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Global Visual Processing and Self-Rated Autistic-like Traits

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Abstract The current research investigated, firstly, whether individuals with high levels of mild autistic-like traits display a similar profile of embedded figures test (EFT) and global motion performance to that seen in autism. Secondly, whether differences in EFT performance are related to enhanced local processing or reduced global processing in the ventral visual stream was also examined. Results indicated that people who scored high on the Autism-spectrum Quotient (AQ) were faster to identify embedded figures, and had poorer global motion and global form thresholds than low AQ scorers. However, the two groups did not differ on a task assessing lower-level input to the ventral stream. Overall the results indicate that individuals with high levels of autistic-like traits have difficulties with global integration in the visual pathways, which may at least partly explain their superior EFT performance.

Keywords Autistic-like traits · Autism · Visual perception · Dorsal pathway · Ventral pathway · Weak Central Coherence

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Introduction

A common finding is that children with autism perform well on visuo-spatial tasks for which there is an advantage in local or piecemeal rather than global or holistic processing (Morgan et al. 2003; Mottron et al. 1999; O'Riordan et al. 2001; Pellicano et al. 2006; Shah and Frith 1983). Indeed, there are now several reports that individuals with autism perform equivalently to (Kaland et al. 2007; Ropar and Mitchell 2001) or outperform (Jarrold et al. 2005; Morgan et al. 2003; Pellicano et al. 2005, 2006; Shah and Frith 1983) matched samples of typically developing individuals on several versions of the embedded figures test (EFT; but see Minshew et al. 2008). Each item of the EFT requires locating a previously seen simple figure within a larger complex figure (Coates 1972; Witkin et al. 1971). According to the designers of the test, competence in the EFT requires "specifically the 'breaking up' of an organized field in order to separate out a part of it" (Witkin et al. 1971, p. 4). If this interpretation is accepted, then superior EFT performance associated with autism could reflect as much a weakness in global processing (restricting the negative influence of the organized field) as a strength in local processing (heightening awareness of parts in order to discriminate the simple shape). Although some evidence is beginning to emerge as to the nature of the local search processes that may be facilitated in autism (e.g., Jarrold et al. 2005), there has been relatively limited research on whether a deficit in the processing of global form also characterizes the disorder. One recent approach used to investigate disorders such as autism involves assessing the abilities of individuals who show a profile of subclinical traits that is similar to, but less extreme, than what is seen in the condition proper. Such experimental designs are able to access a broader sample base and administer tasks that otherwise may not be viable in a clinical population. Using this approach, the aim of the current research was to investigate whether individuals with high levels of mild autistic-like traits display a similar profile of embedded figures test (EFT) performance to that seen in autism and whether these differences are related to atypicalities in the processing of visual form.

Measuring Local and Global Visual Processing

Psychophysical measurement is a useful way of assessing local and global processing in the visual system because the processes invoked by such tasks are relatively well understood, both functionally and neuroanatomically. In the primate visual system, three types of cells relay visual information through the lateral geniculate nucleus: the magnocellular, parvocellular and koniocellular streams (Merigan and Maunsell 1993; Xu et al. 2001).[1] While there is considerable intermixing of magnocellular and parvocellular signatures in the cortex, the parvocellular pathway feeds predominately into the ventral stream and is implicated in form perception (Beason-Held et al. 1998; Kourtzi and Kanwisher 2000), whereas the magnocellular pathway provides substantial input to the dorsal stream, and has an important role in the processing of motion (for a review, see Culham et al. 2001).

Small cellular receptive fields ensure that the earlier stages of visual perception perform more local processing, whereas larger receptive fields result in global processing occurring in higher visual areas (Van Essen and Gallant 1994), although there are extensive feedback connections within the visual system that can increase effective spatial extent (Sillito et al. 2006). Braddick et al. (2003) suggest that the local aspects of form and motion are initially processed by the 'simple cells' in the primary visual cortex (V1). While the integration of orientation across several local elements begins in V1 (Li and Gilbert 2002), the integration of complex patterns (i.e., patterns where information must be pooled across local elements for the global structure to be apparent) first occurs in area V4 of the ventral stream (Badcock and Clifford 2004; Wilson and Wilkinson 1998). Global motion perception is often purported to first occur within area V5 of the dorsal stream (Badcock and Khuu 2001; Movshon et al. 1985), but has also been reported in human area V3a (Braddick et al. 2001).

[1] The koniocellular pathway is currently thought to be concerned primarily with blue-yellow color perception (Morand et al. 2000), and will not be considered further here.

Visual Psychophysical Performance in Autism

Research assessing ventral stream global processing in autism is inconsistent. Milne et al. (2006) and Spencer et al. (2000) reported no differences in form coherence thresholds when comparing children with autism and typically developing children using a task that required detecting the presence of a global pattern revealed by giving small line segments an orientation appropriate for the global pattern. In contrast, Spencer and O'Brien (2006) reported higher thresholds for children with autism compared to typically developing controls when the task required detecting global form composed of aligned dot triplets as opposed to line segments. There are many differences between these studies which could account for the inconsistent findings, but one possible factor is that the line segments used in the earlier studies would more strongly stimulate narrow, orientation-tuned units in V1 and, perhaps more critically, would be treated as a single unit (Field and Hayes 2004; Li and Gilbert 2002). In contrast, the dot triplets used by Spencer and O'Brien require grouping to obtain the orientation and individual dots are more readily paired with others to create additional orientation noise, which could then feed into the global calculation at higher levels of the ventral stream (Tse et al. 2002; Wilson and Wilkinson 1998).

