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Sentence recall in children with autism spectrum disorder

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Sentence Recall in Children with Autism Spectrum Disorder

by

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Table of Contents

History and Etiology of Autism

Autism, or autism spectrum disorder (ASD), was first named by Asperger (1938). The origin of this name was based on an old symptom of Schizophrenia called Autist (Breuler, 1919). This term covered symptoms of schizophrenia such as being cut off from reality, but also being cut off socially. Initially autism used to be thought of as a form of schizophrenia (Asperger, 1938). In Asperger's essays (1938), he found that generally, the children he saw and interviewed had the social disconnect prevalent in some forms of schizophrenia, but that the children lacked the psychosis of personality that is a prerequisite of schizophrenia. He also found that through interviews with and simple observations of some children and their parents that autism may have a heritable component. Another trait he noticed is that while some children are not able to solve simple problems, others can solve advanced math problems for their age. In addition, other children seemed to solve problems in a creative but inefficient ways. Asperger (1938) administered a series of cognitive tasks would be viewed that test false and working memory. Based on these tasks his conclusion could not be generalized. He (1938) observed some children displayed an inability to complete the task, others showed proficiency, while for others Asperger believed they intentionally failed the task. Information regarding false or inaccurate memory, and short term working memory are described in some detail in subsection below.

Autism is currently defined as a pervasive developmental disorder, which both affects and is affected by development. Autism is considered to be the earliest developing neuropsychiatric disorder (American Psychiatric Association, 2013). It frequently emerges at infancy and is easily diagnosed, due to the individual's impairment in age typical behaviors. Behaviors such as significant deficits in understanding verbal and nonverbal behavior, delayed understanding of cause and effect, and so forth.. Some believe that the deficits associated with autism begin as developmental delays that eventually lead to long-term deficits if they are allowed to persist. Since Asperger's initial essay (1938), autism has clear symptoms associated with it as well as its prevalence has more carefully been examined. Autism has been shown to be a neurological disorder but the etiology is unknown (Baker, 2012) and there is no unifying theory regarding it (Matson & Sturmey, 2011). Autism also has very apparent symptoms. The most apparent symptoms are prosody, inability to pick up on social cues, inappropriate affect, and other social impairments as well as the cognitive impairments mentioned above (Matson & Sturmey, 2011). They also tend have certain behavioral quirks such as repetitive and restrictive behavior that is extremely rigid (Baker, 2012). The prevalence of each of these symptoms varies among children. Interestingly, while autism is not synonymous with intellectual disorders (ID), IQ scores do predict symptom severity in autism (Baker, 2012). Symptoms such as rigidity and social ability are highly correlated with IQ (Matson, 2011). Those with low IQ tend to have much greater impairment in prosody, ability to pick up on social cues, and other social impairments associated with autism, if they can communicate at all. Those individuals low in IQ also tend to have much more rigid repetitive behaviors (Matson 2011). While autism cannot be prevented, early interventions can address developmental delays so that the deficits can be mitigated.

Questions of what causes autism and in what part of the spectrum children, and in general people, with autism land are very important. It is hypothesized that the etiology of autism is multifactorial (Eapen, 2011; Grafodatskaya, Chung, Szatmari, & Weksberg, 2010). Both Eapen (2011) and Grafodatskaya et al. (2010) asserted that there are multiple genes that play a role in the development of autism. Both also pointed out that the cause of autism varies among individuals. Eapen (2011) proposed three different genetic causes of autism: autism caused by a rare single-gene disorder, autism caused by variation in a single or multiple genes, and autism caused by a rare “de-novo” mutation. Of these three, Eapen’s (2011) second proposed cause of autism seems to be the most common and the cause that is most influenced by the interaction between genes and the environment and interaction between genes and other genes. In regards to the environmental causes of autism, Grafodatskaya et al (2010) noted that mothers taking anticonvulsants such as Valporate is a risk factor for autism as well as other developmental abnormalities, due to the alterations it causes to the development of the central nervous system. Similarly, the use of reproductive technologies seems to be correlated with developmental abnormalities.

As Eapen (2011) noted the interaction of genes and the environment can contribute to the autistic phenotype, but the interaction of genes and the environment does not end postnatally. Martin and Horriat (2012) found that in families with multiple children with ASD the differences in symptoms between first and second child differed significantly. The second ASD child on average displayed significantly worse verbal and non-verbal IQ and the second child’s daily function was more severely impacted by their ASD symptoms. Martin and Horriat (2012) proposed that, in addition to immunological factors related to the mother, that epigenetic and environmental factors play a role in these differences. The researchers proposed that the second child receives less social interaction than their older sibling. This seems to be supported by another significant difference the researchers found between the first and second ASD child, namely that if the second child is less than two years younger than the first, that they are significantly less socially responsive.

In addition to social responsiveness, diet plays a role in long term developmental gains. Prandota (2011) found that dietary triggers may in fact play a role with the onset of autism in children. It has been found that children with ASD produce more Glycosaminoglycans (GAG) than their neurotypical counterparts (Endreffy, Bjorklund, Dicso, Urbina, & Endreffy, 2016). These sugars aid in the development and protection of neurons. As noted by Endreffy et al. (2016), an overproduction of a sugar such as GAG can cause severe developmental issues in the long term, though the actual role GAG plays is currently unknown. The researchers noted that diets can lessen the amount of GAG present in the body.

Overall, it seems that an interaction between genetics and the environment plays a role in both causing autism and how severe the symptoms eventually become. Based on the research by Eapen (2011) and Grafodatskaya et al. (2010), it seems that genetics play a larger role in the onset of ASD, and the severity is determined by the environment.

A large amount of research has been conducted with autism and the various neural areas that support cognition and related activities. One of the more prominent areas of cognition studied in relation to autism is executive functioning (EF). EF has been shown to be related to social function and to theory of mind (ToM). Some coverage of ToM is presented here because in the current study, one of the cognitive tasks that was employed required the ASD participants to engage in inferential reasoning. Devine, White, Ensor, and Hughes (2016) found that in children there were concurrent associations between ToM and EF, but no longitudinal connections. They also found that a positive significant relationship existed between teachers' related social competence and ToM. This is unsurprising as ToM is thought of the ability to think from another perspective, and it largely thought to play a role in successful social interactions. Despite this there was still a significant relationship between ToM and EF. As to why there was no longitudinal, but there was a concurrent connection, Devine et al. (2016) believed the design of the study may have hid the longitudinal effect, and stated that it is possible that ToM and EF are developing in tandem with each other. Yao et al. (2015) found evidence to support this, and more evidence showing a link between social adaptability and EF. In their study they found that for children with autism those with poor social adaptability had poor ToM and EF. Stichter et al. (2016) looked at previous research on the relationship between EF and social competence, as well as analyzed data provided by case studies. The researchers found supporting the hypothesis that the relationship between EF and social competence is bidirectional in its nature. Sticher et al. (2016) did note that EF as a construct is multifaceted and very complex. This leads to difficulty in measuring and does present a flaw with their hypothesis. The researchers also noted that more research should be undertaken in both experimental and natural settings. One of the most studied aspects of EF is working memory

Working Memory

Working memory is arguably one of if not the most critical aspect of cognition, in particular as it relates EF. Working short-term memory allows for the storage and manipulation of information, which is necessary for activities such as language comprehension, learning, and the ability to reason (Baddeley, 1992). Working memory is one of the strongest indicators of intellectual potential as there has been consistent reporting of a high correlation between working memory and intelligence. Colom, Flores-Mendoza,and Rebollo (2003) conducted a study in which they calculated the correlation between working memory performance and the results of an IQ test that led them to conclude that at least half of a person's intelligence is due to the individual's working memory abilities. Colom et al. (2003) also found evidence that indicates that working memory is one general cognitive resource that is tapped into whenever an individual attempts to perform an intense mental task. This also lends to support the notion that working memory is one of the most important factors that influences intelligence, though, not the only factor.

Working memory is theorized to be composed of three subcomponents. These components are the central executive, which is attention based, the visuospatial sketch pad, which deals with the manipulation of visual information, and the phonological loop, which deals with the manipulation of speech-based information (Baddeley, 1992). Going back to the processing of information, it is theorized working memory is important for the development of social skills, as it the ability to process the social information effectively that allows for the refinement of social skills (Moriguchi, 2014). It seems, though, that the relationship between social skills and executive functioning is not unidirectional. There appears to be evidence that increased social interactions increases working memory capacity, and by extension the EF, of individuals (Moriguchi, 2014). Like data for neurotypical children, for children with ASD there is no correlation between IQ and working memory, but a moderate relationship does exist in adults with ASD (Williams, Goldstein, Carpenter, & Minshew, 2005).

