University of Nevada, Reno

Investigating False Memory Phenomenon with Hybrid Lists in Autism Spectrum Disorders

A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Psychology.

by

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Abstract

The purpose of this study was to further our understanding of how individuals with Autism Spectrum Disorders (ASD) process information. A false memory paradigm was used to test how susceptible ASD subjects are to false memories. Previous studies have shown robust levels of false memories in typical individuals (Budson et al., 2006), and studies examining false memory effects in autism have been mixed which is due in large part to diagnostic differences in ASD participants (Gaigg & Bowler, 2009; Kamio & Toichi, 2007). In addition, previous studies have only examined either semantic or phonological word lists. The goal of this study was to investigate false memories using "hybrid" lists, which include both semantic and phonological word lists. The importance of studying susceptibility to false memories in autistic populations is that it may help us to better understand the way in which association networks that are thought to underlie the false memory phenomenon in neurotypicals are constructed in participants with ASD.

Three false memory subtests were given to each of 20 participants. There were 10 ASD and 10 Control participants. A computer program presented the words from each word list separately and instructed the participant to begin recalling as many words as they could remember once they pressed the enter key. They were given 60 seconds per list to write down as many words as they could remember. There were 12 lists per substudy. There were three list types: semantic, phonological and hybrid. Semantic words within a list were all semantically related to the critical lure that was not presented while phonological words within a list were phonologically related to the critical lure that was not presented. The hybrid words within a list were either semantically or phonologically related to the critical lure word that was not presented. Therefore

presentation of such words within a list should activate the networks in which they are associated with.

It was predicted that ASD participants would be less susceptible to false memories given that previous studies have shown that ASD participants process information in a more local rather than global way (Jolliffe & Baron-Cohen, 1997). Results showed several interesting patterns that emerged. -It was found that ASD and control participants did not differ on the number of words correctly recalled or on the number of errors produced. They did show an interesting pattern of differences for the total number of critical lure items falsely recalled in which ASD participants always produced fewer critical lures than control participants. In addition, the number of critical lures produced did not differ across list type for ASD participants, but as expected control participants produced the most critical lures for the hybrid list. Finally, ASD participants produced significantly fewer critical lures on the hybrid list related to control participants. These findings support previous research that has highlighted the more restricted less distributed neuronal networks that might exist in ASD subjects. This work is important in that it allows researchers to better understand how those with ASD may be processing and categorizing information into their memory systems. This may in turn help us to create behavioral modification techniques that take into account processing differences that exist in ASD populations.

Dedication

This dissertation is dedicated to my parents, Abdul and Pari Ahad for their endless support and love.

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I would first like to thank my advisor, Dr. Jeffrey Hutsler. You have not only taught me a great deal about the field of cognitive neuroscience, but more importantly, how to critically analyze and interpret scientific information in this vast field. These are skills that I will take with me throughout my academic career.

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Investigating False Memory Phenomenon with Hybrid Lists in Autism Spectrum Disorders

Autism Spectrum Disorders (ASD) are a combination of behavioral deficits that include impaired social interaction, impaired communication, and repetitive behaviors (DSM-IV; American Psychiatric Association, 1994). While observable behavioral impairments are the primary means of diagnoses, such measures fail to take into account underlying neurological abnormalities that are shown to be associated with ASD. Investigating memory functioning has been one way in which researchers have attempted to examine brain organization differences that exist in ASD. For the past three decades, memory research in ASD has yielded widely varying conclusions on whether memory impairments are a core deficit in ASD (Minshew & Goldstein, 2001). Early research related an amnesia theory based upon studies that showed impaired recall and recognition memory and improvement of recall with cuing (Boucher & Warrington, 1976). The belief that amnesia was a single primary core deficit in ASD held for nearly two decades. It wasn’t until a growing number of studies (Bennetto, Pennington, & Rogers, 1996; Minshew & Goldstein, 1993; Mindshew, Goldstein, Muenz, & Payton, 1992; Rumsey & Hamburger, 1988) showed the absence of amnesia in ASD that researchers began examining memory characteristics in ASD. As explained by Minshew & Goldstein (2001), recent investigations on the characterization of memory function in autism have largely been driven by two hypotheses. The first that memory impairment is secondary to executive dysfunction (Bennetto, Pennington, & Rogers, 1996) and the second that memory impairment is one of multiple primary coexisting deficits related to complex information processing (Minshew, Goldstein, & Siegel, 1997).

Beversdorf et al. (1998) relate that individuals with ASD demonstrate superior performance on certain tasks, particularly those that require minimal semantic association or generalization. An explanation for this cognitive profile was put forth by Frith (1989) that proposed those on the autism spectrum demonstrate “weak central coherence”, or a relative failure to integrate diverse information, which also results in enhanced attention to detail. Such findings have been supported by research using tasks where attention to detail or local information is advantageous and have shown that those with ASD demonstrate superior performance. Studies have shown children with ASD show superior performance (in relation to their general mental age) on the Embedded Figures Task (Shah & Frith, 1983). Superiority in the Embedded Figures Task was also shown in a group of mentally handicapped children with ASD, when matched with a non-autistic mentally handicapped control group (Jolliffe & Baron-Cohen, 1997). They have also been shown to resist visual illusions (Happe, 1996). While cognitive abnormalities in autism tend to be thought of as deficits, such findings highlight their superiority on certain tasks. It leads to the idea that autistics may possess a different type of information-processing system (Jolliffe & Baron-Cohen, 1997).

One way in which to study information-processing systems in ASD is through memory tasks. Examining the reconstruction and accuracy of memory in ASD can provide feedback on ways in which they process important information. One particular way in which to study memory in ASD is through false memory paradigms.

False Memory

Barlett (1932) has been credited with conducting the first experimental study examining false memories. He had subjects read an Indian folktale and recall it repeatedly. His results showed distortions in subjects' memories over repeated attempts to recall the story. While his results were never successfully replicated by later researchers, his defining contribution was distinguishing between reproductive and reconstructive memory. Whereas reproductive memory refers to accurate, rote production of material from memory, reconstructive refers to the active process of filling in missing elements while remembering, with errors frequently occurring (Roediger and McDermott, 1995).

The study of false memory effect continued with most research showing an effect with recognition measures. In 1959 Deese published an experimental report that showed false recall in a standard list learning paradigm. He tested memory for word lists in a single-trial, free-recall paradigm. His interest was in predicting the occurrence of extralist intrusions in single-trial free recall. He developed 36 lists which contained 12 words per list. Each list consisted of 12 primary associates of a critical non presented word. His results showed that some of the lists induced subjects to produce the crucial non presented word as an intrusion during an immediate free recall test.

Deese's false memory study went virtually unnoticed for 36 years. It wasn't until Roediger and McDermott (1995) chose to replicate Deese's findings of reliable, predictable extralist intrusions in a single-trial free recall paradigm.

Roediger and McDermott False Memory Study

Roediger and McDermott's study consisted of two experiments. In experiment one, the goal was to examine both false recall and false recognition of critical non presented words and the confidence with which subjects accepted or rejected the critical non presented words as having been in the study list. In experiment two, the goal was to test other lists constructed to produce extralist intrusions in single-trial free recall as a way to attempt to generalize the findings across a wider set of materials. Researchers also examined the extent to which the initial false recall of items led to later false recognition of those same items. Following this, a remember-know procedure was employed to examine subjects' phenomenological experience during false recognition of the critical non presented items.

Experiment One

Six critical words were chosen that had produced the highest intrusion rates in Deese's experiment. Six lists were constructed for each critical word. Each list was read out aloud and the researcher would say "recall" at the end of each list. Subjects were then given 2.5 min to recall each list. After the six lists there was a brief conversation followed by instructions for the recognition test. Subjects would see words on a sheet of paper and had to rate each as to their confidence that it had occurred on the list. A 4 point rating scale was used where 4 was sure that the item was old/ (or studied), 3 was probably old, 2 was probably new, and 1 for sure it was new. Subjects worked at their own pace through the recognition test. Results showed that immediate free recall tests the non presented associates were recalled 40% of the time and were later recognized with high confidence.

Experiment Two

The goal of experiment two was to extend the recall and recognition results of Experiment one to a wider set of materials. Twenty-four 15-item lists were developed. In Experiment one, a high level of false recognition for the critical non presented words was obtained. One concern was that the lists had been recalled prior to the recognition test and in 40 percent of the cases the critical item had been falsely recalled as well. Therefore in experiment two, researchers wanted to examine the effect of recall on the subsequent recognition test. False recognition both for lists that had been previously recalled and for those that had not been recalled were examined. Researchers also wanted to determine the false-alarm rates for the critical non presented items when the relevant list had not been presented previously. Lastly, researchers wanted to obtain subjects' judgments about their phenomenological experience while recognizing non presented items. Subjects were asked to distinguish between two states of awareness about the past: remembering and knowing. Subjects were told to (a) to judge each item to be old (studied) or new (non studied) and (b) to make an additional judgment for each item judges to be old: whether they remember or know that the item occurred in the study list. A remember experience was defined as one in which the subject can mentally relive the experience while a know judgment is made when subjects are confident that the item occurred on the list, but are unable to re-experience its occurrence.

