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ORIGINAL ARTICLE

A study of short-term nonverbal visual memory in high-functioning autistic children

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Background Visual memory in children with high-functioning autism (HFA) is an area of debate, as few studies have examined visual memory in those children, the memory profile appears to vary, according to the memory process and type of stimuli, contrasting results may be found, also, it was found that selective impairment in visual memory may not affect cognitive system.
The aim of the study is to compare the visual short-term nonverbal memory (visual–spatial memory, visual memory of shapes/numbers, visual memory of shapes/letters, and total) function deficits between children with HFA and typically developing control.

Procedure The study was done to 40 HFA children with autism (mean age 10.3) and children were matched to 40 healthy controls (mean age 9.5), aged 812 years old, also, Raven's Progressive Matrices Scale IQ score took part in the study. Associative and recognition (shapes/numbers) (shapes/letters) memory as well as visual–spatial short-term memory (STM) were assessed by Short Term Nonverbal Visual Memory Assessment scale.

Results The resulting profile of STM abilities in the children with HFA was significantly less and revealed poor memory for visual–spatial memory, shape/letter, shape/number, and the total visual memory scored more than normal children (*P*<0.001 for each).

Conclusions It is suggested that nonverbal visual STM deficit was a characteristic finding of HFA, so autism-spectrum disorder children need supportive memory programs for visual memory to help them to integrate well in usual educational programs.

Keywords High-functioning autism, Shapes/letters, Shapes/numbers, Short-term nonvisual memory, Visual–spatial memory.

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INTRODUCTION

Autism-spectrum disorder (ASD) is a neurodevelopmental disorder, characterized by deficits in social interaction, social communication, and restricted, repetitive patterns of behavior, interests including unusual sensory perceptions (American Psychiatric Association, 2013).

Visual perception is the ability to receive, recognize, analyze, and elaborate the visual stimulus from objects and events; visual processing is a complex process, including visual recognition, visual memory, visual–spatial orientation, and the perception of graphics (Zhang *et al.,* 2020).

Williams *et al.,* (2006) also added that memory abilities in the children with autism were 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.

Short-term memory (STM) is the ability to retain small amounts of information for a short period of time

(Anunciação *et al.,* 2021). Accumulating evidence suggests that STM is important for almost every cognitive ability and plays a critical role in intelligence and attention (Fukuda and Vogel, 2010).

There are two main aspects of STM: the presence of temporal decay and a chunk capacity limit (Cowan, 2008). Much evidence suggests that STM is an important mediator of visual awareness, long-term phonological learning, and communication (Leclercq and Majerus, 2010).

Visual–spatial working memory, specifically, represents the ability to briefly maintain and manipulate spatial information (e.g. shapes and colors, as well as their locations) in mind. Thus, poor visual–spatial working memory may have implications for how individuals with ASD process their social and academic environments. For instance, children with ASD may struggle to process visual cues (e.g. nonverbal language, facial expressions) during social interactions, making it challenging for them to carry on conversations and to relate to their peers (Vogan *et al.,* 2019).

Memory dysfunction is one of the underlying bases for the social, language, and behavioral abnormalities in autism. Children with autism do not use organizational strategies to support memory, children with autism remember randomly organized words (Williams *et al.,* 2006).

Boucher (1981) reported that children with autism encode less information from a complex stimulus such as a social interaction or conversation. Since memory has an impact on learning, its assessments could create strategies to improve the impaired abilities. Thus, the present study aims to compare the visual short-term nonverbal memory (visual–spatial memory, visual memory of shapes/numbers, visual memory of shapes/letters, and total) function deficits in children with high-functioning autism (HFA) to a group of matched typically developing healthy control children in addition to the detection of correlations between visual short-term nonverbal memory, IQ levels, and age.

