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Memory Functioning in Children and Adolescents With Autism

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Abstract

Objective—Memory functioning in children and adolescents ages 5–19 with autism (n = 50) and typically developing controls (n = 36) was assessed using a clinical assessment battery, the Test of Memory and Learning (TOMAL).

Method—Participant groups were statistically comparable in age, nonverbal IQ, handedness, and head circumference, and were administered the TOMAL.

Results—Test performance on the TOMAL demonstrated broad differences in memory functioning in the autism group, across multiple task formats, including verbal and nonverbal, immediate and delayed, attention and concentration, sequential recall, free recall, associative recall, and multiple-trial learning memory. All index and nearly all subtest differences remained significant even after comparing a subset of the autism group (n = 36) and controls that were matched for verbal IQ (p >.05). However, retention of previously remembered information after a delay was similar in autism and controls.

Conclusions—These findings indicate that performance on measures of episodic memory is broadly reduced in autism, and support the conclusion that information encoding and organization, possibly due to inefficient cognitive processing strategies, rather than storage and retrieval, are the primary factors that limit memory performance in autism.

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Keywords

autism; memory functioning; verbal; nonverbal; processing strategies

Impairments in cognitive functioning are commonplace in neurodevelopmental disorders (Bishop, 2009), including disrupted memory functioning in autism (Ben Shalom, 2003; Frith & Hill, 2003). Kanner (1943) was the first to clinically describe fascinating memory profiles in individual children with autism, puzzling over why phenomenal ability in a specific type of memory was often combined with impairment in other aspects of memory in the same affected individual, and why impairments in memory and learning were so pervasive in autism.

Even though memory impairments have been reported in autism, an autism-specific profile of dysfunctional memory has not been established (Minshew & Williams, 2007), but several theories have been proposed to explain the heterogeneity of cognitive impairments observed in autism. Most fall under the proposition that higher-level cognitive functions that require organization or strategy such as memory are affected, while more basic perceptual processes are left intact or even enhanced in some individuals with autism (Jeste, Friedman, & Urion, 2009; Mottron, Dawson, Soulières, Hubert, & Burack, 2006). For example, Ben Shalom (2009) has recently suggested a 3-tiered model of cognitive functioning in autism, consisting of basic, integrative, and higher-order or “logical” levels of processing. Within a memory framework, the autism condition thus spares, or relatively spares, low-level perceptual and procedural information processing, while disabling the consolidation of higher-level or event-related information (i.e., episodic or autobiographical memory). Higher-level memory for context-independent facts (i.e., semantic memory), however, is thought to be either not affected or minimally affected and used to compensate for the lack of integrative episodic memory among high-functioning individuals. Similarly, others have suggested that the semantic or visual complexity and volume of information to be processed, integrated, and retained are key factors that define memory performance deficits in autism (Williams, Goldstein, & Minshew, 2006a, 2006b).

Recent studies of memory in autism have focused on individual profiles from broadband neuropsychological batteries, which assess episodic memory functions through a variety of stimuli and task requirements, incorporating visual, verbal, list learning, associative, and working memory paradigms. Minshew and Goldstein (2001) administered a mixed clinical and experimental memory battery, investigating effects of stimulus complexity on memory performance among high-functioning adolescents and young adults with autism matched on verbal and performance IQ. They found that the autism group often performed equal to controls on verbal or visual tasks with low processing load. When evaluated using tasks with similar content but increased stimulus complexity, however, memory deficits relative to controls became increasingly apparent in the autism group.

More recent studies of autism have reported on memory functioning in childhood, using standardized, commercially available test batteries. Lajiness-O’Neill et al. (2005) reported results using the Test of Memory and Learning (TOMAL; Reynolds & Bigler, 1994), which was administered to a size-limited sample of children with high-functioning autism (HFA). Participants were characterized by mean verbal reasoning scores in the borderline range, with performance IQ in the high average range. Analyses of memory scores indicated functioning in the low average range on composite TOMAL measures of overall, verbal, nonverbal, and delayed recall memory. In a separate study, Williams, Goldstein and Minshew (2006b) reported on memory functioning in childhood autism among a relatively large sample, in which HFA and controls were matched on both verbal and performance IQ.

Using the Wide Range Assessment of Memory and Learning (WRAML, Sheslow & Adams, 1990), they found evidence for reduced memory performance across verbal and visual domains compared to the control sample, matched in intellectual ability. Consistent with prior research on the effects of stimulus complexity on memory performance, Williams and colleagues found that HFA and controls performed similarly on perceptually simple tasks, while complex task performance discriminated between the groups.