Subjects were presented with 16 lists. After half of the lists, they received an immediate free recall test and after the other half they did math problems. After all of the lists had been presented, subjects received a recognition test containing items from the 16 studied lists and 8 comparable lists that had not been studied. During the recognition test, subjects made old-new judgments, followed by remember-know judgments for items judged to be old. Results showed a false recall rate of 55 percent. On the recognition test, subjects produced false alarms to these items at a rate comparable to the hit rate. Roediger and McDermott's paper illustrated the relative ease of creating a false memory for a non-presented word. Following such robust results, the use of the Deese-Roediger-

McDermott (DRM) word lists quickly became a fundamental paradigm for studying the creation of false memories by way of false recall of non-presented words. These results have been replicated and extended by many subsequent researchers. Such work has revolved around manipulating and changing different stages of the memory task. For instance, research has investigated the encoding period, or study experience, as what happens during encoding plays a key role in the likelihood of false recall at test (Hicks & Marsh, 1999; Watson, McDermott & Balota, 2004).

The study of false memories in autism spectrum disorders (ASD) has also been investigated. Autism has been associated with impaired social interaction and communication (DSM-IV; American Psychiatric Association, 1994). These behaviors have been attributed to “weak central coherence” or impaired ability to use context, which may manifest as dysfunction of the neural networks that interrelate the meanings of words/semantics (Beversdorf et al., 2000). Typically when words are placed into syntactic or semantic context, individuals will remember more words than when words are not placed into context (Miller, 1950). Studies have shown that autistic individuals show less of an increase in recall when words are placed into syntactic or semantic context (Budson et al., 2001). To date, only four studies have used the DRM paradigm in ASD individuals to study false memory. These four studies will be reviewed so as to provide a strong foundation for the proposed plan of study. Please see Table 1 for an overview of all four studies.

ASD False Memory Studies

Gaigg & Bowler (2009) investigated illusory memories of emotionally charged words in ASD individuals. Numerous studies over the past four decades have shown that individuals across the autism spectrum are severely compromised in various aspects of affectively patterned communication (Gaigg and Bowler, 2009; Sigman et al., 1992; Moore et al., 1997; Corona et al., 1998). The current study chose to investigate the role of affective disturbances in ASD by assessing how the emotional significance of stimuli impacts on processes that are not primarily of a social nature. In order to investigate this, a memory paradigm was implemented given that its influences and emotional factors in this domain are well established and understood (Gaigg & Bowler, 2009). Within this domain, studies have shown that emotionally significant information is better remembered than neutral information (Kensinger and Corkin, 2003). While ASD studies examining processing of emotional information have shown mixed findings, the majority suggest that individuals with ASD do not process and store emotional material distinctly from memories of non emotional information (Gaigg & Bowler, 2009; Beversdorf et al., 1998). Gaigg & Bowler hypothesized that based on such findings individuals with ASD would be as likely to succumb to illusory memories of emotionally charged as neutral words. In addition, they were interested in whether individuals with ASD would be as susceptible to the illusory memory phenomenon as typically developed individuals. Twenty-two individuals with a diagnosis of ASD and 22 typically developed individuals participated. The study material was taken from Pesta et al.'s (2001) study which included 12 groups of 10 orthographically related words, 12 target lures, and 3 so-called 'distinctiveness attenuators'. Of the 12 orthographic word groups, six were designated as Set A and six as Set B. Within each of these sets, three groups of words included the orthographic neighbors of three neutral target lures while the other three groups included the orthographic neighbors of three emotionally charged target lures. The emotional and neutral target lures were matched on word frequency and letter length while the lists comprising the orthographic neighbors of each type of target lure were matched as close as possible in terms of the number of strict orthographic neighbors of their respective target lure. The three ‘distinctiveness attenuators’ were presented during the study phase of the experiment and served to satisfy the participants’ expectations of seeing emotionally charged words during the experiment. During the study phase, participants were presented with a sequence of 67 words, including the sixty words from the orthographic word groups of either Set A or Set B, the three ‘distinctiveness attenuators, and four buffer words (2 at the beginning and 2 at the end of the list). During the recognition test participants were presented with a random selection of 18 words that they had studied (3 from each orthographic word group), 18 words from the set that they had not studied (3 from each orthographic word group) and all 12 target lures. The order of presentation was random. Participants were presented with to-be-remembered list of words. Immediately after the last word, participants were given instructions about the impending recognition memory test. The instructions specified that the participants would again see a list of words and that this list would include some of the words that they had just seen and some new words. Participants were instructed to indicate whether or not they had seen a particular word before and the experimenter noted these responses on an answer sheet. Results related that control participants are far less likely to experience illusory memories of emotionally charged as compared to neutral words. Individuals with ASD did not exhibit this emotional modulation of false memories. The researchers put forth an interpretation of these results. They explain that throughout development, individuals with ASD accumulate representations of emotionally significant information that are indistinct from representations of neutral information. Autonomic responses during emotionally charged situations in ASD are atypically integrated with the subjectively experienced perception of the situation, resulting in an alteration in how relevant information is consolidated into long-term memory. This study was a prime example of how an illusory memory paradigm could be used in ASD individuals to study atypical processing of emotional information. Also, while many false memory studies use the typical false memory word lists that are semantically related, this study used orthographically related words. This highlights the fact that words are processed both semantically and orthographically.

Kamio & Toichi (2007) investigated memory illusions with semantically related sentences as opposed to traditional word lists. The researchers argued that prior studies have indicated that individuals with autism have perceptual processing that predominates semantic processing, leading to intact rote memory that might, in some cases, manifest as echolalia or savant abilities. Furthermore, the authors hypothesized that given that perceptual processing increases the accuracy of true memory, individuals with autism would be less susceptible to memory illusions. The researchers chose to separately investigate semantic associative processing in both high functioning autistic individuals and those diagnosed with Asperger's disorder (AD) which had not been mutually compared previously. As opposed to using word lists, sentences were used. The reasoning behind this was that memory performance in high functioning autism (HFA) becomes increasingly impaired as the complexity of the material increases from letters to words to sentences (Minshew & Goldstein, 2001). Participants were 13 HFA individuals, 15 AD individuals and 15 individuals who served as a control group. All participants had similar chronological age, verbal IQ and full scale IQ. Four complex sentences were made in Japanese which represented four different ideas: 1. The rock rolling down the slope crashed into the small car running along the road 2. The cat that lives next door ate the golden carp in the pond 3. The cherry blossom in bloom in the park dropped down on the wind from the sea 4. The old man watched a series of TV dramas sitting in a chair. Each of these sentences have four semantic propositions and were denoted as FOURs. Each FOUR was broken down into simple sentences (ONEs). Two ONE sentences were recombined to create a TWO sentence. Three ONEs were combined to create a THREE sentence. Six NONCASE sentences were made by combining fragmented information within and across the original idea sets so that the meaning of the sentences were changed but were not considered nonsense. There were two phases, the acquisition phase (incidental learning phase) and the recognition phase. The acquisition list contained 24 sentences consisting of two ONEs, two TWOs, and three THREEs from each of the four idea sets. The 24 sentences were arranged in a random order with no two sentences from the same set occurring consecutively. In addition to the 24 sentences, 3 unrelated sentences were put from the beginning to the end to prevent primacy and recency effects. Sentences in the acquisition list were read aloud at a rate of 5 s per sentence. Participants were asked to answer orally a color-naming task after each sentence. This was used for intervening purposes. The recognition phase consisted of a recognition list of 30 sentences. From each set, two ONEs, two TWOs, one THREE, and one FOUR were chosen. All were new sentences that had not been presented in the acquisition phase. Six NONCASE sentences were also included in the list. Participants were asked to read a recognition list and to evaluate whether or not each sentence had been heard before.

They were to rate their confidence of each sentence as to its occurrence on a 5-point Likert scale.

Results showed that all groups falsely recognized semantically related sentences more often than unrelated ones. Memory illusion for sentences occurred with similar frequency in the HFA and AD group as in the Control group. The rate of false recognition was higher for semantically related sentences than for unrelated sentences across groups. The confidence ratings did vary by group depending on the number of semantic propositions embedded in a sentence after controlling for age and VIQ. In the AD group and in the Control group, sentences comprising multiple semantic propositions were more likely to be recognized falsely than those with only one semantic proposition. On the other hand, in the HFA group, THREEs containing the second most semantic propositions, rather than FOURs, were the most susceptible to false recognition. To summarize, individuals with both HFA and AD are susceptible to memory illusions for semantically related sentences, comparably to age and IQ-matched controls, in terms of the occurrence rates. Those with HFA showed reduced memory illusion for the sentences that expressed the most complete semantic information of the previously studied idea. In contrast, memory illusion in AD and control participants was more likely to occur when the sentences expressed more complete semantic information. Therefore the researchers argue that their findings show that individuals with HFA are less susceptible to memory illusions than those with AD and controls.