When it comes to working memory and executive functioning as a whole those with ASD tend to have impaired performance. In general, poor performance on working memory tasks is typical for ASD children (Englund, Decker, Allen, & Roberts, 2013). This impairment typically does not improve over time. As individuals age their working memory ability developed at a slower speed than their neurotypical counterparts (Luna, Doll, Hegedus, Minshew, & Sweeney, 2007; Richmond, Thorpe, Berryhill, Klugman, & Olson, 2013). This delay has been argued to be impacted by plasticity (See Appendix I) of the children with ASD (Luna et al., 2007). Plasticity is ability the central nervous system has to adapt and change in response to external stimuli. Like with IQ, there is a relationship between working memory and the severity of ASD. As the severity of ASD increased the individual's working memory tended to be poorer (Takahashi & Gyoba, 2012). In regards to those with low functioning ASD, there is very little information on how they perform on working memory tasks. As Boucher, Mayes, and Bigham (2012) noted in their review there is very little data, but what is known is that while working memory is intact it is lower in capacity than both HF autistic individuals and neurotypicals. Boucher et al. (2012) further reported that those with low functioning ASD tend to score about as well as people with other intellectual disabilities like downs syndrome. That said, due to the dearth of research no concrete assertions can be made at this time.

Those with ASD also tend to have different rates of neurological activity when compared to their neurotypical counterparts. Those with ASD seem to have higher rates of deactivation in the right temporal lobe and cerebellum, as well as decreased activity in cerebellar regions (Rahko et al., 2016). In addition, those with ASD seem to have poorer synchronization of the frontal and temporal brain regions that are associated with working memory when compared to their neurotypical counterparts (Urbain et al., 2016).

False Memory

Another commonly discussed aspect of cognition is false memory, or inability to remember accurately. False memories occur when an individual's attempt to remember information is done so incorrectly in a distorted fashion or they remember completely fabricated information (Toglia, Read, Ross, & Lindsey, 2007). These differences can range from being confident that a word or item was in a presented list to misremembering entire events. The Deese-Roediger-McDermott (DRM) paradigm is used to study the malleability of memory. In this paradigm participants begin by studying lists of words. Each list is associated with a non-presented word, also known as a critical lure. For example, participants hear a list that begins with the words *bed, rest, awake, dream, pillow* that are all related the missing item “sleep.” Later during memory testing they often falsely recall or recognize “sleep” as having been presented on a study list e. Participants say that these non-presented words appeared in the study list with high confidence (Prohaska, DelValle, Toglia, & Pittman, 2015). Given that DRM lists are thematic in nature, it is hypothesized that schemas play a major role in falsely recollecting events. Schemas, which organize knowledge around themes, are based on the expectations or beliefs an individual may have concerning events or people, and they allow for people to more easily process information by grouping bits of information into chunks (Toglia et al., 2007). While an efficient form of information processing, it can produce memory errors that are consistent with the theme of a schema As seen above in the DRM paradigm remembering the word “sleep:” could be considered a schema consistent error. An individual’s confidence in these false memories can be very strong. For example, when informed ahead of time of the nature of the thematic lists to be studied and to avoid remembering critical lures, individuals will still show the same confidence as those unaware of the critical lures existence (Gallo, Roberts, & Seamon, 1997). It seems that individuals will inaccurately remember information as correct if that information falls in line with their schema. In addition to the thematic nature of schemas, they also tend to be associated with spatial and temporal features. For example, if individuals are asked to recall the locations of items highly related to each other, it is likely that an individual will inaccurately recall the items related to each other in close proximity even if that is in fact incorrect (Lew & Howe, 2016). For example, when participants were asked to recall where something appeared in atypical location, they tended to claim that the location where a knife was positioned in a previous picture, was incorrectly on a cutting board instead of correctly stating that it was on a chair.

The area of the brain most commonly associated with semantic comprehension forms of false memories (Chadwick, Anjum, Kumaran, Schacter, & Spiers, 2016) and false memories related to events is the temporal lobe. The hippocampus (Ramirez et al., 2013) also plays a significant role in that it facilitates the processing and storing of memories. Providing evidence for the role that the temporal lobes play in remembering, Melo (1999) found that those with lesions on their medial temporal lobe had significant impairment with accurate memory recall compared to the control group. The researchers noted that while the damage to the medial temporal lobe did encourage the use of gist recall, the efficiency of gist recall was also somewhat degraded by the damage. The thematic nature of gist traces can be the basis for errors similar to those seen in DRM tasks. While the left temporal lobe plays a big role in accurately recalling memories, Abe et al. (2013) found that the right superior temporal gyrus plays a significant role in accurately recalling items or events. This gives some evidence that children with ASD may in fact be more susceptible to false memories than their neurotypical counterparts due to the impairment in cortical structures that play a role in false memory.

In addition to the temporal lobe, other brain regions play a significant role in the accurate recollection of events or items including the frontal and parietal lobes. More specifically, it is predominantly the right frontal and parietal lobes that play a role with accurate recollection (Abe et al., 2013). The right striate cortex seemed to play a role in Abe et al.'s (2013) study, but due to the task being completely visual in nature it is possible that this may not hold true for false memory paradigms that are auditory based such as the DRM paradigm. Furthermore, the sentence recall tasks employed in the current study were presented in an auditory format.

A critical point is how the groundwork laid above relates to the present study, and perhaps more importantly, how does it relate to children? When typically developing individuals are around the ages of eight and nine the individual begins to rely on the use of schemas to recall information (Brainerd, Forrest, Karibian, & Reyna, 2006). In fact, as individuals get older they seem to be more reliant on using schema-based memories. Brainerd and Reyna, (2015) found that as individuals got older they became more susceptible to DRM forms of false memories. They also found that 11-year old children who are mentally disabled are more likely to be as susceptible to false memories as those that are around seven-years old but not mentally disabled. The researchers believe that the cause of these results was the increased reliance on gist recall. This leads to the concept of fuzzy trace theory.

Fuzzy Trace Theory

Fuzzy-trace theory also breaks down memory representations down into two types: verbatim and gist traces (Brainerd et al., 2006). Verbatim memory deals with true events by remembering specific details. Gist memory on the other hand is related to the recollection of events, both true and false, that are consistent with the meaning of the experience. Access to verbatim traces supports true memories and suppresses false ones. Gist traces may also aid in accurate recall and/or recognition memory (Brainerd et al., 2006).

This naturally leads us to inquire about the potential relationship between working memory and false memory. Hypothetically, as working memory increases the susceptibility to false memory might be expected to increase due to the increased use of gist based remembering. Unfortunately, the results concerning this are mixed. Leding (2012) found that as an individual's working memory increases their susceptibility to false memories actually decreases. Leding

(2012) believed that this is due to superior editing strategies at retrieval by people with higher levels of working memory capacity. Prior to Leding's (2012) study, Peters, Jelicic, Verbeek, and Marckelbach (2007) found that those with poor working memory were more susceptible to remembering critical lures in the DRM false memory paradigm. This implies that perhaps that those with high working memory are more prone to using verbatim recall. Maciaszek (2016) also found that working memory influences false memory rather than the other way around. There may be a a complexity involved in this relationship, as when individuals are not aware to the nature of the false memory task, working memory did not seem to have an effect on false memory (Bixter & Daniel, 2013). This may be due to conscious activation of working memory processes to compensate for expected critical lures. Contrary to the prior results, in an earlier study Chapman et al. (2006) found that children with brain damage demonstrated impairments in both working memory and gist recall. The children in the study either were reliant on verbatim traces or were simply unable to recall information. This implies that gist recall is not only related to working memory but that they share many of the same cognitive resources.

There is also some evidence that gist memory and working memory are related due to results acquired through studies looking at autism spectrum disorder (ASD). Those with ASD are characterized by having rigid behaviors and an inability to engage in social interactions as well as their neurotypical counterparts (Matson, 2016). Children with ASD also show impaired IQ, and the more severe the symptoms the greater the severity of the IQ deficit. Naturally children with ASD tend to do poorly on working memory tasks with higher severity leading to poorer working memory scores. For example, Kercood, Grskovic, Banda, and Begeske (2014) asserted after reviewing the literature that children with ASD were significantly less likely to perform well compared to their neurotypical counterparts on working memory tasks, though, some evidence did indicate that the gap in scores between neurotypical and ASD children with less severe symptoms on a verbal working memory task is not as large as the gap between performance on visuospatial working memory tasks. While children who are described as neurotypical, or typically developing children, eventually begin to use gist based memory recall at around eight and nine years of age, those with ASD tend to use verbatim recall well after that age, if they develop the use of gist recall at all (Miller, Odegard, & Allen, 2014). Given these age trends, one might expect that ASD children would tend to not have high levels of false memory.

