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The Profile of Memory Function in Children With Autism

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Abstract

A clinical memory test was administered to 38 high-functioning children with autism and 38 individually matched normal controls, 8–16 years of age. The resulting profile of memory abilities in the children with autism was characterized by relatively poor memory for complex visual and verbal information and spatial working memory with relatively intact associative learning ability, verbal working memory, and recognition memory. A stepwise discriminant function analysis of the subtests found that the Finger Windows subtest, a measure of spatial working memory, discriminated most accurately between the autism and normal control groups. A principal components analysis indicated that the factor structure of the subtests differed substantially between the children with autism and controls, suggesting differing organizations of memory ability.

Keywords

autism; memory assessment; discriminant analysis; principal components analysis

The nature of memory function in autism has been under study for decades. Memory has been characterized as both the cardinal cognitive domain largely responsible for the clinical manifestations of the disorder or as secondary to a more generalized cognitive deficit that transcends memory, such as executive dysfunction. In the 1970s and 1980s, the amnesia theory, one of the first neurobehavioral models of autism, was based on the assumption that memory dysfunction was the underlying basis for the social, language, and behavioral abnormalities in autism (Boucher & Warrington, 1976). However, subsequent research refuted the amnesia theory (Minshew & Goldstein, 1993; Rumsey & Hamburger, 1988). More recent models have proposed that the memory deficits are a reflection of core deficits in executive function (Bennetto, Pennington, & Rogers, 1996; Russell, Jarrold, & Henry, 1996) or of a basic deficit in the processing of complex information (Minshew & Goldstein, 2001; Minshew, Goldstein, Muenz, & Payton, 1992; Minshew & Payton, 1988). No agreement has been reached with

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respect to the role of memory functioning in the syndrome of autism, and the characterization of the status of memory abilities in autism is not adequate.

Inconsistency of findings has always been problematic in autism research. This problem is related to the high degree of variability in the autism population, which is the result of developmental differences and differences in cognitive levels among subject groups. However, a number of the findings have been replicated across studies indicating that they are characteristic of memory function in this population. Children with autism do not use organizational strategies or context to support memory. For example, children with autism remember randomly organized words as well as mentally retarded controls but do not demonstrate the expected benefit of semantic or syntactic organization (Frith, 1970a, 1970b; Fyffe & Prior, 1978; Hermelin & O'Connor, 1970). Other studies have demonstrated that children with autism encode the meaning of words and can benefit from externally provided cues, but they do not spontaneously use semantic, syntactic, or temporal sequences effectively to facilitate retrieval of information (Tager-Flusberg, 1991). The memory deficits reported by these various studies do not appear to be the result of language deficits, as groups were matched on language level. Significant differences remained after covarying for language level and a deficit was present for temporal sequences as well as for syntactic and semantically organized sequences.

The complexity of the to-be-remembered material appears to be an important factor that influences the memory performance of children with autism. Fein et al. (1996) reported that memory function in autism was characterized by a dissociation between intact memory for material with low levels of structure and impaired memory for material with more complex levels of organization; young children with autism had the least trouble with recall of digits, more trouble with sentences, and the most difficulty for stories. Boucher (1981) reported that high-ability children with autism remembered significantly less about recently experienced events than normal age-matched and retarded age- and ability-matched controls. She proposed that, as a result, children with autism might encode less information from a complex stimulus such as a social interaction or conversation.

Visual memory for some types of material has been found to be an area of strength for children with autism but complexity of the stimuli appears to affect memory function in this modality as well. Children with autism have been reported to perform as well as matched controls on a delayed response visual discrimination task (Prior & Chen, 1976); on a delayed match-to-sample visual memory task (Barth, Fein, & Waterhouse, 1995); and on recall of pictures of everyday scenes (de Gelder, Vroomen, & van der Heide, 1991), buildings (Boucher & Lewis, 1992), and shoes (Gepner, de Gelder, & de Schonen, 1996). However, results from other studies indicate that, similar to findings with verbal material, the visual memory of children with autism is susceptible to a lack of response to organizational support and to the influence of complexity of the stimuli, resulting in the stereotyped use of simple patterns or rules regardless of the inherent organization of the stimuli (Frith, 1970b). Several studies have reported that children with autism exhibit deficits in memory for visual sequences that are analogous to those reported for auditory memory (Boucher & Warrington, 1976; Minshew, Goldstein, & Siegel, 1997; Rapin, 1996); however, others have reported adequate visual memory for pictures of common objects arranged randomly or sequentially (Hermelin & O'Connor, 1970; Prior & Chen, 1976). Children with autism have been consistently reported to have difficulty remembering previously viewed faces (Boucher & Lewis, 1992; Boucher, Lewis, & Collis, 1998; de Gelder et al., 1991; Gepner et al., 1996; Klin et al., 1999), which are considered highly complex stimuli reliant on the formation of a prototype or specific organizational strategy for optimal recall.

