Vision Research 103 (2014) 109–115

Contents lists available at ScienceDirect

Vision Research

journal homepage: www.elsevier.com/locate/visres

Enhanced global integration of closed contours in individuals with high levels of autistic-like traits

Renita A. Almeida [a], J. Edwin Dickinson [a], Murray T. Maybery [a], Johanna C. Badcock [a,b], David R. Badcock [a,*]

[a] School of Psychology, University of Western Australia, Australia
[b] Centre for Clinical Research in Neuropsychiatry, Graylands Hospital, Australia

ARTICLE INFO

Article history:
Received 28 May 2014
Received in revised form 23 August 2014
Available online 29 August 2014

Keywords:
Autism-spectrum Quotient
Global contour integration
Visual search
Embedded Figures Test
Radial frequency patterns
Visual processing

ABSTRACT

Individuals with autistic traits (measured with Autism-spectrum Quotient, AQ) often excel in detecting shapes hidden within complex structures (e.g. on the Embedded Figures Test, EFT). This facility has been attributed to either weaker global integration of scene elements or enhanced local processing, but 'local' and 'global' have various meanings in the literature. The function of specific global visual mechanisms involved in integrating contours, similar to EFT targets was examined. High AQ scorers produced enhanced performance on the EFT and an alternative Radial Frequency Search Task. Contrary to 'generic' interpretations of weaker global pooling, this group displayed stronger pooling of contour components that was correlated with search ability. This study therefore shows a global contour integration advantage in high AQ observers.

1. Introduction

Individuals with autism demonstrate superior performance relative to matched controls on visual search tasks such as the Embedded Figures Test (EFT; Witkin et al., 1971), which requires detecting a closed-contour shape hidden within a more complex structure (Edgin & Pennington, 2005; Frith & Happé, 1994; Jolliffe & Baron-Cohen, 1997; Morgan, Maybery, & Durkin, 2003; Pellicano et al., 2005). Similar findings have been observed in typically developing individuals with high levels of autistic-like traits (Almeida, Dickinson, Maybery, Badcock, & Badcock, 2010a, 2010b; Grinter et al., 2009a, 2009b; Russell-Smith, Maybery, & Bayliss, 2010), as measured by the Autism-spectrum Quotient (AQ; Baron-Cohen et al., 2001). These findings are suggestive of similar mechanisms in the two groups and the existence of an underlying continuum; however the nature of these mechanisms is still unclear.

Several alternative explanations have been provided to account for superior visual search in these groups. One proposed explanation is that they have weak central coherence (WCC), which describes a relatively weaker ability to perceive the global structure of a visual display, allowing easier access to the target elements in the search array (Frith & Happé, 1994; Happé, 1996, 1999; Shah & Frith, 1983, 1993). In contrast, the enhanced perceptual functioning (EPF) framework (Mottron & Burack, 2001; Mottron et al., 2006) describes superior low-level and local processing with no accompanying global or 'integrative' deficit (Manjaly et al., 2007; Mottron, Burack, Iarocci, Belleville, & Enns, 2003; Mottron, Burack, Stauder, & Robaey, 1999; Ozonoff et al., 1994; Plaisted, Swettenham, & Rees, 1999). The explanations above concur in proposing better use of local than global cues by individuals with autism or those with high levels of autistic-like traits, however, they take different positions as to whether global processing is limited in these groups. While each of these explanations refers to local and global processes, the terms 'local' and 'global' have acquired a broad range of meanings that at times are poorly specified and at other times seem to refer to quite different aspects of visual processing (Milne & Szczerbinski, 2009). This creates a challenge when trying to reconcile findings from different studies, and conceptualise the co-occurring deficits and strengths present in these groups.

Almeida et al. (2010a) constructed a new visual search task using radial frequency (RF) patterns (see Section 2). RF patterns are created by deforming a circle through varying its radius sinusoidally as a function of polar angle, with the number of modulation cycles required to complete one revolution corresponding to the RF number (Wilkinson, Wilson, & Habak, 1998). These patterns were chosen because, like the simple target shape in the EFT, they

* Corresponding author. Address: School of Psychology (M304), University of Western Australia, 35 Stirling Highway, Crawley, WA 6009, Australia. Fax: +61 8 6488 1006.
E-mail address: david.badcock@uwa.edu.au (D.R. Badcock).

http://dx.doi.org/10.1016/j.visres.2014.08.015
0042-6989/

are also closed contours, but they can be adjusted to evoke well-defined global or local closed-contour processing mechanisms (Bell & Badcock, 2009; Hess, Wang, & Dakin, 1999; Loffler, Wilson, & Wilkinson, 2003). The terms 'local' and 'global' used here do not refer to a small figure within a larger pattern or array (as proposed by WCC), but rather refer to detection of local features of the RF pattern (e.g., curvature maxima) and the global integration of that information around the whole closed contour. RF patterns can provide evidence of either global or local closed-contour processing (Loffler et al., 2003). This can be achieved by measuring the amplitude of distortion required to discriminate between a circle and an RF pattern. The efficiency of global integration can be assessed by using stimuli of a particular RF and varying the number of cycles of modulation (i.e., curvature maxima) at that frequency inserted into the otherwise circular contour. For instance, for an RF3 pattern, 1, 2 or 3 cycles of deformation could be applied to the contour (see RF stimuli presented in Fig. 2a). A decrease in threshold with more cycles of modulation is expected, even in the absence of global integration, due to probability summation, which refers to the increasing probability of detecting single cycles as the number of cycles present increases (Graham, 2001). However for low-frequency patterns (RF < 10), sensitivity to curvature maxima improves too rapidly to be explained by the processing of local cues (single cycles) in isolation, but rather requires global integration of the local shape information around the contour to explain the improvement (Bell & Badcock, 2008; Dickinson et al., 2012; Loffler et al., 2003). In contrast, for high RF patterns the rate of threshold improvement matches the rate predicted by probability summation, indicating only local processing of pattern features (Loffler et al., 2003).