The stimuli most commonly used to investigate global motion perception in the dorsal stream are sparse fields of dots in which a proportion of the dots move coherently in a certain direction while the remaining dots move in random directions (Burr et al. 1998; Edwards and Badcock 1994; Newsome and Paré 1988). Several researchers have found higher global motion thresholds in children with autism when compared to typically developing children on tasks that require the observer to identify either the direction of motion (Del Viva et al. 2006; Davis et al. 2006, in the 1,000 ms discrimination condition; Milne et al. 2002; Pellicano et al. 2005; but see de Jonge, et al. 2007) or the presence of coherent motion (Milne et al. 2006; Spencer et al. 2000; Tsermentseli et al. 2008, autism group compared to Asperger's and control groups). Higher global dot motion (GDM) coherence thresholds in autism spectrum disorders (ASD) have been found to occur in conjunction with evidence of intact low-level magnocellular processing (Pellicano et al. 2005; and see Bertone et al. 2005, for similar results using different motion stimuli) suggesting that the GDM impairment in autism reflects high-level impairment in the dorsal motion pathway.

Decreased sensitivity to these GDM stimuli occurs across several developmental disorders (Braddick et al. 2003) and is therefore not unique to autism. Nevertheless, this diminished sensitivity in combination with superior performance in identifying embedded shapes appears to be specific to autism. For instance, in William's Syndrome, poor global motion processing occurs (Atkinson et al. 1997, 2005) in conjunction with *equivalent* performance on the EFT relative to typically developing groups (Farran et al. 2001). In dyslexia, while there have been reports of impaired processing of global motion (Cornelissen et al. 1995; Hansen et al. 2001; but see Skottun 2000, for a critical review) *impaired* detection of embedded figures has also been reported (Brosnan et al. 2002). Therefore, it is the unique combination of GDM difficulties and EFT capabilities that is of interest when focusing on the autism spectrum. However, currently lacking in the literature is an understanding regarding which visual mechanisms best account for EFT performance in autism. The EFT is a complex task involving a number of cognitive processes and cortical regions (Manjaly et al. 2003; Ring et al. 1999), although one might expect that form processing differences should be more central to EFT performance than motion processing differences. Consequently, in the current research we have chosen tasks which target the ventral form-processing stream, including one that requires global grouping to solve the task.

Autistic-like Traits in the General Population

Recent discussion has conceptualised autism spectrum disorders as reflecting developmental difficulties lying at the extreme end of a continuum (Happé et al. 2006; Mandy and Skuse 2008), with Asperger's disorder and Pervasive Developmental Disorder-Not Otherwise Specified falling between autism on one end and typical development on the other. Accordingly, there is strong evidence that autism spectrum disorders are of genetic origin (Szatmari et al. 2007) and that subclinical levels of autistic traits can be found in family members of individuals with autism (Bishop et al. 2004; Bolton et al. 1994; Constantino et al. 2006; Losh and Piven 2007; Murphy et al. 2000; Joseph Piven and Folstein 1994; Piven et al. 1997). Continuously distributed autistic traits have also been found in the general population, not limited to relatives of autistic individuals, with no evident boundary between normality and psychopathology (Constantino and Todd 2003; Posserud et al. 2006).

One instrument developed to detect variation in autistic symptomatology within the general population is the Autism-spectrum Quotient (AQ; Baron-Cohen et al. 2001). The AQ has been shown to discriminate individuals with an ASD from unaffected individuals, with a score of 32 or higher indicative of clinically significant levels of autistic traits (Baron-Cohen et al. 2001) and a score of 26 or higher indicative of Asperger's traits (Woodbury-Smith et al. 2005). There is also evidence that the instrument differentiates relatives of individuals with autism, who show the "broader autism phenotype" from relatives of unaffected individuals (Bishop et al. 2004). Further, and of particular significance for the present study, cognitive differences between groups of university students scoring high versus low on the AQ have been reported (Bayliss et al. 2005; Bayliss and Tipper 2005; Grinter et al. 2009; but also see Kunihira et al. 2006). Importantly, the behavioural characteristics of high AQ scorers are of a qualitatively similar pattern to those seen in autism, albeit of a much milder degree, which would usually not warrant a clinical diagnosis (Baron-Cohen et al. 2001). If individuals within the general population who score high on autistic-like traits can share similar cognitive characteristics to individuals with autism, then it may be possible to enhance our understanding of EFT performance in ASD by examining EFT and visual performance in this high AQ population.

Accordingly, in the current study, we administered the EFT and a GDM task, similar to that used in previous studies of ASD, in order to determine whether high AQ scorers share a similar profile of visual processing on these particular tasks to ASD. Given that high AQ scorers have previously been found to demonstrate superior performance on the EFT compared to low AQ scorers (Grinter et al. 2009), we also examined functioning at local and global levels in the ventral stream for those scoring high versus low on the AQ. Early processing in the ventral pathway was examined using a contrast detection task developed by Pokorny and Smith (1997). This "pulsed-pedestal" task focuses on the local contrast response of the parvocellular system, and therefore addresses lower-level functioning of the dominant inputs to the ventral stream (McKendrick et al. 2004). A Glass pattern detection task (Badcock et al. 2005) was used to assess global form perception at higher levels in the ventral pathway. As discussed above, glass patterns are preferable for assessing global processing in the ventral stream to the randomly oriented line segment tasks used by Milne et al. (2006) and Spencer et al. (2000). This is due firstly to the potential for line segment integration to occur earlier in the visual system (Field and Hayes 2004; Li and Gilbert 2002; Loffler 2008), and secondly to the fact that the Glass-pattern stimuli chosen are very similar to the GDM stimuli (in both the local elements are dots presented in a concentric configuration) and so minimize stimulus differences. Neuroimaging evidence supports an important involvement of V4 in the processing of the global structure in Glass patterns (Tse et al. 2002; Wilkinson et al. 2000).

