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BRIEF REPORT

Individuals with Autistic-Like Traits Show Reduced Lateralization on a Greyscales Task

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Abstract Individuals with autism spectrum conditions attend less to the left side of centrally presented face stimuli compared to neurotypical individuals, suggesting a reduction in right hemisphere activation. We examined whether a similar bias exists for non-facial stimuli in a large sample of neurotypical adults rated above- or below-average on the autism spectrum quotient (AQ). Using the "greyscales" task, we found the typical leftward bias in the below-average group was significantly reduced in the above-average group. Moreover, a negative correlation between leftward bias and the social skills factor of the AQ suggested a link between atypical hemispheric activation and social difficulties in high-AQ trait individuals that extends to non-facial stimuli.

Keywords Autistic-like traits · Left visual field (LVF) bias · Brain laterality · Spatial attention

Introduction

Individuals with autism spectrum conditions (ASC) display many atypical behaviours ranging from impaired social interactions to superior visuospatial skills (Shah and Frith 1983; Soulières et al. 2011). Evidence from pragmatic language measures (Ozonoff and Miller 1996; Siegal et al. 1996), functional and structural magnetic resonance imaging (Di Martino et al. 2011; Jou et al. 2010) and electrophysiological recordings (Lazarev et al. 2009; Orekhova et al. 2009) suggests that right hemisphere (RH) abnormalities may contribute to the development of these behaviours. Here, we investigate whether high levels of autistic-like traits are also linked to RH-based atypical biases in spatial attention.

There is substantial evidence that spatial attention is RH lateralized (Davidson and Hugdahl 1996; Hellige 1993). Stroke patients with RH parietal lesions preferentially focus on stimuli in the right visual field and ignore those in the left (Adair and Barrett 2008; Bartolomeo 2007), while neurotypical participants display the opposite pattern. Neurotypical individuals bisect lines to the left of veridical centre (*pseudoneglect*; Bowers and Heilman 1980) and on the "greyscales" task (Mattingley et al. 1994), in which observers must choose the "darker" of two symmetrical, equiluminant bars (see Fig. 1), they preferentially choose the bar that is darker on the left (Dellatolas et al. 1996; Jewell and McCourt 2000). Both of these tasks elicit a reliable left visual field (LVF) bias and are suggestive of relatively greater involvement of the RH in spatial attention (Nicholls et al. 1999).

With respect to autism, findings on lateralization of attention are mixed. Adults with ASC show reduced fixation-time to the LVF when viewing centrally-presented faces (Dundas et al. 2012) and reduced LVF bias for identification of chimeric faces (Ashwin et al. 2005) compared to neurotypical adults. However, on a numerosity-judgement task with non-facial stimuli, adults with ASC show a LVF bias while neurotypical adults do not (Ashwin et al. 2005). Finally, in children, Rinehart et al. (2002) reported that neither a neurotypical group nor a group of children with ASC showed LVF biases. The significant disparities across these studies could reflect a unique role for face-specific mechanisms or differences between adults and children. Alternatively, inconsistencies might also stem from relatively small samples or insufficient trial numbers to obtain reliable measures of spatial

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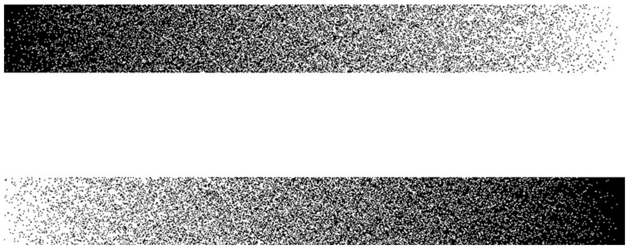

Fig. 1 Example of a stimulus presented in the *greyscales* task

biases (Nicholls et al. 1999). Finally, task engagement could not be monitored in Ashwin et al. (2005) and Rinehart et al. (2002) because stimuli in the greyscales task were actually equiluminant, making it impossible to measure performance accuracy.

To address these methodological issues, we modified the greyscales task (Nicholls et al. 1999) by increasing the number of trials and introducing a luminance difference between the bars on each trial. This allowed us to screen for task engagement, as well as estimate spatial attention bias. We also tested a large sample of adults classified as having low versus high levels of autistic-like traits using the autism spectrum quotient questionnaire (AQ; Baron-Cohen et al. 2001).