The construct of working memory, a domain of executive function, has received specific attention in investigations of the disorder of autism. Studies of working memory in autism have largely used Baddeley's (1986, 2003) model that consists of four components called the central executive, the articulatory/phonological loop, the visuospatial scratchpad, and the episodic buffer. However, tasks have not always been designed to clearly address the individual components of the model and have more typically been divided according to the cognitive domains of verbal and spatial skills. Verbal working memory has been considered by some investigators to be a core cognitive deficit in autism (Pennington et al., 1997). However, complexity of the stimuli also appears to be an important consideration in this aspect of memory function. Direct measures of verbal working memory, ones that use only a minimal processing load, have failed to confirm a deficit in this area in children with autism (Ozonoff & Strayer, 2001; Russell et al., 1996; Williams, Goldstein, Carpenter, & Minshew, 2005). Results from studies of spatial working memory in autism are less clear. Children with autism have been reported to be unimpaired in spatial memory (when defined as recall of a location of a picture on a page; Klin et al., 1999), in a spatial memory-span task, and in a search task (Ozonoff & Strayer, 2001). However, children with autism have been found to have a spatial working memory deficit on other behavioral tasks (Williams, Goldstein, Carpenter, & Minshew, 2005). A study completed with adolescents and young adults with autism found deficits in spatial working memory as measured by the oculomotor delayed response task, the classic paradigm for assessing spatial working memory (Minshew, Luna, & Sweeney, 1999). This task assesses the capacity for making a saccadic eye movement to the location of a target previously presented in the periphery and has been widely used in primate and human research to define the circuitry of the prefrontal cortex. Studies of working memory in individuals with autism have yielded inconsistent results. This inconsistency is probably related to variation in the way in which working memory has been defined, the component of the model studied, and the specific measures that have been used. In addition, there may be a dissociation based on the type of information that must be manipulated in working memory.

The pattern of memory observed in children with autism can be conceptualized within the model of autism as a disorder of information processing that disproportionably affects complex information processing abilities (Minshew & Goldstein, 1998). According to information processing models of memory function, such as the model of working memory proposed by Just and Carpenter (1992), the more complex the task and the information being processed, the more taxed the resources of the memory system become. At the same time, whereas working memory capacity may be finite, processing large amounts of verbal information such as sequences of sentences is possible because the context facilitates processing by preactivating related concepts and schemas (Just & Carpenter, 1992). Storage capacity may be relatively intact, but complex information processing or the central executive (Baddeley, 1986) may be disproportionately impacted with implications for numerous aspects of behavior. Deficits may emerge and become more pronounced with increasing cognitive load (Minshew et al., 1997). Problems in the memory domain occur because of the inadequacy of context facilitation and reduced concepts and schemas for access.

The complexity of information is a dynamic concept that is relative to the age and general level of ability of the individual. A standard memory battery is a useful tool for examining functioning in varying aspects of memory within the same individuals. In this way, the effect of complexity on memory functioning can be compared in both auditory and visual modalities and in different components of the memory system without the confound of variation in age and ability level that is introduced when trying to compare results from separate studies. In adults, the most widely used battery of this type is the Wechsler Memory Scale—Third Edition (WMS–III; Wechsler, 1997). In two studies of older adolescents and adults with autism, the WMS–III was used to study the auditory and visual memory of high-functioning adolescents and adults and group-matched normal controls (Minshew & Goldstein, 2001; Williams, Goldstein, & Minshew, 2005). Results indicated that basic associative memory abilities were intact, but that the use of cognitive mediating strategies to support memory was impaired, and that memory impairments were progressively worse as the complexity of the material increased in both the auditory and visual modalities. The adults with autism performed as well as the normal controls except when the subtests involved social stimuli (e.g., memory for faces and memory for social scenes) or spatial working memory—stimuli that were also high in information-processing demands.

