
Article:
Milne, E. orcid.org/0000-0003-0127-0718 and Buckley, D. orcid.org/0000-0001-9140-8543 (2010) Contrast sensitivity thresholds in children with autistic spectrum disorder. British and Irish Orthoptic Journal, 7. pp. 62-65.

10.22599/bioj.29

Br Ir Orthopt J 2010; **7:** 62–65

Contrast sensitivity thresholds in children with autistic spectrum disorder

ELIZABETH MILNE PhD[1] AND DAVID BUCKLEY PhD[2]

[1]*Department of Psychology, University of Sheffield, Sheffield*

[2]*Academic Unit of Ophthalmology and Orthoptics, University of Sheffield, Sheffield*

Abstract

Aims: **To compare a basic visual ability, contrast sensitivity, in participants with autistic spectrum disorder (ASD) and neuro-typical controls. There has been recent interest in visual perception in individuals with ASD but with the exact nature and aetiology of any abnormality yet to be defined. While some theories postulate that high-level cognitive and/or neuronal deficits underlie any perceptual abnormalities this may be premature given that very little is known about the basic integrity of the visual system in individuals with ASD. This is explored here.**

Methods: **We used the Vector Vision CSV-1000 to measure contrast sensitivity at a range of spatial frequencies (3–18 cpd) in 30 children diagnosed with ASD and 30 typically developing controls.**

Results: **There were no significant differences between the two groups, and all children tested showed contrast sensitivity within normal levels at all spatial frequencies.**

Conclusion: **At a gross level visual perception is intact in ASD. Therefore, theories postulating reduced, or enhanced, contrast sensitivity are not supported as an explanation for atypical perception observed at higher levels.**

Key words: Autistic spectrum disorder, Contrast sensitivity, Spatial frequency, Visual ability

Introduction

Although autistic spectrum disorder (ASD) is diagnosed on the basis of impairments in social behaviour, communication and imagination, there has been a recent resurgence of interest in atypical visual perception that seems to be a secondary symptom of ASD. The literature contains anecdotal reports of unusual perceptual experiences[1,2] and behavioural symptoms involving atypical perception such as atypical gaze[3] and visual self-stimulation.[4] However, empirical data which clearly outline areas of spared visual function and/or areas of abnormal visual function are lacking in this field. The majority of research to date has focused on high-level aspects of vision such as perceptual style (with a focus on global or local perceptual bias) and visual integration. The range of documented atypicalities in ASD includes: enhanced perception of local detail,[5] reduced drive for global perception,[6] impaired motion perception[7] and impaired complex form perception.[8] It remains unclear, however, whether this varied array of visual abnormalities arise from abnormality at a cortical level (for example, reduced neuronal integration,[9] abnormalities in attention[10] and/or extra-striate cortical deficit[11]) or as a result of lower level deficits of the visual system. The few studies that have attempted to document low-level vision in ASD suggest evidence of oculomotor dysfunction such as hypometric saccades and reduced saccadic velocity,[12,13] atypical optokinetic nystagmus,[14] higher incidence of strabismus,[14] and deficits in pursuit eye movements[15] (for review see[16,17]). However, a recent study[18] has reported highly enhanced visual acuity in adults with ASD (but see later discussion).

The aim of the present study was to evaluate whether children with ASD show abnormal contrast sensitivity across a range of spatial frequencies compared with typically developing children. Abnormal perception of spatial frequencies in ASD is suggested by the finding that children with ASD use high-spatial frequency cues when matching pictures of faces, in contrast to typically developing controls who use low-spatial frequency cues.[19]

Contrast sensitivity has been measured in studies that test the integrity of basic vision in other clinical populations, for example dyslexics,[20] deaf individuals[21] and children with Down's syndrome.[22] To our knowledge there are four published studies that have tested contrast sensitivity in ASD.[23–26] In all these studies, however, the participants were considered to be high-functioning individuals. In our study we tested a larger sample of children/adolescents covering a larger range of cognitive abilities and investigated whether any differences in contrast sensitivity are dependent on these cognitive factors.