PATIENTS AND METHODS

Participants

The sample included forty children with ASD, of ages ranging between 6 and 12 years, to be included in the research, the IQ must be 90 or more and no comorbid diagnosis. While the control group included 40 healthy children of matched age and sex, and had no history of neurological impairment or developmental disabilities. All participants were boys and in the elementary school. The participants were recruited from the Neuropsychiatry Department and outpatient clinic in Benha University Hospital, while the controls were recruited from a primary school for boys in Benha city.

Children with ASD were assessed in Benha child psychiatry clinic and the control group children were assessed in their school.

The assessment was performed in a quiet room on the same day of their visit by the same certified psychologist.

Clinical diagnoses of mild and moderate autism was done by DSM-IV R (American Psychiatric Association, 2000) and the Gilliam Autism Severity Assessment Measure (Version III) (Gilliam, 2014). Participants with ASD children showed more than 90% IQ levels according to Raven's Progressive Matrices Scale IQ score Arabic version: this is a Non-verbal Intelligence Test used to measure intellectual capacity (Raven *et al.,* 1990).

Tools

Gilliam Autism Severity Assessment Measure (Version III)

For diagnosis of autism disorder for individuals aged 3–22 years and consists of 58 items spread over six submeasures (restricted or repetitive behaviors, social interaction, social networking, emotional responses, cognitive style, and inappropriate speech (Abdelrahman and Khalifa, 2020).

Raven's Progressive Matrices Scale

To assess the intelligence of individuals aged 4.5–68 years, consisting of 36 items spread over three groups a, ab, and b, each group consists of 12 matrices (Ali, 2016).

Short-Term Nonverbal Visual Memory Assessment Scale

The scale consists of three subscales (visual–spatial memory, visual memory of shapes/numbers, and visual memory of shapes/letters), each subscale comprises 20 items, each one is measured in 5–30 s, so that the total items of the scale are 60 items (Matar, 2016).

Ethical consideration

An informal written consent was obtained from the children's guardians before participation. parents were informed by the results and recommendations, possibility of withdrawal from the study at any time without any consequences was assured, and all procedures were revised and approved by Research Ethics Committee in Benha Faculty of Medicine.

Statistical Analysis

The collected data were revised, coded, tabulated, and introduced to a PC using Statistical Package for Social Science (IBM Corp. Released 2017) (IBM SPSS Statistics for Windows, Version 25.0.; IBM Corp., Armonk, New York, USA).

Mean, SD, minimum, and maximum were used to describe numerical data.

Student *t* test was used to assess the statistical significance of the difference between two study group means.

The receiver-operating characteristic (ROC) curve provides a useful way to evaluate the sensitivity and specificity for quantitative diagnostic measures that categorize cases into one of two groups. The optimum cutoff point was defined as that which maximized the AUC value.

AUC is that a test with an area greater than 0.9 has high accuracy, while 0.7–0.9 indicates moderate accuracy, 0.5–0.7, low accuracy, and 0.5 a chance result (Fischer *et al.,* 2003).

Correlation analysis

To assess the strength of association between two quantitative variables, the correlation coefficient defines the strength and direction of the linear relationship between two variables.

All reported P values were two-tailed and P value less than 0.05 was considered to be significant.

RESULTS

The present study was a case–control study, conducted on 40 high-function autistic children whose IQ scores were higher than 90, their mean IQ was 101.48, SD= 3.85, and ranged from 94 to 107. Their mean age was 9.5 years, SD= 2.11, which ranged from 6 to 12, in addition to 40 healthy participants of matched age (mean of age= 10.03, SD= 1.9, range of age 6–12) and Raven's Progressive Matrices Scale IQ score (mean= 102.28, SD=2.5, ranged from 100 to 108) as shown in Table 1.

The means, SDs, and *t* test were used for comparison of short-term nonverbal visual memory among studied groups and are presented in Table 2 and Fig. 1. It showed a statistically significant difference between the HFA group and healthy controls in all short-term nonverbal visual memory tests. High-functioning ASD was significantly associated with lower visual–spatial, shapes/numbers, shapes/letters, and total score when compared with the control normally developing children ($P<0.001$ for each).