We hypothesised that the high AQ group would be faster at the EFT and have higher GDM thresholds than the low AQ group, consistent with the autism literature (Milne et al. 2002, 2006; Pellicano et al. 2005; Spencer et al. 2000). If a global processing impairment contributes, at least in part, to superior EFT performance in individuals reporting high levels of autistic-like traits, then the high AQ group should have higher thresholds on the Glass pattern task relative to the low AQ group, and shorter latencies on the EFT should be associated with elevated Glass pattern detection thresholds. Alternatively, if superior local processing makes a contribution to superior EFT performance, then the high AQ group may demonstrate superior performance on the pulsed-pedestal task relative to the low AQ group, but with equivalent Glass pattern thresholds. In this instance, shorter latencies on the EFT should be associated with lower contrast detection thresholds on the pulsed-pedestal task.

Methods

Participants

Following institutional ethics approval, 595 undergraduate students were recruited from the University of Western Australia and completed the AQ. Next, participants were randomly sampled from the upper and lower quintiles of the AQ distribution for invitation to participate further in the study. There were 29 individuals (9 males and 20 females) in the low AQ group and 26 (12 males and 14 females) in the high AQ group. All participants had normal or corrected to normal vision and gave their informed consent prior to their inclusion in the study. Summary statistics for the two groups are presented in Table 1.

Table 1 Descriptive statistics for the high and low AQ groups for all measures

Measures	Low AQ			High AQ		
	N	Mean	SD	*N*	Mean	SD
AQ score	29	8.14	2.26	26	26.15	3.57
Age	29	21.76	5.84	26	22.85	8.67
RAPM (sets I + II raw scores)	29	35.62	6.30	26	38.46	7.01
WTAR (standard score)	27	110.11	7.47	23	113.17	7.98
EFT RT	29	29.58	12.62	26	20.61	11.82
EFT errors	29	4.31	2.45	26	2.38	2.43
GDM threshold	29	18.31	6.19	26	22.31	6.46
Glass pattern threshold	29	20.52	4.53	25	23.62	5.57
Pulsed pedestal baseline[a]	23	−.09	.41	25	.18	.34
Pulsed pedestal low luminance[a]	23	.17	.22	25	.17	.56
Pulsed pedestal high luminance[a]	23	1.15	.20	25	1.19	.26

Negative numbers reflect lower thresholds

[a] Values reported are the log of the luminance threshold in cd/m^2

Apparatus

All psychophysical stimuli were presented on an LG L1730SF 271 mm × 340 mm resistive touch screen driven by a Sony Vaio VGNSZ34GP laptop computer. The screen was 1,024 × 768 pixels and had a refresh rate of 75 Hz. Stimuli were drawn using MATLAB 6.1 and displayed using the WinVis toolbox. Responses were recorded via touch screen input to the Matlab protocol. Extensive pilot testing was conducted with experienced adult observers to ensure thresholds were comparable to those obtained with CRT-based displays.

General Procedure

The EFT, Raven's Advanced Progressive Matrices and the Wechsler Test of Adult Reading were given in this fixed order, separated by the psychophysical tasks. The psychophysical tasks were presented in a counterbalanced order across the participants in each AQ group.

Traditionally, Glass pattern and GDM tasks use a two-interval-forced-choice presentation schedule, whereby the target appears at a fixed location in one of two consecutive temporal intervals. This requires that the observer maintains in working memory the stimulus that was presented in the first interval for comparison with the second. In order to minimize memory demands and simplify the mapping of target to response, the current study used a two-*spatial*-forced-choice paradigm whereby the target appeared in one of two possible spatial locations during the same presentation interval. Pilot testing indicated that thresholds for Glass pattern and GDM detection were not affected in normal observers by the change in presentation method.

For the psychophysical tasks, participants sat in a darkened room, 0.75 m from the screen. They were given 30 practice trials for each of the GDM and Glass pattern tasks, and 10 practice trials for each of the three conditions of the pulsed-pedestal task. Viewing was binocular and no feedback concerning response accuracy was given except during practice.

Stimuli and Procedure

Autism-Spectrum Quotient

The AQ is a 50-item self-report questionnaire measuring tendency towards autistic traits (Baron-Cohen et al. 2001). Responses are made on a 4-point scale and scores range from 0 to 50, with higher scores indicating greater inclination towards autistic traits.