The purpose of the current study was to use a parallel instrument to the WMS–III, the Wide Range Assessment of Memory and Learning (WRAML; Sheslow & Adams, 1990), to evaluate memory in children with autism with the aim of determining whether a similar pattern of memory functioning was seen in autism at an earlier developmental stage. We were interested in examining several facets of memory processing in a single group of children with autism using stimuli that varied by level of complexity as well as modality of presentation (auditory or visual). In addition, we wanted to investigate the use of strategies to facilitate memory functioning. Baddeley's (1986, 2003) components of working memory were also considered because there are tasks that relate to the central executive, the articulatory loop, the visuospatial scratchpad, and the episodic buffer. That is, tests of associative verbal memory, spatial memory, and prose recall were used. The central executive would be involved in several of the more complex tasks such as those involving recall of stories and complex pictorial material. Although the opportunity was available to confirm our earlier finding (Williams, Goldstein, Carpenter, & Minshew, 2005) of impaired spatial relative to verbal working memory in autism, we note that there is a persistent problem of equating verbal and spatial tasks for difficulty level.

Method

Participants

The participants for this study consisted of 38 high-functioning children with autism and 38 individually matched control participants between 8 and 16 years of age. All participants had Wechsler Full Scale and Verbal IQ scores greater than 80. Demographic characteristics of the two groups are provided in Table 1. We determined socioeconomic status using a modification of the Hollingshead procedure (Hollingshead, 1957). The two participant groups did not differ significantly with regard to age, Verbal IQ, Performance IQ, Full Scale IQ, race, or socioeconomic status.

The University of Pittsburgh Medical Center Institutional Review Board approved this study. Procedures were fully explained to all participants and to their parents or guardians. Written informed consent was obtained from participants and their parents or guardians. All participants were recruited through the Subject Core of the University of Pittsburgh Collaborative Program of Excellence in Autism funded by the National Institute of Child Health and Human Development.

For the participants with autism, confirmation of their diagnosis was established through obtained scores on two structured research diagnostic instruments—the Autism Diagnostic Interview (Le Couteur et al., 1989; Lord, Rutter, & Le Couteur, 1994) and the Autism Diagnostic Observation Schedule (Lord et al., 1989)—and expert clinical evaluation in accordance with accepted clinical descriptions of high-functioning individuals with autism (Minshew, 1996; Minshew & Payton, 1988; Rapin, 1991; Rutter & Schopler, 1987). Participants included in this group met or exceeded the cutoffs for autism on both the Autism Diagnostic Interview and Autism Diagnostic Observation Schedule and had positive evidence of past and current language/communication impairments. Individuals with impairments in social interaction and restricted patterns of behavior but without impairments in language/communication development, cognition, or adaptive behavior were considered to have Asperger's Disorder and were excluded from the study. Potential participants were also excluded if found to have evidence of an associated neurologic, genetic, infectious, or metabolic disorder, such as tuberous sclerosis, fragile X syndrome, or cytomegalovirus. Exclusions were based on neurologic history and examination, physical examination, chromosomal analysis, and, if indicated, metabolic testing. Two thirds of the participants with autism (25 of 38) were taking medication at the time of the study. These medications were for the management of anxiety, attention, sleep, and restricted–repetitive behaviors, conditions that are often part of autism.

Neuropsychiatrically normal, medically healthy control participants were recruited from community volunteers. Potential control participants were screened by questionnaire, telephone, face-to-face interview, and observation during screening psychometric tests. Exclusionary criteria, evaluated through these procedures, included a history or evidence of birth or developmental abnormalities; acquired brain injury; poor school attendance; a learning or language disability; a current or past history of psychiatric or neurologic disorder; a medical disorder with implications for the central nervous system or requiring regular medication usage; or a family history in first-degree relatives of autism, developmental cognitive disorder, learning disability, mood disorder, anxiety disorder, alcoholism, or other neuropsychiatric disorders thought to have a genetic or familial component.

Materials

The WRAML (Sheslow & Adams, 1990) was designed to be an inclusive memory battery that is normed for children between 5 and 17 years of age. An advantage of using a clinical test such as the WRAML is that it provides a number of memory tasks that are all based on a common normative group and that have known intercorrelations and factor structure. This allows for meaningful comparison across tasks both within and between groups.

