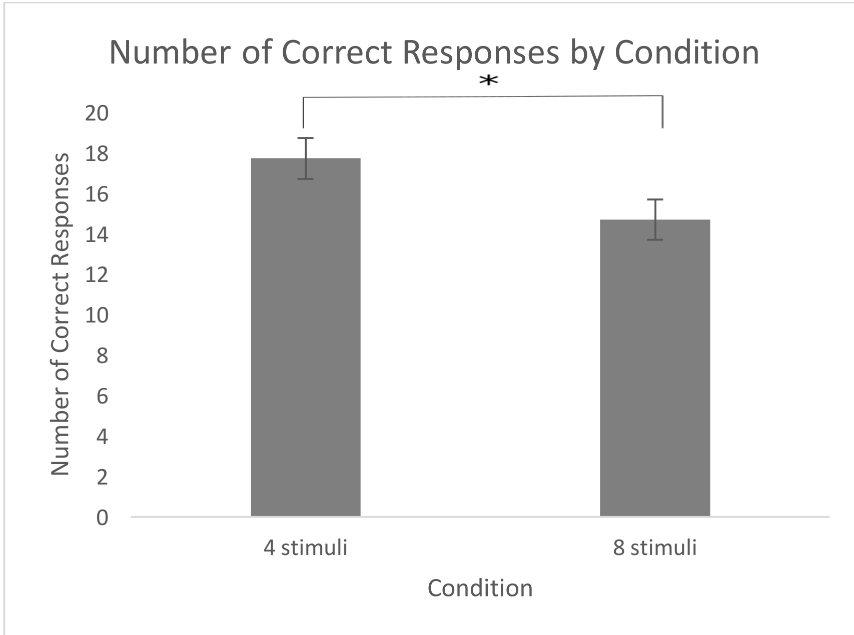

Figure 6: Average number of correct responses selected by the participant with each number of response options. Standard error bars are shown.
* denotes significance at p = 0.05 level

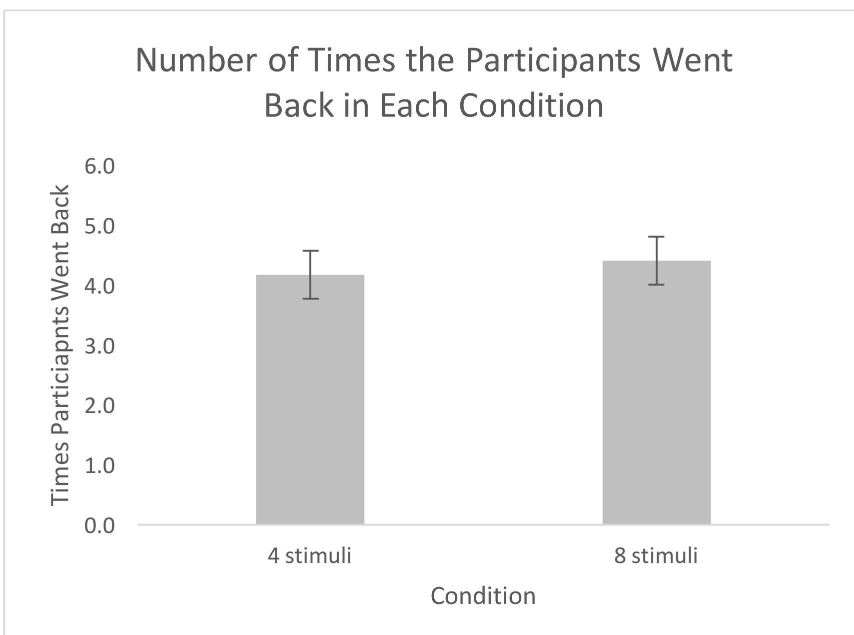

Figure 7: Average number of times the participants chose to go back and look at the original stimulus by the number of response options. Standard error bars are shown.