Past research suggests that the autism-spectrum extends into the 'normal' population (Baron-Cohen and Hammer 1997; Baron-Cohen et al. 2001; Bishop et al. 2004), with non-clinical individuals exhibiting high levels of autistic-like traits, as measured by the AQ, showing similar behavioural patterns to ASC-diagnosed individuals (Bayliss and Kritikos 2011; Grinter et al. 2009a, b; Rhodes et al. 2013; Russell-Smith et al. 2012; Sutherland and Crewther 2010). Some researchers have also raised potential issues with the use of AQ-selected groups as proxies for ASC (Gregory and Plaisted-Grant 2013), arguing that undiagnosed individuals with ASC who are included in the high-trait group might drive differences between low- and high-trait groups. We addressed this issue in two ways; first, by testing a particularly large sample of participants and, second, by comparing the entire distribution rather than just the extreme ends. Thus, while undiagnosed individuals with ASC may form part of the high-trait group, they are unlikely to be the sole source of group differences. Of course, all this being said, additional work will still be necessary in order to verify that similar results are found in ASC-diagnosed participants.

Methods

Participants

Participants were 332 right-handed psychology students (93 male; mean age 21.27 years) at The University of Western Australia.

Materials

Questionnaires

The AQ (Baron-Cohen et al. 2001) is a 50-item self-report questionnaire assessing autistic-like traits and behaviours in neurotypical individuals (items scored 1–4 using Austin's (2005) method; higher scores indicate more autistic-like traits). We calculated scores for overall AQ and three subfactors: social skills, Details/Patterns, and Communication/Mind Reading (Hurst et al. 2007; Russell-Smith et al. 2011). Handedness was assessed using the Edinburgh Handedness Inventory (Oldfield 1971).

Greyscales Task

Stimuli were presented using custom software, following the procedure of Nicholls et al. (1999). Participants were seated approximately 50 cm from a monitor (HP L2245wg) and instructed to keep their eyes fixated on the display's centre. Two horizontal bars were presented above and below the display centre on each trial (Fig. 1) for 5000 ms with one bar slightly darker than the other (200px difference). Participants identified the darker bar by pressing the 'T' or 'B' key to indicate the top or bottom bar respectively. A trial terminated when a response was made. This meant that a response could still be recorded when the bars had been removed, although participants were encouraged to respond while the bars were present. The next trial began 1500 ms after the previous response. Participants completed 96 trials, with the darker bar appearing equally often on the top or bottom and shaded darker to the left or right.

Results

Task accuracy was calculated as the percentage of correct identifications of the darker bar on trials with response times from 200 to 5000 ms. Participants with $\leq$50 % accuracy ($n = 43$) or with more than 1/3 of trials with response times $\leq$200 ms or $\geq$5000 ms ($n = 16$) were excluded from the analysis (four participants met both exclusion criteria). The remaining 277 participants were divided into Low and High AQ groups based on a median split of AQ scores (Median = 105; see Table 1 for descriptive statistics).

As summarized in Fig. 2, mean accuracy for both groups was significantly better than chance (both groups: $p < .001$, both d's > 2.54), and did not differ between groups ($p = .92$, $d = .01$). Spatial bias was measured as the percentage of responses indicating the bar shaded to the left was darker, irrespective of actual luminance. Both groups made significantly more leftward responses than expected by chance (Low-AQ: $p < .001$, $d = 1.21$; High-

AQ: $p = .005$, $d = .48$), indicating a leftward spatial attention bias. A between-groups analysis of variance was conducted to determine if there was a difference in spatial bias between AQ groups. As the High-AQ showed a significantly greater proportion of male participants compared to the Low-AQ group following a Chi square test, $\chi^2(1) = 5.04$, $p = .03$, participant sex was entered as a between-groups factor in addition to AQ group in a 2 × 2 mixed-design analysis of variance. This analysis yielded a main effect of AQ group, $F(3,273) = 5.28$, $p = .02$, $\eta_p^2 = .02$, with the Low-AQ group reporting a significantly greater proportion of leftward responses compared to the High-AQ group (see Fig. 2). However, neither the main effect of sex nor the interaction was significant (all p's $> .18$, all $\eta_p^2 < .01$).

Table 2 summarizes correlations between spatial bias and scores for the AQ and its subfactors. Scatterplots were also produced comparing spatial bias against overall AQ and each of the three AQ-subfactors (see Fig. 3). As sex was not reported to significantly influence bias in the prior analysis, data for the two sexes were combined for the correlational analysis. As can be seen in Table 2, the negative correlation between spatial bias and overall AQ approached significance, while the negative correlation of spatial bias with the social skills subfactor was significant.

Finally, to address concerns raised by Gregory and Plaisted-Grant (2013), we re-conducted all analyses whilst excluding participants whose AQ was above the 95th percentile (AQ > 127, 12 participants). This was designed to omit participants most likely to be those with undiagnosed ASC. The resulting analyses yielded the identical pattern of results.

