Autistic-Like Traits in Children are Associated with Enhanced Performance in a Qualitative Visual Working Memory Task.

Running Head: Child ALTs associated with enhanced visual memory

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Abstract

Prior research has suggested that individuals with Autism Spectrum Disorders (ASD) demonstrate heterogeneity in cognitive efficacy, challenged executive resources but efficient visual processing. These contrasts lead to opposing predictions about visuospatial working memory competency in both ASD and the broader autism phenotype (BAP); compromised by constrained executive processes, but potentially scaffolded by effective visual representation. It is surprising therefore, that there is a paucity of visual working memory (VWM) research in both the ASD and BAP populations. focusing upon the visual features of the to-be-remembered stimulus. We assessed whether individual differences in VWM were associated with autistic-like traits (ALT) in the BAP. 76 children carried out the Visual JND task, designed to measure high fidelity feature representation within VWM. ALTs were measured with the Children's Empathy Quotient and Systemizing Quotient. Analyses revealed a significant positive relationship between Systemizing and VWM performance. This complements ASD studies in visual processing and highlights the need for further research on the working memory – long-term memory interface in ASD and BAP populations.

Lay Summary

This study was interested in how well children with high levels of autistic-like traits (ALTs) carry out a task which involved memorizing, for brief time, the precise size of coloured shapes. The results suggested that children with high levels of ALTs performed the task relatively well. This finding is in contrast to many previous studies suggest that ALTs are associated with poor memory, and suggests that future research needs to look more finely at how individuals carry out these tasks.

Key terms: broader autism phenotype, children, cognition, visual working memory, long-term memory.

Introduction

Autism Spectrum Disorder (ASD) is characterized by sustained challenges in reciprocal communication, social interaction and restricted behaviors or activities; these behaviors are present in early development and may limit everyday activities (DSM-5; APA, 2013). In recent years, there has been an increasing recognition that the characteristics associated with ASD form a continuum and are continuously distributed throughout a wider population (Constantino & Todd, 2003; Le Couteur et al., 1996). The Broader Autism Phenotype (BAP) refers to the subclinical possession of these characteristics. One key characteristic of this continuum conceptualization is that observations made within ASD can generate research questions within the BAP population, and vice versa (Wallace, Budgett & Charlton, 2016)

Individuals with ASD frequently present with an uneven profile of cognitive efficacy (e.g., Shah & Frith, 1983). A major contrast lies in the cognitive processes of visual perception and executive function (Chouinard, Parkington, Clements, & Landry, 2015). Extensive research findings have emphasized efficient perceptual processing relating to 'attention to detail' of visual stimuli (Baron-Cohen, 2009; Happé & Frith, 2006; Mottron, et al., 2006). However, with executive and attentional control resources, the findings have indicated severe challenges. This is evidenced across a number of functions: verbal fluency/long term memory (LTM) access difficulties (Demetriou et al., 2017), generic executive challenges (Geurts, de Vries, & van den Bergh, 2014), and is congruent with Frith's (2012) suggestion of challenged top-down control processes. This also appears to be the case in the BAP population (Christ, Kanne & Reiersen, 2010).

These contrasting competencies raise interesting questions about the efficacy of working memory in ASD and BAP populations. Working memory has been defined as the limited amount of information held in memory when undertaking tasks such as comprehension, learning and problem solving; a process containing domain-general executive attentional resources interacting with domain-specific maintenance processes (Cowan, 2014). Within this definition, working memory in these populations could experience discrete and opposing impacts: impaired by challenged executive attentional resources but scaffolded by domain specific representations underpinned by efficient visual perceptual encoding. A first glance at the ASD working memory literature indicates that the challenged executive resources appear to have the greatest impact with Kercood, Grskovic, Banda, and Begeske, (2014) and Wang and co-authors (2017) concluding that visuospatial working memory is compromised in the ASD population. However, both raise caveats in their conclusions, emphasizing that in the majority of studies, it was spatial working memory (SWM) which was being examined and was impaired.

