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WORKING MEMORY ABILITIES IN CHILDREN WITH AUTISM SPECTRUM DISORDER

Maria A. Estratopoulou[1],
Maria Sofologi[2]
[1]Dr., Bishop Grosseteste University,
Special Education and Inclusion,
School of Social Sciences,
United Kingdom
[2]Dr., Aristotle University Thessaloniki,
Psychology Department,
Greece

Abstract:
Aim: The aim of the present study was to investigate possible differences on working memory abilities between children with Autism spectrum disorder and typical children. The potential facilitating effect of verbal mediation on working memory was investigated measuring children's ability to use language-based encoding and rehearsal processes to enhance working memory. **Method:** Participants were divided into two groups: a group of 26 children diagnosed with Autism spectrum disorder (16 boys and 10 girls) and to a group of 25 typical controls (17 boys and 8 girls) matched on non-verbal intelligence. Examination of working memory was based on non-verbal variants of the non-spatial, self-ordered pointing test (SOPT) devised by Petrides and Milner (1982). Both the Verbal Span Test and the Self-ordered tests were performed to the participants. **Results**: The resulting profile on memory abilities in children with autism was characterized by relatively poor memory for complex verbal and visual test. The different pattern of memory performance between the two groups indicates that the more complex the task and the information being processed, the more taxed the resources of the memory system become**.** **Discussion**: The results provide useful information to take into consideration when designing interventions for children with Autism spectrum disorder in clinical and educational settings.

Keywords: autism spectrum disorder, working memory, non-verbal intelligence, memory abilities

1. Introduction

Educational research indicated that autism may not be an excessively rare disorder, but it could represent the extreme of a quantitative distribution of autistic traits that are present in the general population (Constantino & Todd, 2003; Spiker, Lotspeich, Dimiceli, Myers, & Risch, 2002). Recent surveys of the prevalence of autism in the community indicate not only an increase in the number of cases meeting conventional criteria, but a disproportionate increase in the number of milder cases that fail to reach full criteria (Chakrabarti & Fombonne, 2001; Yeargin-Allsopp, Rice, Karapurkar, Doernberg, Boyle, & Murphy, 2003).

Problem behaviors observed with autism include physical aggression, self-injury, property destruction, stereotyped behaviors, and tantrums are highly disruptive to classroom, community, and home environments and without intervention, and they are more likely to increase than improve (Efstratopoulou, 2017; Horner, Carr, Strain, Todd, & Reed, 2002). During physical activities, children with ASD, indicate stereotyped and repetitive motor mannerisms, impairments of facial expression, postures, and gestures, are often clumsy and face many problems in motor coordination (Efstratopoulou, Janssen, & Simons, 2012; Piek & Dyck, 2004).

Clinicians and researchers usually include autistic disorder, Asperger syndrome, and pervasive developmental disorders not otherwise specified as subtypes of ASD. Although not part of the diagnostic classification and not formal subcategories of ASD, a distinction is also often made between low-functioning autism (LFA) and high-functioning autism (HFA). No consensus criteria regarding LFA and HFA exist, but low-functioning individuals with autism are generally considered to have an IQ below 70 or 85, whereas high-functioning individuals with autism tend to have an IQ above 70 or 85 (depending on the preferred IQ cut-off point of one or two standard deviations below mean). Although estimates vary, the prevalence rate of ASD is approximately 6 per 1,000 children, with males being affected two (autism disorder) to four (Asperger syndrome) times more often than females (Geurts, Verté, Oosterlaan, Roeyers, & Sergeant, 2004).

Autism is a developmental condition in which executive function has been hypothesized as playing an important role (Pennington et al., 1996; Bishop, 1993; Hughes, Russell, & Robbins, 1994; Joseph, 1999) and for which the remediation of the central executive has been proposed as a treatment strategy (Ozonoff, 1998). However, the exact nature of the working memory and executive deficits seen in autism is not entirely clear and is currently the topic of some debate. Several studies have reported finding working memory deficits in children with autism (Bennetto, Pennington, & Rogers, 1996; Minshew & Goldstein, 2001; Pennington et al., 1996) whereas others have not (Russell, Jarold, & Henry, 1996). A similar situation exists for different measures of executive function, with some studies reporting impaired performance (Ozonoff, 1998) and others not (Griffith, Pennington, Welner, & Rogers, 1999). One explanation for these inconsistent findings is that children with autism have impaired development and use of organizational strategies and that their performance suffers in situations where planning and strategy are important for optimal performance (Minshew et al., 2001).