Evidence of superior search by individuals with high, relative to those with low, levels of autistic-like characteristics has been reported on tasks that employed either globally or locally processed RF stimuli (Almeida et al., 2013). In the present study, the use of RF stimuli has been extended to examine the efficacy of global integration mechanisms in groups differing in levels of autistic-like traits. As mentioned above, the terms 'local' and 'global' are used here in a very specific sense, referring to clearly identified mechanisms with known neural bases (Gallant, Shoup, & Mazer, 2000; Wilkinson et al., 2000). The repeated findings of superior RF search task performance suggest that the high AQ group may have narrower RF channel bandwidths (Almeida et al., 2010a, 2013) or higher sensitivity to the parameters underlying global processing of RF patterns (Dickinson, Bell, & Badcock, 2013). This implies that global pooling will be more selective for RF number and that global integration could be stronger, not weaker for high AQ individuals.

Grinter et al. (2010) compared children diagnosed with an Autism Spectrum Disorder (ASD) and typically developing children on their ability to differentiate between a circle and an RF pattern. They found that the ASD group required greater deformation of an RF3 to reach threshold than controls, however no group difference in threshold was observed for an RF24 pattern. Based on these findings, it was suggested that children with autism may have difficulty with global processing, yet have intact local ventral-stream processing, consistent with WCC (Grinter et al., 2010). However as detection threshold differences were only inspected when all three cycles were present on the RF3 pattern, no measure of the efficiency of global integration could be calculated and compared between groups. Detection threshold differences observed when three cycles of deformation are presented on the RF3 pattern could reflect varying sensitivity to coarser-scale curvature (local), integration of signal around the contour (global), or both, and thus do not provide a direct measure of the efficiency of integration. Therefore, the present study employed the RF integration task, described above, to extend the work of (Grinter et al., 2010) and to examine the ability of individuals with either high or low levels of autistic-like characteristics to use global processing when detecting modulation in RF3 contours.

The aim of this study was to investigate whether those with a high AQ would show evidence of differences in the ability to integrate the components of a closed form relative to a group with low AQ. The task employed for this purpose (the RF integration task) assessed thresholds for discriminating an RF3 pattern with 1, 2 or 3 cycles of modulation from a circle. The high and low AQ groups also completed the EFT and a version of the RF search task previously used in earlier studies (Almeida et al., 2010a, 2010b). For the latter task, participants searched for a target RF3 pattern among varying numbers of distractor RF4 patterns. If the proposition of weaker global pooling of low RF patterns, arising from work investigating children with an ASD (Grinter et al., 2010) is supported in research on typically developing adults selected to vary in levels of autistic-like traits, then for the RF integration task, the high AQ group may also have higher RF3 detection thresholds when three cycles of modulation are present on the contour relative to the low AQ group. More critically, we may expect the high AQ group to show evidence of weaker global integration relative to the low AQ group, as reflected in a shallower improvement in thresholds as more cycles of deformation are added to the RF3. However, if previous results of Almeida et al. (2010a, 2010b) are replicated, and the proposition of narrower RF channel bandwidths in high AQ scorers is supported, we would predict that the high AQ group would show evidence of greater global pooling on the integration task and faster RF search times relative to the low AQ group, along with a correlation between performance on these two RF tasks.

2. Method

2.1. Participants

Undergraduate psychology students ($N = 640$) at the University of Western Australia completed the AQ. Cut-off scores of $\leqslant 11$ and $\geqslant 22$ (delineating the lowest and highest quintiles) were used to create low ($n = 16$) and high ($n = 15$) AQ groups (see Table 1). The two groups did not differ in IQ ($t(29) = 1.064$, $p = .296$) or gender distribution ($\chi^2(1, N = 31) = .008$, $p = .930$). Each observer had normal or corrected-to-normal visual acuity (assessed using a Snellen chart). The study was approved by the University of Western Australia's Human Research Ethics Committee and conducted in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki) for experiments involving humans.

Table 1
Descriptive statistics of high and low AQ group characteristics. Male–female ratio and means (and SD) for age (years), AQ, IQ, EFT RT (s) and EFT errors.

	Low AQ ($N = 16$)	High AQ ($N = 15$)
Male:female	1:4.3	1:4
Age	18.56 (2.42)	22.4 (5.73)[a]
AQ	8.25 (2.79)	27.27 (2.49)
Cut-off	$\leqslant 11$	$\geqslant 24$
IQ	109.50 (10.26)	113.80 (12.22)
EFT RT (s)	33.45 (9.06)	15.07 (9.38)
EFT errors	6.19 (4.64)	2.87 (2.42)

[a] *Note:* This small difference in mean age is statistically significant (Welch-corrected $t(18.59) = 2.401$, $p = .027$) however it arises because of two older observers in their mid-30s in the High AQ group. The difference reduces to 2 years (with equated variances) and is non-significant without them. All major results in the paper have also been analysed without those two observers, to check whether this age difference was critical to our conclusions, and no outcome changed as a result of their removal. We, therefore, report the values with all participants included.