The generalizability of the Williams et al. (2006b) findings of reduced memory performance in children with autism is unknown using other similarly standardized measures of memory function. Accordingly, the present investigation examined memory performance and provides descriptive neuropsychological test information in an autism sample of children and adolescents using the TOMAL. Given the past observations of reduced memory performance in autism compared to controls we expected to find that as a group the subjects with autism would exhibit reduced memory performance on the TOMAL. We anticipated a profile of generalized reduction in memory functions across TOMAL subtests. As aggregate measures, the TOMAL composite indices were expected to show greater group differences.

Compared to the Williams et al. (2006b) study with the WRAML, the current investigation included a broader range of verbal intellectual ability and subjects were not matched on verbal intellectual ability but were statistically comparable on nonverbal intellectual ability. Because of the diagnostic requirement for having “qualitative impairments in communication” in autism, matching on verbal abilities runs the risk of overcontrolling for a core cognitive dimension of the disorder. Dennis et al. (2009) provide the rationale for why IQ does not necessarily need to be a matching variable or a statistical covariate in investigations of developmental disorders. Nonetheless, also recognizing the importance of examining how memory performance may differ between subjects with autism and controls with similar intellectual abilities, results are also presented for a subgroup that was matched for both verbal and nonverbal intellectual ability.

Method

Subjects and Assessment

Ascertainment—Autism and comparison subjects were recruited over a 10-year period (1997–2007) predominantly from community sources, including parent support groups, youth groups, and schools, and from clinic social skills groups. After complete description of the study to subjects and parents, written informed consent was obtained. The subjects in this study are a subset of participants in a longitudinal investigation of late brain development from 3 years of age through early adulthood. The subset for this investigation was selected from the larger sample based on age within the reference norms of the TOMAL, having complete, high quality TOMAL data from the time of initial assessment, and closeness of matching on age, PIQ, handedness, and head circumference. In all cases only the TOMAL data from the first assessment was used to insure the aspect of novelty was consistent across all subjects. All facets of this investigation were undertaken with the understanding and written consent of each subject or legal guardian, with the approval of the University of Utah or Brigham Young University Institutional Review Boards, where testing was performed, and in compliance with national legislation and the Code of Ethical Principles for Medical Research Involving Human Subjects of the World Medical Association.

Subject groups—All subjects were males, 5–19 years of age, and had nonverbal ability standard scores greater than 85. Additional details about the samples have been previously published (Bigler et al., 2003). All subjects also underwent brain MRI studies, but those findings will not be discussed in this publication, other than to mention that all imaging was

interpreted clinically to be within normal limits and no subject had a major developmental abnormality of the brain. Potential sex differences in memory were not examined because only male subjects are included in the longitudinal study and this investigation.

Idiopathic autism sample—Autism was rigorously diagnosed. The subject's mother was interviewed using the Autism Diagnostic Interview–Revised (ADI-R; Lord, Rutter, & LeCouteur, 1994), a semistructured, investigator-based interview with good reliability and validity. All autism subjects were also directly assessed using the Autism Diagnostic Observation Schedule–Generic (ADOS-G; Lord et al.; 2000), which is a semistructured play and interview session designed to elicit social, communication, and stereotyped repetitive behaviors characteristic of autism. All autistic subjects met ADI–R, ADOS–G, and the *Diagnostic and Statistical Manual of Mental Disorders –Fourth Edition* (*DSM–IV*; American Psychiatric Association, 1994) criteria for autistic disorder. History, physical exam, Fragile-X gene testing, and karyotype, performed on all subjects, excluded medical causes of autism.

Control sample—To test for autism-related differences in memory and other neurocognitive performance variables, a comparison sample was composed of typically developing individuals. Control subjects had no developmental, neurological, or clinical history for major psychiatric disorders. Control subjects likewise completed an assessment with the ADOS-G and were rigorously assessed for autism spectrum disorders to ensure none met criteria.