Overall, research seems to indicate that average or high working memory should lead to an increased use of gist based recall, and as such a higher likelihood of being susceptible to false memories. That said, most of this is inferential. Research into children with brain damage has not revealed direct links between working memory and gist based recall. In fact the only direct look into this area (Leding, 2012) showed that those with high working memory actually seem to use verbatim recall instead of the more efficient gist based recall. Another issue is comparing those with ASD with neurotypical individuals. Studies have shown that the brains of those with ASD develop differently. Luna et al. (2002) showed that those with ASD develop different neurocortical structures, and that structures not typically associated with working memory will be used instead of the brain areas used by neurotypical individuals. This study was only conducted with adults and it seems children with ASD would be a better comparison in this scenario.

Towards the relationship between those with ASD and false memory, the evidence is not as strong as the amount of working memory due to a dearth of quantitative studies. Beversdorf et al. (2000) found that high functioning children with ASD could more easily identify critical lures accurately than neurotypical children, as evidenced by their high confidence in critical lure. In his study, participants rated their confidence that a word (e.g. white, dark, cat, etc.) appeared during an encoding phase using a scale of one to four, with four referring to the greatest confidence and one indexing the least. This has been refuted by a replication performed by Hillier, Campbell, Keillor, Phillips, and Beversdorf (2007) who found no significant differences between neurotypical children and children with ASD in regards to verbal false memory. Additionally, they looked at false memory as it relates to shapes and found that children with ASD performed significantly better on false memory tasks that used shapes than neurotypical children. Further compounding the results found with verbal false memory, is that it is not uncommon for those with ASD to have impairments with comprehending semantic information (Mammarella, Giofrè, Caviola, Cornoldi, & Hamilton, 2014).

Study Goals

There is a substantial amount of information on working memory in those with ASD and working memory in relation to those with false memories. Due to the dearth of quantitative research there is no study on the relationship that working memory and false memory has for those with ASD. As such the current study is very important as it could provide new information on this neglected area. Few studies have looked at false recognition or false memory related to sentences in those with ASD. The lack of studies in this area also means that there is a lack of information on the relationship false memory has with verbal and spatial working memory. Such studies could be interpreted in terms of several memorial frameworks, including fuzzy trace theory. Based on the studies reviewed, it is hypothesized that like neurotypicals, those with ASD and high working memory should also have a high correct recall, for false memory tasks. Due to prior studies frequently using only verbal working memory and not spatial working memory tasks, we will analyze them separately with false memory scores instead of looking at the sum total score of working memory with false memory. To study Sentence recall in children with autism spectrum disorder fuzzy trace theory, we tested children with both verbal and spatial working memory tasks followed by recall and recognition to assess true and false memory. This false memory paradigm incorporates questions based on fuzzy trace theory.

Method

Participants

Ten children diagnosed with ASD participated in this study. In order to be recruited into the study participants must have been between the ages of seven and 16, the participants must have an IQ of at least 85 and their receptive and expressive scores must be at least be at least 85. Children in the ASD group must be diagnosed with ASD, while participants in the neurotypical group must not be diagnosed with ASD. Other neurological impairments were also a disqualifier for both groups. None of the participants displayed any behavioral issues. Participants varied in comorbidity with psychopathologies (Table 1).

Ten high functioning ASD participants were recruited from two sites: Keystone Behavioral Pediatrics and Beacon Pediatric Behavioral Health. Of these ten participants, nine were recruited from Keystone Behavioral Pediatrics and one was recruited from Beacon Behavioral Pediatrics. Of these nine recruited from Keystone Behavioral participants, eight participants were male and one was female. In addition to sex, their IQ scores were also collected.

Participants at the multiple sites were recruited through different means. The children from Keystone Behavioral Pediatrics were recruited through a Clinical Psychologist on site reviewing the capabilities of the children at the site, and then referring those children to the researchers. In total 11 children from Keystone Behavioral Pediatrics were referred. Of those 11, five children had severe behavioral issues that prevented them from taking part in the study. The second child engaged in severe oppositional behavior in his classroom in response to the assessment. Of the six children that did participate in the study, there were very few behavioral issues.

At Beacon Pediatrics, two children were referred for the study. The recruitment process at Beacon was volunteer based as any who saw the advertisement for the study were allowed to make inquiries regarding the experiment and ultimately be referred to take part in the assessment. One child referred for the assessment failed the first assessment intentionally and the data had to be thrown out. The second child suffered from anxiety as a comorbidity and required the presence of both her therapist and mother to be present in the room during the assessment. The participant also required to have a stress ball to use while taking the assessment. Overall there was only one distraction that occurred during the study when the participant dropped the stress ball and missed part of question eight during the false memory assessment. The participant performed adequately in the other areas. The site informed us after agreeing to be a part of the study that recently they were receiving significantly fewer children with ASD than before they began participation with the study. Overall, the participant pool available for this study was low.

Attempts were made to secure an age and IQ matched neurotypical control group. First Coast Christian School, a private school, agreed to a part of the study, but many parents that were contacted to be a part of the study decided to not participate in the study or did not respond to our follow-up attempts to contact them. We were only able to get one participant for the control group. Unfortunately, this number was insufficient to be included in the analysis or the study. If more participants for the control group are recruited then this participant will be added to the analysis.

Materials

The researchers used an HP laptop running the Automated Working Memory Assessment (AWMA; Alloway, 2007) to assess participant visuospatial and verbal working memory via the Mr. X and Processing Letter Recall tasks, respectively. After completion, the researcher computed the working memory scores. To run the false memory task, the researchers used Microsoft PowerPoint with a voice recording used to facilitate each part of the false memory paradigm. The researchers recorded the participant's responses on a print out of the entire procedure out of view of the participant.

Procedure

Each participant engaged in two working memory tasks, using the Automated Working Memory Assessment (Alloway, 2007), followed by a false memory task. In the order they were taken, the two working memory tasks are the Processing Letter Recall task and the Mr. X.

In the Processing Letter Recall task, participants received sets of trials. For the initial set, they would hear one letter, and then they would see a letter appear on-screen. The participants would then click either "yes" or "no" to indicate that was the letter they heard. If answered, the participant would proceed to a set of three two-letter trials, followed by attempting to recall the letter sequence. This patterned continued to trials of three letters, four letters, and so forth. This functioned as a distractor. The participants would then recall the letter(s) they heard, in the order that they heard them. At some point, participants would fail to recall a set of letters, say five, and the letter recall task would be considered complete. The scale is normed between 60 and 160 with 100 representing the average of the neurotypical population.

In the Mr. X task, participants would see two figures (Mr. Red and Mr. Blue). In the first phase of each string, participants would state whether Mr. Red and Mr. Blue were holding a ball in the same hand. Mr. Red would always be upright at 90̊ angle while Mr. Blue would be either upright or at a tilted angle. This phase functioned as the distractor task. In the second phase participants would recall the locations of Mr. Blue's ball was in the order they were presented. The better participants did the longer the strings the participants would see and have to recall. The scale is normed between 60 and 160 with 100 representing the average of the neurotypical population.

In the false memory task, participants would hear a sentence (ex. The FROG jumped into the pond). The participants then heard a list of four words (TOAD, DOG, PENCIL, CHAIR). Participants would then be asked if a specific word was on the list (Ex. "Was the word PENCIL on the list?"). The word that participants were asked about was never the critical lure. Also during this recognition phase half of these words asked about did appear on the word list. After this recognition phase, participants would then be asked to remember the sentence they heard prior to the word list. This is where you might see a false memory if a participant recalled TOAD rather than FROG having been in the sentence. The participant would then be asked a factual question (Ex. Where did the frog jump?) and an inferential question (Ex. "Why did the frog jump into the pond?"). The participant's responses to the questions would then be encoded and marked as correct or incorrect. For the purposes of this study the inferential questions had a broader correct response range than the factual questions. Each participant was only assessed once and each participant was assessed with no other participant in the room. Correlations were used to check the relationship between the five variables. We looked at these for the ten participants recruited as well as the seven that finished the paradigm.

Table 1. Participant Demographics.