The WRAML consists of nine subtests that in many ways resemble the WMS–III subtests. However, rather than being divided into visual and auditory domains, it is divided into visual, auditory, and learning domains. Numerous scores may be obtained, including standard scores for each of the subtests and index scores for the three domains and general memory. Separate scores for delayed recall and recognition memory are also available. Conversion of the raw scores to standard scores allows for production of a profile from which relative levels of performance on the various subtests can be directly compared. Similar to the WMS–III, the WRAML contains tests involving immediate memory span, story recall, and associative learning. The Verbal Memory scale consists of a Number/Letter sequence memory task in which the child repeats a random mix of auditorally presented numbers and letters, a Sentence Memory task in which the child repeats progressively longer meaningful sentences, and a Story Recall task in which the child recalls details of two short stories that were read aloud. The Visual Memory scale assesses recall of geometric designs, picture scenes, and sequences. The Design Memory subtest requires the child to draw one of four designs after a 10-s delay. In the Picture Memory subtest, the child views a complex meaningful scene, then looks at a second, similar scene and indicates what is now different. The Finger Windows task requires the participant to recall the sequential placement by the examiner of a pencil into a series of holes placed in a plastic card. It is considered a measure of spatial working memory and is comparable with the Spatial Span subtest of the WMS–III. The Learning scale consists of a word list recall task, a sound symbol association task, and a design location recall task. The WRAML subtests were meant to vary in meaningfulness of content. In a review of the test, Miller, Petrie, Bigler, and Adams (2003) pointed out that meaningfulness refers both to task complexity and relevance to everyday life. Thus, there are tests of simple associative memory with little meaningful content and tasks such as story or picture recall that are quite complex.

The WRAML was normed on a group of 2,363 children on the basis of a stratified model that reflected national demographic data (Sheslow & Adams, 1990). The subtests and composite indices demonstrate high internal consistency reliability according to item separation statistics (ranging from .99 to 1.0), person separation statistics (ranging from .70 to .94), coefficient alphas for the nine individual subtests (ranging from .78 to .90), and median coefficient alphas for the Verbal Memory Index, the Visual Memory Index, and the Learning Index (.93, .90, and .91, respectively). Criterion-referenced validity for the WRAML has been established by examining the relationship between obtained scores on the WRAML and obtained scores on other standardized assessments of memory in children. The results of these studies as presented in the WRAML administration manual range from a high degree of relationship (.90 correlation for the WRAML Verbal Memory Index and the McCarthy Scales of Children's Ability Memory Index; .80 correlation for the WRAML General Memory Index and the Stanford Binet Memory Index) to lower degrees of relationship (.10 correlation for the WRAML Learning Memory Index and the McCarthy Memory Index) (Sheslow & Adams, 1990). WRAML indices are positively correlated with academic achievement measures of reading, spelling, and arithmetic (Miller et al., 2003).

Procedure

All participants received the Wechsler Intelligence Scale for Children—Third Edition (WISC–III; Wechsler, 1991) to determine whether they exceeded the minimal Verbal and Full Scale IQ scores required for admission to the study. Means and standard deviations for the two groups on the individual WISC–III subtests are provided in Table 2. The WRAML was administered according to instructions contained in the administration manual (Sheslow & Adams, 1990) after the WISC–III at a separate testing session. Trained technicians under the supervision of a professional psychologist administered both tests. Measures used were the scaled scores from the individual subtests, delayed recall subtest scores, and the Story Memory Recognition score.

Data Analysis

The data were initially analyzed with individual t tests comparing the means of the autism and control groups on all scores. To evaluate classificatory accuracy, we performed discriminant function analyses using the nine immediate memory subtests as a multivariate combination. All variables were entered in the initial analyses to determine overall level of significance; if statistical significance was obtained ($p < .05$), stepwise analyses were planned. Default F to enter and an F to remove options were used in the stepwise analysis, followed by application of a more liberal tolerance test ($F = 1.00$ and $F = 0.95$). The more liberal tolerance test was used to determine the order of entry of the subtests beyond what was entered on the basis of a conservative tolerance test. This procedure was accomplished for the purpose of evaluating the distinction previously noted between intact associative memory and relatively poorer complex memory in individuals with high-functioning autism, because the WRAML contains measures of both types. To determine whether the organization of abilities assessed by the WRAML was the same in the autism group as in the control group, we performed a preliminary principal components analysis with Varimax rotation for each group. Factor structures were compared with each other and with the principal components analysis contained in the WRAML manual.

Results

Individual Subtest Comparisons

The t-test results comparing the autism and control groups on the WRAML scales are presented in Table 3. Significant ($p < .05$) differences were found for the Sentence Memory, Story Memory, Finger Windows, Design Memory, and Picture Memory subtests. Significant differences were not found for the Number/Letter, Verbal Learning, Sound Symbol, and Visual Learning subtests. Significant differences were all associated with medium effect sizes (Cohen, 1988). The pattern of differences between the autism and control groups was characterized by the autism group's worse performance on measures of visual memory, verbal memory involving syntactic and discourse elements, and spatial working memory. The groups did not differ on measures of associative memory and immediate memory span.