IQ—Verbal skills are often diminished in autism, as *DSM–IV* standards require the presence of a qualitative impairment in communication (Rapin, 1999). In addition, there can be wide splits between verbal and performance IQ in autism (Deutsch & Joseph, 2003). For these reasons, a PIQ ≥85 was designated as the inclusion factor for level of intelligence in this study, with verbal intellectual level free to vary. Verbal IQ (VIQ) and nonverbal IQ (NVIQ) were selected as dimensional variables in the autism and control samples to be used descriptively. Since this investigation recruited children and adolescent subjects over a diverse age range, the study is not intended to be an investigation of psychometric intellectual functions in autism. Different versions on intellectual tests were used because of the age range of participants in the study (5 to 19 years) and because of changes in IQ test instruments over the 10 years of recruiting subjects for the parent project. For the present investigation, VIQ and PIQ were measured using the *Wechsler Intelligence Scale for Children–Third Edition* (WISC–III; Wechsler, 1991; verbal comprehension and perceptual organization indexes), *Wechsler Adult Intelligence Scale– Third Edition* (WAIS-III; Wechsler, 1997; verbal comprehension and perceptual organization indexes), *Wechsler Abbreviated Scale of Intelligence* (WASI; Wechsler, 1999; VIQ and PIQ indexes), or *Differential Ability Scales* (DAS; Elliott, 1990; verbal and nonverbal reasoning clusters). In the present investigation, we chose to use Verbal Comprehension and Perceptual Organization indexes from the WISC–III and WAIS-III instead of Verbal IQ and Performance IQ because the broader IQ indexes (VIQ and PIQ) incorporate tests of immediate memory and concentration, which were believed to overlap with some of the TOMAL tasks assessed, such as serial digit and letter recall. Thus, more restricted measures of verbal and perceptual reasoning were used. The composite indexes selected primarily measure semantic memory, verbal reasoning, and non-verbal and spatial reasoning.

Head circumference and handedness—Because this investigation constituted a neuroimaging as well as a neuropsychological and neurobehavioral study, it was important to ensure that no unusual developmental anomaly was in the sample. Macrocephaly occurs with a greater frequency in autism (Lainhart et al., 2006), and in this study the control

sample is group-matched with regards to head-size, with the typical developing control sample containing a few subjects with benign macrocephaly. We matched cases and controls on head circumference because aspects of cognitive processing may differ in macrocephalic and normocephalic children (White, O'Reilly, & Frith, 2009). Head circumference was measured in all subjects using the standardized methods and reference data described by Farkas, Hreczko, and Katie (1994). Handedness was measured using the Edinburgh Handedness Inventory (Old-field, 1971). A score of +100 signifies complete right handedness and −100 indicates complete left handedness.

Memory—Memory was assessed using the TOMAL (Reynolds & Bigler, 1994). The TOMAL samples various domains of memory in children and adolescents, ages 5 years 0 months through 19 years 11 months, 30 days. The TOMAL is composed of a core battery of 10 subtests, including five verbal and five non-verbal subtests, as well as supplementary subtests (three verbal, one nonverbal). Four TOMAL subtests assess retrieval both immediately upon stimulus presentation and following a 30-min filled delay. Among the 10 core subtests, Memory for Stories involves immediate and delayed free recall of short verbal narratives; Word Selective Reminding is a verbal list-learning task that includes a delayed free recall condition; Object Recall requires immediate verbal recall of paired verbal-visual stimuli; Digits Forward involves repetition of a number series; and Paired Recall involves learning verbal paired associates. In Facial Memory arrays of pictured faces are presented which must be recognized and selected among distractors immediately and following a delay; Visual Selective Reminding is a test of spatial learning with a delayed recall condition; Abstract Visual Memory involves immediate recognition and discrimination of abstract geometric figures; in Visual Sequential Memory a set of abstract figures must be recalled sequentially; and Memory for Location is a spatial recall task. Supplementary subtests consist of three additional auditory span and working memory tasks, Digits Backward, Letters Forward, Letters Backward, and Manual Imitation, which involves serial repetition of basic hand gestures. The TOMAL has been shown to have high reliability using standard methods for estimating the internal consistency of the subtests and composites (Reynolds & Bigler, 1994). The TOMAL assesses declarative memory for novel information that was encountered within a specific context. Thus, in the present study these results are broadly described as measures of episodic memory functioning.

Statistical analysis—Given the descriptive nature of this investigation, group means were calculated and compared for autism and control subjects, using independent samples *t* tests whose *p* values have not been adjusted for multiplicity. TOMAL composite, index, and subtest scores were compared. Immediate and delayed percent recall was also assessed for tasks with a delayed recall component.

Results

Sample characteristics

Table 1 summarizes the demographic, IQ, head circumference, and handedness characteristics of the samples. There were no differences in handedness with the sample predominantly right-handed, and head circumference did not differ between the two groups. The aggregate verbal IQ scores were significantly lower in the autism group, but group differences did not reach significance for nonverbal IQ scores ($p > .05$).

Test of Memory and Learning

Results for TOMAL composite, index, and subtest scores are reported in Table 2. Cohen's *d* values serve as an estimate of effect size. Group comparisons for the TOMAL measures were significant for Composite, Verbal, and Delayed memory indexes, for all supplemental

indexes, and for all 18 subtests (p <.05), as depicted in Table 2. Effect sizes for TOMAL subtests were large, with the exception of a spatial recall task (Memory for Location), sequential motor imitation (Manual Imitation), and word list recall after a 30-min delay (Word Selective Reminding Delayed). These subtest comparisons were associated with moderate effect sizes. Large group effects were found for all TOMAL index scores.