Research has suggested that visual working memory (VWM) and SWM can be dissociated both at the cognitive level (Darling, Della Sala & Logie, 2007; Della Sala, Gray, Baddeley, Allamano & Wilson,., 1999; Hamilton, Coates & Heffernan, 2003; Logie, 2011; Logie & Pearson, 1997) and at the neural level (Bellgowan et al., 2009; Konstantinou, Constantinidou, & Kanai, 2017). In addition, evidence has suggested that SWM is more demanding of executive resources (Logie, 2011; Rudkin, Pearson & Logie, 2007; Vandierendonck, 2004). Consequently, one could argue that whilst SWM could be challenged in ASD, VWM on the other hand could be more efficient due to enriched visual perceptual representation. What is therefore surprising, given the emphasis upon efficient visual processes within ASD, is the relative paucity of VWM research within both the ASD and BAP populations. Cui, Gao, Chen, Zou and Wang (2010) carried out a study with children with Asperger's syndrome and observed that in a task demanding memory for visual patterns, the Asperger group were impaired in performance. However, Hamilton (2011; 2013) has argued that tasks such as the one employed in Cui et al., demand executive attentional control resources in the form of grouping, organization and LTM underpinning (Unsworth et al., 2014). Consequently, performance in such VWM tasks could still be compromised due to executive resource impairment. Mammarella, Giofrè, Cornoldi and Hamilton (2014) found in a small ASD sample that when the visual patterns were manipulated in order to afford opportunities for semantic underpinning from LTM, the ASD group was particularly challenged. This indicated that the source of the difficulty was not necessarily in the memory process per se, but in a compromised executive attentional scaffolding memory performance (Wang et al., 2017).

There is also a lack of VWM studies in the BAP population; one exception to this is the Richmond and co-authors (2013) article. This study looked at the relationship between autistic-like traits (ALT) as measured by the Autism Spectrum Questionnaire (Baron-Cohen et al., 2001) and VWM performance in adults. An important element of their protocol was the use of memory stimuli that were difficult to verbalize. This manipulation most likely precluded the requirement for attentional control in the form of re-coding and recruitment of verbal LTM semantics. They found that participants high in ALT characteristics performed the task more effectively. Unfortunately, one limitation in their protocol was that a sequential presentation format was employed and prior research has indicated that the final (recency) item presented is likely to have a different underlying visual memory representation from the pre-recency items (Allen et al., 2014; Phillips & Christie, 1977). Consequently, it is uncertain which component(s) contributed to the high ALT advantage in the Richmond et al. study.

The present study recruited a child sample and employed a qualitative VWM paradigm which aimed to minimize the requirement for semantic underpinning of the representation as it focuses upon the quality or fidelity of the memory stimulus being maintained. To the authors' knowledge, no prior research has investigated qualitative VWM performance in the BAP. A simultaneous presentation procedure derived from the Thompson et al. (2006) was employed. In this protocol, participants were exposed to a memory stimulus and, after a maintenance period of 1second were shown a probe stimulus and had to determine whether this probe stimulus was larger or smaller compared to the initially encoded stimulus. The Children's Empathy Quotient and Systemizing Quotient (Auyeung et al., 2009) was employed to identify systemizing characteristics in children. Baron-Cohen (2009) has argued that systemizing characteristics should be associated with attention to detail in perception and memory. Age and gender were recorded as control variables. It was predicted that children high in systemizing ALT characteristics would perform the qualitative VWM task more effectively.

Methods

Participants

The study involved 76 children (29 boys and 47 girls) recruited from within mainstream schools in the XXX. Exclusion criteria were impaired visual acuity and the presence of any developmental disorder. The age, Systemizing Quotient (SQ) and visual memory scores are shown in Table 1.

Insert Table 1 here

Materials

Children's Empathy Quotient and Systemizing Quotient Questionnaire (Auyeung, et al., 2009)**.** This ALT questionnaire was given to the children's parents/carers to complete; and is composed of 28 Systemizing items. Systemizing scores conventionally range from 0 – 56. With the current Systemizing data, Cronbach's $\alpha = 0.72$.

Size JND (Just Noticeable Difference). This task was adapted from Thompson et al., (2006) (see Figure 1a, b below). Children. The retinal misalignment of the memory and probe stimuli ensured that iconic memory did not contribute to task performance (Phillips, 1974).