It is well to understand the role of memory in autism because very few aspects of higher cognitive function and learning could operate successfully without some memory contribution. Memory is often treated as a unitary construct but should be recognized as comprising multiple interrelated systems. Both the behavioral and neuropsychological research evidence suggests the usefulness of considering different aspects of memory in autism. Some such individuals show extraordinary memory for discrete domains of knowledge. At the same time, they are observed to have tremendous difficulty navigating their daily environment, such as remembering their schedule of classes and activities or morning routine further, the capacity of higher functioning individuals to provide a reliable account of the day's activities or to recollect personal experiences is more limited than might be predicted base on level of language or cognitive functioning alone (Russell et al., 1996). Clinical observations suggest that individuals with autism typically achieve learning trough rote memory, classical conditioning (e.g. stimulus-response learning), and procedural mechanisms, but show a more limited capacity for flexibility, abstraction, and generalization (Minshew, Goldstein, Muenz, & Payton, 1992).

Executive function' is traditionally used as an umbrella term for functions such as planning, working memory, impulse control, inhibition and shifting set as well as the initiation and monitoring of action (Frith, 1992) These functions share the need to disengage from the immediate environment to guide actions. Executive functions are typically impaired in patients with acquired damage to the frontal lobes as well as in a range of neurodevelopmental disorders that are likely to involve congenital deficits in the frontal lobes. Such clinical disorders include attention deficit hyperactivity disorder (ADHD), obsessive compulsive disorder, Tourette syndrome, phenylketonuria, schizophrenia and autism spectrum disorder. It should be noted that executive dysfunction can be observed in those with acquired damage to non-frontal brain areas. (Ozonoff et al., 1991).

Executive functions are comprised of a number of mental operations necessary for the conscious, deliberate, and flexible control of non-routine actions. There is evidence of a broad range of executive function impairments in autism, including deficits in working memory, combined working memory and inhibitory control (Hughes & Russell, 1993), mental set shifting (Hughes, Russell, & Robbins, 1994; Ozonoff & Strayer, 1997; Ozonoff, Strayer, McMahon, & Filloux, 1994), and planning, particularly as measured on the Tower of Hanoi and Tower of London tasks (Ozonoff & Jensen, 1999; Ozonoff & McEvoy, 1994; Ozonoff et al., 1991; Roberts & Pennington, 1996).

Working memory is a key component of executive control that has received significant attention in autism research, but for which the findings have been inconsistent. The most commonly used cognitive model of working memory is the revised working memory model proposed by Baddeley (2012). This model contains a central executive (attention control center), an episodic buffer (which comprises a limited capacity storage system and integrates information into coherent objects and episodes) and two slave systems: one for visual and/or spatial information (the visuospatial sketchpad) and one for auditory information (the phonological loop). The model also describes links between working memory, long-term memory, and perception, and has proven to be very valuable in working memory studies that focus on abstract information processing, such as for numbers, locations of objects, words, and sentences (Baddeley, 1986) the so-called 'cold' cognitive processes (auditory and visuospatial).

Bennetto, Pennington and Rogers (1996) and Russell, Jarrold and Henry (1996) investigated working memory skills in children with autism using measures, all of which required participants to respond to a series of items from a focal processing task (e.g., counting the dots on a card, supplying a word missing from a sentence) while simultaneously maintaining a mental record of all prior responses. Whereas Bennetto and colleagues (1996) found that their high-ability participants were significantly impaired relative to normal controls, Russell and colleagues (1996) found that the performance of their relatively low-ability participants with autism, although inferior to a normal control group, was similar to that of a mental-age-matched, non-autistic control group. 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. In addition, in a recent study using a variety of tasks, Ozonoff and Strayer (2001) failed to find working memory deficits in high-ability children and adolescents with autism.