Verbal IQ-matched subset: Characteristics and analysis

Table 3 summarizes the demographic, IQ, head circumference, and handedness characteristics of a subset of the autism group matched on verbal IQ. All IQ comparisons were nonsignificant (p >.05). Results for TOMAL composite, index, and subtest scores are reported in Table 4. Group comparisons remained significant (p <.05) for the TOMAL Composite and all index scores. Likewise, all subtest comparisons remained significant, except for Memory for Location, Manual Imitation, and the delayed recall portion of Word Selective Reminding.

Immediate versus delayed memory

As shown in Table 5 immediate and delayed recall were not significantly different for the autism or control group. Retention percentage values were calculated to reflect the extent of participants' delayed memory for previously recalled story elements (Memory for Stories), words from a list-learning task (Word Selective Reminding), and dot locations from a spatial learning task (Visual Selective Reminding). For the selective reminding tasks, immediate memory was defined by the number of items recalled on the final of eight learning trials. Retention percentage values should be sensitive to meaningful differences between immediate and delayed memory performance. Thus, to prevent the occurrence of extreme retention scores arising from trivial discrepancies between immediate and delayed recall (e.g., recalling one story unit initially and then subsequently two story units would indicate 200% retention), the scores of individuals with very low initial recall were excluded from this analysis (i.e., <10 story units initially recalled on Memory for Stories, less than four words recalled on the final learning trial of Word Selective Reminding, or less than 4 dots recalled on the final learning trial of Visual Selective Reminding). Results are presented in Table 5. No group differences were observed in percentage of story units, words, or dot locations successfully recalled both before and after a delay. Delayed retention was also examined for the Facial Memory subtest. Retention percentages were not used in this analysis because the number of faces to be identified during the immediate and delayed stages of Facial Memory was not equal (max. immediate raw score = 41; max. delayed raw score = 15). Instead, age-adjusted scaled scores for immediate and delayed Facial Memory were subjected to paired-sample t tests. Neither the autism nor control group exhibited a significant difference between immediate and delayed facial recognition.

Memory in autism with low versus high VIQ

All autism subjects had at a minimum an average range nonverbal IQ. Because VIQ was not a selection criterion for this study, those autism subjects with low VIQ scores could be compared to autism subjects with higher VIQ. In the current autism sample those with a VIQ standard score below 85 consisted of a subgroup of 14 individuals we classified a "low verbal ability" or LVA (mean VIQ = 71.8, SD = 8.0) subgroup. These individuals were matched for nonverbal functioning to a high verbal ability autism group (HVA) and typically developing controls, such that there were no group differences in nonverbal IQ, $F(2, 83) = 1.91$, p =.16. Global reductions in memory were observed in the LVA subgroup, (Verbal Index = 69.4, SD = 15.8; Nonverbal Index = 83.3, SD = 13.2) relative to the HVA subgroup (Verbal Index = 110.6, SD = 15.6, p <.001; Nonverbal Index = 108.4, SD = 12.9, p =.02). Among the combined autism group, there was a significant association between VIQ and verbal episodic memory (r =.65; p <.001) but not nonverbal memory (r =.19, p =.

19). The verbal memory – VIQ association was also significant among typically developing controls (Verbal Index – VIQ, Pearson r =.52, p =.001). A nonverbal memory – VIQ association approached statistical significance (p >.0125) after Bonferroni correction (r =. 37, p =.03).