Table 1 Characteristics of AQ comparison groups

N	Low-AQ		High-AQ	
	135 (26 male)		142 (44 male)	
	AQ	Age (years)	AQ	Age (years)
Mean	94.90	22.56	115.14	20.33
Median	97	19	113	19
SD	7.84	8.50	8.56	3.64
Range	36 (68–104)	39 (18–57)[a]	44 (105–149)	18 (18–36)

[a] The 12 oldest participants in the study were all classified as Low-AQ, explaining the larger range and standard deviation for this group relative to the High-AQ group. As subsequent analyses showed the same pattern of results regardless of the inclusion or exclusion of these participants, they were not removed from the dataset

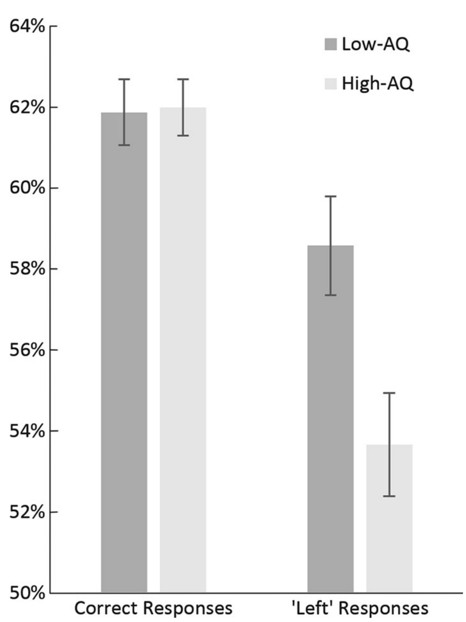

Fig. 2 Percentage of trials in which participants correctly selected the *darker bar*, and the *bar* with the black end oriented towards the *left-side* of the screen. *Error bars* represent *SEM*

Discussion

The present results reveal a robust LVF bias of spatial attention that is significantly reduced in High- compared to Low-AQ observers. This echoes previous results using ASC samples and facial stimuli (Ashwin et al. 2005; Dundas et al. 2012), while also extending this previous work by showing a reduced LVF bias with non-facial stimuli for individuals with high levels of autistic traits. In contrast to Ashwin et al. (2005) and Rinehart et al. (2002) who did not find a LVF bias in their control groups, we demonstrate the typical LVF bias in our Low-AQ group in conjunction with reduced LVF bias for the High-AQ group. In the case of Rinehart et al. (2002), this discrepancy is unlikely to reflect effects of maturation, as previous studies have found robust LVF biases in children (Dellatolas et al. 1996) and a decline in bias with age (Jewell and McCourt 2000). Instead, we suggest that differences stem from our larger sample, additional trials, and screening to ensure task engagement.

Our correlation analysis revealed a somewhat surprising association between LVF bias and the social skills subfactor of the AQ, where greater levels of social difficulty were associated with reduced LVF bias. A similar pattern of results has been previously reported by Russell-Smith et al. (2012), who found that high scores on the social skills subfactor (greater social difficulty) were associated with superior performance on the Embedded Figures Test (EFT; Witkin 1971) in which participants must locate a simple geometric shape within a relatively complex scene. Like the greyscales task, high- and low-AQ groups perform differently on the EFT, with high-AQ participants typically

Table 2 Correlation of spatial bias with AQ total and subfactor scores

Overall AQ	Social skills	Details/patterns	Communication/mindreading
Spatial bias			
−.09	−.12*	−.01	−.04
(*.12*)	(*.046*)	(*.90*)	(*.56*)