Ability Tests

Sets one and two of Raven's Advanced Progressive Matrices (RAPM; Raven 1938) were used to assess non-verbal ability. The Wechsler Test of Adult Reading (WTAR; Wechsler 2001) yields an estimate of IQ and was administered as a brief measure of verbal ability. The reading test was given only to those participants whose first language was English (27 Low AQ, 23 High AQ).[2]

Embedded Figures Test

Form A of the EFT was used. It includes 12 cards with complex figures and 8 cards with simple forms. Following the procedure outlined in the EFT manual (Witkin et al. 1971), the test involved locating one of the simple shapes within each of the complex designs. Participants completed one practice and 12 test trials. If a shape was incorrectly identified, the participant was allowed as many additional opportunities as necessary to find the shape, but each incorrect attempt was recorded as an error. The maximum time limit was 3 min. Indices of performance were the mean time taken (RT) for the participant to locate the simple figure over the 12 trials, and the number of times the simple form was incorrectly traced.

Global Dot Motion

Two spatially separated GDM stimulus displays were presented simultaneously, one containing a proportion of dots moving in a coherent direction—either clockwise or anticlockwise—and the other containing only randomly moving dots. The displays were presented within two 6.48° diameter circular apertures positioned side-by-side and separated by 2.28°. Each of the two stimulus displays consisted of 50 white dots of luminance 203 cd/m^2, presented on a gray background of luminance 30 cd/m^2. Each dot measured 0.16° in diameter, resulting in a dot density of 0.66 dots/°^{2}. For each dot the spatial step size was 0.27° resulting in a stimulus speed of 5.4°/s. Stimuli were presented as eight-frame sequences, with a total duration of 426 ms. All dots lasted the entire stimulus duration unless they moved outside the aperture, in which case they were randomly repositioned inside the aperture; however, the subset of dots which moved in the signal direction was randomly chosen for each frame transition. There was a 1 s period between a response being registered on the touch screen and the presentation of the next stimulus during which a blank screen was shown at the background luminance. An individual's motion coherence threshold was the lowest proportion of dots required to move coherently for the observer to correctly identify the presence of coherent motion.

The GDM staircase started with a signal strength of 50% and an initial step size of eight dots, which was halved after each of the first three reversals resulting in a step size of one dot for the last six reversals. Prior to the first incorrect response, signal level was changed by eight after each correct response to facilitate rapid movement towards the threshold value. Following the presentation of each stimulus pair, the participant decided which of the two contained dots that rotated coherently by touching the left or right side of the screen. Thresholds were established using a staircase procedure converging on the 79% correct performance level (three down, one up; Levitt 1971). Eight reversals were collected, with the threshold being taken as the mean of the last four reversals.

Glass Patterns

A Glass pattern (Glass 1969) is composed of a number of dot pairs (dipoles), the orientations of which are specified relative to imaginary lines projecting from the centre of the pattern to the centre of each dot pair. Concentric Glass patterns are created when the dot pairs are oriented at 90° to these radiating lines (see Fig. 1a).

The Glass pattern stimuli also contained two spatially separated displays, both of which consisted of randomly distributed dot dipoles. The target display contained a variable proportion of concentrically oriented dot dipoles while the remainder were randomly oriented. All were randomly oriented in the noise display. Like the GDM task, the presentation duration was 426 ms. The characteristics of the individual dots, the gray background, extent of the 50 dot-pair displays and the procedure exactly matched the features of the GDM task. The separation between the dots in a dipole also matched the dot step size in the GDM task (0.27°). The stimuli were equivalent in appearance to simultaneously presenting two consecutive frames of the GDM stimuli.

The Glass pattern staircase began with a signal strength of 70% and measured the minimum proportion of appropriately oriented dipoles required for the detection of orientation structure. Following the presentation of each stimulus pair, the participant decided which of the two contained dots that were aligned in a concentric pattern by touching the left or right side of the screen. This task used the same step sizes and staircase procedure as the GDM task.

[2] There were no significant differences in the performance of the participants who did not have English as a first language compared to the rest of the participants on any of the psychophysical tasks or the EFT [largest t (52) = 1.6, p = .12].

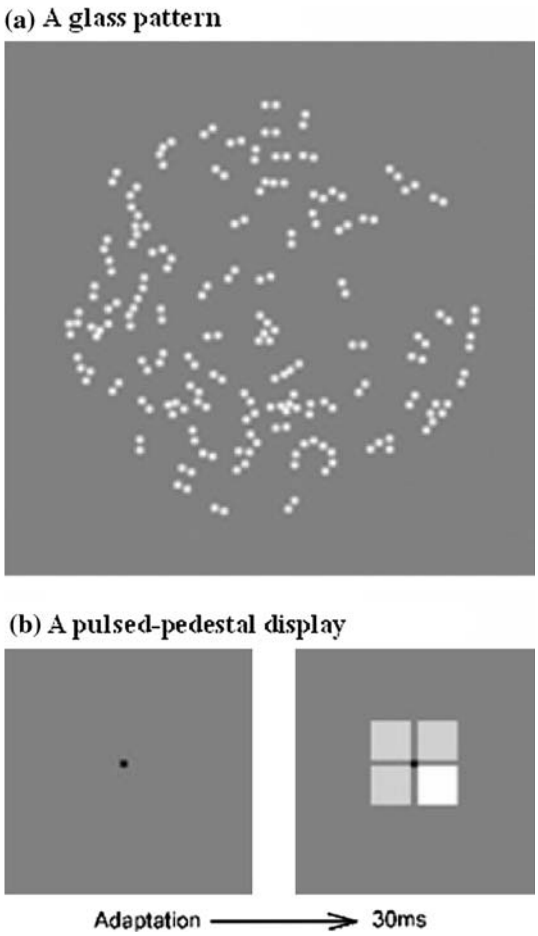

Fig. 1 Examples of **a** a Glass pattern with 50% concentric signal pairs and **b** a pulsed-pedestal stimulus (adapted from McKendrick et al. 2004)