Red or blue elliptical and rectangular stimuli were employed. The maintenance duration was 1 second following conventional change detection protocols (Luck & Vogel, 1997, 2013). All size changes were in the horizontal dimension. In no trial was the shape change categorical, e.g. elliptical to circular; across the 24 trials, changes in horizontal axis varied from 5%, to 30%, in either a larger or smaller extent (see Figure 1b below). The maximum score was 24. The internal reliability of the Size JND was $\alpha = .683$. All viewing was within the child's arm reach of the laptop keyboard.Prior research has indicated that the Size JND task significantly reduces the demands upon executive attentional control (Hamilton, 2013; Phillips & Hamilton, 2001; Thompson et al., 2006). The Size JND task is categorised as a visual working memory task (Cornoldi & Vecchi, 2003; Mammarella, Borella, Pastore, & Pazzaglia, 2013; Mammarella, Pazzaglia & Cornoldi, 2008) which requires the precise memory for the size of a shape. This is in contrast to tasks viewed as simultaneous-spatial such as the Visual Patterns Task (VPT, Della Sala et al., 1999), where participants have to remember stimulus elements presented across space in a simultaneous manner. Also, in contrast to spatial-sequential tasks where spatially discrete elements of stimulus to be remembered are presented in a temporal sequence, such as the Corsi Blocks task.

Insert Figure 1 here

General Procedure

Children carried out the tasks in a quiet location within their school, and in the presence of the research assistant. The task took 10-15 minutes to complete. Ethical consent was granted by the Department of Psychology, xxx. Written informed consent was obtained from the schools and the participants' families, along with oral assent from the children.

Statistical analyses

Hierarchical regression was employed initially, with subsequent regression moderation analysis using PROCESS (Hayes, 2017)

Results

Hierarchical regression analysis was used to identify whether age, gender and the SQ score significantly predicted participants' Size JND performance. The three predictors explained 19.7% of the variance in Size JND task performance, $F(3,72) = 5.878, p = .001$. Age significantly predicted Size JND performance ($\beta = .245, p = .033$), however gender did not ($\beta = -.134, p = .229$). Having controlled for age and gender, the SQ score uniquely predicted Size JND performance ($\beta = .476, p < .001$), and in addition, uniquely accounted for 18.9% of the variance in the memory scores (see figure 2 below). Additional PROCESS analysis revealed that neither gender ($p = .610$) nor age ($p = .433$) moderated the relationship between the Systemizing score and Size JND task scores.

Insert Figure 2 here

Discussion

This study investigated visual working memory performance and its association with Systemizing characteristics in children. A qualitative task was employed where participants had to briefly remember the precise size of the memory stimulus; a task emphasizing the quality of the memory representation, rather than the quantity of information held in working memory. Given the executive challenges found in ASD and BAP population it was anticipated that Size JND task demands would minimize recruitment from executive attentional control resources and thus reveal an advantage in the task for high Systemizers. This was indeed the case, with the Systemizing Quotient accounting for almost 19% of unique variance in visual memory performance. The present findings support the suggestion that observations of attention to detail in ASD (Baron-Cohen, 2009; Frith, 2012; Mottron et al., 2006) have positive implications for VWM task performance in the BAP population in a task context where the executive resource demand is attenuated.

The present study with children reveals a similar pattern of results to that of Richmond et al. (2012) study with adults in that higher autistic-like-traits (ALT) were associated with improved VWM task performance. However, it should be noted that this earlier study by Richmond et al. employed the AQ measure to assess *attention to detail* and *imagination* autistic-like characteristics (Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001). The VWM stimuli were random object shapes designed to preclude the recruitment of verbal semantics. Thus, the Richmond et al. study looked at object representation as opposed to the requirement of the retention of a surface visual feature (shape) in this current study (Dent, 2011). It is possible that the Richmond et al. and the current study found an advantage for individuals high in autistic-like characteristics because the two task protocols precluded the use of long-term memory verbal semantics in order to underpin task performance. Whereas in VWM tasks known to provide opportunities to recruit LTM verbal semantics, tasks such as the VPT, ASD individuals seem unable to access and/or recruit these verbal semantics (Mammarella et al., 2014).