Methods

We recruited 60 children: 30 diagnosed with autistic spectrum disorder (ASD)* and 30 typically developing

Correspondence and offprint requests to: Dr David Buckley, Academic Unit of Ophthalmology & Orthoptics, The University of Sheffield, K Floor, School of Medicine & Biomedical Sciences, Beech Hill Road, Sheffield S10 2RX. e-mail: d.buckley@sheffield.ac.uk

* Note that 6 of the ASD participants in this study also took part in another study[25].

Table 1. Mean ages and IQs of the ASD and TD groups

	ASD ($n = 30$)	TD ($n = 30$)	*t*-score, *p* value (d.f. = 58)
Chronological age			
Mean	11y, 5 m	12y, 5 m	−1.439, 0.156
SD	*2,5*	*2, 11*	
Range	6y, 9 m to 18y, 0 m	6y, 1 m to 18y, 4 m	
Full-scale IQ			
Mean	93.9	109.7	−3.375, 0.001
SD	*20.3*	*15.6*	
Range	63–134	76–145	
Verbal IQ			
Mean	91.8	108.8	−3.295, 0.002
SD	*22.4*	17.2	
Range	55–136	80–139	
Performance IQ			
Mean	97.0	107.0	−2.455, 0.017
SD	*18.1*	13.2	
Range	64–127	75–126	

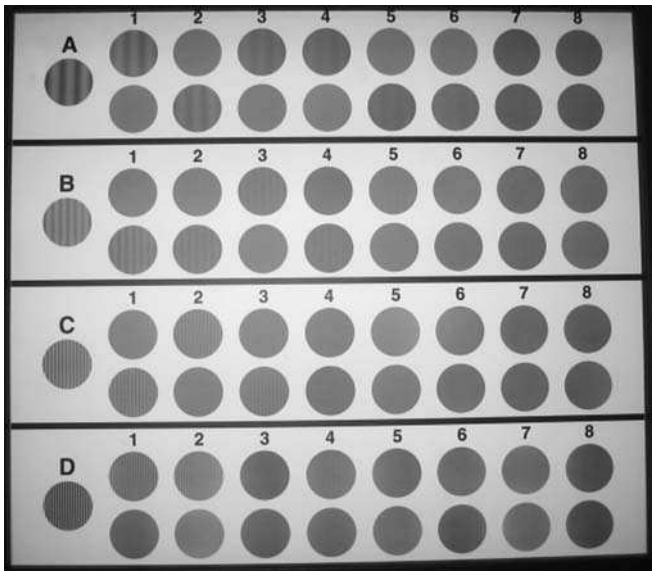

Fig. 1. The CSV-1000 test face. (Due to variations in printing the target grating is not visible in all patches.)

controls (TD). Participants were recruited via letters including an information sheet about the study and an invitation to participate that were sent to parents of children in selected classes (the classes were selected based on the age of the children in the class, and the class teacher being happy for the research to take place during their teaching time.) Only children whose parents consented to them taking part in the research were tested. The children with ASD included diagnoses of classic autism ($n = 16$), Asperger's syndrome ($n = 9$) and Pervasive Developmental Disorder Not Otherwise Specified (PDDNOS; $n = 5$). These children had been diagnosed according to DSM-IV criteria by qualified professionals using the Diagnostic Interview for Social and Communication Disorders (DISCO[27]) and were attending special schools or units for children with ASD. The TD children attended and were recruited from local mainstream schools.

Ethics approval for the study was granted by the University of Sheffield, Department of Psychology Ethics Committee and, as stated above, the parents of all children provided informed consent for their child to participate in the study.

All participants were reported by parents or teachers as having normal or corrected-to-normal vision. The inclusion criteria for the ASD group were having a diagnosis of ASD and being willing and able to take part (with parental consent), and for the TD group the inclusion criterion was being willing and able to take part (with parental consent). The exclusion criterion for the ASD group was having a neurological disorder in addition to ASD and for the TD group was having any neurological disorder.