Pulsed-Pedestal Task

The pulsed-pedestal task assessed parvocellular pathway contrast discrimination. The task consisted of four squares presented in a 2 × 2 configuration, with three squares presented at a constant luminance increment with reference to the surround—the pedestal, and the fourth square—the target—presented with an additional luminance increment that varied in magnitude from trial to trial (see Fig. 1b). Each of the four squares was 1.25 × 1.25° and squares were separated by 16 min of arc. The black fixation dot was 16 min of arc in diameter and remained visible throughout the duration of the trial. The pedestal squares were presented simultaneously within a 30 cd/m^2 gray surround. There were three luminance levels for the pedestals: a baseline level equal to the background so that absolute threshold levels could be determined (pedestal = 30 cd/m^2, Weber contrast = 0), a low luminance contrast level (pedestal = 38 cd/m^2, Weber contrast = 0.27), and a high luminance contrast level (pedestal = 60 cd/m^2, Weber contrast = 1.0). Thresholds are expected to increase with increasing pedestal luminance levels (Pokorny and Smith 1997). The surround was presented during the adapting phase (1 s) and the four squares were present only during the test interval. During the test interval (30 ms) one of the four squares, the location of which was chosen at random for each trial, was higher in luminance. Participants were asked to identify the location of the square showing different luminance using a binary left/right forced choice procedure.

The initial, easily detectable, target square luminance was 43 cd/m^2 for the baseline pedestal level, 54 cd/m^2 for the low luminance level, and 80 cd/m^2 for the high luminance level. Thresholds were determined using the same procedure as described for the GDM task whereby three correct responses elicited a decrease in the luminance increment of 25% or one incorrect response caused a 25% increase. The three different luminance conditions were presented in random order.

Results

Data for each group were screened for normality and for outliers meeting the criterion of a score more than three standard deviations from the mean. One high AQ individual was excluded from all analyses involving Glass pattern detection as the threshold was above this criterion.[3] The means and standard deviations for each task are presented in Table 1.

Demographic Variables

There were no significant differences between the high and low AQ groups in gender distribution, $\chi^2(1) = 1.33$, $p = .25$, chronological age, $t\ (53) = .55$, $p = .58$, nonverbal ability (as measured by Raven's Advanced Progressive Matrices), $t\ (53) = 1.58$, $p = .12$ and Wechsler Test of Adult Reading scores, $t\ (48) = 1.4$, $p = .17$.

Group Comparisons on Visual Tasks

A 2 × 2 between-groups ANOVA was conducted on four of the dependent variables with gender and AQ group as the two factors. The high AQ group completed the EFT faster than the low AQ group, $F(1, 51) = 4.60$, $p < .05$, and made significantly fewer EFT errors, $F(1, 51) = 6.45$,

[3] It is not clear whether this individual did not perform the task correctly or if the high threshold is a reflection of poor form integration capabilities, but it must be noted that removing the outlier reduced the magnitude of the difference between the two groups.

$p < .05$ (see Fig. 2). Further, the high AQ group had significantly higher GDM thresholds, $F(1, 51) = 5.40$, $p < .05$, and higher Glass pattern detection thresholds, $F(1, 50) = 4.17$, $p < .05$, than the low AQ group (see Fig. 3).

The only significant effects of gender were main effects for both reaction time and accuracy in the analysis of EFT performance. Males ($M = 19.82$ s, SD = 11.81) were faster than females ($M = 28.74$ s, SD = 12.61), $F(1, 51) = 5.46$, $p < .05$, and made fewer errors ($M = 2.38$, SD = 1.88) than females ($M = 4.03$, SD = 2.85), $F(1, 51) = 4.18$, $p < .05$. These effects are consistent with previous research which has shown that men tend to outperform women on the EFT (Baron-Cohen and Hammer 1997; Witkin 1950). None of the AQ group × gender interactions were significant (largest $F(1, 51) = 1.69$, $p = .20$), suggesting that the effects reported for AQ group are independent of gender.

A 3 × 2 × 2 repeated-measures ANOVA was conducted on the pulsed-pedestal task thresholds, with the three levels (baseline, low luminance and high luminance) as the repeated measures factor, and gender and AQ group as between-groups factors. There was a main effect of

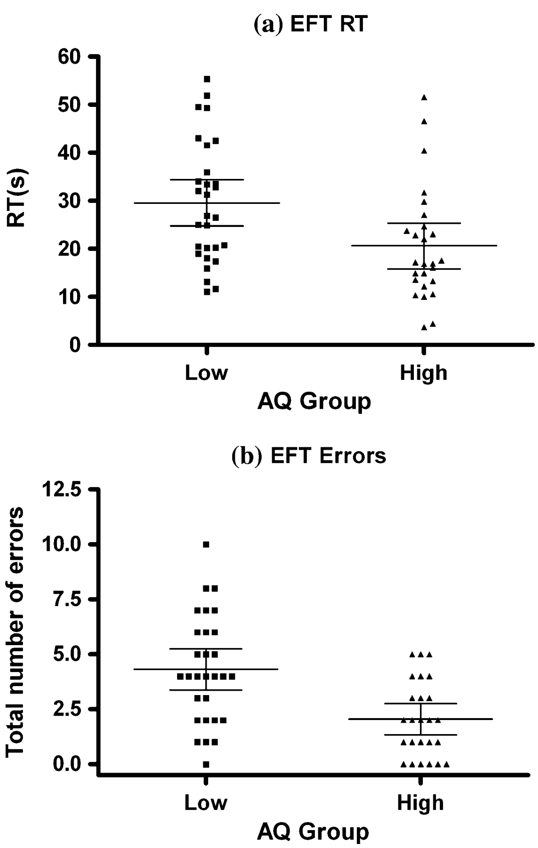

Fig. 2 *Scatterplots* showing **a** reaction time and **b** number of errors on the EFT for low and high AQ groups (*lines* show means and 95% confidence intervals)