Discussion

The objectives of this descriptive study were to provide summary findings on a battery of clinical memory measures from the Test of Memory and Learning in children and adolescents with autism. By definition subjects with autism have "impairments in communication"—this criterion alone is associated with a broad spectrum of cognitive profiles and deficits (Happe, Ronald, & Plomin, 2006; Munson, Dawson, et al., 2008; Munson, Faja, Meltzoff, Abbott, & Dawson, 2008). In the current study only autism subjects with nonverbal intellectual abilities ≥85 were included, but verbal intellectual abilities were free to vary. Indeed, in this autism sample although the mean VIQ was average, it was almost a standard deviation below the control sample and likewise, reflected considerably more variability in the range of verbal abilities. Variability in cognitive performance represents a common finding in autism (Towgood, Meuwese, Gilbert, Turner, & Burgess, 2009). Clearly, the reduced overall level of verbal intellectual functioning in autism creates natural differences in cognitive abilities between the autism and control subjects in this investigation. Increased variability in verbal and semantic functions also clouds group comparisons, where some children with autism may have frank deficits and others no impairment, all within the same grouping. Although verbal abilities were reduced and more variable within the autism group, their overall levels of verbal and nonverbal intellectual functions were nonetheless in the average to above average range. As already mentioned, Dennis and colleagues (2009) argue that when examining children with developmental disabilities controlling for IQ may unduly constrain how a disorder affects cognition, understanding that the IQ variable represents a commonality factor reflecting nonspecific cognitive ability often discussed in terms of a general variable or "g" (Oberauer, Schulze, Wilhelm, & Suss, 2005). One way to overcome such issues is to first examine within group comparisons within a cognitive domain compared to a reference point. For example, on psychometric testing IQ and memory metrics are significantly correlated (Oberauer et al., 2005; Leeson et al., 2010), including IQ and CMI correlations on the TOMAL (Hoerig, David, & D'Amato, 2002). A common clinical interpretive method in examining memory performance is to compare memory scores to IQ scores, with the assumption that the IQ score represents a reference where in nonpathological circumstances memory scores should approximate the reference intellectual score (Lezak, Howieson, & Loring, 2004). In fact, in other studies examining diverse pediatric conditions excluding autism (Allen et al., 2010; Thaler, Allen, McMurray, & Mayfield, 2010; Howes, Bigler, Lawson, & Burlingame, 1999; Gutteling et al., 2006; Porter, Lawson, & Bigler, 2005), the TOMAL CMI consistently was within a few points of the intellectual reference measure in the control samples. Consistent with this observation, the CMI in the controls for this investigation differed only by .35 and . 5 standard deviations for VIQ and NVIQ, respectively. However, in the autism group the CMI was .85 and 1.42 standard deviations lower than VIQ and NVIQ, respectively. Clearly, these subjects with autism not only had lower memory performance in comparison to the typical developing control sample, but also exhibited within group lower memory performance compared to their average to above average intellectual scores.

Turning to the other TOMAL index memory and subtest scores when statistically compared to the control sample, overall memory performance in autism reflected reduced ability across all aspects of memory. Large between-groups effect sizes were found for all composite scores and for a majority of subtests. Even for the memory tasks where autism subjects performed more closely to controls, including Memory for Location, memory span

for imitating simple hand positions sequences (Manual Imitation), and word list selective reminding (Word Selective Reminding-delayed condition only), moderate effect sizes were present. Given the exploratory nature of this study and to facilitate comparison of present results to previous research, statistical controls for multiple comparisons were not employed. However, the robustness of observed effects across TOMAL scores suggests that most of these differences would survive correction.

These findings of generally reduced memory performance in autism using a clinical battery of memory tests are similar to those of Lajiness-O'Neill et al. (2005), who reported composite TOMAL scores in the low average range among a younger sample of participants with autism. It should be noted that five subjects with autism from the original Utah cohort, were included in the Lajiness-O'Neill et al. investigation, so there was some overlap in subject composition. The Williams et al. (2006a) study matched and controlled for verbal IQ so their approach was statistically different than the analysis of the current investigation, but still demonstrated lowered memory performance on the WRAML in subjects with autism. The extent and scale of reduced memory performance in the present study was greater than the findings of Williams et al. (2006a), who reported a more restricted profile of decreased memory performance in their sample of children and adolescents with HFA, but their autism group did not differ from their control sample in VIQ whereas in the current study VIQ was significantly lower in the autism group. In the Williams et al. (2006b) study tasks involving complex verbal and auditory recall revealed deficits in the autism group, while simpler auditory and visual-spatial tasks did not (Williams et al., 2006b). To investigate the possibility that verbal ability discrepancies may partly account for the broad pattern of reduced memory performance on the TOMAL, a subset of the autism group was matched with controls on verbal IQ. In this more conservative analysis, *t* tests revealed that group differences remained significant for all but those TOMAL subtests that were associated with moderate effect sizes in the VIQ-uncontrolled analysis: memory for location, manual imitation, and delayed word selective reminding (see Table 4). This matched IQ comparison confirms in this sample that subjects with autism displayed reduced memory ability on the TOMAL even after controlling for IQ.

Comparing autism performance to the national normative standard for the TOMAL, only Object Recall and Digits Forward were performed below the average range. The autism group in this study performed best on the Manual Imitation task, a nonlanguage sequential recall test using simple hand gestures, where performance by the subjects with autism was exactly at the norm for the TOMAL standardization sample. This type of recall is consistent with previous findings suggesting that basic serial recall may be intact in autism (Bennetto, Pennington, & Rogers, 1996; cf. Bowler & Gaigg, 2008; Williams, 2006a). Other TOMAL subtests with scaled scores ≥9.0 included Paired Recall, Abstract Visual Memory, Memory for Location and Word selective Reminding. Likewise, delayed recall was not significantly different from immediate recall in either the autism or control group, indicating no abnormal decay in retained information.