Intellectual ability was measured by the Wechsler Abbreviated Scale of Intelligence.[28] Five participants with ASD had full-scale IQs of ≤ 70 so are defined as being 'low functioning'. The mean chronological ages and verbal, performance and full-scale IQ scores of both groups are presented in Table 1. There was no significant age difference between the two groups, although the participants with ASD had lower IQ scores than the TD participants.

We used a standardised contrast sensitivity test (the CSV-1000, Vector Vision;[29] see Fig. 1) to measure contrast sensitivity to spatial frequencies in the 3 to 18 cycles per degree (cpd) range. This test consists of a fluorescent luminance source which provides back-lighting to a translucent chart containing the contrast defined stimulus patches. The instrument self-calibrates to maintain a constant illumination of 85 candellas/m^2, which is the light level recommended for vision testing by the National Committee on Vision of the National Academy of Sciences, working group for Vision Standards.[30]

At a viewing distance of 2.45 metres, the CSV-1000 tests contrast sensitivity at four spatial frequencies. Each spatial frequency was presented in a separate row: row A = 3 cpd, row B = 6 cpd, row C = 12 cpd, row D = 18 cpd. A stimulus patch illustrating the spatial frequency of the test grating was presented at the far left of each row at a contrast of 0.2 (3 cpd), 0.13 (6 cpd), 0.25 (12 cpd) and 0.67 (18 cpd). The remaining 16 gratings per row were presented in 8 columns. At each of the 8 contrast levels, the target grating appeared in only one of the patches (either the top or bottom patch), the remaining patch consisting of uniform grey. Moving from left to right, the contrast value of the target grating decreased by approximately 40% or 1.15 log units in each column.

The participants were tested individually either in a quiet room in their school, or in a testing room within our laboratory. As described above the CSV-1000 self-calibrates so that the testing light level is standardised over a wide range of ambient luminance, thus reducing potential data noise by not testing all children in the same room. Each participant was familiarised with

Table 2. Mean contrast sensitivity values (and standard deviation) for the ASD and TD groups

	ASD	TD	*t*-score, *p* value (d.f. = 58)
3 cpd	1.82 *(0.17)*	1.80 *(0.18)*	0.56, 0.578
6 cpd	2.02 *(0.18)*	2.07 *(0.24)*	−1.01, 0.321
12 cpd	1.72 *(0.18)*	1.68 *(0.23)*	0.734, 0.466
18 cpd	1.31 *(0.24)*	1.26 *(0.26)*	0.762, 0.449

Note. No significant group differences were found, which is to be expected given the lack of a significant main group effect.

the testing environment and asked to stand on a line marked 2.45 metres from the testing equipment. Each section, rows A to D, of the CSV-1000 test chart was illuminated separately so that it was clear which row the participant should attend to. The participant was asked to indicate whether the target grating ('the stripy lines') appeared in either the top or the bottom row. After the participant had provided an answer for column 1, the experimenter pointed to the patches in column 2, and again the child was asked whether the target grating appeared in the top or bottom row. This continued for all 8 stimulus patches. The child was asked to attempt each set, but was permitted to say 'I don't know' if they could not see the target grating. The order of spatial frequency presentation was counter-balanced across participants. The last correct response of a consecutive series of correct responses was recorded as the contrast threshold for each spatial frequency value.