The lack of consistent evidence of a working memory impairment in autism has been somewhat surprising given that the most consistently replicated and robust finding of executive dysfunction in autism comes from studies using the Tower of Hanoi or Tower of London, which as complex planning tasks would be expected to draw upon the ability to generate, maintain, and continuously update a sequence of actions in working memory. Furthermore, although there is no evidence of an impairment in simple response inhibition in autism (Hughes et al., 1993; Ozonoff et al., 1997), tasks that require a combination of working memory and inhibition (Roberts et al., 1996) appear to be especially challenging for individuals with autism (Hughes et. al., 1993; Russell, 1997), suggesting that working memory capacities may be deficient at least under some circumstances in autism. In sum, although research thus far has failed to isolate an autistic deficit in working memory per se, the possibility that weaknesses in some aspects of working memory contribute to the broader executive impairment seen in autism remains unresolved and worthy of further scrutiny.

Based on prior findings (Russell et al., 1996), we did not expect that children with autism would be impaired in verbal rehearsal skills associated with the phonological loop, but would rather exhibit deficits in their ability to spontaneously adopt verbal mediation strategies to monitor and maintain their choices in working memory. This would point to a failure of the central executive of working memory in autism.

Examination of working memory was based on non-verbal variants of the non-spatial, self-ordered pointing test (SOPT) devised by Petrides and Milner (1982). Each stimulus set was presented repeatedly, in a new spatial arrangement each time, for as many times as the number of stimuli in the set. Participant's task was to point to a different picture on each presentation. An important conceptual distinction bearing upon this investigation comes from Baddeley and Hitch's (1974, 1994) (Baddeley, 1996a,b) tripartite model of working memory, which distinguishes between a "central executive" and two modality-specific subsystems that participate in the online maintenance of verbal and visuospatial information. The central executive of working memory functions as a top–down, attentional selection and control mechanism which in the SOPT would involve monitoring the pointing choices made thus far, and generating subsequent choices based on continuously updated mental representations of prior choices. The central executive is dependent on two subsidiary information maintenance subsystems. The phonological loop is responsible for maintaining verbal information in active memory, whereas the visuospatial sketchpad is responsible for the maintenance of visual and spatial information. 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).

In the present study we examined children's phonological rehearsal skills, using a verbal span task. This task required participants to listen to a sequence of words (objects) and then point to the corresponding items in a picture array in the same order as the words were spoken. The aim was to estimate the ability to maintain verbal information in the phonological loop without the 'central executive' demands entailed by the visual and verbal test (i.e., generating, monitoring, and continuously updating a pointing sequence).

The aim of this study was to estimate the verbal and nonverbal working memory skills in children with autism and compare them with children without developmental deficiencies. We investigated the potential facilitating effect of verbal mediation on working memory, such that children would be able to use language-based encoding and rehearsal processes to enhance working memory. Based on existing research data indicating that visual memory has been found to be an area of strength (Efstratopoulou 2014; Klin, Sparrow, de Bildt, Cicchetti, Cohen, & Volkmar, 1999; Barth et al., 1995) for children with autism but complexity of the stimuli appears to affect memory function, we hypothesized greater dependence for the autism group on visual representation in working memory.

2. Method

2.1 Participants

The first group consisted of 26 school-age children diagnosed with autism (18 boys and 8 girls) with chronological age ranged from 6–13years (M=10.59, SD=2.09). All the children with autism from the first group spoke Greek as their mother language. Comparison group was consisted of 25 children (17 boys and 8 girls) whose chronological age ranged from 4.5-5.5 years (MN= 4.76, SD=0.25). The non-verbal intelligence test by Raven (1965) was used in order to match the two groups of children on non-verbal mental age. Means and standard deviations for the two groups are in Table 1. Data used in present study were collected from two educational settings in Greece. The first data (clinical group) were derived from students attending special elementary school and the second data (comparison group) obtained from children attending typical school.