In that delayed recall was not disproportionately degraded in the autism subjects compared to their immediate recall implies intact retrieval once the information has been processed. These findings are in line with previous research (Minshew & Goldstein, 1993; Williams et al., 2006b), further supporting the proposition that recall for adequately encoded information is intact in autism. Overall, the current finding that memory in autism is not disproportionately affected by a delay corresponds with previous research (Lajiness-O'Neill et al., 2005; Williams et al., 2006a) that suggests that initial information encoding and organization, rather than storage and retrieval, are the primary memory deficits in autism. Likewise, since the majority of TOMAL memory measures were performed within the average range suggests basic cognitive functions in autism associated with memory

processing may be adequate, but somewhat inefficient resulting in reduced performance when compared to within Group IQ measures or the control sample. Some have postulated that the child with autism is challenged by the complexity of a stimulus to be processed resulting in a "part-oriented strategy" that is simply less efficient, disrupting memory processing and ability level (Bertone, Mottron, Jelenic, & Faubert, 2005; Tsatsanis et al., 2011).

While the use of clinical and nationally standardized memory measures constitutes a strength in the present study, in that a broadband assessment of memory functioning using a conormed set of tasks was possible, such an approach does not allow for systematic test modifications that can elucidate cognitive processes and mnemonic strategies. The current findings document reduced memory performance but without more experimental methods, do not provide an explanatory mechanism why reduced memory performance occurs in autism. Nonetheless, some qualitative speculations about the data from the present study can be made. For example, some of the largest between group effect sizes were exhibited on tests requiring recall of contextually organized information (Memory for Stories, Facial Memory and Abstract Visual Memory). Experimental investigations of cognitive style in autism have suggested that affected individuals are less likely to make spontaneous use of relational information to enhance memorization and recall (Bowler, Gaigg, & Gardiner, 2010). Thus, as the information load increases, as in a story content or array of faces, the use of relational information may become more essential to effective memory performance.

Recent research on the neurodevelopmental underpinnings of abnormal language development in lower functioning individuals with autism has turned to episodic memory functioning as a potential contributing factor (Boucher, Mayes, & Bigham, 2008). Boucher, Bigham, Mayes, and Muskett (2008) hypothesized that language impairment in low-functioning autism arises in part from the effects of declarative memory dysfunction on semantic-linguistic development (Ullman, 2004). In this model, dysfunction in explicit memory processing, present early in development, disrupts the formation and integration of episodic memories that eventually become semantic memories or knowledge. In an early test of this "declarative memory hypothesis," Boucher, Bigham et al. (2008) measured visual recognition memory in children and adolescents with autism who had low or high verbal functioning, compared to nonverbally matched, same-mental age peers with and without intellectual disability. They found disproportionately impaired recognition memory that was uniquely related to episodic tasks for the low-functioning autism group. The results of a supplemental analysis in the current study showed that performance on an extensive clinical battery of episodic memory tasks is moderately related to measures of semantic-verbal conceptual abilities, both for typically developing children and adolescents and those with autism.

In addition to limitations already mentioned, several limitations are apparent in this research. Although the TOMAL is standardized from ages 5 to 19, which encompassed the age ranges of the current sample, a host of developmental issues may influence memory performance that simply cannot be addressed by this type of cross-sectional design (Shing et al., 2010). As already identified, the issues of general cognitive ability versus specific memory impairment in autism remain unresolved by the design of the current study and its descriptive analysis. Ideally, in future studies cognitive ability in a number of domains (i.e., language, including language subtypes (Rapin, Dunn, Allen, Stevens, & Fein, 2009), visuospatial ability, executive skill, etc.), in addition to just an IQ metric, could be stratified both in typical developing as well as autism subjects to better explore relationships between general cognition, other cognitive domains, and memory function. There are probably complex interrelationships across different cognitive domains in autism, where examination of memory function should not be viewed as a single factor (Gustafsson & Paplinski, 2004).

While the current cross-sectional study demonstrates reduced memory performance in a sample of children and adolescents with high functioning autism, generalization of such findings cannot be made from a single investigation. The current study is the first to use the TOMAL to show reduced memory performance in autism, but additional studies would be needed to show how generalizable this TOMAL pattern of memory performance is in autism.

Autism is a clinical diagnosis with no proven diagnostic biomarker. However, tremendous strides are being achieved in terms of genetic markers which may define certain aspects of the disorder. For example, recently loci on chromosomes 10 and 16 have been identified that relate to the common profile of lowered VIQ to NVIQ that often characterizes an autism sample (Chapman et al., 2010), including the one in this investigation. If a cognitive biomarker is proven to be present in autism, this could prove to be an exceptional method to study memory differences in autism.