Paired sample t-tests were also conducted to look at differences between participant responses (again, the average response time, the number of correct responses and number of times the participant chose to go back) in the 4 stimuli and 8 stimuli conditions. A t-test revealed a significant difference between the 4 and 8 stimuli conditions for both response time ($t(42) = 7.55$, $p < 0.001$; *Fig. 5*) and number of correct responses ($t(42) = 5.95$, $p < 0.001$; *Fig 6*). However, there was no difference in the amount of times participants chose to go back to look at the original stimulus in the two conditions ($p = 0.40$; *Fig 7*).

Validity of the DMTS task

Three indicators of metamemory (described in detail beginning on page 15) were used from the DMTS task to examine metamemory. The first was the number of times the participant chose to go back. Second, after having gone back, the percentage of correct answers was considered. Finally, the number of times the participant's answer improved (i.e. their answer choice went from incorrect to correct) was considered.

The total number of times the participant chose to go back was correlated with the participant's responses on the MMI ($r = 0.45$, $p < 0.01$; *see Fig. 4*) and approached significance with the MMQ ($r = 0.27$, $p = 0.08$). For both the MMI and the MMQ, higher scores reflect more awareness of their memory (or self-reported awareness in the case of the MMQ). The MMI and the MMQ were not significantly correlated with each other ($r = 0.28$, $p = 0.07$). The percentage of correct responses after going back was significantly correlated with the MMI ($r = .55$, $p < 0.001$), but not with the MMQ ($r = 0.23$, $p = 0.14$). Similarly, *improvement in recall* was correlated with the MMI ($r = .52$, $p < 0.001$) and again not with the MMQ ($r = 0.25$, $p = 0.11$). Correlations with the total number of correct responses the participant made initially, called *initial memory* (i.e. before going back, as a measure of total memory ability, not metamemory) are provided in Table 3 below.

Table 3

Correlations between measures of metamemory and memory.

	MMI	MMQ	# of times participant went back	% of correct responses after back	Improvement in recall	Initial memory (correct responses)
MMI	1	0.28	0.45**	0.55**	0.52**	-0.07
MMQ		1	0.27[a]	0.23	0.25	-0.09
# of times participant went back			1	0.34*	0.45*	-0.01
% of correct responses after back				1	0.83**	0.01
Improvement in recall					1	0.02
Initial memory (correct responses)						1

* = signicant at 0.05 level
** = significant at 0.01 level

Autism Spectrum Quotient

The short form of the Autism Spectrum Quotient (AQ) was used to assess autism-like traits in the sample. The short form of the AQ has been effective in screening for autism (Allison, Auyeung, & Baron-Cohen, 2012). Higher scores on the AQ reflect the presence of more autism-like traits. The average score for this sample on the 10-item scale was 3.70 (*SD* = 1.47) with five participants meeting the criterion for further testing for ASD (criterion identified by the authors