Table 1: Chronological age and mental age of the children by group

Variable	ASD Group		Control Group	
	M	SD	M	SD
Age (years)	10.59	2.09	4.76	0.25
NIQ	6.83	0.96	6.73	3.35

Footnotes: NIQ: Non Verbal IQ scores

2.2 Measuring Instruments

2.2.1 Verbal Span

Children heard the examiner speak a sequence of words at the rate of one word per second. For each trial, a fixed sequence was randomly presented from a set of nine words, all of which were single-syllable, high-frequency concrete nouns (arm, boat, brush, chair, dress, knife, mouse, ring, tree). After each sequence was spoken participants were immediately presented with a 3x3 grid containing nine line drawings corresponding to the set of nine words, and were instructed to touch the pictures in the same as the words were spoken. For each trial the arrangement of the pictures in the grid changed so as to prevent children from using a fixed visual representation of the array to help encode the word sequence. The changing array also introduced a visual search component to the task. Children were given two different trials of each sequence length, which ranged from two to seven words. One point was given for each trial correct. Testing was discontinued when a child failed both trials of any one sequence length.

2.2.2 Self-ordered Pointing Test

In the verbal condition children viewed pictures of concrete, familiar and nameable objects (car, book, etc.). These pictures were taken from the standardized set developed by Snodgrass and Vanderwart (1980). In the non-verbal condition, children saw abstract designs that were difficult to encode verbally. Each condition included 4 test trials of increasing length (4, 6, 9 and 12 items) proceeded by a 4-item demonstration and a 4-

item practice trial to ensure that the task demands were well understood. In a four-item trial, for example, four sheets of paper were presented sequentially, with each sheet depicting the same four stimuli, but in a different spatial arrangement each time. Children were instructed to touch a different picture on each presentation. For any given trial, the number of sheets presented was equal to the number of stimuli on the first sheet. Each of the different sized sets was composed of unique stimuli. Further, within each set, each picture came from a different category so as to preclude the use of semantic or visual clustering strategies that have been observed in studies using the original Petrides stimuli (Bryan & Luszch, 2001). Administration, of the test was facilitated by fitting all the sheets of pictures for each condition into transparent sleeves and presenting them with the aid of a loose leaf binder. During administration, if a child pointed to the same location consecutively (a strategy that would be highly successful given that no picture ever appeared in the same place), he or she was told prior to the next trial. We assessed SORT performance by calculated the number of errors, defined as points to any pictures already selected.

2.2.3 Raven Test

The Colour Progressive Matrices by Raven (1965) was used in order to estimate the non-verbal mental age of the children who participated in this study. The test requires the examinee to scan a series of abstract designs, each of which has a missing section. The examinee's task was to complete each design by selecting the appropriate section from a number of alternatives. Raven’ s test is a useful tool to estimate the non-verbal mental age of 3-12 years old children and to make comparisons between children of the same chronological age.

3. Results

Statistical analysis of the data was conducted using the Statistical Package for Social Sciences (SPSS 25.0). Table 2 shows mean scores (MN) and standard deviations (SD) for the two groups for each of the three different measurements (Verbal span task, Self-Ordered Pointing test and Non-verbal intelligence). Means scores for Verbal Span test (MN= 6.75. SD= 4.32) and for Self-ordered Pointing Test (MN=4.56, SD=3.24) for the children with autism were lower than the scores of the children without autism [Verbal Span Test (MN=14.33, SD=1.23) (Self-order Pointing Test: MN=11.60, SD=1.92)]. Furthermore, mean score on non-verbal measurement was lower for children with autism (MN= 7.27, SD= 0.96) than the scores of the children from the typical group (MN=8.88, SD= 2.27).

Table 2: Means, Standard Deviation and t-values for the Verbal Span, Self-ordered Pointing Test and Raven Test by group

Variables	**ASD Group**		**Control Group**			
	M	SD	M	SD	t	p
VST	6.75	4.23	14.33	1.23	-6.69	.00
SOPT	4.56	3.24	11.60	1.92	-7.28	.00
NIQ	7.27	0.96	8.88	2.27	2.53	.01

Footnotes: VST: Verbal span test; SOPT: Self-ordered pointing test; NIQ: Non Verbal IQ scores

Independent t-tests were performed to compare working memory performance on verbal and non-verbal memory subtest and to examine differences among two different groups. More specifically, in order to investigate if measurements within two different groups are statistical significant an independent t-test was conducted. Findings revealed that individuals with autism were significantly poorer on memory subtests measures than the comparison group. More specifically, statistical significant differences ($p<.05$) were found for the Verbal Span task, $t(29) = -6.69$, $p<.00$, and Self-ordered Pointing Test $t(29) = -7.28$, $p<.00$. Children with autism performed significantly lower in terms of mean scores than the typical comparison group on two different memory measurements. In addition statistical significant ($p< .05$) differences were found for the non-verbal intelligence measure $t(29) = 2.53$, $p<.01$.between the two groups.