Beversdorf et al. (2000) argue that individuals with autism spectrum disorder (ASD) have impaired ability to use context, which may manifest as alterations of relatedness within the semantic network. Furthermore, they state that such impairments with context may be more difficult to detect in high functioning adults with ASD. A false memory test was administered by using stimuli and procedure from Roediger and McDermott (1995). Their hypothesis was that comparison of illusory and true recognition from this test might prove sensitive to variations in use of semantic and associative context. Therefore, subjects with ASD would be expected to discriminate true items from "false" items better than matched control subjects on this test. The study consisted of eight high-functioning adults with ASD and 16 nonautistic adults, matched for age, gender, performance scale Wechsler Adult Intelligence Scale-Revised Intelligence Quotient (WAIS-R IQ), verbal scale WAIS-R IQ, full-scale WAIS-R IQ, and educational level, were studied. A false memory test was administered using stimuli and procedure modified from Roediger and McDermott (1995). Subjects were presented with an audiotape consisting of the first 12 of the 15 words from each of the 24 word lists of Roediger and McDermott (1995). After each word list, the tape was stopped and subjects were given a seven item recognition test for that list. Two of the test words from this recognition test were items from the list. Two words were distantly related to the index items but were not on the list. One word was the index item, a closely related item that was not on the list. The placement of the index item among the seven recognition test words was varied from fifth to seventh in order of presentation, such that subjects would be less likely to detect a pattern.

For each recognition trial, subjects were asked to respond verbally "four" if they were certain the prompted word was on the list, "three" if they though the word was probably on the list, "two" if they thought the word was probably not on the list, and "one" if they were certain the word was not on the list. Half of the subjects heard an audiotape starting with list 1 and proceeding through list 24 of Roediger and McDermott (1995) while the other half heard a tape starting with list 24 and proceeding in reverse order. Subjects were also given a California Verbal Learning Test as a way in which to compare results of this test with previously studied tests of the role of semantic relatedness in memory. Such a test involves learning word lists in which several items come from the same semantic category. In normal individuals, semantic relatedness improves recall performance.

As a way in which to generate an index for comparison of the ability of subjects with ASD and control subjects to discriminate true items from false items, d’ was calculated for each subject comparing recognition of true items and index (false memory) items. Separate calculations of d’ were performed for “definitely” responses (replies of “four”) and “yes” responses (sum of replies of “three” and “four”). ANOVA showed that subjects with ASD discriminated true items from false index items (d’) significantly better than control subjects for “definitely” responses. Further ANOVA calculations showed that subjects with ASD discriminated true items from false index items significantly better for “yes” responses but not “definitely” responses. It should be noted that while subjects with ASD performed better than controls at discriminating true items from index items, control subjects did not recognize significantly more false index items than subjects with ASD for “definitely” responses. Yet control subjects did recognize significantly more false index items than subjects with ASD for “yes” responses. Subjects with ASD did not recognize significantly more true items than control subjects for “definitely” responses or “yes” responses. The authors summarize these results as showing that the critical difference between subjects with ASD and those without ASD is the finding that those without ASD were more inclined to endorse the index items as previously viewed, when other differences in their pattern of responding were controlled statistically. Overall, the two groups did not differ significantly in terms of the criterion they used to distinguish between true and false recognition of items and none of the subjects showed any serious responses biases.

Verbal working memory was also compared between the groups by using the California Verbal Learning Test. The authors argued that subjects with greater verbal working memory would be expected to perform better at discriminating true from false index items. Results showed that control subjects and subjects with ASD showed no significant difference in verbal working memory. When d' scores were compared while controlling for individual differences in verbal working memory by using analysis of covariance, subjects with ASD demonstrated better discrimination of false memories for both "definitely" responses with d' and "yes" responses with d'.

To test whether subjects with ASD performed better because of a change in strategy during the test, the authors used a repeated measures ANOVA to look for an interaction between group (ASD vs. control) and order within the test (first half vs. second half). No group-order interaction effect was found for "yes" responses or "definitely" responses for either true or false index items.

The authors summarized their findings that individuals with ASD were better able to discriminate false memory items from true items significantly better than control subjects in line with the "weak central coherence" argument. Beversdorf et al. (2000) argue that with decreased use of context, subjects with ASD are less susceptible to the influences of associatively related (frequently co-occurring) and semantically related (similar in meaning) words in inducing illusory recognition of index items not presented on word lists. For this reason, individuals with ASD have an advantage on false memory tests. While such a processing system may allow for superior performance on false memory tests, it may impair their performance in daily life. Given that context is important for many forms of learning, problem solving and determining appropriate responses in a particular social setting, individuals with ASD may be at a disadvantage.

Bowler et al. (2000) investigated false recall and recognition in adults with Asperger's syndrome, which falls within the wide spectrum of autistic disorders (Wing, 1997). Adults with Asperger's syndrome show no evidence of impaired language function and have intellectual abilities that fall within the normal range (Volkmar et al., 1996). Previous studies have shown that in groups of adults with Asperger's syndrome there is evidence of selective episodic memory impairment (Bowler, Gardiner & Grice, 2000; Bowler, Matthews, & Gardiner, 1997). In particular, those with Asperger's syndrome do not show higher free recall of conceptually categorized word lists compared with unrelated word lists (Bowler et al., 1997). Furthermore this may suggest that such individuals are unable to utilize conceptual relations among list words to improve their recall. Taking this a step further, this could also suggest that it could be possible that adults with Asperger's syndrome would be less prone to illusory memories than matched controls (Bowler et al., 2000). Yet given that adults with Asperger's syndrome possess poor source monitoring (Schacter et al., 1998) as in remembering which lists include particular words in memory tasks. This could suggest that they might be at least as prone to these memory illusions as other adults, if not more so.

Therefore Bowler et al. (2000) chose to investigate whether adults with Asperger's syndrome were more or less prone to illusory memories than matched controls. Two experiments were constructed, with the first investigating false recall and the second investigating false recognition in the converging associates paradigm.

Experiment one consisted of 10 adults with Asperger's syndrome and 15 control participants. Both groups studied 12 of the 15-word lists used by Roediger and McDermott (1995). Each list consisted of the 15 highest associates of a critical nonpresented word. Participants were told that they would be presented with a series of lists of words and that the end of each list would be marked by a tone. On presentation of the tone, they were instructed to try and remember as many of the words on the list as they could, in any order. An analysis of the data showed that the Asperger group was just as prone to the false recall effect as was the matched control group, despite recalling significantly fewer studied words. The Asperger group also made significantly more noncritical intrusions, mostly of other words that were associatively related to the list currently being recalled.

For experiment two, 10 adults with Asperger's syndrome and 10 individually matched control participants studied five lists of nine words each, presented in a single continuous sequence. The nine words in each set were the strongest associates of three nonpresented words. These three nonpresented words (false targets) were included in a subsequent recognition test in which there were also three presented words from each list (true targets) and three other unrelated words (lures). In the recognition test, participants in each group also made remember and know responses to identify recognition accompanied by recollective experiences and recognition accompanied only by feelings of familiarity. Results showed that individuals with Asperger's syndrome are also susceptible to false recognition effects. It was also found that in both groups false recognition effects were almost entirely associated with remember responses, slightly more so in the Asperger group. Overall, this study is one of the first to show that individuals with Asperger's syndrome are subject to illusory memories. When compared with individually matched controls, there was little evidence that individuals in the Asperger's group were any more or any less prone to memory illusions. It should be noted though that the sample size was very low, which may have played a role in the statistical significance. This can be supported by a power analysis that was calculated that showed the sample sizes used would have yielded insufficient statistical power to reveal significant group differences.

In summary, the ASD studies described in this section have very contradictory findings. This most likely is due in large part to a number of different factors, such as, diagnostic category, age and intellectual level. Thus the hypothesis that individuals with ASD are more or less susceptible to false memories has not been supported consistently. The investigation of false memories and ASD should continue to be studied with more rigid parameters as a means to better understand the way in which ASD individuals process and store memory related information.

Taking into consideration the mixed results of ASD individuals and their performance on false memory paradigms, there are suggestions that high functioning ASD subjects are less susceptible to false memories. There are several explanations as to why this may occur. One such is that high functioning ASD individuals may have difficulties in forming schemas (Cohen, 1994). This is based upon Barlett's "schema" theory (Bartlett, 1932) which states that we normally reconstruct incoming information based on our own “schema” that comprises past experiences. Incoming information is often added, ignored, or transformed through such an active process, and false memory is considered to be its by-product. Therefore it may be that ASD individuals may have difficulties in forming schemas. If schemas are not formed correctly then new information may remain fragmented.

Mottron & Burack (2001) have suggested an enhanced perceptual processing account which hypothesizes that the deficiency in higher-order processing in ASD facilities overdevelopment of low-level functioning through a compensatory mechanism. This may explain why certain studies have shown ASD individuals are less susceptible to false memories due to a deficiency in higher-order processing.

Frith (1989) put forth a weak central coherence account, which hypothesizes a biased cognitive style towards local rather than global information processing in ASD. This account would predict good performance on rote memory of words or phrases, and poor performance on higher-order semantic processing. Previous studies with high functioning ASD individuals have shown their superior performance on rote memory tasks (Kamio & Toichi, 2003), which supports this viewpoint.