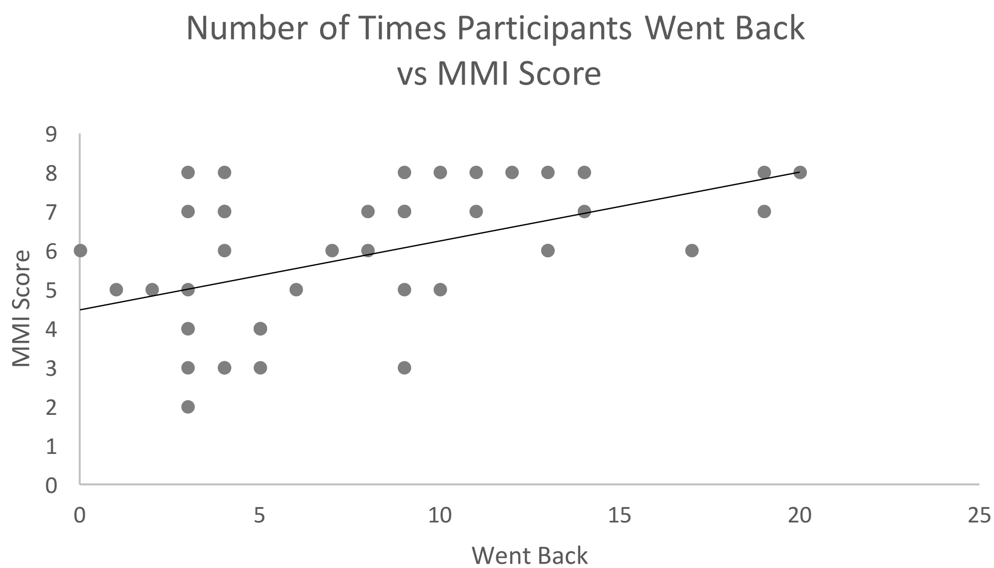

Figure 8: Scatterplot depicting the relationship between the number of times participants chose to go back and view the original stimulus compared with their MMI score.

was a score greater than six; that is, participants who endorsed six or more of the 10 items). The number of times the participant went back, the percentage of correct responses afterwards and *improvement in recall* were not correlated with the AQ (r = 0.12, p = 0.26; r = 0.22, p = 0.18; r = 0.11, p = 0.50). The MMQ and the AQ were not correlated either (r = -0.07, p = 0.67). The MMI however, did have a significant correlation with the AQ (r = -0.31, p = 0.04). That is, the higher the AQ score (more autism-like traits), the lower the MMI score (weaker metamemory abilities).

Table 4

Correlations of the metamemory measures with the Autism Spectrum Quotient.

	MMI	MMQ	% of correct responses after back	# of times participant went back	Improvement in recall
Correlation with AQ	-0.31	-0.07	0.22	0.18	0.11
Sig. 2-tailed	0.04	0.64	0.18	0.26	0.50

WASI subscales, FSIQ-2, and Expressive Vocabulary

In order to determine whether IQ and expressive vocabulary were not affecting metamemory on all the different measures (or vice-versa), the subtests from the Weschler Abbreviated Scale of Intelligence – Second Edition (WASI-II) and the Expressive One Word Picture Vocabulary Test – 4^{th} Edition (EOWPVT) were given to the participants. Average scores of the full scale intelligence quotient derived from the two subscales (FSIQ-2) was 102.63 (*SD* = 10.99). None of the metamemory measures, including the indicators derived from the DMTS task, were correlated with any of the *Vocabulary*, *Matrix Reasoning* or FSIQ-2 from the WASI-2 or the expressive vocabulary score from the EOWPVT. The *Vocabulary* and *Matrix Reasoning* subscales were not correlated with each other. The EOWPVT score was correlated with *Vocabulary*, *Matrix Reasoning* and *FSIQ-2* (r = 0.59, 0.49 and 0.68, all p < 0.001). The relationship between the total number of correct responses initially made (referred to as *initial memory*) and *Matrix Reasoning* approached significance (r = 0.23, p = 0.055).

Table 5

Correlations of metamemory and intelligence and vocabulary measures.

	# of times participant went back	WASI - Vocabulary	WASI – Matrix Reasoning	WASI-FSIQ-2	EOWPVT	Initial Memory (correct responses)
# of times participant went back	1	-0.04	-0.17	-0.16	-0.11	-0.01
WASI - Vocabulary		1	0.23	0.79**	0.59**	0.03
WASI – Matrix Reasoning			1	0.77**	0.49**	0.30
WASI-FSIQ-2				1	0.68**	-0.05
EOWPVT					1	0.21
Initial Memory (correct responses)						1

* = signicant at 0.05 level
** = significant at 0.01 level

Discussion

The primary goal for this study was to develop a measure of metamemory that does not rely on language. A delayed match to sample task (DMTS) was used, similar to ones developed in the animal literature (e.g. Goto & Watanabe, 2002). Participants were allowed to choose to go back and look at the original stimulus after looking at the response set at the cost of virtual coins (which were used as an in-task reward). Participants were not given any verbal instructions about the task before completing the DMTS task in this study; instead the first three trials were training trials where participants were allowed to become familiar with the task.