Discriminant Function Analyses

For the direct method discriminant function analysis, a Wilks' lambda (*3*) of .78 was obtained, which is statistically significant ($p < .05$). The classification matrix is contained in Table 4.

Of the cases, 68.4% were correctly classified. Kappa was equal to .37 ($p < .001$), which is statistically significant but falls into the "poor agreement beyond chance" Landis and Koch category (Fleiss, 1981). Using default options, only Finger Windows was entered in the stepwise analysis. When a more liberal tolerance test was used (F to enter = 1.00; F to remove = 0.95), Finger Windows, Design Memory, Picture Memory, and Sound Symbol were entered. In the case of Sound Symbol, the mean score for the autism group was slightly better than that of the control group. Thus, the WRAML profile as a whole produced a statistically significant but not a highly accurate classification of autism and control participants. However, there were numerous significant group differences for the individual subtests. The most powerful discriminator was Finger Windows, a test that appears to assess spatial working memory.

The Principal Components Analysis

Differences in memory between children with autism and typically developing children may not only lie in separate abilities but also in the way in which those abilities are organized. The principal components analysis for children age 9 years and older that appears in the WRAML manual involves three factors (Table 7.11 in the manual). The first of these, called *Visual*, receives its highest loadings from the Picture Memory and Design Memory subtests, with slightly lower loadings from Finger Windows and Visual Learning. The second factor, called *Verbal*, receives high loadings from Sentence Memory and Number/Letter Memory. The third factor, called *Learning*, receives high loadings from the Verbal Learning, Story Memory, and Sound Symbol subtests.

The principal components analysis with Varimax rotation for our control group is presented in Table 5. Although the application of Kaiser's Rule produced a four-factor solution, we also requested a three-factor solution for purposes of comparison with the principal components analysis in the WRAML manual. The four-factor solution did not differ substantially from the three-factor solution, as the fourth factor only received a high loading from Finger Windows; therefore, we refer to the three-factor solution for our comparisons. The first factor of the three-factor solution received high loadings from Design Memory, Visual Learning, and Sound Symbol. It therefore resembles the WRAML manual Visual factor with high loadings from two of the four visual subtests. The second factor received high loadings from Sentence Memory and Number/Letter Memory; these are the same subtests that constituted the Verbal factor from the WRAML manual. The third factor received high loadings from Verbal Learning, Story Memory, and Picture Memory—two of the three subtests that had high loadings on the Learning factor from the WRAML manual. Clearly the results obtained from the small sample used in our study differed somewhat from the factor solution obtained from the larger normative sample for the WRAML, but, with some exceptions, our control group produced what can reasonably be interpreted as Visual, Verbal, and Learning factors.

This solution is in sharp contrast to what was found for the autism group. The rotated factor matrix is presented in Table 6. Applying Kaiser's Rule, two factors were extracted. The first one received high loadings from all of the subtests except for Picture Memory and Story Memory. The second factor received high loadings only from those two subtests. This pattern shows essentially no resemblance to the Visual, Verbal, and Learning structure found in the WRAML manual and the control group from this study. It is particularly interesting to note that in the WRAML manual factor analysis, Picture Memory and Story Memory loaded on different factors, whereas they loaded on the same factor for our group with autism. This might be the result of an organization that involves thematic nonsocial and social components to explain the factor structure for the autism group. Whereas these two subtests also loaded on the same factor in the current study's control group, Verbal Learning loaded on the same factor as well, making it less of a factor specifically associated with social thematic content. When we forced a two-factor solution for the normal control group, the pattern was quite different from what was found for the autism group. All of the subtests had high loadings on the first factor except for Sentence Memory and Number/Letter Memory, both of which received high loadings on the second factor. Thus, in the two-factor solution for the control group, there was no suggestion of a distinct factor for subtests with social thematic content.

Delayed Recall and Recognition Memory

The WRAML contains 20–40 min delayed recall procedures for Verbal Learning, Story Memory, Sound Symbol, and Visual Learning subtests, and there is also a recognition memory procedure for the Story Memory subtest. Group comparisons are contained in Table 7.