There are also neurological studies, which have shown abnormal processes within the autistic brain. In particular, Hebb (1949) explains that memories are stored by forming associative connections between neurons that are simultaneously active. An increase in synaptic strength or long-term potentiation has been described in the hippocampus. In addition, the hippocampus may be an essential component in the development of semantic networks (Gabrieli et al., 1998). Decreased dendritic arborization and increased neuronal cell-packing density have been shown in the CA4 and CA1 subfields of the hippocampus in ASD (Mottron et al., 1996). Beversdorf et al. (2000) has argued that it may be possible that in ASD the diminished degree of hippocampal neuronal arborization results in a reduction in the amount of associative information stored in neocortical areas being used in CA-1 subfield N-methyl-d-aspartate-mediated associative long-term potentiation. Taken together, such studies may explain the decreased use of context in select groups of ASD individuals.

Hybrid Study

The DRM paradigm consists of semantically related word lists. Since Roediger and McDermott’s 1995 study, researchers have replicated their results and continue to show significantly high levels of false recall and false recognition (Lampinen et al., 2006). While these studies typically use semantic associates, an increasing number are also incorporating phonological associates. As explained by Watson et al. (2004) semantic lists may include lexical and/or semantic associates (e.g. lion and tiger) while phonological lists may include orthographic and/or phonological associates (e.g. log and dog). Therefore, there are memory networks for semantic associates that deal with the meaning of words, orthographic associates which deal with the spelling of words and phonological associates which deal with the pronunciation of words. Robust levels of false recall and false recognition to the critical item have been found in studies using phonological and orthographic lists in typical subjects (Watson et al., 2003).

Given that memory can be stored based upon it’s semantic, phonological and orthographic information, studies which only investigate one particular type, may not be getting the complete picture of memory failures. Studies which investigate both semantic, phonological and a combination of both coined “hybrid” lists, allow researchers to have a more detailed picture of memory processes and failures in typical subjects. Holliday and Weekes (2006) investigated memory failures to semantically and phonologically related word lists at 8, 11, and 13 years old. Results showed that false memories in the two tasks showed opposite developmental trends, increasing with age for semantic relatedness and decreasing with age for phonological relatedness. These findings may suggest that as we age, our higher order functioning increases and therefore we are better able to rely on semantically related information. Thus the study of both semantically and phonologically related word lists would prove beneficial in understanding how the autistic brain processes information.

Watson et al. (2003) investigated the influence of combining both semantic and phonological associates into a single hybrid list using 66 typical subjects. The goal of their first experiment was to determine the contribution of additional phonological associates to false memories in a list that primarily included semantic associates. Results showed that there was a dramatic increase in false recall by simply adding 1,2, or 3 phonologically related words. The goal of their second experiment was to determine if the effect of mixing semantic and phonological associates is additive, under-additive, or over-additive in a 72 item list. Results again showed that false recall of a non-presented critical item dramatically increased with hybrid lists and were over-addictive in nature. For experiment three, the researchers chose to use shorter lists than the 72-item list in experiment two by using 16-item lists of semantic and/or phonological associates. This consisted of lists of 8 semantic associates and 8 phonological associates. Results showed that such lists produced greater false recall and recognition than the average produced in lists containing 16 semantic or 16 phonological associates. The researchers argued that taken together, these results provide evidence that lists of semantic and phonological associates produce over-additive false recall and false recognition of non-presented critical items relative to pure semantic or pure phonological lists.

While there has currently not been a hybrid list type study published with ASD subjects, Watson et al. (2001) investigated semantic, phonological and hybrid veridical and false memories in healthy older adults and in individuals with dementia of the Alzheimer type. Their study showed that individuals with dementia were three times more likely to recall the critical nonpresented word than a studied word as compared to typical subjects.

Taken together, there is growing evidence that shows hybrid lists constituting a combination of semantic and phonological words tend to increase the rate of recall and recognition as compared to semantic or phonological word lists alone. Investigating hybrid lists in ASD individuals may provide more detailed information on how they process and store both semantic and phonological information as compared to typical individuals. In addition, it will also provide a more detailed look into how autistics process and store complex information that they would be accustomed to during their daily lives.

Brain Regions Associated with Memory and False Memory

A growing number of studies have examined brain regions involved in memory using various neuroimaging techniques. In particular both PET and functional MRI (fMRI) have shown consistent activations of the frontal cortex in a number of different memory tasks (Fletcher & Henson, 2001). As explained by Fletcher and Henson, functional neuroimaging offers the possibility of detecting differences in the strategies that subjects or patients employ. In addition, they can elucidate different stages of a memory process. For instance, they can examine separately the encoding and retrieval of memories, a dissociation that cannot be made with confidence from anterograde memory deficits following frontal lobe lesions. In regards to working memory, functional imaging of human working memory has shown evidence that broad anatomical divisions within the lateral FC subserve different processes. In particular, the ventrolateral frontal cortex is more often activated during tasks requiring maintenance and dorsolateral frontal cortex is more often activated during tasks requiring manipulation (Christoff and Gabrieli, 2000).

A fundamental yet poorly understood issue concerns the neural basis of false recognition as related to true recognition. In a positron emission tomography study participants heard semantically associated words at study. On a subsequent test they made old-new recognition decisions to old words (studied items), related words (critical nonstudied lures) and new words. True recognition-related activity was greater than false recognition-related activity in the left temporoparietal region, which may have reflected memory of auditory/phonological information (Schacter et al., 1996). In an fMRI study (Cabeza et al., 2001), two videotaped speakers read lists of semantically associated words and categorized lists to participants during the study phase. During the test phase, participants were scanned as they made old-new recognition memory decisions when presented with old words, related words and new words. They showed robust levels of true and false recognition, both of which were associated with activity in the prefrontal cortex, the parietal cortex and the hippocampus, regions that have been associated with veridical old-new recognition memory in other studies (Buckner et al., 1998). In addition, true recognition, as compared with false recognition, was associated with greater activity in the parahippocampal gyrus, a region that has been associated with contextual processing. Such parahippocampal activity may have reflected true recognition-related contextual memory (for the videotaped speakers). Interestingly, recent studies examining memory retrieval have provided converging evidence for true recognition-related sensory reactivation of the same cortical regions involved in processing stimulus materials during encoding, including reactivation of motor processing regions during memory for motor sequences (Nyberg, 2001), reactivation of auditory processing regions during memory for sounds (Nyberg et al., 2000), and reactivation of visual processing regions during memory for pictorial stimuli (Wheeler an Buckner, 2003).

Research has also centered on understanding how both phonological and semantic information is processed. Herbster et al. (1997) hypothesized that the left inferior frontal gyrus may be part of a phonological pathway whereas the fusiform gyrus may be part of a semantic pathway based on cerebral blood flow findings. Zatorre et al. (1996) reviewed a number of neuroimaging studies and suggest that the left inferior frontal gyrus is involved in phonological processing. For example, greater activation in the left inferior frontal gyrus was found when subjects performed a phononological versus an orthographic discrimination task on visually and auditorily presented words (Fiez et al., 1995). Suprisingly, the left inferior frontal gyrus activation has also been shown in studies examining semantic processing (Petersen et al., 1989). Many neuroimaging studies have implicated posterior regions in semantic processing Bookheimer et al., 1995;

Vandenberghe et al., 1996). Such findings are not contradictory in that quantitative analyses of left inferior prefrontal activations have provided clear evidence that it contains functionally distinct subregions (Buckner et al., 1995). Therefore within the inferior frontal cortex, more specific localization can be made. For example, semantic processing has been most often located anteriorly within the ventral inferior prefrontal cortex, whereas activations attributed to phonological processing has been more frequently located posteriorly within the triangular and opercular portions of the inferior frontal gyrus (Fiez, 1997).

Aim of Current Study

The aim of the current study was to investigate false memory in ASD using a) semantic lists b) phonological lists c) hybrid lists consisting of both semantic and phonological word items as a way in which to investigate all factors involved in false memory. In particular, Watson et al. (2003) was used as a procedural template so as to compare previous findings with our own.

Methods

Participants

Participants were 10 Autistic individuals and 10 age matched control individuals. Participants were between the ages of 8-16. ASD subjects met the DSM-IV criteria for ASD (i.e., autism, pervasive developmental disorder, or Asperger syndrome), were verbal, and did not have behavioral problems that interfered with testing. Their diagnosis was confirmed using the Gilliam Autism Rating Scale (GARS - 2). All participants were given an IQ test. The Wechsler Abbreviated Scale of Intelligence (WASI) was administered. Full scale measurements were taken, which included both verbal and performance measurements. It should be noted that all IQ measurements were taken by one researcher. All participants were given a short memory test individually before they began the experiment. This test consisted of the participant watching words as they appeared on a computer screen one at a time for a one second presentation. At the end of the 10^{th} word, the computer instructed the participant to write down as many words as they could remember being presented on the computer screen. They were told they would have 60 seconds to do so. Participants were deemed fit to proceed to the actual experiment if they were able to list at least 5 words that were presented. All subjects were male.