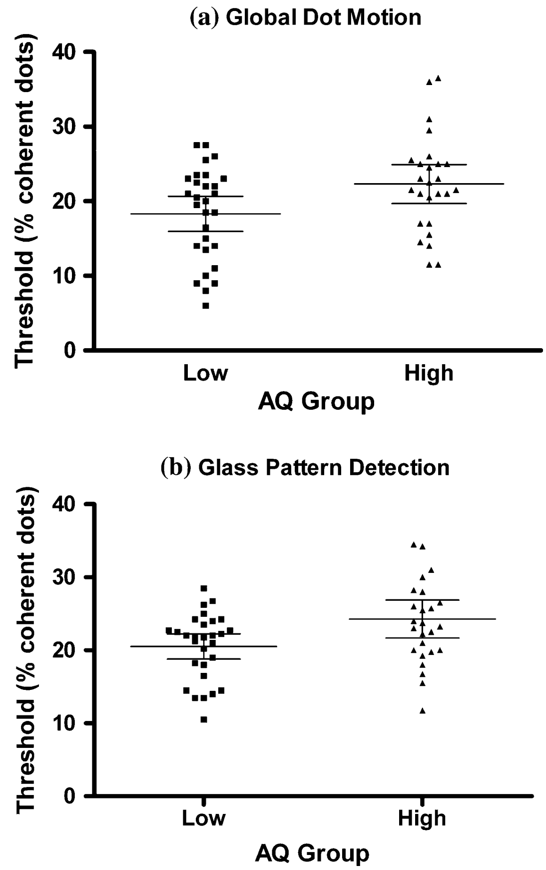

Fig. 3 *Scatterplots* showing thresholds on **a** the GDM task and **b** the Glass pattern task for low and high AQ groups (*lines* show means and 95% confidence intervals)

level, $F(2, 88) = 123.13$, $p < .001$, indicating that thresholds for the baseline task were lower than those for the low luminance task, which in turn were lower than those for the high luminance task. This increase in thresholds as pedestal luminance increases is consistent with Pokorny and Smith (1997). None of the effects involving AQ group or gender were significant (largest $F(1, 44) = 2.14$, $p = .15$, see Fig. 4).

Correlations

In examining correlations across the two AQ groups combined, none of the variables taken from the visual tasks correlated with the reading ability measure. Only EFT RT, $r(54) = -.31$, $p = .02$, and EFT errors, $r(54) = -.46$, $p < .001$, correlated negatively with non-verbal ability, consistent with Witkin et al. (1971). The differences between the high and low AQ groups on these EFT measures were unchanged when the effect of non-verbal IQ was accounted for using partial correlations.

If superior EFT performance in individuals reporting high levels of autistic traits partly reflects difficulty

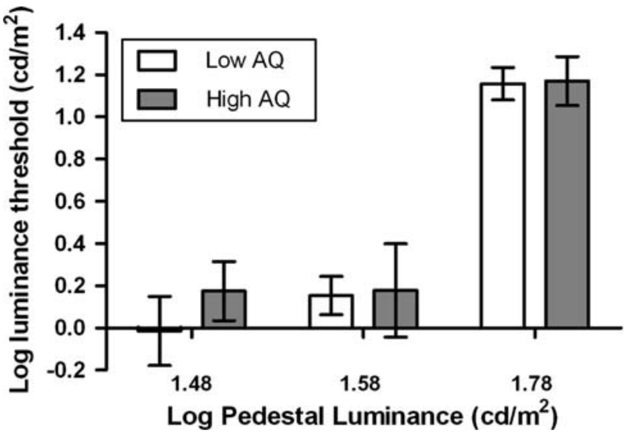

Fig. 4 Threshold functions for low and high AQ groups on the pulsed-pedestal tasks with 95% confidence intervals

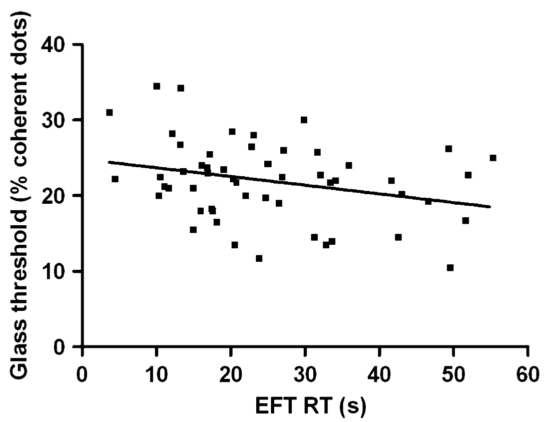

Fig. 5 *Scatterplot* showing the relationship between Glass pattern thresholds and EFT RT

integrating visual information globally in the ventral stream, then Glass pattern detection thresholds should correlate negatively with EFT performance. Consistent with this prediction we found a small, but significant negative correlation between Glass pattern thresholds and EFT RT, $r(53) = -.28$, $p < .05$ (see Fig. 5). The correlation between EFT errors and Glass pattern thresholds, while not significant, $r(54) = -.189$, $p = .172$, was in the direction indicated by the relationship between these thresholds and EFT RT. Notably, EFT performance did not correlate with performance on the GDM task, or the pulsed-pedestal task.