The task was constructed in order to have a mixture of easy and difficult items. To systematically adjust the difficulty, the initial delay after stimulus presentation was varied (there was either a 2, 15, or 25 second delay). As well, the number of response options from which the participant was asked to select the original stimulus was varied (there were either four or eight options). The 15 and 25 second conditions both proved to be more difficult than the 2 second condition indicated by the average amount of time participants took to make a choice, the number of correct responses participants made, as well as the number of times participants chose to go back and look at the original stimulus. Participants had the most incorrect responses in the 25 second condition, but among the other measures of difficulty (time to choose a response and the number of times they chose to go back), there was no significant difference between the 25 and 15 second conditions. A similar pattern was observed in the four vs. eight response stimuli conditions, where participants had the greatest number of correct responses and made their choices quicker in the four response stimuli condition compared to eight stimuli condition.

Generally, this pattern of results shows that DMTS task was functioning as intended, and the measures taken to vary the difficulty of the task were effective. However, differences between the 15 and 25 second conditions were not always observed. Much working memory literature suggests that the amount of time that people are able to hold information without rehearsal (or other strategies) is between 10-15 seconds (Portrat, Barrouillet & Camos, 2008; Luck & Vogel, 2013). Once the delay exceeded the usual assumed limit for working memory, memory performance was not affected by any more delay (i.e. 10-15 seconds additional delay time does not seem to increase the difficulty of the task).

There were no significant interactions between the delay length (2, 15, or 25 seconds) and the number of response stimuli (4 or 8 stimuli) for any of the difficulty measures (which were "time to make first response", "number of correct responses" and "times the participant went back"). This indicates that the combination of longer delay and greater number of response stimuli did not significantly increase the difficulty of the test beyond the individual effects of each. Overall, the task's characteristics are an appropriate reflection of the tasks seen in animal (Sutton & Shettleworth, 2008) and human literature (Amit, Yakovlev & Hochstein, 2013).

Validity

The validity of the DMTS task can be examined in several ways. Immediately apparent is the face validity. In the DMTS task, participants have to make a choice that allows them to choose to go back and look at the original stimulus or not. At the very least, the task is directly measuring the uncertainty of the participant in the response that they have selected. As long as participants are sufficiently motivated to complete the task well, they must access their metamemory and make judgments about whether they should continue with their answer or not.

Evidence for the convergent validity of the task with existing measures was also queried using the Metamemory Inventory (MMI) and the Multifactorial Memory Questionnaire (MMQ). In the MMI, participants answer questions that demonstrate their metamemory (e.g. by asking them to predict how many words from a set they will remember), while the MMQ requires participants to identify how strong they believe their metamemory is, through self-report on a Likert scale. Research comparing self-report measures and more behaviorally guided measures have shown weak or modest correlations in many domains (e.g. with ADHD, cf. Toplak, West, & Stanovich, 2013; with schizophrenia, cf. Elliott & Fiszdon, 2014; everyday functioning, cf. Schmitter-Edgecombe, Parsey, & Cook, 2011). In order to examine whether the self-report measures and the more behaviorally based measures would follow the same pattern seen in other cognitive areas, the relationship between the MMI and the MMQ was examined. The MMI and MMQ had a weak correlation with each other (r = 0.28) that was not significant.

The current DMTS task provides many different methods to assess metamemory, and the goal of this study was to provide a simple and effective way of doing this. The number of times the participant chose to go back to look at the original stimulus was chosen as the primary indicator of metamemory. Comparative cognition studies have used this to indicate how often animals experienced a state of uncertainty (e.g. Goto & Watanabe, 2002; Basile et al., 2015), in which the choice to go back (and having to experience some delay again) is assumed to be more desirable than choosing an answer at the cost of some reward.