Materials

The present study used eighteen 16 item list of words. In particular the Semantic list type consisted of six 16-item lists, the Phonological list type consisted of six 16-item lists, and the Hybrid list type consisted of six 16-item lists. These list types were based on Watson et al. (2003) published semantic and phonological lists. Please see Table 3 for a list of all list types. A counterbalance design was created which took into consideration a) number of participants per group, b) order of list presentation. Only two conditions were created due to the a) previous studies that have shown ease at which false memories can be shown using the type of paradigm this study employed and b) the low number of participants. The two conditions, A and B, included 10 participants in each (5 ASD and 5 Control). Condition A consisted of first presenting semantic, phonological and hybrid while Condition B consisted of phonological, hybrid and semantic. Please see Table 2 for a detailed overview of counterbalance design.

Procedures

Participants were tested individually in a quiet room with no distractions. At the beginning of the experiment, participants were told to memorize lists of words that would be presented on a computer screen. A recall packet was given, which consisted of instructions and eighteen sheets of paper on which to write their responses. Each piece of paper was labeled according to the eighteen lists (e.g., “List 1”) with 16 blank spaces, which correspond to the total number of words presented on a single list. Participants were told that further instructions would be given on the computer screen. The researcher then began the computer program. The computer program stated that participants would be given 60 s after each list to recall the words that were presented. In addition, participants were instructed not to guess when trying to remember the words from the lists and to only write down words if they were sure that those words had been presented. The computer program then stated:

> Please feel free to ask the experimenter any questions that you may have at this point. If you feel that you understand these instructions, you may begin this portion of the experiment.

On each trial of the experiment, the following sequence of events occurred: a) participant pressed the ENTER key to begin presentation of a study list, upon which the screen was blanked; b) a 1 s delay, c) a 300 ms tone, d) a 32 ms inter-stimulus interval, e) a study word appeared in the middle of the computer screen and remained for 1 second f) the screen was blanked and steps d through f repeated for the remaining words on a list, g) after all 16 words in a list had been presented there was a 500 ms delay followed by an instruction to begin recall, with the computer providing a 1 minute countdown for the participant, h) after the 1 minute recall period was complete, a 1 second tone sounded followed by an instruction to stop recall, and there was a 5 second inter-trial interval, i) the screen was blanked and steps a through i repeated for the remaining lists of words.

The analysis plan is to examine a number of different variables. First, correlational measurements for a) age b) verbal IQ c) performance IQ d) full IQ and e) GARS scores (for ASD participants) will be analyzed to explore the relationships, if any, exist across these variables. Next, differences between and within subjects for a) number of critical lure items falsely recalled b) number of words correctly recalled and c) number of errors made will be examined for both groups. The main analysis consisted of three mixed-model ANCOVAS that explored the impact of group, list type, and order of presentation (condition) on a) the number of critical lure items falsely recalled b) the number of words correctly recalled and c) the number of errors listed. Because of its known influence on list recall performance (Chai & Ceci, 2005), FSIQ was used as a covariate in each model.

Results

Table 4 shows mean values (along with standard deviations) for age, verbal IQ, performance IQ, full IQ and GARS scores for both groups (ASD and Control). In addition, a statistical analysis was conducted examining these same variables across groups to determine whether there were significant differences between ASD and control participants. Table 5 shows the results of this analysis and reveals no significant differences across groups for any of the variables listed (age, verbal IQ, performance IQ and full IQ). Effect sizes (Cohen’s d) were also reported in table 5 for each comparison, due to the modest size of the subject groups. A negligible effect size ($d = 0.040$) was shown for age, a medium effect size for verbal IQ ($d = 0.422$) and full IQ ($d = 0.533$)

while a large effect size was shown for performance IQ (d= 0.794). In summary, ASD and control participants were well-matched on age, but did show modest average differences in IQ values of approximately ten to twelve points.

Correlational measurements were conducted to explore the relationship between the various subject characteristics and dependent measurements in the current study. The largest of these bivariate correlations are reported in tables 6 – 10. Because of the exploratory nature of this analysis, all p values are uncorrected for family-wise error. For each group, bivariate correlations were calculated for a) full scale IQ and verbal IQ, b) full scale IQ and performance IQ and c) performance IQ and verbal IQ. All IQ subscales are correlated with each other, with moderate correlational values for verbal IQ and performance IQ for control participants. Please see table 6 for these correlational measurements.

A second set of correlational measurements were taken to determine the relationship between full scale IQ and a) the number of words recalled for each list type (phonological, semantic and hybrid) b) the number of list errors for each list type (phonological, semantic and hybrid) which represents participants who recalled words that were never presented during the experimental session and c) the number of critical lure items recalled for each list type (phonological, semantic and hybrid). Full scale IQ never correlated significantly with any of these dependent measures (please see table 7).

A third set of correlational measurements were taken to investigate the relationship between age and a) the number of words correctly recalled per list type (phonological, semantic and hybrid) and b) the number of critical lure items recalled per list type (phonological, semantic and hybrid). Interestingly, age was found to be positively correlated with the number of words correctly recalled for both the phonological ($r = 0.702$, $n = 10$, $p < .05$) and hybrid ($r = 0.647$, $n = 10$, $p <.05$) list types in ASD participants. It should also be mentioned that there was a modest correlation between age and semantic list type for ASD participants ($r = 0.571$, $n = 10$, $p = .085$) that did not reach statistical significance. Older aged control participants produced fewer critical lure items while ASD participants did not show a decline in critical lure items recalled. These results are interesting in that they may be hinting at a pattern in which ASD participants do not show a decline in critical lure items recalled as they mature. Please see table 8.

A fourth set of correlational measurements were taken to investigate the relationship between GARS scores for ASD participants and a) the number of words correctly recalled per list type (phonological, semantic and hybrid) b) the number of words falsely recalled per list type (phonological, semantic and hybrid) which represents participants who recalled words that were never presented during the experimental session and c) the number of critical lure items recalled per list type (phonological, semantic and hybrid). While higher scores on the GARS report, which indicates more autistic symptomologies, is not correlated with the number of words recalled or the number of errors produced, there were other interesting relationships. Participants with higher GARS scores recalled fewer critical lure items for the semantic lists, but there was no relationship between GARS score and the number of critical lure items produced in the phonological or hybrid list. It should be mentioned that an interesting pattern here is found. Namely, there is no relationship between GARS and number of critical lure items falsely recalled on the phonological list but there is a modest to large relationship between GARS and both the semantic and hybrid list. In particular, ASD participants with the highest level of autistic symptomology tended to produce the lowest number of critical lure items for both the semantic and hybrid lists. -Please see table 9.

Also, correlational measurements were conducted to investigate the relationship between the number of words recalled for each list type. In particular, was there a positive relationship between the number of words correctly recalled for the following list comparisons: a) phonological and semantic lists b) phonological and hybrid lists and c) semantic and hybrid lists. Please see table 10.

To summarize, the correlational measurements that were reported show interesting patterns. In particular, age was found to be positively correlated with the number of words correctly recalled for both the phonological and hybrid list types in ASD participants. While older aged control participants produced fewer critical lure items, older aged ASD participants did not show a decline in recall of critical lure items. In addition, it was found that ASD participants with the highest level of autistic symptomology tended to produce the lowest number of critical lure items for both the semantic and hybrid lists.

Analysis of Covariance Measurements

Mixed analysis of covariance were conducted for three dependent measures: a) the number of critical lure items recalled b) the total number of errors listed and c) the total number of correctly recalled words. First, an analysis of covariance for total number of critical lure items recalled, using full scale IQ as a covariate, was measured for both within subject and between subject effects. Within subject effects for the total number of critical lure items recalled included a) main effect of list type b) list type by group c) list type by condition and d) list type by group by condition. While results showed no statistical significance across any of these variables, there was a modest interaction of list type by group ($F_{2,30}$ = 3.163; p = .057). It should be noted that partial eta squared value of ηp_2 = .174 was found for this interaction with a power value of .562. Please see table 11. In addition, to explore the modest interaction between group and list type, the simple main effects of list type were calculated for ASD and did not reveal statistical significance ($F_{2, 18}$ = .545; p = .589). Simple main effects of list type were also calculated for control participants. Statistical significance was found for list type ($F_{2, 18}$ = 3.669; p = .046). The number of critical lures produced changed across list type for control participants, but remained constant in the ASD group. Effect size was calculated using the method described in Morris and Deshon (2002) given that list type was a repeated/ within subjects measure and therefore may be correlated. Please see table 19 for simple main effects for both ASD and control participants. Furthermore, pairwise comparisons for control participants were measured for a) semantic v. hybrid b) phonological v hybrid and c) phonological v semantic lists. While statistical significance was not found for any of the pairwise comparisons, two comparisons were close to significance. In particular, these were phonological v. hybrid ((LSD test, p = .074) which had an effect size of d = 2.045 and a power equal to .445 and semantic v. hybrid (LSD test, p = .057) which had an effect size of d = 2.281 with a power of .491. It should be noted that both pairwise comparisons that were close to significance had very large effect sizes. To directly assess differences between ASD and control participants, post hoc t tests for each of the three list types were also measured. There was no difference between the two groups for the semantic word list, t (18) = -.453, p = .669. ASD and control participants did show a trend toward differing on the phonological list, t (18) = -1.832, p = .083). Effect size was calculated to be d = .819 with a power value of .41. ASD and control participants did differ on the hybrid list, t (18) -2.861, p = .010). An effect size was calculated to be d = 1.279 with a power of .773. Please see figure 1 for an overview of these results. In sum, the largest differences in the number of critical lures produced were found for the hybrid list type. Please see table 17 & 18.