Finally, correlations were computed within the high AQ group between AQ scores and measures of performance taken from the EFT and the visual threshold tasks. None of these correlations was significant (largest $r(24) = .17$, $p = .41$), indicating that performance differences for this group compared to the low AQ group are not attributable to those with especially high AQ scores.

Discussion

The aims of the current study were: (1) to establish whether the strengths on the EFT and weaknesses on GDM tasks found in autism also extend to individuals self-reporting high levels of autistic-like traits; and (2) to examine higher- and lower-level processing in the ventral stream and its relationship to EFT performance in the general population. The first important finding was that individuals scoring high on the AQ were faster at detecting embedded figures, and did so with fewer errors than the low AQ group. This outcome replicates results from two studies reported by Grinter et al. (2009) and shows that superior performance on the EFT is not only a commonly reported finding in individuals with autism, but is also apparent within individuals who self-report high levels of autistic-like traits. A second important finding of this study was that high AQ participants had significantly higher GDM thresholds, indicating difficulty with higher-level integrative processing within the dorsal visual stream, compared to those scoring low on the AQ. Again, this outcome suggests a continuity of performance for the high AQ group with the autism spectrum, since impaired processing of this type has previously been reported in groups with autism (Milne et al. 2002, 2006; Pellicano et al. 2005; Spencer et al. 2000).

As argued in the introduction, while difficulty perceiving GDM is not a characteristic specific to the autism population (it is found in many other disorders susceptible to altered neurological functioning; see Atkinson et al. 1997; Bertone and Faubert 2006; Chen et al. 2003; Kogan et al. 2004; McKendrick and Badcock 2004; Talcott et al. 2000), its co-occurrence with enhanced EFT performance has only been found in autism spectrum disorders. In the current study however, there was substantial overlap between the low and high AQ groups in thresholds for the GDM task, indicating that some high AQ individuals were actually scoring within the typical range. This overlap in distributions is consistent with the subgroups demonstrating high motion coherence thresholds in the autism literature (Milne et al. 2002, 2006), and indicates that while reduced sensitivity to GDM is a characteristic associated with autism and, as the current study demonstrates, autistic-like traits, it is not a universal feature. Significantly, in the present study the mean GDM threshold in the high AQ group was not attributable to a few extreme scorers in this group, given that a substantial proportion (69%) had thresholds above the 95% confidence interval for the low AQ group.

With reference to the central aim of the study, a critical finding was that the high AQ group demonstrated higher global form thresholds when compared to the low AQ group, while performance on the pulsed-pedestal task did not vary in effectiveness as a function of level of autistic-like traits. The results from these psychophysical tasks provide important information regarding the cortical functioning of the high AQ group in comparison to the low AQ scorers. Given that the coherent structure in Glass patterns have been shown to activate V4 of the ventral visual stream (Wilkinson et al. 2000; Wilson and Wilkinson 1998), impaired performance on this task among high AQ individuals suggests relatively poorer global grouping capability within the ventral cortical pathway. In contrast, the pulsed-pedestal task assesses low-level visual processing in the parvocellular stream, which provides the dominant inputs to the ventral pathway. The equivalent performances of the high and low AQ groups on the pulsed-pedestal task indicate that poor performance on the Glass pattern task cannot be simply attributed to overall poor performance on psychophysical tasks, nor to lower contrast sensitivity in the lower visual areas leading to weak inputs to V4. Rather, these data suggest that for individuals self-reporting high levels of autistic-like traits the mechanisms required to combine local form signals into a global form percept may function less effectively. The current study also found impaired thresholds on the GDM task for the high AQ group, indicating difficulty with higher level integrative processing within the dorsal visual stream, providing additional evidence for extrastriate dysfunction, particularly in global grouping.

This interpretation is consistent with three related theoretical views. Bertone et al. (2003, 2005) suggested that the deficits in global processing and assets in local processing observed in visual perception in ASD are contingent on the complexity of the neural networks required to process given types of stimuli. Bertone et al. (2005) argued that atypical lateral connections may result in heightened sensitivity and thus a superior ability to process local information in ASD, whereas limited integration between higher and lower visual areas may constrain the global processing required for more complex types of information. Thus, according to this theory, deficits are linked to tasks that activate more complex neural networks and assets to tasks that activate less complex neural networks in ASD. Minshew et al. (1992, 1997) also argue that additional cortical processing leads to differentiation between the two groups by suggesting that autism is a disorder of information processing that disproportionately impacts complex or integrative processing while sparing simple information processing. Consistent with this view, deficits in autism are significant when tasks impose high demands for integration of information but are reduced or absent when these demands are low (Steele et al. 2007; Williams et al. 2006). Imaging studies have also suggested that altered cognition in autism entails a lower degree of integration of information across cortical regions compared to controls (Just et al. 2004, 2007; Kana et al. 2007; Koshino et al. 2008). Given that perception of coherence in GDM and Glass patterns requires additional processing beyond that required for luminance discrimination in the pulsed-pedestal task, the present study is consistent with this position with respect to global grouping in the visual system . Finally, according to the Weak Central Coherence (WCC) account (Frith 1989), individuals with autism demonstrate a relative failure to extract overall meaning from visual displays, resulting in a reduced awareness of the global aspects of stimuli combined with a relatively heightened awareness of the details or parts of stimuli (Happé et al. 2001). In the present case, relative to the low AQ group, the high AQ group showed difficulties restricted to the tasks that invoked more complex perceptual networks required to identify coherence in form or motion across multiple stimulus elements.