Using this measure of metamemory, a score comprised of the number of times each participant chose to go back was assigned. The measure was significantly correlated with the MMI (r = 0.45) but the correlation with the MMQ was not significant (r = 0.27). Consistent with the correlation between the two validation measures, the behavioral assessment of metamemory given by this task was moderately correlated with the MMI, which is a combined questionnaire and behavioural measure, but did not share a significant correlation with the self-report score given by the MMQ. As mentioned earlier, this likely reflects the common lack of agreement found between behavioral measures when compared with self-report.

A second indicator of metamemory, the percentage of responses the participant answered correctly after going back, was significantly correlated with the MMI (r = 0.55). The rationale for this indicator was described earlier. In summary, different types of metamemory have been reported. The number of times the participant chooses to go back in the DMTS task has been conceptualized as an uncertainty judgement (Smith et al., 2013). In contrast, some questions of MMI require the participant to make an ease of learning judgement; that is, to reflect on how likely they are to learn a specified number of words from the list. In order to find an analogous measure in the DTMS task, I examined the percentage of times the participant made the correct response after going back. Participants who were most likely to go back in hopes they would then be able to identify the correct response would receive the highest scores on this measure if they were able to correctly assess their ease of learning.

The final indicator of metamemory derived from the DMTS task in this study was the improvement in recall. The function of metacognitive abilities is to improve cognition and the percentage of times memory recall was improved as a result of looking at the original stimulus again was calculated, and associations with the other metamemory measures were examined. Improvement in recall was significantly correlated with the MMI ($r = 0.52$). The significant correlations of the percentage of correct responses after going back, and improvement in recall with the MMI, lend evidence to the validity of the DMTS task as a behavioral measure of metamemory that does not rely on language. While correlations with the MMQ are generally non-significant, the discrepancy between self-report measures and behavioral measures are common (e.g. Elliot & Fiszdon, 2014).

The Autism Spectrum Quotient

Relationships with the AQ were also examined. Previous studies looking at metamemory in autism have found a deficit when not matching for verbal ability (Wojcik et al., 2013; Grainger et al., 2014). In contrast, when studies control for verbal ability, the evidence is mixed (Farrant, 1999). Bebko and colleagues (2015) have previously suggested that when assessing for improvements in metamemory, current instruments rely heavily on language and are likely to underrepresent the abilities of children on the autism spectrum. For this reason, this study included the AQ as a measure of autism-like traits in the general population. The MMI was found to have a small but significant negative correlation with the AQ (r = -0.31). All three indicators of metamemory given by the DMTS task were not significantly correlated with the AQ (r = 0.11 - 0.22). The MMQ was also not correlated with the AQ (r = -0.07).

The negative correlation with the MMI suggests that people with more autism-like traits may struggle with a verbal, behavioral task assessing metamemory. It is important to note that this was a sample of typically developing university students; a clinical sample with autism may have an even lower correlation on tasks similar to the MMI. On the other hand, there were only small, non-significant correlations with the DMTS and the MMQ. Since the MMQ is a self-report measure, when trying to measure improvements in metamemory after intervention or training, the MMQ is unlikely to be of objective use. The evidence for the validity of the DMTS, along with the lack of relation between the measure and autism-like traits, makes it a strong candidate for use when delineating the growth or improvement of metamemory apart from language.

Intelligence and Expressive Vocabulary

IQ, as measured by the WASI-II, and expressive vocabulary, on the EOWPVT, were used to determine whether they would have some relation to the various measures. The EOWPVT and the Vocabulary subtest on the WASI-II were significantly correlated with one another (r = 0.59). Since they were both measures of language based skills, this was expected. None of the metamemory measures, including the DMTS were correlated with either IQ or expressive vocabulary. It was likely that the lack of wide variability in IQ and language ability in the university sample used for the study contributed to the lack of correlations. If there was a more significant amount of variability in the IQ or expressive language ability, differences may be observed. Further, all participants were over 18 years old. A child's developing brain shows much variability relative to their peers in language development (Huttenlocher, Waterfall, Vasilyeva, Vevea, & Hedges, 2010) and different relationships between language dependent tests of metamemory and nonverbal tests of metamemory with IQ or language skills may be observed in those populations.