Table 1AWMA	Letter Recall	Mr. X	Nonverbal IQ	Diagnosis	IQ Measure	Age
207	98	109	86	ADHD Combined, Conduct Disorder	SB5	9
227	96	131	99	N/A	SB5	13
182	84	98	101	N/A	SB5	7
212	106	106	103	N/A	SB5	12
251	114	137	107	ODD, ADHD Inattentive,	SB5	13
188	111	77	117	Anxiety	WISC-V	13
204	103	101	132	N/A	SB5	16

Results

Inter-rater Reliability Analysis

An inter-rater reliability analysis was performed on the scoring of Sentence Recall. The analysis showed that there were no significant differences between the two raters. In fact, the Cohen K values revealed very strong inter-rater reliability for all factual and inferential question comparisons, except for one value for a factual question that dipped below .600 at .588. More specifically, there was perfect agreement on 10 of the factual questions wherein the mean K value was .933 and perfect agreement on 8 of the inferential questions with the mean K value being .870.When disagreements occurred, which were few, they were resolved by discussion between the raters,

All Participants

For the purposes of all of the analyses we divided the total Automated Working Memory Assessment (AWMA-2, 2010) into verbal and spatial measures. We performed a series of simple correlational analyses using the following variables: Working Verbal Memory, Working Spatial Memory, Sentence Recall, Recognition, Inferential Question, Factual Question, and Intelligence Quotient (IQ). Before we performed any analyses, we looked at the histogram for each of these seven variables (Fig. 1-7) to determine if the data failed the normality assumption. We found that Inferential and Factual Question variables failed the normalcy assumption. To control for this failed assumption, we performed a Spearman correlation analysis. Lastly, due to the lack of a control group we performed a nonparametric one sample t-test to compare the participant's scores on both working memory measures and IQ with the median of the standardized population.

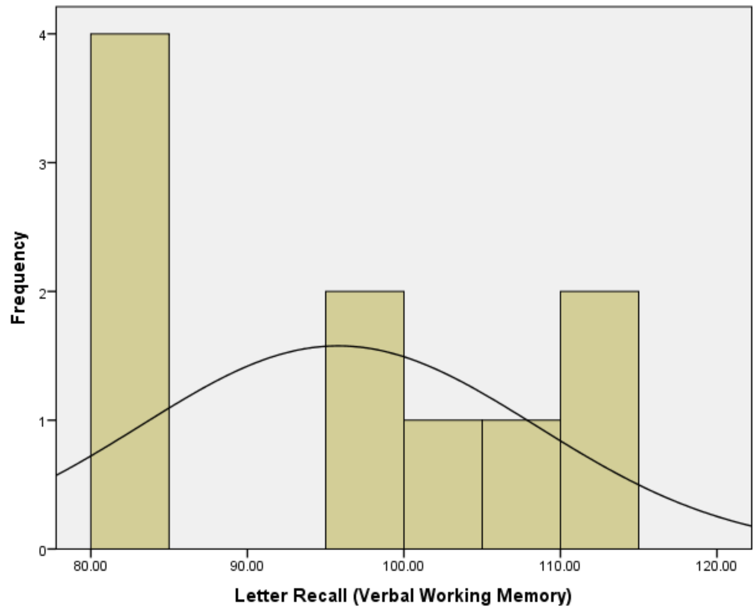

Figure 1. Frequency of scores for Letter Recall (Verbal Working Memory).

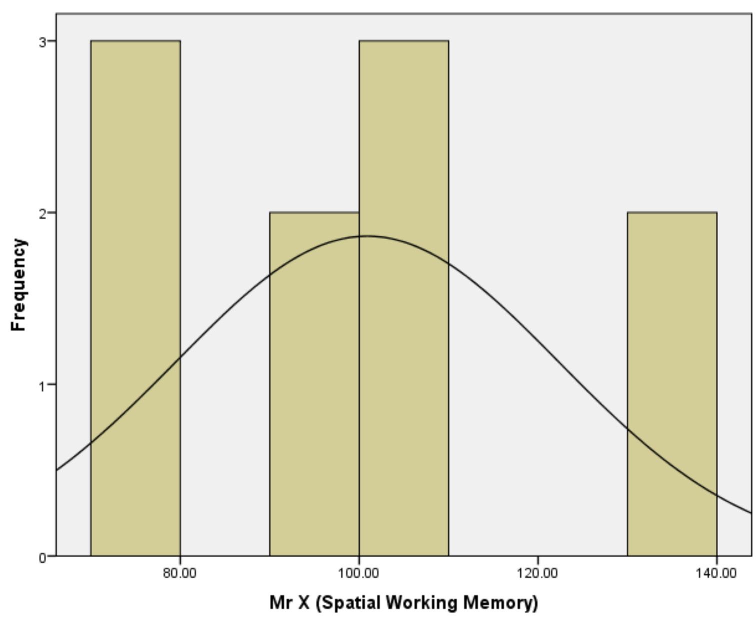

Figure 2. Frequency of scores for Mr. X (Spatial Working Memory).

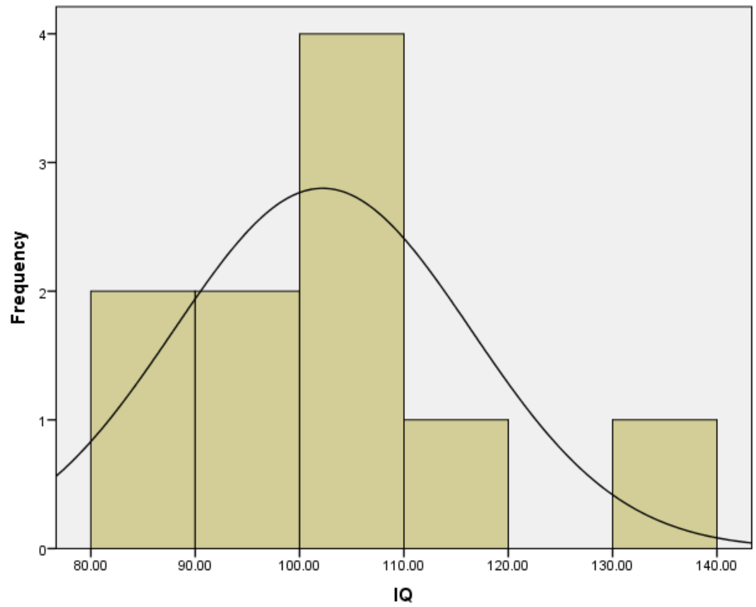

Figure 3. Frequency of scores for IQ.

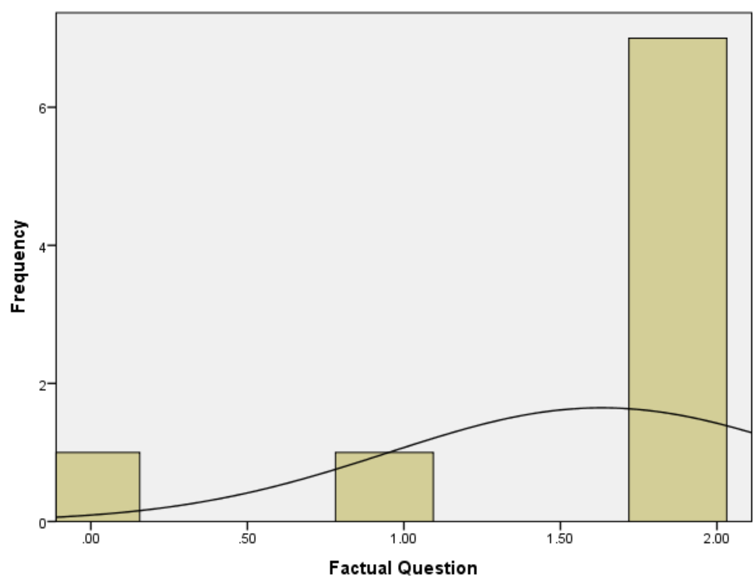

Figure 4. Frequency of scores for Factual Questions.

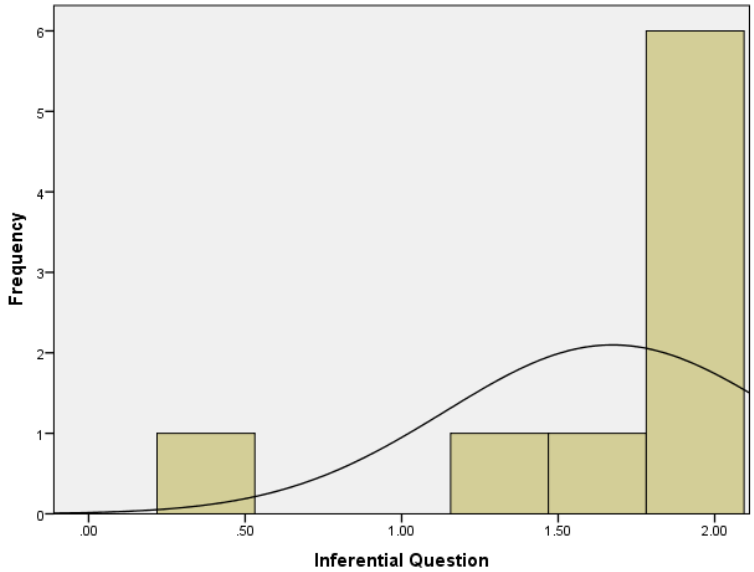

Figure 5. Frequency of scores for Inferential Question.