The only significant difference was for Story Memory but only for delayed recall not the recognition measure. A comparison of the discrepancy between immediate and recognition memory scores for the Story Memory showed little difference between the groups. The autism group obtained a mean score of 8.89 for immediate recall and 11.16 for recognition, whereas the controls obtained corresponding mean scores of 10.63 and 12.05. Both groups did better on recognition than on free recall, with only a minor amount of improvement suggesting that the children with autism did not have a deficit in retrieval. The difference between the groups was in the initial encoding process. In summary, the autism group showed a difference in delayed recall for complex thematic verbal material and did not show a specific retrieval deficit.

Discussion

The administration of the WRAML yielded a profile of memory abilities in children with autism that was substantially different from the profile found in a control group of typically developing children. The memory profile of the autism group was characterized by relatively poor memory for both complex visual (Design Memory and Picture Memory) and complex verbal (Sentence Memory and Story Memory) stimuli, with relatively intact associative learning ability (Sound Symbol), verbal working memory (Number/Letter), and recognition memory (Story Memory recognition score). Spatial working memory of the children with autism (Finger Windows) was also impaired relative to the control group; however, spatial memory as defined as memory for location (Visual Learning) was not. Delayed recall of the children with autism was not generally different than that of the matched controls, with the exception of thematic verbal material as assessed by recall of stories. Principal components analysis of the WRAML subtests indicated a very different ability structure from that demonstrated by the typically developing control group and from that of the normative sample for the WRAML.

The memory profile for the children with autism as measured by the WRAML was similar but not identical to that for our group of adults with autism as measured by the WMS–III (Williams, Goldstein, & Minshew, 2005). Both the adults and the children with autism performed significantly worse than the normal control group on complex visual memory tasks and the spatial working memory task. No difference was obtained for the verbal working memory task or verbal memory list learning in either the children or adults with autism. However, the children with autism differed from their matched controls on sentence and story memory tasks, whereas no difference was found for the adults with autism compared with controls on a similar task. Sentence and story memory tasks are affected by language development, which may explain the difference in performance on this task between the adults and children with autism. Story memory is enhanced by the development of a “story grammar” or the understanding of the basic structure of a story (Mandler & Johnson, 1977; Thorndyke, 1977). This is a skill that the children with autism did not appear to have but that appeared to be present in the adult group with autism and in the children with typical development. The conclusion that the children with autism lacked the memory support provided by a story grammar is supported by the relative difficulty that they had on the delayed story memory task. It is possible that adults with autism have the support of a story grammar because they have been taught it. Alternatively, it could be a skill that is acquired through a combination of natural brain development and cognitive maturation during the second decade of life and exposure to written language through reading.

A comparison of the results from our study with the experimental literature on memory in autism reveals numerous consistencies. As expected, our child participants with autism had intact memory for recall of lists of random words as has been reported by prior studies (Frith, 1970a, 1970b; Hermelin & O’Connor, 1970; Minshew & Goldstein, 1993). The children with autism also had strong associative learning as was reported earlier (Boucher & Warrington, 1976). They performed the visual learning task, which involved recalling object locations, as well as the typical children. This task is very similar to the Spatial Memory task of the Kaufman Assessment Battery for Children (Kaufman & Kaufman, 1983), for which Klin et al. (1999) found no group differences among their children with autism, pervasive developmental disorder, and non-pervasive-developmental disorders. Consistent with Fein et al. (1996), our group of children with autism had relative difficulty with recall of sentences and stories. These results also correspond to the pattern of increasing memory deficits with increasing stimulus complexity reported for older adolescents and adults with autism (Minshew et al., 1997; Minshew & Goldstein, 2001). Verbal working memory as measured by the number–letter sequence task was intact—a result supported by a small number of previous studies (Ozonoff & Strayer, 2001; Russell et al., 1996; Williams, Goldstein, Carpenter, & Minshew, 2005). In contrast, spatial working memory as assessed by Finger Windows was relatively poorer when compared with the performance of the control group. This result is consistent with prior reports of impaired performance on the oculomotor delayed response paradigm for the assessment of spatial working memory in adolescents and adults with autism (Minshew et al., 1999). Performance on the oculomotor delayed response task has also been linked to decreased activation in prefrontal and posterior cingulate circuitry during functional MRI (Luna et al., 2002). As discussed earlier, Finger Windows was entered first in the stepwise discriminant analysis indicating that it strongly discriminated between the autism and control groups.