Memory

While it was not focal to this research, a total memory score was also able to be calculated through the DMTS task. In this task, participants would have to select a response and then choose if they wanted to go back or continue with their choice. This first response was either correct or incorrect and was recorded by the program as well. Participants' original responses were recorded even when they chose to go back and look at the original stimulus. Their total number of correct initial responses, or total memory, on this visual memory task was not correlated with any of the measures of metamemory (e.g. $r = -0.01$ with the number of times the participant chose to go back). Metamemory serves many functions for participants independent of overall memory ability (Short, Schatschneider, & Friebert, 1993; Cavanaugh & Perlmutter, 1982). For example, someone with a poor overall memory may use strategies effectively to compensate for deficits in their memory, demonstrating strong metamemory ability. Conversely, participants may also have a strong memory and have relatively little need to supplement their memory with effective strategies. On this task, someone who is unlikely to remember many visual images may choose to go back often, correctly reflecting their lack of knowledge as to what the correct answer is. Alternatively, someone with poor visual memory skills may rarely choose to go back, and thus demonstrate issues with metamemory in addition to memory. Given further variability in a broader sample, differences in memory ability may be associated with IQ as well because of the link between perceptual reasoning and visual memory.

In this study, IQ was not related to total memory. The Matrix Reasoning subtest of the WASI was not correlated with IQ ($r = 0.30$). Other tasks of visual memory have been associated with perceptual reasoning tasks (Jiang, Lee & Asaad, 2016), indicating an ability to detect patterns quickly may assist in remembering useful pieces of information in visual memory tasks.

Future Directions and Limitations

In summary, the pattern of findings in this study suggests that metamemory can be measured nonverbally. While there are correlations with verbal measures, the type of metamemory being assessed must be considered as well (uncertainty judgements, ease of learning judgements, etc.). In addition, the weak to moderate correlation suggests that there may be other components of metamemory that are uniquely associated with the nonverbal metamemory measure. Still, the nonverbal DMTS task outlined in this study seems to be a strong indicator of metamemory, robust against the influence of other traits present in the broader autism phenotype.

However, given the lack of variability in the task in terms of the language ability and IQ of the participants, it is difficult to know what relation, if any, there is among these variables and metamemory. One hypothesis of the study was that verbal measures like the MMI are associated with language and/or IQ measures, and that this could result in an important confound when studying clinical populations such as autism that have associated deficits in language or cognitive ability (for a summary, see Leekam, 2007). It is difficult to know if these relationships exist; given the lack of variability found in language ability and IQ in this study, no evidence of this relationship was found. Furthermore, language is a complicated construct and this study did not take into account other aspects of language (such as semantics).

The original inspiration for the study and the DMTS task came from the autism literature. This study lends to the evidence for the validity of the task as a measure of metamemory. It also raises some warnings that the traits found in autism may have an impact on verbal measures of metamemory, which are not necessarily found in the nonverbal task outlined in this study. Specifically, since the MMI was negatively correlated with the AQ, it may be the people with some of the traits found in the broader autism phenotype have a difficult time answering the (verbal) questions that ask them to posit a future mind state (i.e. how many words they will learn or which set of items will be easier to remember). This difficulty does not seem to persist in the nonverbal task.

Future studies looking at levels of metamemory in autism should endeavor to use a nonverbal approach in order to limit the effects of language impairment and determine true metamemory deficits. The evidence of a metamemory deficit in autism is equivocal (e.g. Grainger et al., 2014; Farrant, 1999) and a task similar to the one outlined here can help to separate language and metamemory abilities. Language and metamemory ability are known to be linked in development (Cantor et al., 1985; Harris, 2000) and a method of studying metamemory independent of language ability can help elucidate its developmental trajectory. Some evidence shows that language development precedes metamemory in young children but studies have traditionally needed to rely on questionnaires and other verbal methods of eliciting this information (e.g. Ebert, 2015).