While all three of these theoretical views may account for a compromise in global processing abilities associated with autistic-like traits, they differ with respect to their predictions regarding low-level visual processing abilities. The complex information processing hypothesis (Minshew et al. 1992, 1997) predicts less difference between ASD and typically developing groups on low-level tasks relative to the performance differences observed for high level tasks. Alternatively, the complex-specificity hypothesis (Bertone et al. 2005) and WCC account (Frith 1989; Happé and Booth 2008) allow for superior performance on local processing tasks in ASD. The current study did not find superior low-level visual processing in the high AQ group, compatible with Minshew et al.'s position. It must, however, be noted that this study was not an exhaustive examination of local processing in the ventral pathway, as we chose a task that assesses sensitivity to luminance contrast differences minimally detectable by neurons early in the visual system (V1 or earlier). Psychophysical tasks measuring a variety of capabilities in V1 would provide further insight into the local processing mechanisms operating in the early cortical system for individuals expressing high levels of autistic-like traits. Nonetheless, our results are comparable to those reported by Pellicano et al. (2005) using a flicker contrast sensitivity task to assess lower level dorsal stream functioning in ASD.

With respect to psychophysical performance on lower-level tasks in the autism literature, Bertone et al. (2005) reported that individuals with high-functioning autism had superior orientation discrimination thresholds for first-order, luminance-defined static stimuli, when compared with age- and IQ-matched typical adults. In addition, research using visuospatial cognitive tasks suggests that individuals with autism can, under some circumstances, make better use of local visual information than matched controls (Booth et al. 2003; Lopez et al. 2004; Laurent

Mottron et al. 1999; O'Riordan 2004; O'Riordan and Plaisted 2001; Plaisted et al. 1998; Wang et al. 2007). Motivated by this evidence, alternative theories have recently argued that perceptual processing in autism is atypical in such a way as to enhance the salience of local features, but this is not thought to impact on the processes responsible for integrating perceptual information to form global representations (Happé and Frith 2006; Mottron et al. 2006; Plaisted et al. 2003). The essential difference between these theories and the three presented above concerns the predictions regarding the propensity for people with autism to process global or complex information. The evidence from the present study indicates that poor global processing in the cortical ventral and dorsal visual streams characterizes individuals who self-report high levels of autistic-like traits and that perhaps the theories that allow for difficulties in complex, global processing are more applicable to this population than those that posit enhanced local processing in isolation. Importantly, the significant correlation of higher Glass pattern thresholds with faster EFT responses in the current study illustrates that poor performance in global processing in the ventral stream may contribute at least partly to superior EFT performance for those reporting high rather than low levels of autistic-like traits. While this effect is small, it is nonetheless significant in identifying some shared component underlying performance of the EFT and global ventral stream processing tasks.[4]

The pattern of findings seen in the present research is integral to our understanding of EFT performance by individuals who self-report high levels of autistic-like traits. Additionally, the current study provides further evidence for the continuity of autistic-like characteristics in the typical population. The high AQ scores indicate that the social and communication difficulties evident in autism are also present at least to some extent in these individuals, especially for the three participants who scored above Baron-Cohen et al. (2001) recommended cut-off score of 32 for autism, and the 13 participants who scored above the cut-off score of 26 used by Woodbury-Smith et al. (2005) to screen for Asperger's disorder. In addition, the results from the EFT and psychophysical tasks point towards extreme AQ scorers in the wider population sharing a complex pattern of strengths and weaknesses in visual-spatial capabilities with individuals with an ASD diagnosis. Recently, Jobe and White (2007) demonstrated that high AQ scorers exhibited increased levels of loneliness related to lack of social skills and understanding, relative to low AQ scorers. These results suggest that traits self-reported on the AQ are experienced in real-life situations and that there are perhaps clinically detectable differences in the presentation of high AQ scorers relative to low scorers. Jobe and White (2007) and also Austin (2005) refer to high AQ scorers as exhibiting the broader autism phenotype. This hypothesised continuity between autism spectrum conditions and typically functioning persons highlights the possibility of conducting complementary studies of high AQ scores and individuals with ASD diagnoses in furthering our understanding of visual functioning in autism. It will be essential for future research to determine what it is about high AQ scorers and family members exhibiting the broader autism phenotype that enables them to share so many characteristics with individuals with autism, but nevertheless not exhibit the clinical syndrome.

[4] Recently, Pellicano et al. (2005) reported that higher GDM thresholds were associated with superior EFT performance in an ASD population. It is unclear whether the lack of relationship between these variables in the present study are due to the use of a different version of the EFT (we used the adult rather than the children's EFT used by Pellicano et al.), or the fact that the high AQ group is less extreme in autistic-like traits than a clinical population.

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