The present finding with its contrast to earlier SWM and executive resource findings has major implications for learning in both the ASD and BAP populations. The contrast between tasks demanding high quality VWM representation versus tasks demanding executive attentional control; tasks requiring 'effort after meaning' (Frith, 2012). Given the key importance of the working memory - executive attention - long-term memory interface for education and learning (Cowan, 2014; Swanson & McMurran, 2018); future VWM research should be directed at understanding where, within this interface, individuals with ASD and/or high levels of systemizing characteristics have challenges in this complex interaction process. Clarification of this process in ASD may lead to the structuring of more effective learning environments, and putatively more effectively designed working memory intervention (de Vries, Prins, Schmand & Geurts, 2015).

In conclusion, this study investigated the relationship between systemizing characteristics in children within the BAP population and performance in the qualitative Size JND visual working memory task. The results suggest a strong positive relationship between systemizing characteristics and the Size JND performance. This relative competence associated with ALTs is consistent with other VWM research in adults but in contrast to ASD visual working memory research indicating a compromised access to, and/or retrieval of, long-term memory verbal semantics. There is a need for future ASD and BAP working memory research to articulate in more detail the interface between working memory and long-term memory resources, and identify the relevant attentional control processes which are crucial for learning and education.

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Conflict of Interest Statement

Colin Hamilton states that he has no conflict of interest in pursuing and publishing this research. Irene Mammarella states that she has no conflict of interest in pursuing and publishing this research. David Giofre states that he has no conflict of interest in pursuing and publishing this research.

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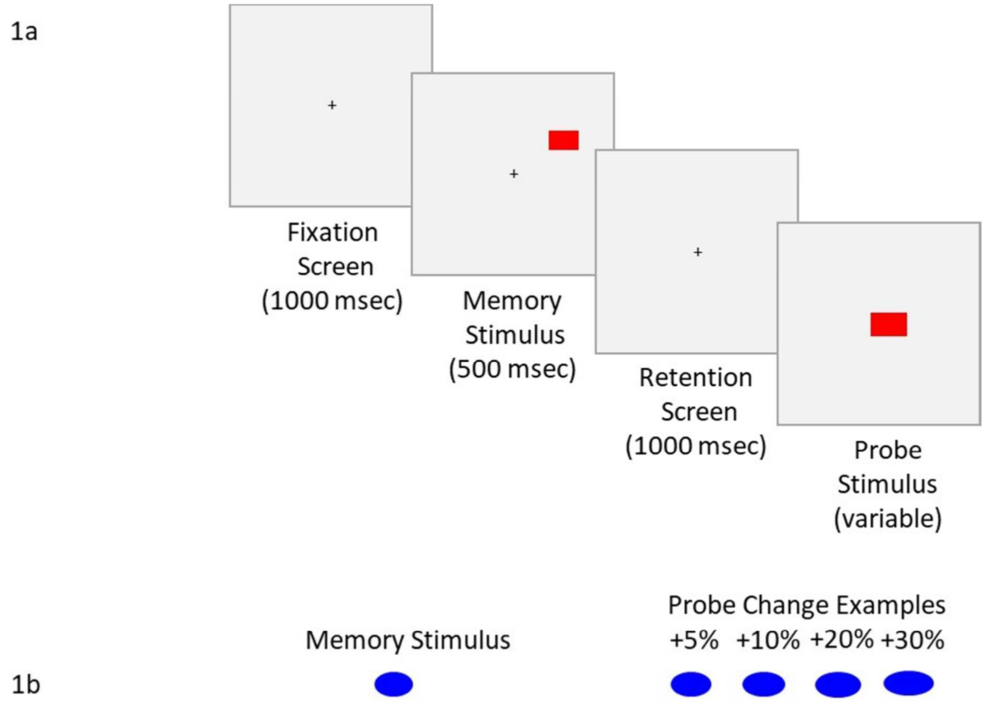
Figure Legends

Figure 1. The size JND task protocol. 1a, the temporal sequence of the procedure, 1b, an example of the memory stimulus and examples of the alternative probe stimuli which could be employed with this stimulus.

Figure 2. The relationship between Systemizing and Size JND visual working memory task performance.