ROC curve of visual–spatial, shapes/numbers, shapes/letters, and total memory was conducted for discrimination of performance characteristic between HFA cases and control normal groups; visual–spatial, shapes/numbers, and shapes/letters showed high-quality AUC (AUC= 0.908, 0.991, and 0.996, respectively), that is, the mean of the performance during the test is high, while total visual memory AUC was perfect (AUC= 1), which denotes that the performance of children during the test is perfect. Cutoff values and performance characteristics are shown in Table 3.

As observed from the correlations of visual–spatial, shapes/numbers, shapes/letters, and total memory score with age and Raven's Progressive Matrices Scale IQ score among HFA and controls are presented in Table 4, the two groups showed significant positive correlations with shapes/numbers and total memory test performance.

The correlations between shapes/numbers and age were significantly positive ($P= 0.002$) and also, with total memory test performance and age ($P= 0.003$). Raven's Progressive Matrices Scale IQ was significantly positive ($P<0.001$) with shape/number and total memory test performance. It indicated that shape/number performance and total memory test performance improved with increased age and nonverbal IQ (Table 4).

Logistic regression analysis was conducted for prediction of HFA, using the age, Raven's Progressive Matrices Scale IQ, and total short-term nonverbal visual memory performance as confounders (Table 5). Lower Raven's Progressive Matrices Scale IQ and total short-term nonverbal visual memory performance was significantly associated with prediction of high-function autism ($P<0.001$) (Figs 2 and 3).

DISCUSSION

STM is a neuropsychological process, meaning the maintenance of information for a short period of time and is important in the cognitive process (Anunciação *et al.,* 2021).

Visual/nonverbal memory is the ability to remember and recreate nonverbal visual experiences and images. It is our visual memory system that gives us the ability to 'picture' in our mind images of what we have seen or experienced when it is not there to see any more (Funabiki and Shiwa, 2018).

Table 1: Comparison of age and IQ matrices among studied groups:

	Normal child (*N*=40)	High-functioning autism (*N*=40)	*t*	*P*
Age (years)				
Mean±SD	10.03±1.9	9.50±2.11	1.067	0.245
Minimum–maximum	6–12	6–12		
IQ matrices				
Mean±SD	102.28±2.5	101.48±3.85	1.067	0.192
Minimum–maximum	100–108	94–107		

t test was used.

Table 2: Comparison of visual memory among studied groups:

	Normal child (*N*=40)	High-functioning autism (*N*=40)	*t*	*P*
Visual–spatial				
Mean±SD	14.03±1	11.78±1.23	8.979	<0.001
Minimum–maximum	12–15	10–14		
Shapes/numbers				
Mean±SD	12.50±1.3	7.73±.67	18.619	<0.001
Minimum–maximum	8–15	7–9		
Shapes/letters				
Mean±SD	13.20±1.4	8.15±.77	18.359	<0.001
Minimum–maximum	9–15	6–9		
Total				
Mean±SD	39.73±2.3	27.65±1.7	25.002	<0.001
Minimum–maximum	35–45	25–31		

t test was used.

Table 3: Receiver-operating characteristic area under the curve and performance characteristics of visual–spatial, shapes/numbers, shapes/letters, and total for discrimination between high-functioning autistic child and control groups:

	Visual–spatial	Shapes/numbers	Shapes/letters	Total
AUC	0.908	0.991	0.996	1
Cutoff value	13.5	9.5	9.5	100
Sensitivity (%)	90	100	100	100
Specificity (%)	77.5	97.5	97.5	100
PPV (%)	80.0	97.6	97.6	100
NPV (%)	88.6	100.0	100.0	100
Accuracy (%)	83.8	98.8	98.8	100

AUC, area under curve; NPV, negative predictive value; PPV, positive predictive value.