Results

Table 2 shows the mean log contrast sensitivity of the two groups of children, and these are plotted in Fig. 2. The area between the dotted lines represents the 5th to 95th percentile of population norms collected from adults (with no ocular pathology) aged between 20 and 50 years.[30] As can be seen from Fig. 2 there appear to be no differences between the groups. This was confirmed with a two-way ANOVA which revealed a main effect of spatial frequency ($F(3, 174) = 215.7$, $p < 0.001$) in line with existing data,[31] demonstrating that contrast sensitivity is modulated by spatial frequency, but no significant difference between the contrast sensitivity of the ASD and TD groups ($F(1, 58) < 1$, $p > 0.1$) and no significant interaction between group and spatial frequency ($F(3, 174) = 1.2$, $p > 0.1$). Given that the ASD group had significantly lower IQ scores than the TD controls, an analysis of covariance was performed controlling for the effect of IQ. Again, no significant group difference ($F(1, 57) = 1.8$, $p > 0.1$) or significant interaction between group and spatial frequency ($F(3, 171) = 1.6$, $p > 0.1$) was observed. Because the range of ages sampled in this study was large (spanning from 6 to 18 years) a correlation analysis was performed to investigate a possible relationship between contrast sensitivity and age. No significant relationships were found ($n = 60$, $r < \pm 0.13$, $p > 0.27$ in all cases).

Discussion

It is known that individuals with ASD show a detail-oriented perceptual style, and reduced performance on

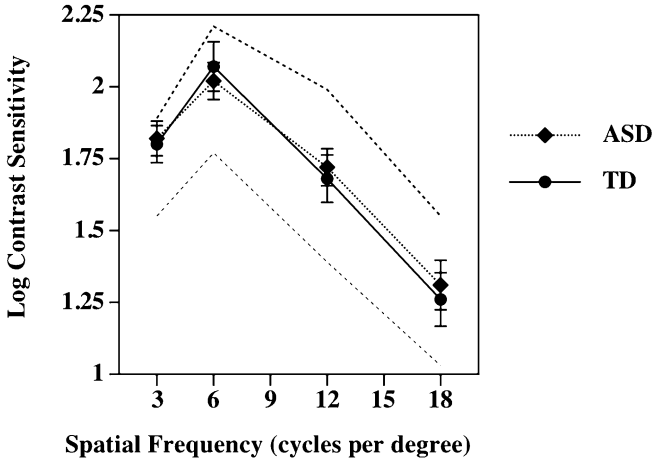

Fig. 2. Mean log contrast sensitivity thresholds for the two groups of children. (error bars = 95% confidence intervals). Adult norm data (5%–95% percentile) are shown between the upper and lower dotted lines.

tasks that require global perception.[32] Because holistic-oriented and detail-oriented tasks require the use of low and high spatial frequency information, respectively,[33] it has been proposed that the detail-oriented bias in ASD individuals reflects an enhanced sensitivity to high spatial frequencies and/or a diminished sensitivity to low spatial frequencies.[23] However, the data presented here demonstrate that the contrast sensitivity threshold of children with autistic spectrum disorders is no different to that of typically developing controls when tested at 3, 6, 12 and 18 cpd. In addition, all children tested obtained contrast sensitivity thresholds within the normal range for this test (compared with adult data). The lack of any relationship between age and contrast sensitivity shows that contrast sensitivity has reached adult levels by at least age 6 years in children with ASD, as in typically developing children. This is to be expected given earlier reports that contrast sensitivity reaches adult levels by age 2–3 years.[31]

Our findings support previous studies that have also reported no differences in contrast sensitivity between individuals with ASD and TD controls. One study[23] tested autistic adults in a face-processing task and included a contrast sensitivity test as a control condition. They found no difference in contrast sensitivity between autistic adults and a control group. A second study[24] tested both adults and children with pervasive developmental disorder (PDD) and found no significant difference in contrast sensitivity between the two groups of observers, although they did report a trend towards lower contrast sensitivity to higher spatial frequencies in the participants with PDD. Their results were averaged over all participants (age range 7–33 years). A third study[25] found no differences in contrast sensitivity between children with ASD and a control group, but did find evidence of atypical processing of simple Gabor patch stimuli using electroencephalography. The fourth study tested adolescents with autism and Asperger's syndrome ($n = 10$) and again found no difference in contrast sensitivity across a range of spatial frequencies in the ASD group compared with the controls.[26] We

report here that even in a larger group of participants with ASD, encompassing a range of intellectual abilities and the broad spectrum of diagnoses within the ASD spectrum, there is no evidence for reduced sensitivity to spatial frequencies in the 3–18 cpd range. Our findings appear at odds with the recently reported hyper-acuity in autistic adults[18] using Landolt-C-type targets, suggesting enhanced sensitivity to high spatial frequencies. However, an earlier study[24] also found no differences in acuity, in either children or adults, using the standard Landolt C chart. A recent discussion by Bach and Dakin[34] has cast doubt on the conclusion of hyper-acuity in autism drawn by Ashwin *et al*.[18]