Between subject effects for total number of critical lure items recalled were measured for a) main effect of group b) main effect of condition and c) group by condition. Again, while no statistical significance was shown for any of the variables measured, a modest effect was shown for the main effect of group ($F_{1, 15} = 3.619$; p= .077). In addition, partial eta squared value was calculated to be $\eta p_2 = .194$ with a power value of .429. Please see table 12.

Statistical analysis were also conducted investigating analysis of covariance for total number of errors for both between subject and within subject effects for the same variables as listed for total number of critical lure items recalled using age as a covariate. Statistical significance was not shown for any of the variables measured and effect sizes were universally small. Figure 2 shows the insignificant difference across list type for both groups. Please see tables 13 and 14 for detailed results. Statistical analysis were also conducted investigating analysis of covariance for total number of correctly recalled words. Full scale IQ was used as a covariate in this analysis. Statistical significance was not shown for any of the variables measured for both between and within group effects. This can be seen in figure 3. Please see tables 15 and 16 for detailed explanation of measurements. In summary, ASD and control participants did not differ on the number of words correctly recalled or on the number of errors produced. They did show an interesting pattern of differences for the total number of critical lure items falsely recalled in which ASD participants always produced fewer critical lures than control participants. In addition, the number of critical lures produced did not differ across list type for ASD participants, but as expected control participants produced the most critical lures for the hybrid list. Finally, ASD participants produced significantly fewer critical lures on the hybrid list related to control participants.

Discussion

The purpose of this study was to further our understanding of how ASD individuals process and store information. In particular, a false memory paradigm was used to test whether ASD individuals are more or less susceptible to false memories. Studies have shown robust levels of false memories in typical individuals (Kensinger and Corkin, 2003). Such ease at which false memories can be induced in the typical population begs the question of how ASD individuals process such information. In summary, the ASD studies examining susceptibility to false memories in select ASD populations described in this paper have had very contradictory findings. This is most likely due to a number of different factors; such as, diagnostic category, age and intellectual level. Thus the hypothesis that individuals with ASD are more or less susceptible to false memories has not been supported consistently. In addition, previous studies have only examined either semantic or phonological word lists. The goal of the current paper was to investigate false memories using a number of different association networks, semantic, phonological and a more comprehensive “hybrid” list. Such lists are constructed by incorporating words that are either semantically or phonologically related to the critical lure. The argument for incorporating three testing conditions (semantic, phonological and hybrid) was that this would be a more comprehensive and realistic attempt at investigating susceptibilities to false memories. For instance, studies consistently relate that we process information based not only on its semantic associates but also its phonological (Zattore et al., 1995). As previous false memory studies examining susceptibility to false memories in ASD to date have failed to take into consideration the multiple ways in which information can be encoded in an associative network, the current study's approach provides a more sophisticated and detailed look at how processing occurs in such a population. Findings in either direction, either increased or decreased susceptibility to false memories, will only enhance our knowledge of how certain stimuli is encoded in the memory related regions of the ASD brain. Practically, these findings and others investigating false memory in ASD will help to educate the greater public on the possibility that individuals with ASD may be processing memory related information differently.

The current study examined a number of different variables related to different aspects of the study. Analysis of covariance were conducted to investigate a number of different variables, such as a) number of critical lure items recalled b) total number of errors and c) total number of correctly recalled items for both between and within subject effects. While there were no statistically significant results for both total number of errors and total number of correctly recalled items, there were some interesting patterns that emerged for the total number of critical lure items recalled. In particular, there was a modest interaction of list type by group. Furthermore, ASD and control participants were not shown to differ on the semantic list, there was a modest but non-significant difference for the phonological list and a significant difference between groups for the hybrid list, t (18) -2.861, p = .010, with control participants producing more critical lure items than ASD participants. This is very interesting in that it may hint at different memory systems in ASD and control participants in this study. As previous studies have highlighted less distributed association networks in ASD subjects, these results may support such findings. Hybrid lists combine both semantic and phonological word lists together, which in turn should activate many more networks than either semantic or phonological lists separately. Therefore the pattern observed in control participants falls in line with this notion, while ASD participants do not show this pattern. They may be processing the information in a less distributed fashion. With an effect size of 1.279 and power of .773, it would be of interest to see if this pattern does hold up with a larger subject pool, as opposed to just 10 participants per group.

Statistical analysis was conducted examining differences across groups in regards to age, verbal IQ, performance IQ and full IQ. It had been our goal to make sure that participants were matched across these different variables to minimize any extraneous variables that could play a role in the false memory task at hand. It was shown that there was no statistical significance across groups for any of these variables, however, there were modest differences in IQ values of between 10 and 12 points (please see table 2).

Next, correlational measurements were conducted to explore the relationship between the various subject and dependent measurements in the study. In particular, correlational measurements were analyzed for both subject groups along IQ values. It was shown that IQ subscales (performance and verbal) are correlated with each other (please see table 3). -In addition, correlational measurements were taken to investigate the relationship between age and the number of words correctly recalled. Interestingly, age was found to be positively correlated with the number of words correctly recalled for both the phonological and hybrid list types in ASD participants. This supports the popular view that as we age, our memory systems continue to develop. In particular, our association networks continue to develop to hold much more information. More importantly, studies show that the capacity of our working memory systems continue to expand as we age, up to a certain age range (Mattay et al., 2005). As our brain continues to form important connections through our teenage years, we are constantly processing and storing significant information in our memory related brain domains. In the present study, the control participants did not show such a correlation.

Correlational measurements looking at the relationship between age and number of critical lure items falsely recalled show that older control participants produced fewer critical lure items, while ASD participants do not show this. This is an interesting correlation that should be further investigated. It may hint at different levels of susceptibility to critical lure items as we age across the two groups.

Further correlational measurements were taken to investigate the relationship between GARS scores for ASD participant and a number of different variables. Higher scores on the GARS report, which indicates more autistic symptomologies, was not correlated with the number of words recalled or the number of errors produced. In addition, while there was no relationship between GARS score and the number of critical lure items produced in the phonological or hybrid lists, participants with higher GARS scores did recall fewer critical lure items for the semantic lists. This highlights the diversity of participants that exist with a diagnosis of ASD. As ASD can be thought of as a spectrum disorder, it is possible to have participants who both place within one category on their GARS report to have remarkably different levels of functioning (low to high) in certain key area, such as memory functioning. These results may be hinting at a more diverse group of ASD participants in this study, with those that score more low functioning compared to others, may be processing the different lists using different types of underlying connections.

Correlational measurements were also conducted to investigate the relationship between the number of words correctly recalled per list type; in particular a) phonological and semantic lists b) phonological and hybrid lists and c) semantic and hybrid lists. A positive correlation between the number of words correctly recalled across lists for both ASD and control participants was found.

To summarize, it was found that ASD and control participants did not differ on the number of words correctly recalled or on the number of errors produced. They did show an interesting pattern of differences for the total number of critical lure items falsely recalled in which ASD participants always produced fewer critical lures than control participants. In addition, the number of critical lures produced did not differ across list type for ASD participants, but as expected control participants produced the most critical lures for the hybrid list. Finally, ASD participants produced significantly fewer critical lures on the hybrid list related to control participants.

The current findings will allow us to create more realistic computational modeling systems that aim to show how neuronal processing may occur in those with ASD. Behavioral impairments that exist in ASD have been attributed to "weak central coherence" or impaired ability to use context (Happe, 1996). This may manifest as dysfunction of the neural networks that interrelate the meanings of words (semantic) or their sound structure (phonological). When words are placed into syntactic or semantic context, typical individuals will remember more words than when words are not placed into context. ASD children demonstrate less of an increase in recall than non-autistic control participants when words are placed into syntactic or semantic context (Beversdorf et al., 2000). This study has shown that ASD participants falsely recalled less critical lure items than control participants. This provides support to the weak central coherence theory, in that ASD participants activate fewer phonologically and semantically related associates relative to control participants. As computation models exist to show association networks that exist in typical populations (Cabeza et al., 2001), the current study will provide support in create models that show possible ways in which those with ASD process, encode and store information. Parents and educators who work with ASD children or adults can use the computation models to better understand the differences that exist in the underlying connections of an autistic individual. Furthermore, vocational therapies can be created that take into account the less distributed networks and lack of integration of sensory information that may exist in select ASD populations. For example, learning tasks exist that take into account that words are better remembered when they are related in a semantic fashion. If autistic children do not process information in this manner, learning tasks can be created to teach children with autism how to encode and store important information.