Table 4: Correlations of visual–spatial, shapes/numbers, shapes/letters, and total with age and matrices (IQ levels) among all studied participants:

	Visual–spatial		Shapes/numbers		Shapes/letters		Total	
	r	*P*	*r*	*P*	*r*	*P*	*r*	*P*
Age	0.004	0.975	0.338	0.002	0.003	0.976	0.336	0.003
IQ matrices	0.102	0.367	0.497	<0.001	0.103	0.365	0.495	<0.001

r, correlation coefficient.

Table 5: Regression analysis for prediction of high-functioning autism:

	P	OR	95% CI	
Age	0.284	0.926	0.804	1.066
IQ matrices	<0.001	0.789	0.707	0.882
Total	<0.001	0.928	0.923	0.934

CI, confidence interval; OR, odds ratio.

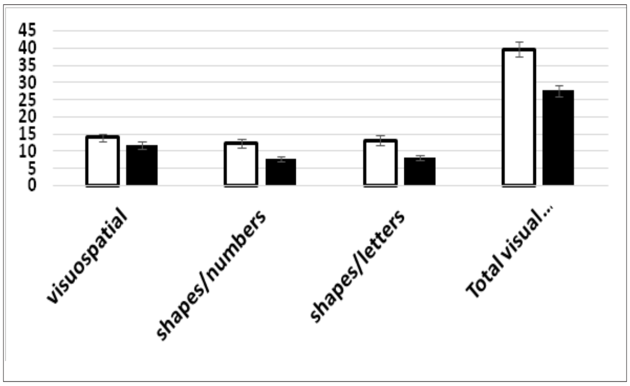

Figure 1: Short-term nonverbal visual memory among studied groups: columns represent means, and error bars represent SDs.

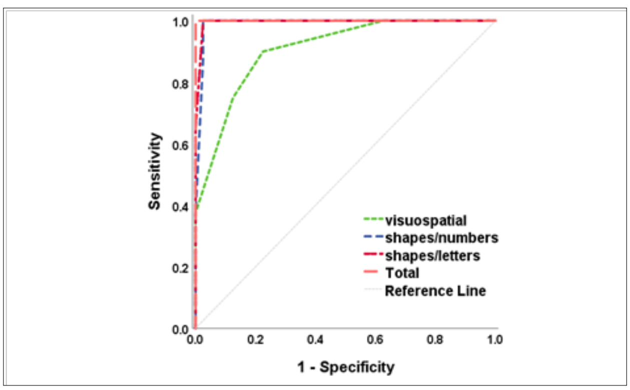

Figure 2: ROC curve of visual–spatial, shapes/numbers, shapes/letters, and total for discrimination between ASD cases and control groups. ASD, autism-spectrum disorder; ROC, receiver-operating characteristic.

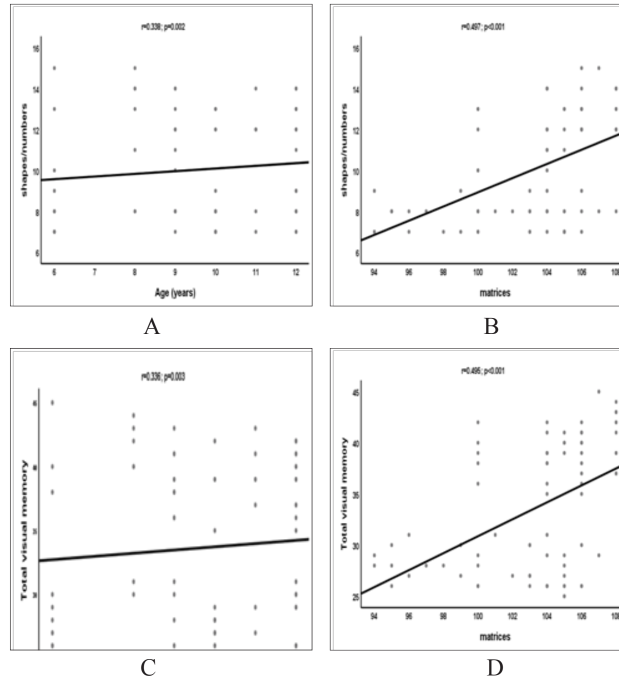

Figure 3: Correlations of age with (a) shapes/numbers, (b) total, and */with (c) shapes/numbers, (d) total among all studied participants. Matrices=IQ levels.

