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Spatial localisation in autism: evidence for differences in early cortical visual processing

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Abstract

Background: Vision in people with autism spectrum conditions (ASC) is reported to be different from people without ASC, but the neural level at which the differences begin to occur is not yet known. Here we examine two variants of a vernier acuity task to determine if differences are evident in early visual processing.

Findings: Abutting and separated vernier acuity was assessed in 16 people with ASC and 14 matched controls. In controls, abutting and separated thresholds were unrelated ($r = 0.13$, $p = 0.65$), suggesting thresholds are determined by two separate mechanisms. In contrast, the abutting and separated thresholds of ASC observers were strongly correlated ($r = 0.88$, $p < 0.0001$), with separated thresholds tending towards being superior to those of controls [$t(28) = -2.46$, $p = 0.02$].

Conclusions: The findings suggest the mechanisms employed by ASC observers in separated vernier tasks are different to those of controls. This psychophysical evidence suggests that visual differences in ASC may begin at an early cortical stage of visual processing.

Keywords: Autism spectrum conditions, Spatial vision, Vernier acuity, Hyperacuity, Psychophysics, Visual processing

Findings

Where in the visual processing system do differences in vision begin to arise for people with autistic spectrum conditions (ASC)? People with ASC appear to have normal responses to basic visual tasks [1], but difficulties with complex face recognition tasks and enhanced attention to local visual information over global in tasks such as visual search [2,3]. To understand the nature and location of differences in visual processing in ASC, Simmons et al. [3] state: "A really basic characterization of the visual processing capabilities of people with ASC would be extremely useful, even if all it could do was say with certainty 'nothing is wrong here'".

Starting with basic visual processing, visual acuity (or the minimum recognisable acuity) is limited by foveal cone spacing [4] and is similar in people with ASC and controls [1]. Moving methodically up the visual pathway, the next logical visual function to examine is the spatial localisation of two features, or the minimum discriminable acuity. Localisation thresholds can be more precise than cone spacing and are limited in the primary visual cortex [5-8].

Here, we assess spatial localisation using a vernier acuity paradigm across two conditions that are thought to be mediated by different neural mechanisms: (1) ***abutting*** line vernier targets, processed by contrast-dependent spatial filters encompassing both stimulus elements [5,6]; (2) line vernier targets ***separated*** by 10 arc min. For lines separated by more than 4 arc min [5,6], vernier thresholds are contrast-independent, the mechanism underlying performance involving position identification of each stimulus element using a local sign process [9], followed by a collator mechanism capable of comparing the responses to the two individual stimulus elements [6-8]. Our hypothesis, based on earlier evidence, is that spatial localisation in ASC and control observers will be similar, with differences arising at higher (attentional) levels of visual processing.

Methods

Procedure

Two-line vernier thresholds were assessed using two long (30 arc min at 8 m), thin (18.9 arc sec at 8 m), bright

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Table 1 Sample characteristics

	ASC (n = 16) Mean ± SD (range)	Controls (n = 14) Mean ± SD (range)	Two-tailed independent t-test (Levene > 0.05; equal variances assumed)
Age	34.4±9.8 years (20–54 years)	38.1 ± 6.3 years (26–48 years)	t = 1.19, df28, p = 0.24
Gender	9 female, 7 male	6 female, 8 male	Pearson chi-square 0.54, p = 0.46
WASI	120.5 ± 10.9 (99–135)	115.5 ± 9.4 (100–130)	t = 1.30, df26, p = 0.20
AQ	40.7 ± 4.6 (29–48)	12.4 ± 4.3 (4–21)	t =16.6, df28, p < 0.0001
VA	−0.15 ± 0.09 logMAR (0.00 - -0.28)	−0.16 ± 0.10 logMAR (0.00 - -0.30)	t = 0.27 df27 p = 0.79

For each block of trials, the number of rightward responses was tallied for each offset position. A cumulative Gaussian function was used to fit the data, from which we derived two important parameters: (1) the offset from the zero-offset condition (the two lines were perfectly aligned) that corresponded to 50%-rightward response, representing the response bias, and (2) the offset between the two lines to change the rightward response on the psychometric function from 50 to 84%, representing the vernier threshold. This definition of vernier threshold is equivalent to 1 SD of the cumulative Gaussian function that was fitted to the observer's responses.

The authors conducting the experiments and analysing the data were blind to whether participants were in the ASC or control groups until after data had been collected and analysed.

Participants

Participants were included if they met the following inclusion criteria: aged over 18 years, an Intelligence Quotient [IQ: Wechsler Abbreviated Scale of Intelligence (WASI)] of at least 90 so as to exclude those with 'low average' IQ or below [11], no self-reported cognitive co-morbidities, corrected habitual binocular visual acuity at least 0.00 logMAR and no manifest strabismus as assessed by optometric screening. In addition, participants with ASC had a clinical diagnosis based on DSM-IV criteria and an Autism Spectrum Quotient (AQ) score of at least 26 [12]. Controls had an AQ score of less than 22. Ethical approval for the study was obtained from Anglia Ruskin University, and informed consent was obtained from all participants.

Data were collected for 17 people with ASC and 16 controls. Data from two controls were excluded from analysis as their AQ scores were >26 and from one person with ASC as their WASI IQ was <90. Data are therefore presented from 16 people with ASC and 14 controls as shown in Table 1. The two groups did not differ in terms of age, gender or IQ (all p > 0.05), but as expected did differ on Autism Spectrum Quotient (AQ) scores (p < 0.0001).

Results

There was no difference in response bias for abutting stimuli [ASC −2.5 ± 4.7, control −2.2 ± 5.7; t(28)-1.15, p = 0.88] or for separated stimuli [ASC −3.2 ± 8.8, control +3.4 ± 9.0; t(28)-2.01, p = 0.06].

Mean vernier thresholds for each group and condition are shown in Table 2. Thresholds for the control group were in accordance with previously published data for similar parameters [5]. There was no significant difference in thresholds between ASC and control observers for abutting vernier stimuli [t(28) = −0.63, p = 0.54; Cohen's d −0.25]. There was a significant difference between groups for separated vernier thresholds [t(28) = −2.52, p = 0.018, Bonferroni corrected; Cohen's d = −0.96, effect size r =−0.43], with ASC observers' thresholds being better than controls'.

However, of greater interest than the mean difference between the groups is the relationship between abutting and separated vernier thresholds for the two groups as shown in Figure 1. In controls (filled points), the abutting and separated thresholds are unrelated (Pearson r = 0.13, p = 0.65). In ASC (open points), the abutting and separated thresholds rise in proportion to one another (Pearson r = 0.88, p < 0.0001).

It would be expected that abutting and separated vernier thresholds would be unrelated, since in typical controls they have been shown to be determined by two separate mechanisms. As previously outlined, abutting thresholds are determined by contrast-dependent spatial filters encompassing both elements [5,6], whilst separated thresholds are determined by a two-step process of local sign designation followed by comparison of features [6-8]. The results of the control observers are consistent with these findings.

The finding of a strong correlation between abutting and separated vernier thresholds in the ASC observers suggests that their thresholds for the two conditions may be determined by the same mechanism. People with

Table 2 Group-mean vernier thresholds (± SD) in log sec arc, taken as the geometric mean of two blocks of responses for each participant

	ASC	Control
Abutting	1.16 ± 0.20	1.21 ± 0.20
Separated	1.35 ± 0.20	1.52 ± 0.15