A potential limitation of the experimental design is that it required participants to make a two-alternative forced choice and consisted of a limited number of trials (8). It is possible that some children guessed the location of the stimulus patch without being able to see it. However, both groups of children had an equal opportunity to guess their responses, and the average contrast threshold for both groups is based on the participants detecting between 6 and 7 consecutive targets. By calculating the dependent variable as the last contrast value at which the target is detected in a consecutive series, the likelihood of a participant detecting 6 consecutive targets when guessing is 0.016.

IQ did not interact with contrast sensitivity, which suggests that the CSV-1000 is suitable for measuring contrast sensitivity even in children with learning difficulties or low-functioning ASD.

Conclusion

Our data provide evidence that children with ASD do not have abnormal contrast sensitivity thresholds within the range tested, which suggests that at a gross level their visual system is intact. Our data also suggest that if an autistic child does exhibit reduced contrast sensitivity in this range then this may be indicative of a visual problem unrelated to their autism.

We gratefully acknowledge the assistance of pupils and staff at the following schools: Birely Spa community primary school, Highview Primary Learning Centre, Hunters Bar Junior School, Nook Lane Junior School, Mossbrook School and Rossington Hall School. We also thank Helen Davis and Helen Griffiths for very useful discussions.

References

1. Grandin T. *Thinking in Pictures: And Other Reports of My Life with Autism*. New York: Doubleday, 1996: 73.
2. Williams D. *Autism: An Inside-Out Approach*. London: Jessica Kingsley, 1996.
3. Leekam SR, Hunnisett E, Moore C. Targets and cues: gaze following in children with autism. *J Child Psychol Psychiatry* 1998; **39:** 951–962.
4. Militerni R, Bravaccio C, Falco C, Fico C, Palermo MT. Repetitive behaviours in autistic disorder. *Eur Child Adolescent Psychiatry* 2002; **11:** 210–218.
5. Plaisted K, O'Riordan M, Baron-Cohen S. Enhanced visual search for a conjunctive target in autism: a research note. *J Child Psychol Psychiatry* 1998; **39:** 777–783.
6. Brosnan M, Scott FJ, Fox S, Pye J. Gestalt processing in autism: failure to process perceptual relationship and the implications for contextual understanding. *J Child Psychol Psychiatry* 2004; **45:** 459–469.
7. Milne E, Swettenham J, Campbell R. Motion processing in autistic spectrum disorder: a review. *Curr Psychol Cognition* 2005; **23:** 3–33.
8. Bertone A, Mottron L, Jelenic P, Faubert J. Enhanced and diminished visuo-spatial information processing in autism depends on stimulus complexity. *Brain* 2005; **128:** 2430–2441.
9. Bertone A, Faubert J. Demonstrations of decreased sensitivity to complex motion information not enough to propose an autism specific neural etiology. *J Autism Dev Disord* 2006; **36:** 55–64.
10. Belmonte MK. Abnormal visual motion processing as a neural endophenotype of autism. *Curr Psychol Cogn* 2005; **23:** 65–74.
11. Spencer J, O'Brien J, Riggs K, Braddick O, Atkinson J, Wattam-Bell J. Motion processing in autism: evidence for a dorsal stream deficiency. *Neuroreport* 2000; **11:** 2765–2767.
12. Goldberg ME, Lasker AG, Zee DS, Garth E, Tien A, Landa RJ. Deficits in the initiation of eye movements in the absence of a visual target in adolescents with high functioning autism. *Neuropsychologia* 2002; **40:** 2039–2049.