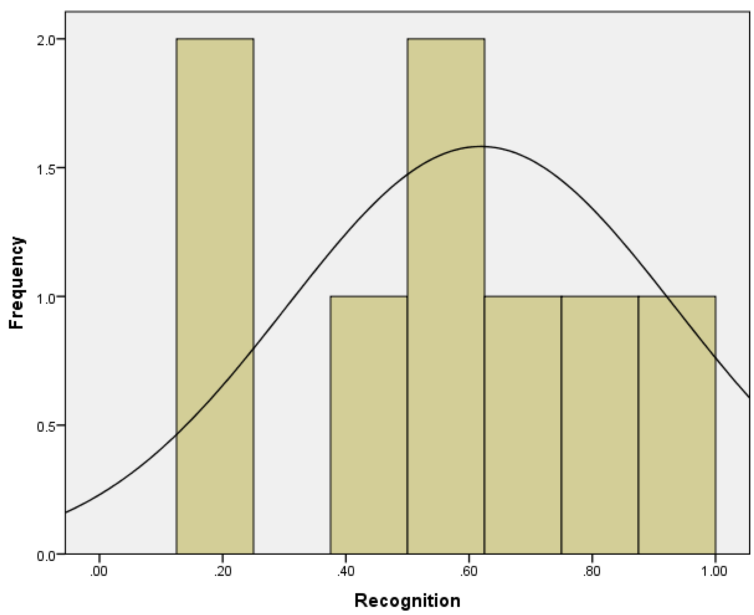

Figure 6. Frequency of scores for Recognition.

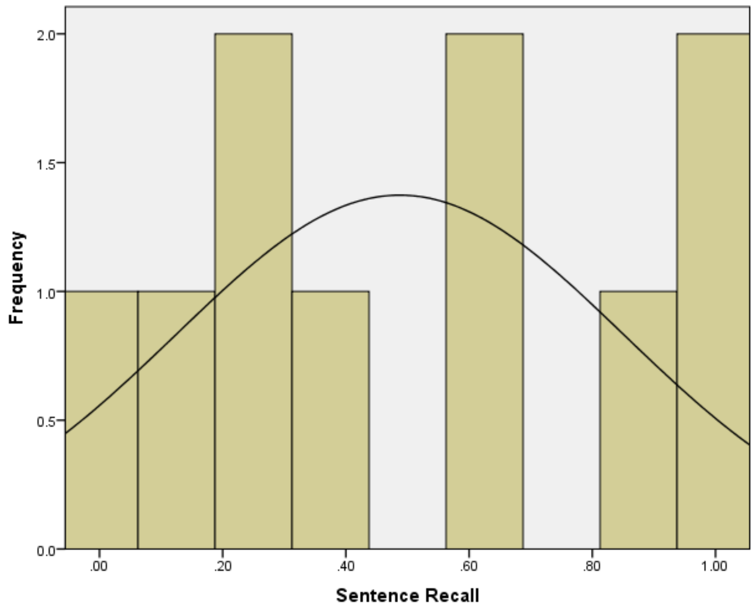

Figure 7. Frequency of scores for Sentence Recall.

For the analysis between verbal working memory and false memory, we found that there was a significant positive correlation for both Sentence Recall and Recognition ($r = .736$, $p < .05$; $r = .742$, $p < .05$) (Fig 8-9). This indicated that as Verbal Working Memory increases, false memory performance on both measures of false memory increase. We also found a significant positive correlation between Spatial Working Memory and Sentence Recall ($r = .722$, $p < .05$) (Fig. 10). This indicates that as spatial working memory increases so does the ability to recall information.

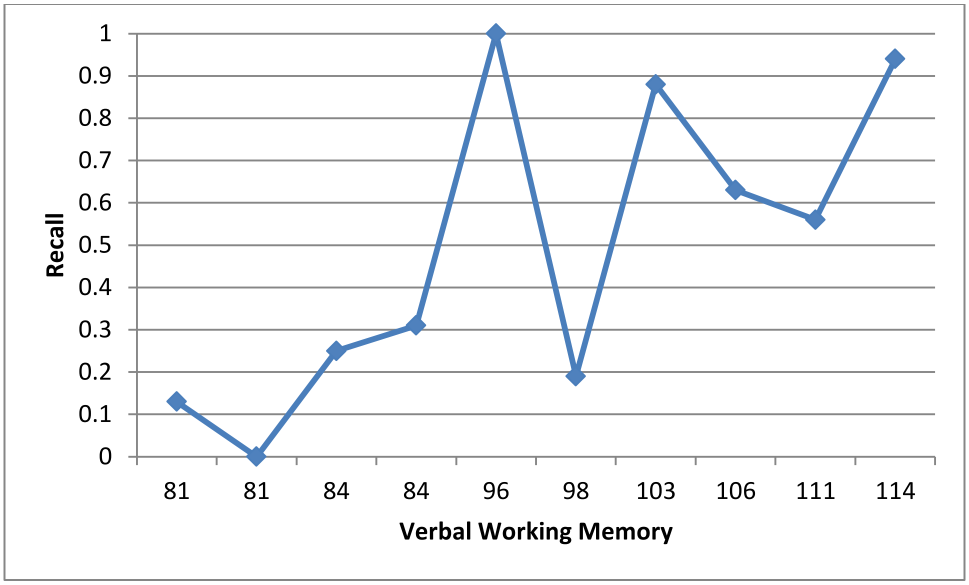

Figure 8. The relationship between Recall and Verbal Working Memory.

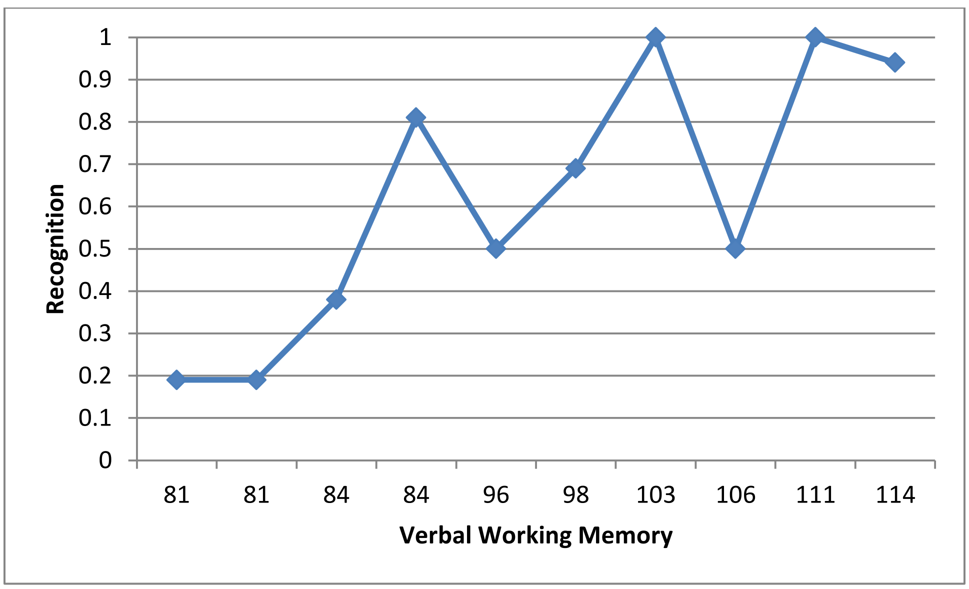

Figure 9. The relationship between Recognition and Verbal Working Memory.

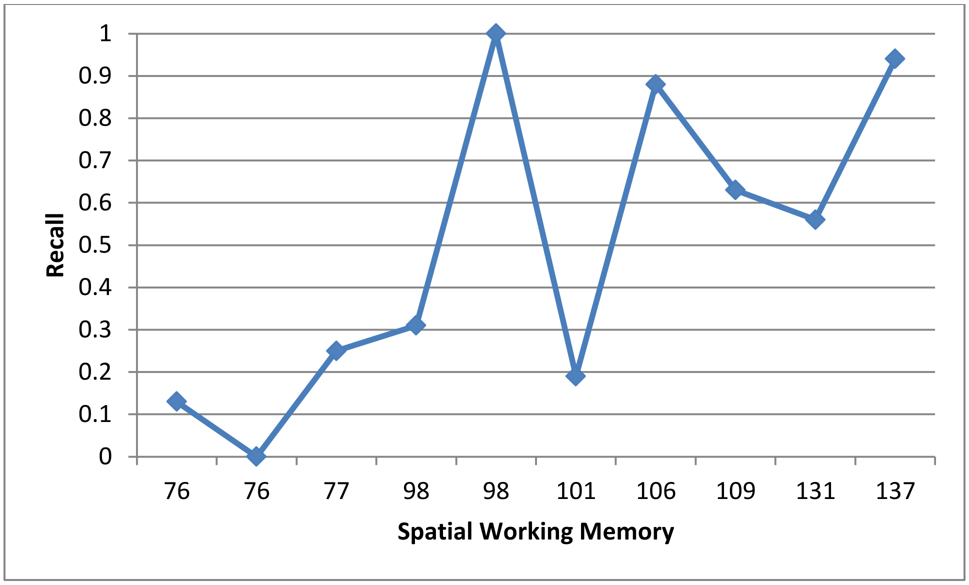

Figure 10. The relationship Recall and Spatial Working Memory.