Table Legends

Table 1. Mean (SD) Age, Systemizing Quotient Score, and Size JND task performance as a function of gender.



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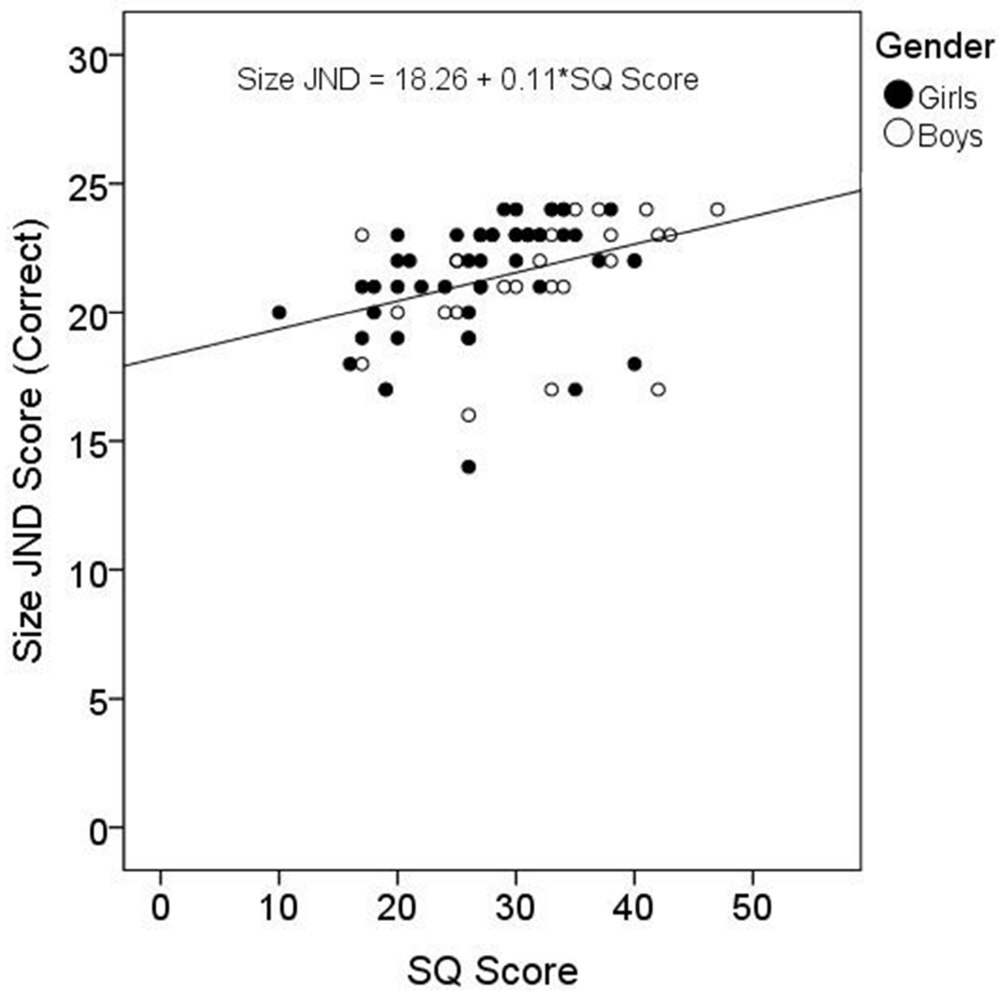

Figure 2. The relationship between Systemizing and Size JND visual working memory task performance.

	Participant Characteristics		
	Age in Months(SD)	SQ Score (SD)	Size JND Task Correct (SD)
Girls n = 47	100.32 (-15.09)	27.43 (-7.05)	21.43 (2.20)
Boys n = 29	102.24 (-15.71)	31.21 (-8)	21.41 (2.40)
Cohen d	*0.13*	*0.51*	*0.01*
(95% CI)	*-0.34, 0.59*	*0.03, 0.97**	*-0.47, 0.45*

Note. CI = confidence intervals for Cohen`s d

*$p < .05$

Table 1. Mean (SD) Age, Systemizing Quotient Score, and Size JND task performance as a function of gender.