13. Rosenhall U, Johansson E, Gillberg C. Oculomotor findings in autistic children. *J Laryngol Otol* 1988; **102:** 435–439.
14. Scharre JE, Creedon MP Assessment of visual function in autistic children. *Optom Vis Sci* 1992; **69:** 433–439.
15. Takarae Y, Minshew N, Luna B, Krisky CM, Sweeney JA. Pursuit eye movement deficits in autism. *Brain* 2004; **127:** 2584–2594.
16. Milne E, Griffiths HJ. Visual perception and visual dysfunction in autistic spectrum disorder: a literature review. *Br Irish Orthopt J* 2007; **4:** 15–20.
17. Simmons DR, Robertson AE, McKay LS, Toal E, McAleer P, Pollick FE. Vision in autism spectrum disorders. *Vis Res* **49:** 2705–2739.
18. Ashwin E, Ashwin C, Rhydderch D, Howells J, Baron-Cohen S. Eagle-eyed visual acuity: an experimental investigation of enhanced perception in autism. *Biol Psychiatry* 2009; **65:** 17–21.
19. Deruelle C, Rondan C, Gepner B, Trardif C. Spatial frequency and face processing in children with autism and Asperger syndrome. *J Autism Dev Disord* 2004; **34:** 199–210.
20. Williams MJ, Stuart GW, Castles A, McAnally KI. Contrast sensitivity in subgroups of developmental dyslexia. *Vis Res* 2003; **43:** 467–477.
21. Finney EM, Dobkins KR. Visual contrast sensitivity in deaf versus hearing populations: exploring the perceptual consequences of auditory deprivation and experience with a visual language. *Cogn Brain Res* 2001; **11:** 171–183.
22. Woodhouse JM, Pakeman VH, Saunders KJ. Visual acuity and accommodation in infants and young children with Down's syndrome. *J Intellect Disabil Res* 1996; **40:** 49–55.
23. Behrmann M, Avidan G, Leonard GL, Kimchi R, Luna B, Humphries K, *et al*. Configural processing in autism and its relationship to face processing. *Neuropsychologia* 2006; **44:** 110–129.
24. de Jonge MV, Kemner C, de Haan EH, Coppens JE, van der Berg TJTP, van Engeland H. Visual information processing in high-functioning individuals with autism spectrum disorders and their parents. *Neuropsychology* 2007; **21:** 65–73.
25. Milne E, Scope A, Pascalis O, Buckley D, Makeig S. Independent component analysis reveals atypical electroencephalographic activity during visual perception in individuals with autism. *Biol Psychiatry* 2009; **65**(1): 22–30.
26. Koh HC, Milne E, Dobkins K. Spatial contrast sensitivity in adolescents with autism spectrum disorders. *J Autism Dev Disord* (in press).
27. Wing L, Leekam SR, Libby SJ, Gould J, Larcombe M. The diagnostic interview for social and communication disorders: background, inter-rater reliability and clinical use. *J Child Psychol Psychiatry Allied Disciplines* 2002; **43:** 307–325.
28. Wechsler D. *Wechsler Abbreviated Scale of Intelligence*. The Psychological Corporation, 1999.
29. Vector Vision. *CSV-1000 Product Manual*. Greenville, Ohio: Vector Vision, 1991.
30. Block DJ, Evans DW. Large sample norms for contrast sensitivity for school age children. *J Optom Visual Dev* 1993; **24:** 21–25.
31. Bradley A, Freeman RD. Contrast sensitivity in children. *Vis Res* 1982; **22:** 953–959.
32. Happé F, Frith U. The weak coherence account: detail-focused cognitive style in autism spectrum disorders. *J Autism Dev Disord* 2006; **36:** 5–25.
33. Badcock JC, Whitworth FA, Badcock DR, Lovegrove WJ. Low-frequency filtering and the processing of local-global stimuli. *Perception* 1990; **19:** 617–629.
34. Bach M, Dakin SC. Regarding 'Eagle-eyed visual acuity: an experimental investigation of enhanced perception in autism'. *Biol Psychiatry* 2009; **66**(10): e19–e20.