Another correlation analysis revealed a significant relationship between verbal working memory and both Inferential and Factual Questions ($r = .691$, $p < .05$; $r = .691$, $p < 05$) (Fig. 11-12). Additionally, no significant relationship between Spatial Working Memory and both Inferential and Factual Questions were found.

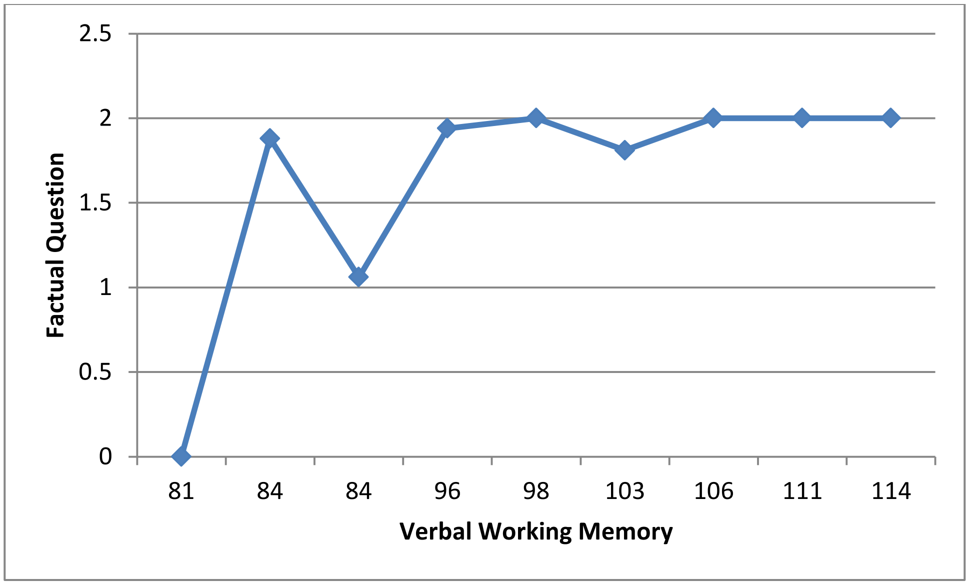

Figure 11. The relationship between Factual Question and Verbal Working Memory.

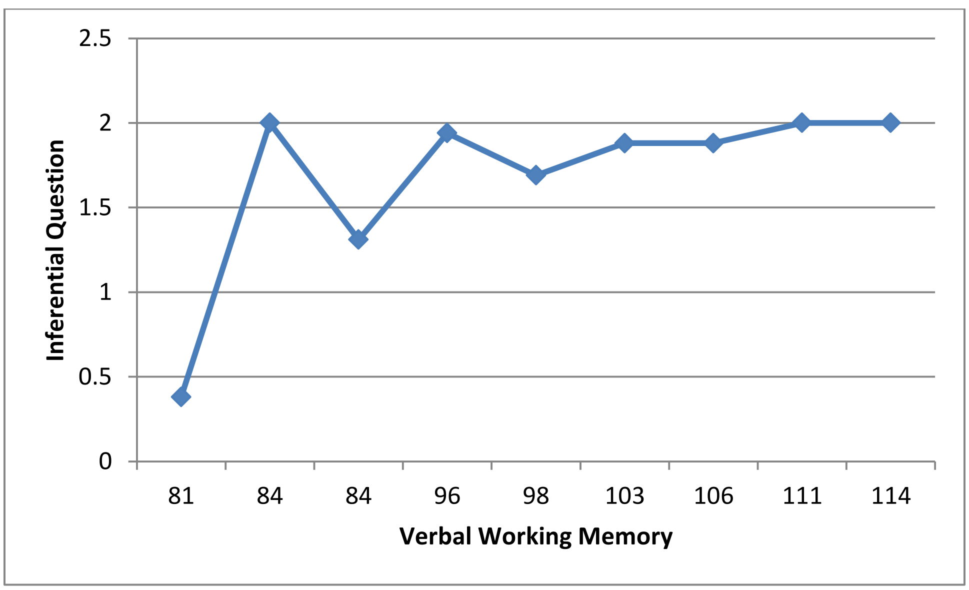

Figure 12. The relationship between Inferential Question and Verbal Working Memory.

Additionally, we found a significant positive relationship between Inferential Question and both Sentence Recall and Recognition (r = .700, $p < .05$; r = .771, $p < .05$). Likewise we also found a significant positive relationship between Factual Question and Sentence Recall and Recognition ($r = .741$, $p < 05$; $r = 750$, $p < .05$).

Due to the high correlation between Verbal Working Memory and Inferential Question variables ($r = .638$, $p < .05$), we tested for the level of tolerance each Verbal Working Memory and Inferential Question scale has for the False Memory variable. We found that the Verbal Working Memory and Inferential Question have a low tolerance for each other when predicting recognition (tolerance = .508, Variance Inflation Factor (VIF) = 1.969). This indicates that the two variables share a moderate amount of variance with each other in regards to False Memory. After controlling for variance, we found that Verbal Working Memory mediates ($t(8) = 2.04$, $p < .05$) the relationship between Sentence Recall and Inferential Question. We also found that Verbal Working Memory and Factual Question had a low tolerance for each other when using both to explain Sentence Recall (tolerance = .522, VIF = 1.915). After controlling for variance, we found that Verbal Working Memory did not moderate or mediate the relationship between Factual Question and Sentence Recall. We did not find any significant relationship between IQ and any other variable.

In order to compare the ASD sample's working memory and IQ scores with the expected population we conducted a one-sample t-test, specifically using the Kolmogorov-Smirnov test. For verbal working memory we found no significant difference in median from the average of the population. Likewise, for spatial working memory and IQ we found no significant difference in median from the average population.

Analyses Confined to Participants who Completed the Full Experimental Design

For the purposes of this analysis we divided the total Automated Working Memory Assessment (AWMA-2, 2010) into verbal and spatial measures. We performed a series of simple correlational analyses using the following variables: Working Verbal Memory, Working Spatial Memory, Sentence Recall, Recognition , Gist Recall, Verbatim Recall, and Intelligence Quotient (IQ). Before we performed any analyses, we looked at the histogram for each of the 6 main variables (Fig. 1-7) to determine if the data failed the normality assumption. We found that gist recall and verbatim recall variables failed the normalcy assumption. To control for this failed assumption, we performed a Spearman correlation analysis. Lastly, due to the lack of a control group we performed a nonparametric one sample t-test to compare the participant's scores on both working memory measures and IQ with the median of the standardized population.

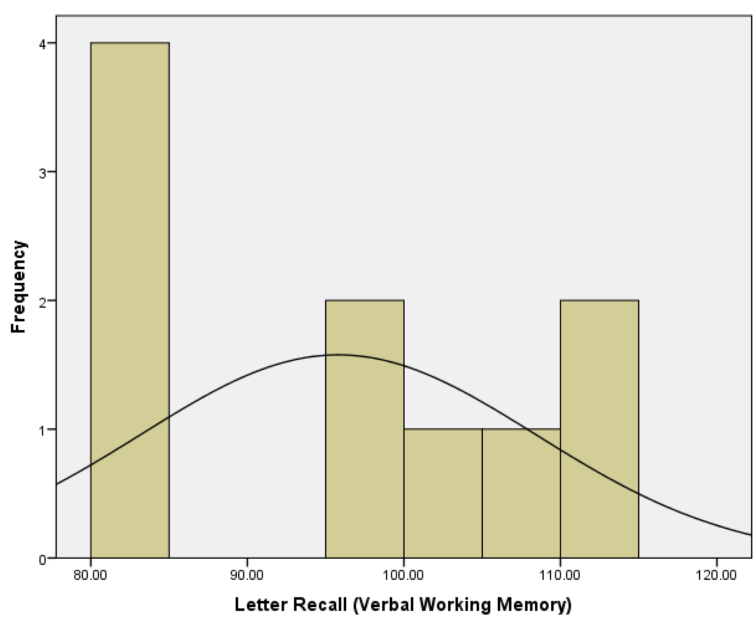

Figure 13. Frequency of scores for Letter Recall (Verbal Working Memory).