Numbers in parentheses indicate significance levels

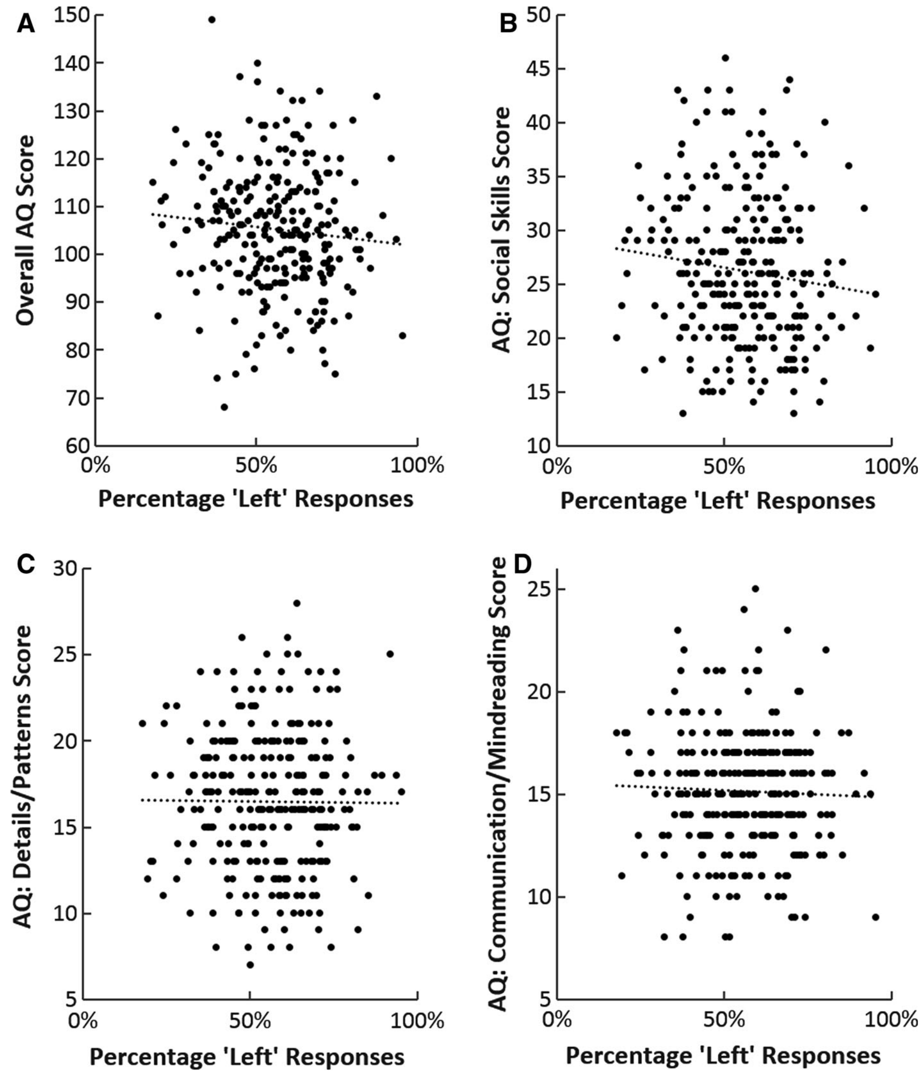

Fig. 3 Scatterplots illustrating the distribution of spatial bias scores against. **a** Overall AQ, **b** AQ social skills subfactor, **c** AQ Detail/Patterns subfactor, and **d** AQ Communication/Mindreading subfactor. Note that the y-axis scale varies due to the variable number of items in each subfactor

outperforming low-AQ participants (Almeida et al. 2010a, b, 2013; Grinter et al. 2009a, b). The performance difference between groups is thought to stem from high-AQ individuals difficulties with global integration (Grinter et al. 2009), a processing style that interferes with the task objective in the EFT by drawing attention away from the details of a scene and instead towards the holistic picture. Importantly, global processing is closely associated with activation of RH regions (Fink et al. 1996; Heinze et al. 1998; Hübner and Studer 2009; Martinez et al. 1997) and thus high-AQ individuals' superior performance on the EFT can be interpreted as further evidence of relatively reduced activation in the RH.

Interestingly, both our study and Russell-Smith et al. (2012) found associations between task performance and the social skills subfactor of the AQ, but not the arguably more visuo-spatially oriented Details/Patterns subfactor. Furthermore, similar patterns of behaviour have been reported between other social constructs and visuo-spatial performance (Baron-Cohen and Hammer 1997; Jarrold et al. 2000; Pellicano et al. 2006). However, the underlying cause of this relationship remains unclear. One potential explanation is that face processing, a skill that is particularly important in regard to processing non-verbal, social information (Speer et al. 2007), is associated with increased activation in RH regions, especially in the right fusiform gyrus (Clark et al. 1996; Haxby et al. 1994, 1999; Kanwisher et al. 1997; McCarthy et al. 1997; Rossion et al. 2003; Sergent et al. 1992). If LVF bias, as measured by the greyscales task, is related to levels of relative RH activity for spatial attention, then it is possible that a relative reduction in LVF bias may also be associated with a reduction in activation of face processing regions and, by extension, potentially-elevated levels of social difficulty. Of course, this explanation is necessarily speculative and awaits further empirical testing.

On a final note, it is important to consider what brain regions might account for the reduced LVF bias in High-AQ observers. Loftus and Nicholls (2012) hypothesized that pseudoneglect in neurotypical samples is due to asymmetrical activation of the left-and-right posterior parietal cortices (PPC), with the right PPC more active than left PPC. Consistent with this, they abolished pseudoneglect in neurotypical individuals by administering anodal (excitatory) transcranial direct current to the left PPC. On this account, we can conjecture that reduced leftward spatial bias in our high-AQ group reflects more balanced reliance on left and right PPCs. Further research will be required to test this possibility and whether it reflects greater activation in left PPC or reduced activation in right PPC. Additionally, as noted above, it will also be critical to replicate the present findings in samples with ASC in order to ensure the broad applicability of our results.

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