In conclusion, these findings indicate that episodic memory performance is broadly reduced in autism. Since retention following a 30-min delay was not disproportionately affected in autism indicating adequate retrieval of information, reduced episodic and declarative memory in autism may be most affected by deficits in information encoding and organization, possibly due to inefficient cognitive processing strategies rather than storage and retrieval as the primary factors that limit memory performance in autism.

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Table 1

Participant Demographics

	Autism (*n* = 50)		Control (*n* = 36)		
Variable	**Mean**	**(*SD*)**	**Mean**	**(*SD*)**	***p***
Age (TOMAL)	11.62	(4.30)	12.35	(4.24)	.43
VIQ	99.76	(22.39)	112.28	(13.27)	**<.01**
NVIQ	108.32	(13.37)	114.53	(15.88)	.05
Edinburgh Handedness Index	65.01	(52.63)	59.57	(44.97)	.66
Head Circumference (cm)	54.78	(2.38)	54.56	(2.32)	.70

Note. TOMAL = Test of Memory and Learning; VIQ = verbal IQ; NVIQ = nonverbal IQ.

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Table 2

Results of Test of Memory and Learning (TOMAL)

	Autism (*n* = 50)		Typical control (*n* = 36)				
	Mean	**(*SD*)**	**Mean**	**(*SD*)**	***t***	***p***	***d***
Composite Memory Index	87.00	13.23	106.94	8.57	8.31	**<.001***	1.76
Verbal Memory Index	83.98	15.66	104.58	10.64	7.17	**<.001***	1.52
Memory for Stories	7.74	3.12	11.56	2.96	5.71	**<.001***	1.26
Word Selective Reminding	8.26	4.29	11.56	2.18	4.66	**<.001***	0.93
Object Recall	6.49	3.51	9.44	2.26	4.71	**<.001***	0.98
Digits Forward	6.69	3.03	9.14	3.13	3.63	**<.001***	0.81
Paired Recall	9.48	3.11	11.72	2.15	3.71	**<.001***	0.83
Letters Forward	6.50	2.90	8.97	3.05	3.68	**<.001***	0.84
Digits Backward	8.16	1.89	10.34	2.41	4.55	**<.001***	1.04
Letters Backward	7.73	2.98	10.23	2.37	4.05	**<.001***	0.93
Nonverbal Memory Index	90.51	13.47	108.22	11.35	6.35	**<.001***	1.42
Facial Memory	7.27	2.52	10.39	3.13	5.10	**<.001***	1.13
Visual Selective Reminding	7.71	3.37	9.81	2.53	3.13	**.002***	0.70
Abstract Visual Memory	9.90	2.75	13.03	2.55	5.35	**<.001***	1.19
Visual Sequential Memory	8.63	2.39	11.42	2.85	4.87	**<.001***	1.09
Memory for Location	9.42	3.89	11.61	3.65	2.63	**.010***	0.59
Manual Imitation	10.82	3.05	12.14	2.76	2.00	**.049***	0.46
Delayed Recall Index	88.60	11.49	102.57	7.79	6.21	**<.001***	1.40
Memory for Stories Delayed	7.10	3.08	11.29	3.14	6.08	**<.001***	1.36
Facial Memory Delayed	7.69	2.78	9.86	2.20	3.82	**<.001***	0.86
Word Selective Reminding	9.42	2.52	10.46	1.50	2.35	**.021***	0.49
Visual Selective Reminding	8.80	2.63	10.24	1.46	3.43	**.001***	0.71
Supplemental Index Scores							

	Autism (*n* = 50)		Typical control (*n* = 36)				
	Mean	**(*SD*)**	**Mean**	**(*SD*)**	***t***	***p***	***d***
Attention/Concentration Index	85.89	12.79	101.40	15.22	4.92	**<.001** *	1.13
Sequential Recall Index	87.66	13.16	102.89	14.18	4.94	**<.001** *	1.13
Free Recall Index	88.60	14.71	107.50	12.02	6.27	**<.001** *	1.41
Associative Recall Index	91.38	15.64	110.00	13.20	5.77	**<.001** *	1.29
Learning Index	86.38	17.50	104.33	8.26	6.24	**<.001** *	1.27

* Indicates *p* values less than 0.05.