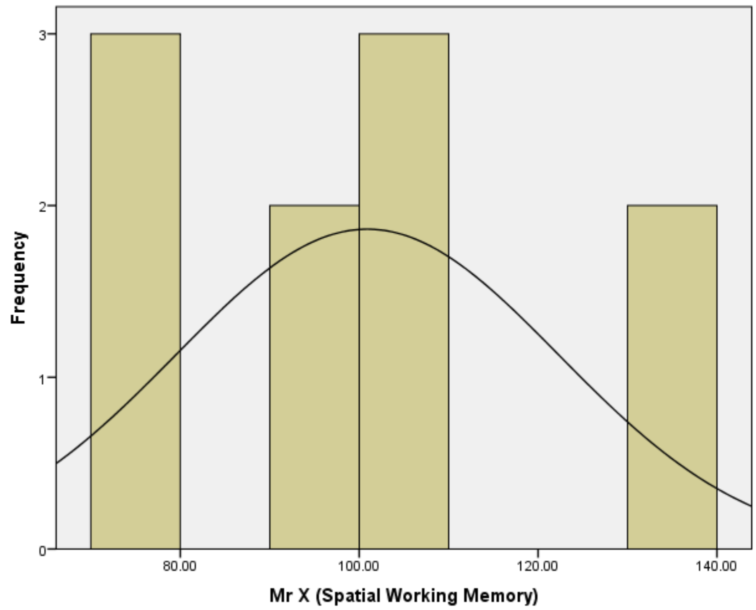

Figure 14. Frequency of scores for Mr. X (Spatial Working Memory).

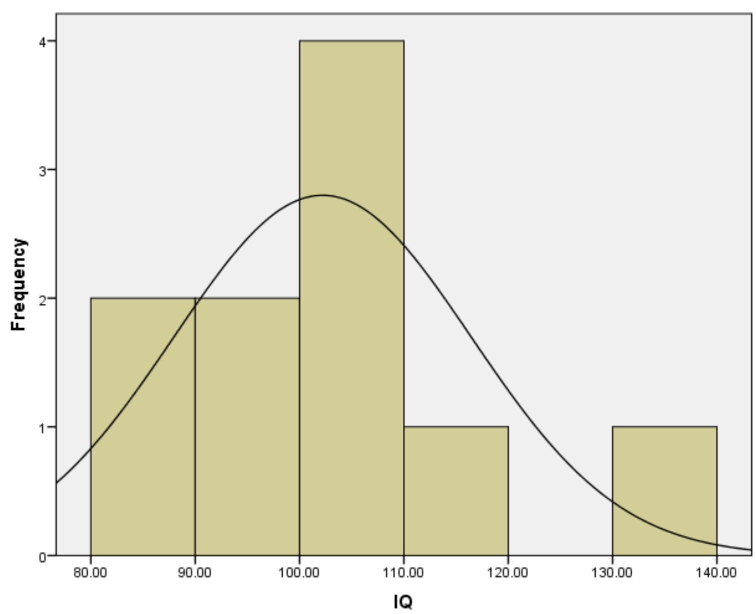

Figure 15. Frequency of scores for IQ

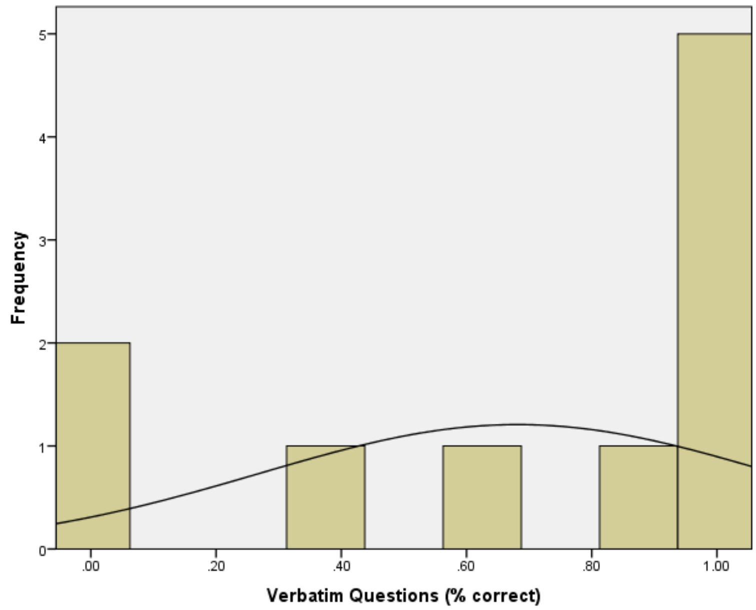

Figure 15. Frequency of scores for Verbatim Questions.

Figure 16. Frequency of scores for Gist Questions

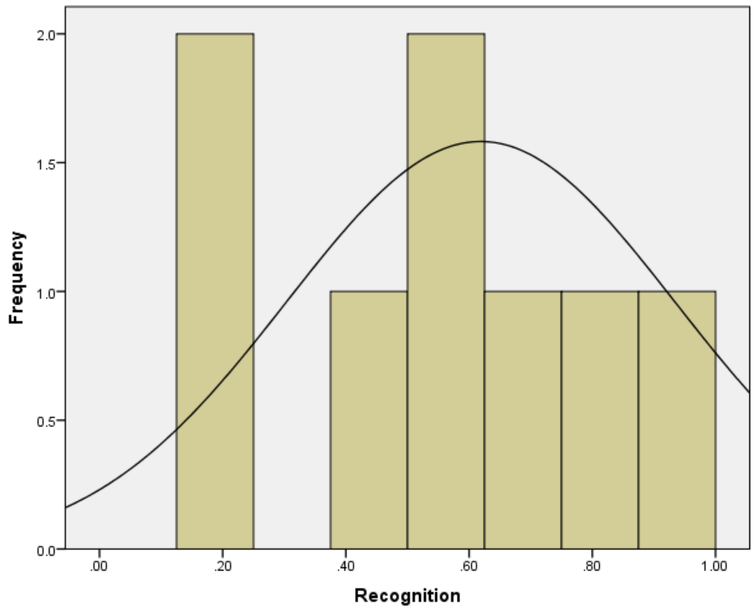

Figure 17. Frequency of scores for Recognition.

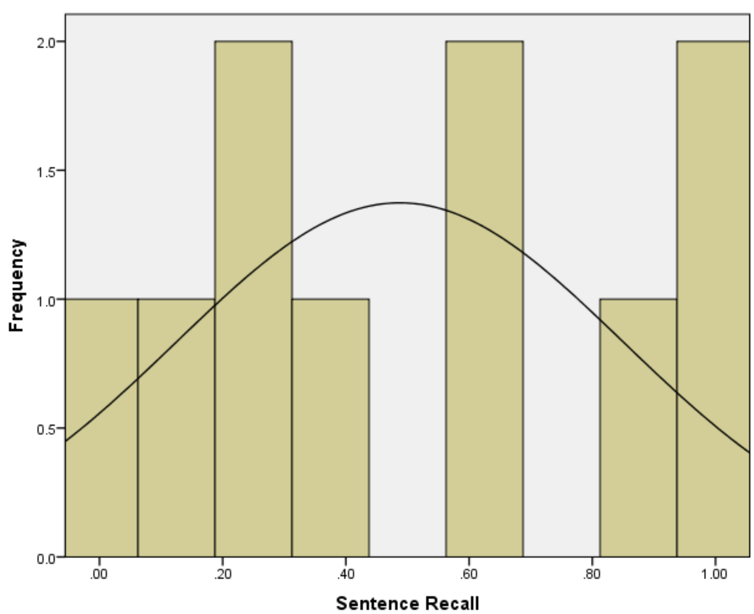

Figure 18. Frequency of scores for Sentence Recall.

For the analyses between working memory and false memory, we found that there were no significant correlations between the working memory variables and the false memory variables. We also found no significant correlation between Spatial Working Memory and Sentence Recall.

Further correlation analyses revealed no significant relationship between Verbal Working Memory and both Inferential and Factual Questions. Additionally, no significant relationship between Spatial Working Memory and both Factual and Inferential Question was found.

Additionally, we found no significant relationship between Inferential Question and either Sentence Recall or Recognition. Likewise we also found no significant relationship between Factual Question and Sentence Recall or Recognition.