While the current study did provide important information regarding differences that exist in the way in which ASD participants performed on a false memory paradigm compared to age matched controls, there are some points that should be raised. First, future studies should use more specific levels of functioning criteria necessary in the ASD participants. For example, Beversdorf et al. (2000) show less susceptibility to false memories in *high functioning* ASD participants. As the current study only required a basic diagnosis of ASD using the Gilliam Autism Rating Scale, it became evident looking at IQ measurements that there were both low to high functioning ASD participants in the study. Using a specific criteria for the required level of functioning necessary for the ASD participants may show patterns that are not as evident in the current study. It may also be of interest to include more than one ASD group: a) those that carry a moderate diagnosis of ASD and b) those that are either categorized as high functioning autistic (HFA) or Asperger's Syndrome. This may help to answer the question as to whether there may be differences in association networks within select autistic populations categorized by level of functioning. Lastly, future studies may want to incorporate presenting word lists both visually and auditory. As we process information through a number of different channels (tactile, visual, auditory, etc.), we may find different patterns of susceptibility to false memories in different sensory modalities. This could again provide further information on the underlying connections that exist within and across different brain domains.

As the experimental design proved to be an efficient way in which to test false memories, future studies should continue to incorporate such a design and further investigate the differences across groups in susceptibility to false memories. In particular, future studies should continue to incorporate hybrid word lists in addition to semantic and phonological lists as a way in which to create a more realistic scenario as to how certain words are encoded and stored.

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Table 1: Autism False Memory Studies using DRM Paradigm

Study	Gaigg & Bowler (2009)	Kamio & Toichi (2007)	Beversdorf et al. (2000)	Bowler et al. (2000)
Test	Whether ASD subjects would be any less likely to falsely remember emotionally significant as compared to neutral words	Investigate memory illusions to semantically related sentences	Whether ASD individuals have impaired ability to use context	Investigate influence of context on memory
Subjects	20 HFA 20 Control	13 HFA 15 AD 15 Control	8 HFA 16 Control	10 AD 15 Control
Results	Both groups showed similar overall recall for the hierarchically organized words but ASD participants made less use of information about relations between words and more use of item-specific information in their recall.	Total rates of false recognition for semantically related sentences were similar among the three groups, however, memory illusions on some aspects reduced in HFA participants.	ASD subjects are able to discriminate false memory items from true items significantly better than Control subjects.	AD subjects recalled similar proportions of non presented strong associate of the study list items compared with Control subjects. Rates of true and false recognition of study list associates did not differ significantly between AD and Control subjects. AD participants made fewer remember and more know judgments than Control subjects for veridical but not for false recognitions
Conclusion	Results provide support that ASD individuals have relational difficulties as they use more item-specific information in their recall.	Results suggest HFA have difficulties in semantic association Although HFA showed no quantitative abnormalities of memory illusion, some contribution factors were atypical.	Memory in ASD individuals may be more accurate than in typical under certain conditions. Semantic representations comprise a less distributed network in HFA adults	Deficits found in aspects of memory in people with AD do not affect their susceptibility to memory illusions.

Table 2: Counterbalance Design

Semantic: Six 16-item lists Phonological: Six 16-item lists Hybrid: Six 16-item lists Condition A 1. Semantic List, begin with item list 1 2. Phonological List, begin with item list 3 3. Hybrid List, begin with item list 5 Condition B 1. Phonological List, begin with item list 5 2. Hybrid List, begin with item list 1 3. Semantic List, begin with item list 3 Condition A 5 ASD subjects 5 Control subjects Condition B 5 ASD subjects 5 Control subjects

Table 3: Experimental Word Lists

SEMANTIC WORD LISTS (6 ITEM LISTS OF 16 WORDS EACH)

Critical Lure	BAD	SLEEP	SWEET	COLD	CHAIR	RIGHT
	Good	Bed	Honey	Chill	Sit	Correct
	Rotten	Rest	Bitter	Hot	Couch	Perfect
	Harmful	Yawn	Nice	Warm	Rocking	Equal
	Worse	Pillow	Ice cream	Sneeze	Swivel	Accurate
	Villain	Snooze	Sugar	Shiver	Cushion	Fair
	Severe	Awake	Tart	Arctic	Seat	Justify
	Trouble	Nap	Taste	Ice cream	Recliner	Left
	Awful	Dream	Fudge	Chilly	Wicker	Turn
	Terrible	Tired	Candy	Freezer	Lazyboy	Angle
	Evil	Pajamas	Syrup	Frigid	Table	Answer
	Corrupt	Snore	Kind	Heat	Stool	Mistake
	Horrible	Doze	Chocolate	Ice	Furniture	Wrong
	Nasty	Drowsy	Dessert	Frost	Sofa	Truth
	Attitude	Coma	Sour	Freeze	Rocker	Ethics
	Mood	Wake	Frosting	Winter	Desk	Direction
	Punish	Slumber	Salty	Snow	Bench	Proper

PHONOLOGICAL WORD LISTS (6 ITEM LISTS OF 16 WORDS EACH)

Critical Lure	SMELL	GLASS	MAN	SLOW	SNAKE	TEST
	Bell	Class	Can	Mow	Brake	Zest
	Swell	Grass	Moon	Crow	Quake	Pest
	Spell	Blass	Main	Slope	Snack	Tossed
	Tell	Lass	Fan	Slaw	Sake	West
	Hell	Glaze	Tan	Owe	Ache	Chest
	Smile	Sass	Pan	Snow	Snuck	Tent
	Yell	Bass	Mean	Blow	Shake	Toast
	Jell	Glance	Map	Throw	Flake	Crest
	Small	Mass	Van	Row	Lake	Fest
	Fell	Brass	Ran	Flow	Make	Best
	Knell	Crass	Mat	Slew	Sneak	Text

	Sell	Gloss	Mad	Hoe	Stake	Taste
	Shell	Glad	Ban	Show	Rake	Vest
	Well	Plass	Mine	Sew	Snail	Hest
	Dell	Pass	Moan	Glow	Take	Rest
	smelt	Gas	An	Low	Wake	Guest

HYBRID WORD LISTS (6 ITEM LISTS OF 16 WORDS EACH)

Critical Lure	BALL	HAND	LAW	RAIN	SICK	WET
	Bounce	Glove	Rights	Umbrella	Healthy	Slippery
	Bile	Sand	Paw	Main	Sink	Watt
	Basket	Shake	Enforce	Weather	Flu	Paint
	Balk	Panned	Lawn	Wren	Sake	Pet
	Golf	Thumb	Lawyer	Cloud	Cancer	Dry
	Fall	Hanged	Claw	Rave	Kick	Bet
	Tennis	Grip	Government	Pour	Virus	Water
	Pall	Canned	Log	Brain	Suck	Well
	Round	Fist	Legal	Thunder	Medicine	Soak
	Bill	Grand	Saw	Raid	Sack	Let
	Pitch	Wash	Rules	Puddle	Fever	Saturate
	All	Hind	Low	Range	Thick	Wit
	Bat	Knuckle	Legislation	Mist	Germ	Towel
	Bull	And	Awe	Lane	Slick	Get
	Racket	Arm	Police	Sunshine	Vomit	Soggy
	Hall	Brand	Loss	Gain	Sip	Wear

Table 4: Descriptive Statistics for ASD and Control Participants

ASD (N = 10)	Means	St. Deviation
Age	12.80	2.486
Verbal IQ	93.60	35.318
Performance IQ	94.60	18.530
Full IQ	95.70	26.558
GARS	101.60	12.633
Control (N = 10)		
Age	12.70	2.497
Verbal IQ	104.50	9.095
Performance IQ	106.50	10.244
Full IQ	106.30	9.117

Table 5: Statistical Analysis for ASD and Control Participants

ASD - Control	t	p value	df	Cohen's d
Age-Age	.090	.929	18	0.040 (s)
Verbal IQ-Verbal IQ	-.945	.357	18	0.422 (m)
Performance IQ – Performance IQ	-1.777	.092	18	0.794 (l)
Full IQ – Full IQ	-1.192	.248	18	0.533 (m)
GARS – GARS	n/a	n/a	n/a	n/a

Table 6: Correlational Measurements

Correlations	ASD (n=10)	p-value	Control (n = 10)	p-value
FSIQ x VIQ	0.964	<.001*	0.869	0.001*
FSIQ x PIQ	0.92	<.001*	0.871	0.001*
PIQ x VIQ	0.796	0.006*	0.521	0.123*

* = $p < .05$

Table 7: Correlational Measurements

Correlations	**ASD (n=10**	**p-value**	**Control (n = 10)**	**p-value**
FSIQ x Phono List Recalled	0.02	0.956	0.268	0.454
FSIQ x Semantic List Recalled	-0.012	0.976	0.41	0.24
FSIQ x Hybrid List Recalled	-0.271	0.499	0.45	0.192
FSIQ x Phono List Errors	0.138	0.703	0.329	0.353
FSIQ x Semantic List Errors	-0.133	0.714	-0.033	0.927
FSIQ x Hybrid List Errors	0.206	0.568	-0.178	0.623
FSIQ x Phono List Lures	0.309	0.384	0.254	0.479
FSIQ x Semantic List Lures	0.131	0.719	0.44	0.203
FSIQ x Hybrid List Lures	-0.341	0.334	0.507	0.133