Table 3

Participant Demographics (VIQ and NVIQ-Matched)

	Autism subset (n = 36)		Control (n = 36)		
Variables	**Mean**	**(*SD*)**	**Mean**	**(*SD*)**	***p***
Age (TOMAL)	12.35	(4.12)	12.35	(4.24)	.99
VIQ	110.64	(15.60)	112.28	(13.27)	.63
NVIQ	108.39	(12.88)	114.53	(15.88)	.08
Edinburgh Handedness Index	66.91	(52.19)	59.57	(44.97)	.59
Head Circumference (cm)	55.32	(2.23)	54.56	(2.32)	.20

Note. VIQ = verbal IQ; NVIQ = nonverbal IQ; TOMAL = Test of Memory and Learning.

Table 4

TOMAL (VIQ and NVIQ-Matched)

	Autism subset (n = 36)		Control (n = 36)				
Tests given	**Mean**	**(*SD*)**	**Mean**	**(*SD*)**	***t***	***p***	***d***
Composite Memory Index	91.38	10.07	106.94	8.57	6.98	**<.001** *	1.69
Verbal Memory Index	89.97	11.16	104.58	10.64	5.61	**<.001** *	1.36
Memory for Stories	8.67	2.89	11.56	2.96	4.19	**<.001** *	1.00
Word Selective Reminding	9.33	3.55	11.56	2.18	3.20	**.002** *	0.77
Object Recall	7.69	2.99	9.44	2.26	2.80	**.007** *	0.67
Digits Forward	6.80	3.10	9.14	3.13	3.16	**.002** *	0.76
Paired Recall	10.53	2.02	11.72	2.15	2.39	**.020** *	0.58
Letters Forward	7.09	2.97	8.97	3.05	2.55	**.013** *	0.63
Digits Backward	8.53	1.65	10.34	2.41	3.62	**.001** *	0.88
Letters Backward	8.31	2.58	10.23	2.37	3.17	**.002** *	0.79
Nonverbal Memory Index	93.26	12.71	108.22	11.35	5.20	**<.001** *	1.26
Facial Memory	7.72	2.36	10.39	3.13	4.08	**<.001** *	0.98
Visual Selective Reminding	7.94	3.10	9.81	2.53	2.78	**.007** *	0.67
Abstract Visual Memory	10.31	2.51	13.03	2.55	4.52	**<.001** *	1.09
Visual Sequential Memory	8.91	2.43	11.42	2.85	3.95	**<.001** *	0.96
Memory for Location	10.00	3.79	11.61	3.65	1.81	.074	0.44
Manual Imitation	10.97	2.72	12.14	2.76	1.75	.084	0.44
Delayed Recall Index	91.62	10.29	102.57	7.79	5.00	**<.001** *	1.22
Memory for Stories Delayed	8.03	2.81	11.29	3.14	4.57	**<.001** *	1.11
Facial Memory Delayed	7.91	2.48	9.86	2.20	3.47	**.001** *	0.84
Word Selective Reminding	9.85	2.13	10.46	1.50	1.36	.180	0.33
Visual Selective Reminding	9.14	2.34	10.24	1.46	2.33	**.023** *	0.57
Supplemental Index Scores							

	Autism subset (*n* = 36)		Control (*n* = 36)				
Tests given	**Mean**	**(*SD*)**	**Mean**	**(*SD*)**	***t***	***p***	***d***
Attention/Concentration Index	88.59	11.29	101.40	15.22	3.88	**<.001** *	0.96
Sequential Recall Index	89.91	12.76	102.89	14.18	3.93	**<.001** *	0.97
Free Recall Index	93.06	12.35	107.50	12.02	4.96	**<.001** *	1.04
Associative Recall Index	97.35	11.44	110.00	13.20	4.27	**<.001** *	1.04
Learning Index	92.41	12.75	104.33	8.26	4.61	**<.001** *	1.13

* Indicates *p* values less than 0.05.

Table 5

TOMAL Immediate vs. Delayed Memory: Subtest Comparisons

	Memory for Stories (% Retained)			**Memory for Faces (Scaled Score; ss)**		
	n	**% Retained (*SD*)**	***t* (*p*)**	***n***	**Immediate–Delay ss (*SD*)**	***t* (*p*)***
Autism	40	77% (36%)		48	0.42 (3.31)	0.87 (.39)
Controls	35	86% (17%)	−1.46 (.15)	35	−0.46 (2.50)	−1.08 (.29)
	Word selective reminding (% Retained)			Visual selective reminding (% Retained)		
	n	% Retained (*SD*)	*t* (*p*)	*n*	% Retained (*SD*)	*t* (*p*)
Autism	40	78% (37%)		35	86% (25%)	
Controls	29	88% (18%)	−1.39 (.17)	29	92% (19%)	−1.02 (.31)

*Indicates paired samples *t*-test.