In order to compare the ASD sample's working memory and IQ scores with the expected population we conducted a one-sample t-test, specifically using the Kolmogorov-Smirnov test. For verbal working memory we found no significant difference in median from the average of the population. Likewise, for spatial working memory and IQ we found no significant difference in median from the average population.

Discussion

We found in some of the analyses that there was a positive relationship between verbal working memory and performance on false memory tasks as well as gist and verbatim recall. This falls in line with what is expected of neurotypical individuals (Leding, 2012). This also goes against the results of Chapman et al. (2006). More specifically, though, we found that this held true for both verbal working memory measures and spatial working memory scores. That said, we did find that verbal working memory mediated the relationship between gist recall and false memory. Both Leding (2012) and (Chapman et al., 2006) primarily focused on the relationship verbal working memory has with false memory. For the relationship between gist recall and false memory performance, Brainerd, Reyna, Howe, and Kevershan (1991) found that false memory is significantly related to gist recall. Brainerd et al. (1991) noted that the direction of the relationship between gist recall and false memory can vary, as it can be negatively or positively correlated with false memory performance. That said, the results of this present study support the common conclusion that the relationship between gist recall and false memory is that they are positively related to each other. This is because as outlined in fuzzy trace theory, the gist of verbal information is consistently remembered better than its verbatim features (Keenan & Kintsch, 1974; Reyna & Brainerd 1995) such that encoding conditions that encourage the extraction of meaning, producing true memories (i.e. straightforward sentences as in the current experiment) should also amplify the occurrence of theme-consistent intrusions (Reyna & Kiernan, 1994).

Turning to the lack of a significant relationship between working memory and IQ, this too falls in line with prior research (Williams et al., 2005). While a neurotypical control group was not available for this study to compare with children with ASD, the present results indicate that there is no significant difference between children with ASD and the median population benchmark in regards to intelligence and working memory.

These results conflict slightly with the results of Chien, Gau, and Isaac Tseng (2016). In their study they found a significant difference between neurotypical children and children with ASD in regards to spatial working memory. There are a few possible reasons for this difference. The first is that their study involved a comparison with a neurotypical control group instead of the predicted average of the population. Another possible explanation for this difference is that in Chien et al. (2016), the minimum IQ that was required for participants was 70 rather than the standard 85 that was employed in the present study. In those with ASD, the lower an individual's IQ the more severe the symptomology which extends from social interaction to executive functioning, such as IQ (Baker, 2012). Unfortunately the results for those above an IQ of 85 as well as the number of participants below 85 further makes the comparison of these two studies difficult.

The results of the present study do resemble those found by Macizo, Soriano, and Paredes (2016). In their study they found no significant difference between neurotypical children and children with ASD when it came to verbal or spatial working memory. The researchers of this study did note that after extensively examining the data that there is reason to interpret the evidence as consistent with the notion that the spatial working memory of children with ASD may increase at a rate that is slower than their neurotypical counterparts; but the caveat is that there is too little information to firmly make this conclusion. Unfortunately, though, the minimum IQ required to participate in this study was not reported by Macizo et al. (2016).

The results of this study have notable implications in regards to the education and courtroom settings. Asperger (1938) and Baker (2012) noted that those with ASD have impaired learning abilities, at least in a classroom setting. Ultimately, it is limited in how easily the results of this study can be applied to a courtroom setting. Future research may wish to use more active suggestions as well as measure the participant's confidence in their decisions. This would allow for a better understanding of how easily memory may be influenced when considering children with ASD. This study implies some of the learning issues are more apparent for those with impaired working memory, as the participants in this study with low working memory had severe limitations recalling sentences or correctly recognizing words. For the courtroom setting these results are less definitive as alluded to above. Goodman and Reed (1986) noted that the primary issue with young children compared to their older counterparts is that their memories are more easily influenced by leading questioning. While it may not be readily apparent these results also indicate that children with high working memory regardless of whether they have ASD or not should be less susceptible to having their memories influenced. Maciaszek (2016) found that young adults with high working memory were not only less susceptible to false memories overall, they actively resisted suggestions to the contrary. It should be noted, however, that when excluding participants that did not complete all tasks the results became insignificant. This indicates that these participants that did not complete some portions of the full paradigm may have skewed the results. These children had significant mental health issues that may have negatively impacted their performance.

The study has notable limitations. The lack of a control group to compare to the children with ASD has already been mentioned. This group would allow for a more accurate representation of where children with ASD line up with their counterparts. Another limitation is the size of the sample. This study met the minimum sample size needed for the analysis. This small sample size negatively impacts the generalizability of this study. Another related limitation involves the sex of the participant. As Baker (2012) noted, symptom severity is significantly greater in males than in females. Unfortunately, an insufficient number of females were recruited to this study to compare the possible differences between the sexes.   Another limitation is that there was no counterbalancing of factual and inferential questions. It is possible that the factual questions were influencing the answers to the inferential questions. The final limitation to this study is that half of the children had some form of psychopathology as displayed earlier in Table 1.

Clearly, the addition of a control condition will put the present study's results in context both empirically and theoretically. A reasonably sized group of neurotypical individuals is of course desirable, especially if accompanied by an increase in participants in the current ASD group because it would also allow for a better exploration of the link between working memory capacity and propensity for false recall. In line with the relationship of gist recall to false memory, fuzzy trace theory predicts this association as explained earlier. Furthermore, high working memory capacity should protect against false memory because fuzzy trace theory predicts that increased working memory capacity advantages verbatim processing resulting in specific and detailed memory traces which increases the accuracy of an individual's memory. A better understanding of memory functioning of individuals along the autism spectrum can only be helpful in future advances in the diagnosis and treatment of ASD.

Appendix I

Plasticity plays a big role in human development in general, not just ASD. The level of plasticity an individual has influences the pathways of development that they take (Baltes, 1987). Generally, brain plasticity is during the early stages of development, rapidly changing throughout childhood and adolescence(Rees, Booth, & Jones, 2016) and tapering off in old age (Baltes, 1987). Such areas with high plasticity are the stress response system (Boyce & Ellis, 2005) and the language acquisition system (Gervain, 2015); however there is great interindividual variability in plasticity. Some research seems to indicate that children with ASD have demonstrated higher levels of plasticity in the occipital, temporal, and parietal lobes than their neurotypical counterparts (Mottron, Belleville, Rouleau, & Collignon, 2014). That said, when it comes to the frontal lobe, in particular learning, children with ASD tend to show much lower levels of plasticity, frequently generalizing information (Church et al., 2015). This seems to indicate that children with ASD tend to have varying levels of plasticity, this is especial apparent when compared to their neurotypical counterparts. This leads to children with ASD exceling over their neurotypical counterparts in some areas but fall short in others.

There are a few possible reasons for this difference in plasticity. Sahin & Sur (2015) noted that children with ASD, through an interaction of hundreds of genes, have an inability to regulate certain proteins leading to less plasticity with synaptic neurons. In addition to this those with ASD have abnormal developed dendritic spines (Chapleau, Larimore, Theibert, & Pozzo-Miller, 2009). These dendritic spines are parts of neurons commonly associated with plasticity in general. While this does add potential new information to the lack of plasticity, this does conflict with Mottron et al.'s (2015) which showed above average levels of plasticity in certain brain areas.

While the cause of the below average plasticity in those with autism is still being researched, the negative impact is potentially damaging. Church et al (2015) noted that, in particular, children with ASD have below average plasticity in brain areas related to social interaction. This can possibly explain why children with below average intelligence tend to have higher levels of symptom severity (Bear & Minke, 2006). Children with ASD would hypothetically be less involved with the contextual model in the unified theory of development noted by Sameroff's (2010). Indeed this relates to one theory on intellectual development is the contextual theory (Sternberg & Berg, 1992). In this theory, intelligence is acquired through the interaction with other people, so if the area of the brain related to social interactions has low plasticity, this could negatively impact the ability a child with ASD has to learn.

Children with ASD have shown a restored level of plasticity in certain situations, though. When children with ASD suffer from a fever, they actually show reduce social impairments often associated with autism (Mehler & Purpura, 2009). The hypothesis involves the locus coeruleus-noradrenergic (LC-NA). When children with ASD suffer from a fever, biological processes activate that restore the functioning of the LC-NA, as well as increase the plasticity of that area of the brain and related subsystems. This also led to increased learning ability, supporting the contextual theory of intellectual development (Sternberg & Berg, 1992).

Taken as a whole, information about plasticity, while conflict exists, is fairly established. In what way it affects the learning processes of those with ASD is hypothetical. That said the results of Mehler & Purpura (2009) are promising, though, ethical issues do arise in the implantation of therapy based on it. It does provide direction in improving the learning abilities of those with severe autism.

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