As expected, our group of children with autism exhibited more difficulty with the recall of complex visual stimuli than the matched control children. The Design Memory task from the WRAML is similar to the Rey–Osterrieth Complex Figure task that has been used in a number of studies demonstrating that high-functioning adults with autism have difficulty with immediate and delayed recall of complex figures (Minshew et al., 1992; Minshew & Goldstein, 2001; Rumsey & Hamburger, 1990). The Picture Memory subtest is a nonmatching-to-sample task without a delay. It is particularly challenging because the child must not only recognize items that were seen previously but must also detect novel items. High-functioning children with autism have been reported to have intact visual memory on delayed-matching-to-sample visual-recognition memory tasks when compared with children with developmental language disorder (Barth et al., 1995). The additional processing requirements of the Picture Memory subtest appear to have decreased the memory performance of the children with autism relative to the performance of the control group.

The conceptualization of memory deficit as a consequence of difficulties with complex information processing now appears to be supported in both children and adults with autism.

Confirmation of this theory requires both negative evidence in the form of intact simple abilities accompanied by impairment in complex areas such as story recall or recall of detailed pictorial material. Both types were present here. Although the limbic-prefrontal theory of Ben-Shalom (2003) remains a possibility, there is growing evidence from functional neuroimaging that the actual difficulty in autism lies in connectivity between perceptual and memory regions and differing information processing strategies (Just, Cherkassky, Keller, & Minshew, 2004; Koshino et al., 2005).

There are several limitations to this research that should be addressed before reaching more definitive conclusions. First, and most obviously, autism is a rare disorder, and it is difficult to obtain samples large enough to complete formal psychometric studies involving epidemiologically accurate stratified sampling and to support advanced multivariate statistics with fully adequate samples. Second, when no behavioral differences between the autism and control group were seen, we do not know whether the children with autism were using the same cognitive strategies as the typically developing control children. Recent functional neuroimaging results with high-functioning adults with autism have raised the possibility that behavioral similarities may actually be arising from differences in cognitive strategies (Just et al., 2004; Koshino et al., 2005). Third, the WRAML clinical measures are relatively brief samples of each behavior; therefore, these results need to be further investigated by the completion of more detailed experimental memory procedures. Fourth, although several studies have indicated an apparent deficit in spatial working memory relative to verbal working memory, it has been difficult to develop verbal and spatial tasks that are of equal difficulty level; this must be done before this distinction can be more definitively established.

In interpreting the findings of the principal components analysis, it should be pointed out that attempts by other groups of researchers to factor analyze the WRAML did not reach the same factor solution as the one reported in the manual (Burton, Mittenberg, Gold, & Drabman, 1999; Dewey, Kaplan, Crawford, & Fisher, 1998). The major difference seems to involve the failure of the original analysis to extract an attention/concentration factor. Although that may be the case, the factor structure found in the autism group does not resemble those found in analyses that extracted an attention/concentration factor. For example, the attention/concentration factor shown in Burton et al.'s (1999) study contained high loadings only from Number/Letter Sequencing and Sentence Memory, whereas the autism group did not produce a factor that was close to that pattern.

From a clinical perspective, the profile of memory strengths and weaknesses supports Boucher's (1981) suggestion that children with autism acquire less information from complex stimuli, including complex scenes, sentences, and stories. This difference in memory functioning may contribute to their impaired adaptive functioning in social communication and problem solving. This is not to suggest that the relative weaknesses in memory functioning seen in children with autism are a major or predominant factor in the impaired social, communication, and problem solving functions associated with autism; however, these weaknesses may be a contributing factor. It is possible that the challenges presented by differences in memory functioning prevent children with autism from acquiring relevant information needed to negotiate their environment. Such differences also may limit their capacity to organize the massive amounts of information with which they are confronted, contributing to their being overwhelmed as the amount and complexity of information increases.

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Table 1

Demographic Data

	Autism group		Control group				
Variable	***M***	***SD***	***M***	***SD***	***t***	***df***	***p***
Age in years	11.68	2.46	12.16	2.19	0.89	74	.38
Years of education	5.90	2.48	5.90	2.06	0.01	58	.99
SES[a]	2.88	1.37	3.36	0.86	1.65	57	.11
VIQ	106.42	15.97	107.34	8.09	0.32	74	.75
PIQ	100.55	14.19	105.95	10.43	1.89	74	.06
FIQ	103.82	14.29	107.18	9.37	1.22	74	.23

Note. SES = socioeconomic status; VIQ = Verbal IQ scores; PIQ = Performance IQ scores; FIQ = Full-Scale IQ scores.

[a] Mean is between business managers and administrative personnel range.