The aim of this study was to investigate the visual short-term nonverbal memory (visual–spatial memory, visual memory of shapes/numbers, visual memory of shapes/letters, and total) function deficits in children with HFA compared with matched typically developing controls.

The studied sample of the HFA children performed significantly worse on visual–spatial, shapes/numbers, shapes/letters, and total memory score compared with the controls ($P<0.001$ for each). However, the deficits in visual memory profile in ASD as deficits in recognition of memory for faces have been found to be impaired and in spatial working memory, this finding comes in agreement with the study of Snow *et al.,* (2011) and Wang *et al.,* (2017).

Previous studies found a relationship between memory and other cognitive skills, such as intelligence and attention (Zanto and Gazzaley, 2009; Veer *et al.,* 2017).

The children in the current study were shown six pictures with numbers and six pictures with letters, then were asked to memorize and recognize, and the children with HFA showed better performance in shape/letter than shape/number. This pattern was also confirmed by Snow *et al.,* (2011) in adolescents with HFA, this may be due to abnormal attention/encoding rather than to memorization process.

Higher intelligence does better during the encoding phase of the STM, enhances mental speed, and improves memory storage capacity that is required to do memory tasks (Colom *et al.,* 2008).

Regarding visual–spatial task, children were asked to memorize and locate cards of pictures (six cards, then nine cards, and lastly 12 cards), it was impaired in children with HFA but better than shape/number and shape/letter.

Children may be supported by the semantic mediation of the meaningful shapes (child with HFA can recall stimuli in the high semantic condition). Also, visual–spatial memory abnormalities were found to be correlated with autism symptom severities in previous study.

ROC curve of visual–spatial, shapes/numbers, shapes/letters, and total memory score was conducted for discrimination between HFA cases and control groups. Visual–spatial, shapes/numbers, and shapes/letters showed high-quality AUC (AUC= 0.908, 0.991, and 0.996, respectively), while total visual memory AUC was perfect (AUC= 1). Cutoff values and performance characteristics are shown in Table 3.

This might be explained that higher intelligence can lead to better strategies during the encoding phase of the STM process, improve memory storage capacity, and enhance mental speed that is needed to perform memory tasks (Colom *et al.,* 2008), but not like normal children.

The correlations of visual–spatial, shapes/numbers, shapes/letters, and total memory with age and Raven's Progressive Matrices Scale IQ score among all studied participants (Table 4) showed significant positive correlations with shapes/numbers and total memory score as they improved with increased age and nonverbal IQ, this could suggest that the effects of nonverbal intelligence and selective attention were predictors of visual STM and skills that are acquired through a combination of natural brain development and cognitive maturation during the second decade of life (Williams *et al.,* 2006).

A meta-analysis of working memory in individuals ranged from school-age children to adults suggested that spatial working memory was more severely impaired than verbal working memory (Zhang *et al.,* 2020).

Thus, it was concluded that the nonverbal visual memory profile of children with HFA showed impaired performance in visual–spatial, shapes/numbers, and shapes/letters as the degree of stimulus more influences memory performance.

Also, it was suggested that nonverbal visual STM deficit was a characteristic finding of HFA. Therefore, it is recommended that children with HFA join supportive memory programs for visual memory and that becomes integrated in normal educational programs. Further studies with larger study groups and both sexes are recommended taking into account all the limitations of the study like the recruitment of participants in this study solely from one psychiatric facility and the sample was only boys in elementary school may have biased the results such that it may not be representative of the general population. Some cases faced difficulties in dealing with the scales and some parents refused to participate in our study as they were conservatives.

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Nil.

CONFLICTS OF INTEREST

There are no conflicts of interest.

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