Table 8: Correlational Measurements

Correlations	**ASD (n=10**	**p-value**	**Control (n = 10)**	**p-value**
Age x Phono List Recalled	0.702	0.024*	-0.37	0.288
Age x Semantic List Recalled	0.571	0.085	-0.407	0.243
Age x Hybrid List Recalled	0.647	0.043*	-0.425	0.22
Age x Phono List Lures	0.305	0.392	-0.653	0.041*
Age x Semantic List Lures	0.153	0.647	-0.745	0.013*
Age x Hybrid List Lures	0.042	0.907	-0.678	0.031*

* = p<.05

Table 9: Correlational Measurements

Correlations	**ASD (n=10**	**p-value**
GARS x Phono List Recalled	-0.433	0.214
GARS x Semantic List Recalled	-0.364	0.401
GARS x Hybrid List Recalled	-0.146	0.688
GARS x Phono List Errors	-0.515	0.127
GARS x Semantic List Errors	-0.14	0.7
GARS x Hybrid List Errors	-0.37	0.292
GARS x Phono List Lures	-0.147	0.685
GARS x Semantic List Lures	-0.682	0.03*
GARS x Hybrid List Lures	-0.515	0.127

* = $p < .05$

Table 10: Correlation Measurements

Correlations	**ASD (n=10**	**p-value**	**Control (n = 10)**	**p-value**
Phono Recalled x Semantic Recalled	0.824	0.003*	0.659	0.038*
Phono Recalled x Hybrid Recalled	0.852	0.002*	0.69	0.027*
Semantic Recalled x Hybrid Recalled	0.849	0.002*	0.645	0.044*

*= $p < .05$

Table 11: ANCOVA of within subject effects for number of critical lure items recalled

	df	F	p-value	Partial eta squared	Power
Main effect of list type	2, 30	1.308	.285	.080	.261
List type x Group	2, 30	3.163	.057	.174	.562
List type x Condition	2, 30	1.399	.262	.085	.277
List type x Group x Condition	2, 30	.454	.640	.029	.117

Table 12: ANCOVA of between subject effects for number of critical lure items recalled

	df	F	p-value	Partial eta squared	Power
Main effect of Group	1, 15	3.619	.077	.194	.429
Main effect of Condition	1, 15	.175	.682	.012	.068
Group x Condition	1, 15	2.521	.133	.144	.318

Table 13: ANCOVA of within subject effects for total number of errors

	df	F	p-value	Partial eta squared	Power
Main effect of list type	2, 30	.050	.952	.003	.057
List type x Group	2, 30	2.118	.138	.124	.400
List type x Condition	2, 30	2.109	.139	.123	.399
List type x Group x Condition	2, 30	.162	.851	.011	.073

Table 14: ANCOVA of between subject effects for total number of errors

	df	F	p-value	Partial eta squared	Power
Main effect of Group	1, 15	.971	.340	.061	.152
Main effect of Condition	1, 15	.483	.498	.031	.100
Group x Condition	1, 15	.299	.593	.020	.081

Table 15: ANCOVA of within subject effects for number of correctly recalled items

	df	F	p-value	Partial eta squared	Power
Main effect of list type	2, 30	.224	.801	.015	.082
List type x Group	2, 30	.120	.887	.008	.067
List type x Condition	2, 30	1.750	.191	.104	.337
List type x Group x Condition	2, 30	.857	.434	.054	.183

Table 16: ANCOVA of between subject effects for number of correctly recalled items

	df	F	p-value	Partial eta squared	Power
Main effect of Group	1, 15	1.478	.243	.090	.207
Main effect of Condition	1, 15	.006	.939	.000	.051
Group x Condition	1, 15	.937	.348	.0591	.148

Table 17: Post-hoc t-tests for number of critical lure items recalled per list type

	t	df	p-value	Effect size	Power
Phonological	-1.832	18	.083	.819	.41
Semantic	-.435	18	.669	n/a	n/a
Hybrid	-2.861	18	.010	1.279	.773

Table 18: Post-hoc t-tests for number of critical lure items recalled per list across groups

	N	Mean	Std. Deviation	Std. Error Mean
PHONOLOGICAL				
ASD	10	.2667	.2249	.0712
Control	10	.4833	.2987	.0944
SEMANTIC				
ASD	10	.3667	.3123	.0988
Control	10	.4333	.3702	.1171
HYBRID				
ASD	10	.3000	.2811	.0889
Control	10	.6500	.2659	.0841

Table 19: Simple main effects of list type for ASD and control participants

	df	F	p-value	Partial eta squared
ASD				
List Type	2, 18	.545	.589	.057
CONTROL				
List Type	2, 18	3.669	.046	.290

Figure 1: Number of critical lure items recalled per list type across groups.

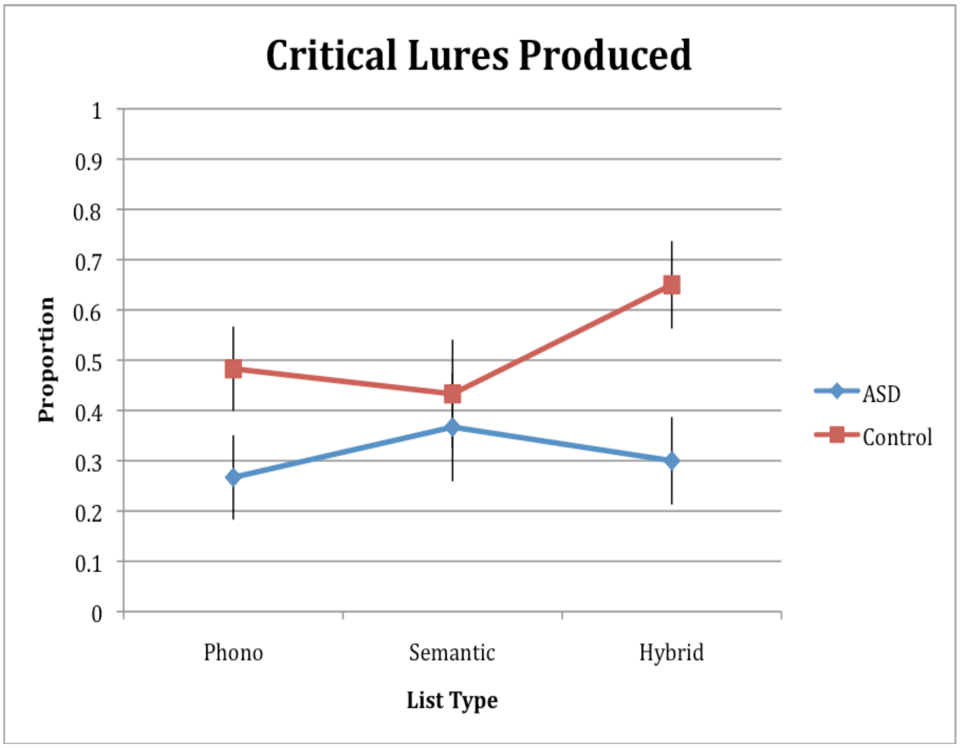

Figure 2: Number of errors per list type across groups.

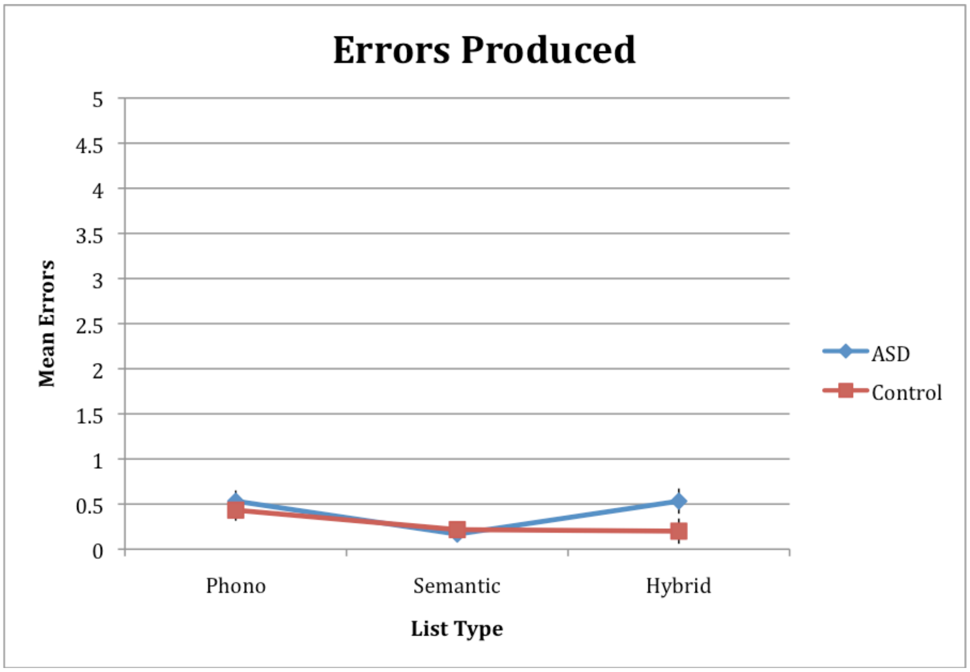

Figure 3: Number of correctly recalled words per list type across groups.