Table 2

Means and Standard Deviations for the WISC–III Subtests

	Autism group		Control group					
Subtest	***M***	***SD***	***M***	***SD***	***t***	***df***	***p***	***d***
Information	13.05	2.48	11.68	2.29	2.59	74	.01	0.57
Similarities	12.08	2.79	11.18	1.86	1.64	74	.10	0.38
Arithmetic	11.13	4.28	11.68	2.62	0.68	74	.50	0.15
Vocabulary	11.34	3.20	11.03	2.01	0.52	74	.61	0.12
Comprehension	7.45	3.75	10.58	2.07	4.51	74	.00	1.03
Digit Span	10.39	3.47	11.03	2.84	0.87	74	.39	0.20
Picture Completion	10.42	2.75	11.18	2.29	1.32	74	.19	0.30
Coding	8.37	3.82	10.74	2.82	3.08	74	.003	0.71
Picture Arrangement	9.71	3.09	10.55	2.88	1.23	74	.22	0.28
Block Design	11.66	3.83	11.84	3.25	0.23	74	.82	0.05
Object Assembly	9.95	3.38	9.92	2.12	0.04	74	.97	0.01
Symbol Search	10.12	4.21	12.25	2.35	2.55	60	.01	0.62

Note. WISC–III = Wechsler Intelligence Scale for Children—Third Edition.

Table 3

Means and Standard Deviations for the WRAML Subtests

	Autism group		**Control group**				
Subtest	***M***	***SD***	***M***	***SD***	t^a	p	d
Finger Windows	8.61	3.00	10.89	3.35	2.86	.002	0.72
Design Memory	8.32	3.16	10.13	2.56	2.76	.01	0.63
Picture Memory	8.63	2.83	9.92	2.66	2.05	.04	0.47
Number/Letter	8.61	3.33	9.26	2.61	0.96	.34	0.22
Sentence Memory	8.87	3.54	10.39	2.50	2.17	.03	0.50
Story Memory	8.89	3.51	10.63	2.84	2.37	.02	0.55
Verbal Learning	10.39	3.51	11.34	2.69	1.32	.19	0.30
Sound Symbol	10.87	3.02	10.76	2.63	0.16	.87	0.04
Visual Learning	10.68	3.50	11.39	2.62	1.00	.32	0.23

Note. WRAML = Wide Range Assessment of Memory and Learning.

[a] $df = 74$.

Table 4

Classification Matrix for Discriminant Function Analysis of the WRAML Subtests

	Predicted group membership		
Group	**Autism**	**Control**	**Total**
Autism	25	13	38
Control	11	27	38

Note. Of the cases, 68.4% were correctly classified. WRAML = Wide Range Assessment of Memory and Learning.

Table 5

Varimax Rotated Component Matrix for the Control Group

Subtest	1 Visual	2 Verbal	3 Learning	4
Design Memory[a]	.83	.12	.19	.00
Visual Learning[a]	.83	.00	.16	.27
Sound Symbol	.66	.00	.00	.00
Number/Letter[a]	.24	.87	.00	.00
Sentence Memory[a]	.00	.82	.23	.00
Story Memory[a]	.15	.17	.78	.11
Verbal Learning[a]	.00	.13	.77	−.25
Picture Memory	.17	−.32	.58	.22
Finger Windows	.12	.10	.00	−.48

[a] Matches principal components analysis from the Wide Range Assessment of Memory and Learning manual.

Table 6

Varimax Rotated Component Matrix for the Autism Group

Subtest	**1**	**2**
Number/Letter	.85	.00
Verbal Learning	.79	.28
Finger Windows	.79	.13
Sentence Memory	.73	.19
Design Memory	.72	.00
Visual Learning	.65	−.12
Sound Symbol	.52	.20
Story Memory	.25	.80
Picture Memory	.00	.82

Table 7

Means and Standard Deviations for the WRAML Delayed and Recognition Memory Subtests

	Autism group		**Control group**					
Subtest	***M***	***SD***	***M***	***SD***	***t***	***df***	***p***	***d***
Delayed Verbal Memory	9.34	2.84	10.29	2.65	1.50	74	.14	0.35
Delayed Story Memory	10.86	5.13	13.63	4.24	2.56	73	.01	0.58
Delayed Sound Symbol	8.05	2.54	8.29	2.53	0.41	74	.68	0.07
Delayed Visual Learning	9.53	3.17	9.89	2.74	0.54	74	.59	0.12
Story Memory Recognition	10.88	3.04	12.15	1.67	2.12	66	.04	0.52

Note. WRAML = Wide Range Assessment of Memory and Learning.