4. Discussion

In an attempt to clarify the inconsistent results of previous investigations on working memory abilities in children with autism, we examined a sample of school-aged children with autism (high-functioning) and compared them with a group of typical developing children on non-verbal and verbal tests of working memory. All the results indicated that children with autism performed worse than the participants from the comparison group on a non-verbal version of SORT test. Furthermore, children with Autism didn't show any improvement on performance when stimuli could be verbally encoded and rehearsed in working memory in the verbal condition of the SORT test. The memory profile of the autistic group was characterized by relatively poor memory for verbal and non-verbal subtests of working memory.

A comparison of the results from our study with the experimental literature on memory in autism reveals that the weak performance by children with autism on non-verbal tests could not be attributed to deficient phonological rehearsal capacities. Rather, their poor performance appears to result from central executive limitations relating to the ability to monitor and maintain a sequence of icons with nameable objects. The differential pattern of associations among test measures for the two groups suggests that for children with autism the purely visual representations cannot be rehearsed and refreshed via the visuospatial sketchpad in working memory as effectively as verbally coded representations can be via the phonological loop (Efstratopoulou, 2014).

Children with autism performed significantly less well than the comparison group on the verbal and non-verbal subtests. The divergence in performance between two groups can explained by the fact that language ability was highly correlated with verbal SORT performance in the comparison group, but not in the experimental group, providing a further indication that experimental group were not exploiting their verbal skills to enhance working memory in the verbal condition of the task. Furthermore, 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.

These findings provide further support for Minshew and Goldstein (2001) hypothesis that individuals with autism may equally encode the meaning of the words presented but be deficient in their ability to employ a strategic search to assist their retrieval of the unrecalled words. Furthermore, tasks requiring a greater level of organization (visually or semantically) also appear to impact the memory performance of autistic subjects, which may reflect a more general deficiency related to complexity of the material to be remembered.

There is well-known evidence that working memory tasks requires the ability to simultaneously attend to, recall, and act on information held in an online state. This aspect of memory function is often considered in the domain of executive function. A possible explanation for impaired performance on SORT test for experimental group is based on theory of memory load which reflects limited capacity and weak cognitive flexibility. Williams, Goldstein, Carpenter, & Minshew (2005) reported more working memory problems in children and adolescents with ASD on the more complex design memory and picture memory measures, whilst finding no working memory problems on a less complex number/letter working memory task. These memory load specific effects may explain why other studies did not find working memory problems in adolescents with ASD. For example, the spatial span that Ozonoff and colleagues (1997) used in their spatial memory-span task had only a limited working-memory load. Participants had to remember the location of one, three or five colored geometric shapes over a 1,000 or 5,000 ms delay. This low task load on working memory did not reveal any difficulties.

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, Soulieres, 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 eventrelated 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).

Studies of working memory in individuals with autism have yielded inconsistent results. The results of the present study indicates that 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 (Efstratopoulou, 2017). 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 pre activating related concepts and schemas (Just et al., 1992). Storage capacity may be relatively intact, but complex information processing or the central executive may be disproportionately impacted with implications for numerous aspects of behavior (Sofologi, 2014). 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.

There are several limitations to this research that should be addressed. First of all, the small number of participants with autism. Working with clinical samples 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 autistic 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. Research finding on functional neuroimaging with high-functioning adults with autism have raised the possibility that behavioral similarities may actually be arising from differences in cognitive strategies (Just, Cherkassky, Keller, & Minshew, 2004; Koshino et al., 2005). Third, 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.

Within its limitations the results of the present study could provide useful information when designing intervention programs for children with ASD in both educational and clinical settings.

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