Further, many studies have targeted memory in autism (Chan, Han, Sze & Lau, 2015; O'Hearn, Schroer, Minshew & Luna, 2010). There is evidence that children with ASD have difficulty using memory strategies (Maister, Simons & Plaisted-Grant, 2013; Bebko et al., 2015; Bebko, Dahary, Goldstein, Porthukaran & Ferland, in prep). Recently, researchers have tried to encourage children with ASD to utilize memory strategies with success (Bebko et al., 2015). However, even when spontaneously using strategies they were not using before, these children do not demonstrate any change in their metamemory ability. Because of the measures assessing metamemory in these studies, it is difficult to know whether children with ASD do not show improvements because of language difficulties. The research described here indicates that a nonverbal approach in studying their ability might be more reflective of their skills compared with the verbal approaches that were previously available. Changes occur in their awareness of their memory and the knowledge of when to use learned skills, and the DMTS task allows us an opportunity to measure this.

There are several limitations of this study, some of which are common to many studies of metacognition. A task asking participants to go back and look at the original stimulus assumes that the reason the participant chose to do this is because they were uncertain about their response. Positing their mental state is problematic. Converging evidence with other indicators of metamemory lends some evidence to the assertion; however, in future studies, researchers should ask participants to identify the reasons for which they chose to go back. Similarly, participant feedback about what they thought about their chances of later selecting a correct answer when they choose to go back can provide us with information about whether they were making ease of learning judgements. However, some evidence indicates that people may choose to make decisions based on general feelings of uncertainty, which these participants have not directly self-identified as related to metamemory (Han, Li & Liu, 2003). Future studies must take into consideration participant responses very carefully.

There are different types of metamemory as mentioned in the study, and care must be taken when comparing tasks across these functions. Evidence that types of metamemory converge is present (Smith et al., 2003) and the results of this study lend some further evidence to this conclusion. However, tasks that assess a variety of responses that investigate metamemory may be necessary to explicate the full nature of these abilities.

Finally, the sample used in this study consisted of a narrow range of participants in terms of age and IQ. Other research has demonstrated that typically studies using university samples have socioeconomic status, education, and other factors that do not reflect the population in general (Delice, 2010). In the study of the development of metamemory and its relation to variables such as language, a more diverse sample will likely lead to additionally informative data.

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Appendix A

Metamemory Inventory

Is one of these groups easier to remember? If yes, which one?

Why?

Is one of these groups easier to remember? If yes, which one?

Why?

I am going to read to you a list of 16 words. At the end, I'll ask you to try and remember as many words as you can. You don't need to say them in order. How many words do you think you'll remember?

1 time
2 year
3 man
4 life
5 child
6 way
7 state
8 group
9 hand
10 part
11 room
12 book
13 eye
14 job
15 kind
16 name

Now tell me as many as you remember.

Did you use any particular strategy to remember the words?

Were there any words you hadn't heard before?

What would you do if you had to remember something difficult?

MMQ

Participants were asked to rate the following items on the point scale given below:

Strongly Agree Agree Undecided Disagree Strongly Disagree

How I Feel About My Memory

Below are statements about feelings that people may have about their memory. Read each statement and think about your feelings over the past *two weeks*. Then, check the box next to the response that best describes how much you agree or disagree.

1. I am generally pleased with my memory ability.

2. There is something seriously wrong with my memory.

3. If something is important, I will probably remember it.

4. When I forget something, I fear that I may have a serious memory problem, like Alzheimer's disease.

5. My memory is worse than most other people my age.

6. I have confidence in my ability to remember things.

7. I feel unhappy when I think about my memory ability.

8. I worry that others will notice that my memory is not very good.

9. When I have trouble remembering something, I'm not too hard on myself.

10.I am concerned about my memory.

11.My memory is really going downhill lately.

12.I am generally satisfied with my memory ability.

13.I don't get upset when I have trouble remembering something.

14.I worry that I will forget something important.

15.I am embarrassed about my memory ability.

16.I get annoyed or irritated with myself when I am forgetful.

17.My memory is good for my age.

18.I worry about my memory ability.

Appendix B

Nonverbal Assessment of Metamemory – Consent Form

James Bebko
PhD – Professor
Clinical Developmental Psychology

Alex Porthukaran
Masters' Candidate
Clinical Developmental Psychology

Purpose of the research:

The purpose of this study is to measure metamemory (the awareness and understanding of one's own memory) nonverbally using an experimental measure and to compare these to measures of intelligence, verbal ability and autism-like traits. This research will ask give us further understanding on how metamemory relates to language.

What you will be asked to do in the research:

Participants will be required to complete standardized measures of IQ and verbal ability. During these, an experimenter will ask you questions, have you form shapes with blocks and choose the correct answer from a set of responses. Then you will complete a questionnaire about memory. After this, you will be asked to play a game where the purpose is to collect enough coins to finish the task. The game will be simple and ask you to look at a stimulus and try and remember it. The entirety of the task should take less than 2 hours to complete with a break in the middle. For these 2 hours, you will receive 2 credits towards your PSYC 1010 class.

Risks and discomforts:

There are no risks associated with the study. However, the testing process might be long. For this reason, the experimental task in the second part of the study was designed to be played like a game.

Benefits of the research and benefits to you:

This research is novel and may help us to gain a deeper understanding of metamemory and how it relates to language and other important psychological constructs. Participating in this study also gives you some exposure into important psychological measures and a glimpse into how research is performed.

Voluntary participation:

Your participation in the research is completely voluntary and that participants may choose to stop participating at any time. Your decision not to continue participating will not influence their relationship or the nature of their relationship with researchers or with staff of York University either now or in the future.

Withdrawal from the study:

You may stop participating in the study at any time, for any reason, if you so decide. Your decision to stop participating, or to refuse to answer particular questions, will not affect your relationship with the researchers, York University, or any other group associated with this project. In the event that you withdraw from the study, all associated data collected will be immediately destroyed wherever possible. Even if you decide to withdraw, you will still receive your course credit for the PSYC 1010 class for agreeing to take part in the research project.

Confidentiality:

All data with identifying information will be replaced with an arbitrary code number to maintain confidentiality. No identifying information will ever be made public. Your responses to the tasks in this study will only be seen by members of this research team and will be stored in a sealed cabinet or on a password protected computer. Any research published will use group trends instead of individual data. Confidentiality will be provided to the fullest extent possible by law. Data and audio-video recordings will be stored for an extended period after the study to enable comparison and combination with data in future studies. Once all projects in this line of research have been completed, all data and recordings will be destroyed (paper materials will be shredded and video will be destroyed).

If you have any questions about the research study or your role in this study, please contact either of the researchers listed above (the supervisor is Dr. James Bebko: xxxxxxxxx, the student researcher is Alex Porthukaran: xxxxxxxxx). You may also contact the graduate office (xxxxxxxxxx).

This research has been reviewed and approved by the Human Participants Review Sub-Committee, York University's Ethics Review Board and conforms to the standards of the Canadian Tri-Council Research Ethics guidelines. If you have any questions about this process, or about your rights as a participant in the study, you may contact the Senior Manager and Policy Advisor for the Office of Research Ethics, 5th floor, York Research Tower, York University. Telephone: xxxxxxxxx or email: xxxxxxxxxxx

If you agree to participate in this study please complete the following:

"I ______________________________ consent to participate in the Nonverbal Assessment of Metamemory project conducted by Dr. James Bebko. I have understood the nature of this project and wish to participate. I am not waiving any of my legal rights by signing this form. My signature below indicates my consent.

_____________________________ _____________________

Signature **Date**