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Autism and a deficit in broadening the spread of visual attention

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Background: This study examines if visual attention in autism is spatially overfocused (Townsend & Courchesne, 1994) and if there is an associated deficit in broadening the spatial spread of attention. **Method:** Two crosshairs were presented on each trial separated by a brief (500 ms) interval. There was a modest difference in the lengths of the two hairs in each crosshair and participants had to decide which one was longest. Previous research (Mack & Rock, 1998) has revealed that in making this judgement people spread their visual attention to embrace the whole crosshair. Varying the overall size of each crosshair was intended to control participants' spread of attention. The impact of the size of the first crosshair gave an indication of participants' default setting for the spread of attention. The impact of the size transition between the first and second crosshair gave an indication of the fluency with which participants could change the spatial spread of visual attention. **Results:** Based on the first proposal it was predicted that individuals with autism ($N = 13$), relative to ability-matched moderately learning disabled ($N = 15$) and typically developing individuals ($N = 15$), would be more accurate and quicker to respond when the first crosshair was small rather than large. However, the results revealed no effects of the size of the first crosshair and no group differences. Based on the second proposal it was predicted that individuals with autism, relative to both control groups, would be less accurate and slower to respond to the second crosshair when the size transition from the first crosshair involved a change from small to large (in comparison with large to large), but would not differ when the change was from large to small (in comparison with small to small). This prediction was confirmed. **Conclusion:** Autism is associated with a deficit in broadening the spatial spread of visual attention. The implications of this for other visual and attentional anomalies observed in autism are discussed. **Keywords:** Autism, learning disability, visual attention, attentional spread. **Abbreviations:** ADD: Attention Deficit Disorder; ADHD: Attention Deficit Hyperactivity Disorder; BPVS: British Picture Vocabulary Scale; CA: chronological age; ISI: interstimulus interval; ITI: intertrial interval; MLD: moderate learning disability; RCPM: Raven's Coloured Progressive Matrices; RT: reaction time; TD: typically developing.

Autism is diagnosed on the basis of qualitative impairments in social behaviour and communication, as well as a restricted repertoire of repetitive and stereotypical activities, including a preoccupation with parts of objects (see *Diagnostic and statistical manual of mental disorders (DSM-IV)*, American Psychiatric Association, 1994). In addition to these diagnostically significant features, some fundamental aspects of visual perception also appear to be atypical in autism. For example, individuals with autism are better able to identify shapes within the complex designs of the Embedded Figures Test (Jolliffe & Baron-Cohen, 1997; Shah & Frith, 1983) and perform better on the Block Design subtest of the Wechsler intelligence scales (e.g., Shah & Frith, 1983, 1993). They also demonstrate atypical behaviour when copying line drawings of objects, being more likely to begin with the local than the global features of the depicted objects and being less perturbed when the drawings are of impossible objects (i.e., when the spatial relationships between the parts of an object violate the rules for global coherence in 3-D space) (Mottron, Belleville, & Menard, 1999).

General psychological theories of autism have relatively little to say about these visual anomalies (see Happé, 1994, for a review). One exception is Weak Central Coherence Theory which attempts to explain the major diagnostic symptoms as well as the islets of superior performance observed in autism (Frith, 1989; Shah & Frith, 1983). Essentially, it is proposed that autism involves a general deficit in the search for meaning and, more specifically, in central control processes responsible for integrating the component features of a situation into a coherent whole.

Weak Central Coherence Theory seems particularly well placed to account for why individuals with autism perform relatively well on the Embedded Figures and Block Design tests (Jolliffe & Baron-Cohen, 1997; Shah & Frith, 1983, 1993). In both of these tests it is assumed that the global aspects of the picture normally interfere with the perceptual segregation of its constituent forms. Hence, to the extent that autism is associated with problems encoding the global aspects of a stimulus, superior performance in these tests would be expected. These same problems could explain why individuals with autism give priority to the local aspects of a line drawing they are copying and why they are less sensitive to the global structural impossibility of the depicted object (Mottron et al., 1999).

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The encoding of local and global visual information, and how these two levels of processing impinge on each other, has been investigated with the Navon task (Navon, 1977). The stimuli created for this task comprise large shapes made up from small shapes. An example would be a large letter H composed of small, carefully positioned Xs. Immediately a compound stimulus is presented participants are required to decide, as quickly as possible, if it contains a pre-designated target shape. The target might appear at one or both levels, and participants might or might not know in advance at which level it will appear.

Research with normal adults (see Kimchi, 1992, for a review) has tended to show that global forms are encoded more fluently than their constituent forms, and this has revealed itself in two effects. The first of these is simply that people respond more quickly and accurately to global forms than to local forms. This is referred to as the *global advantage*. The second effect, which is related to the first, refers to the fact that when people respond to a local form they are susceptible to interference from the global form, whereas when they respond to the global form they are not susceptible to interference from the local form. This is referred to as *global interference.*

Several researchers have used the Navon task to investigate local and global processing in individuals with autism. In light of the proposal that autism is associated with the impoverished encoding of global visual information, researchers have predicted that the global advantage and global interference effects will be much less evident in individuals with autism, and might even be replaced by local advantage and local interference effects. With regard to these predictions, investigations of autism using the Navon task have produced mixed results (e.g., Mottron & Belleville, 1993; Ozonoff, Strayer, McMahon, & Filloux, 1994; Rinehart, Bradshaw, Moss, Brereton, & Tonge, 2000). Whereas a global advantage has sometimes been observed in individuals with autism (Mottron & Belleville, 1993; Ozonoff et al., 1994; Rinehart et al., 2000), a local advantage has also been observed (Rinehart et al., 2000). Similarly, whereas global interference has been found in individuals with autism (Ozonoff et al., 1994), so also has local interference (Mottron & Belleville, 1993; Rinehart et al., 2000). In some studies (e.g., Rinehart et al., 2000) a different picture has emerged depending on whether accuracy or response speed is examined.

There are a number of possible reasons why the results of these and other experiments employing the Navon task have produced mixed results. Some of these reasons are specific to the studies of autism, others apply to the Navon task itself. With regard to the studies of autism, it is worth noting some issues concerning the sampling of participants. For example, Rinehart et al. (2000) note the use of markedly different sample sizes across studies. While they themselves recruited over a dozen individuals with autism, Mottron and Belleville (1993) compared just one individual with autism against six control participants. In view of the individual differences in visual processing observed among individuals with autism (see Allen & Courchesne, 2001, for a review), a sample size of one is less than desirable. In addition, although some authors have taken care to select relatively pure cases of autism, using widely accepted diagnostic criteria (e.g., Plaisted, Swettenham, & Rees, 1999), others have not been concerned to do so. For example, Ozonoff et al. (1994) included individuals diagnosed as Pervasive Developmental Disorder Not Otherwise Specified in their autistic group. Finally, Plaisted et al. (1999) point out that in some studies (e.g., Ozonoff et al., 1994) participants knew in advance at which level (local or global) a target would appear, with this being fixed across a block of trials (referred to as a *selective attention* condition). In other studies (e.g., Mottron & Belleville, 1993) participants did not know in advance at which level a target would appear, and so they needed to monitor the information at both levels (referred to as a *divided attention* condition). To evaluate the significance of this factor within the same individuals, Plaisted et al. conducted a study in which autistic and typically developing controls completed both a selective attention version of the Navon task and a divided attention version. Results confirmed that whether the individuals with autism showed the normal global advantage and global interference effects depended on the version of the task they completed. With selective attention instructions they performed like normal controls, showing a global advantage in their speed of responding and a relatively strong global interference effect. However, with divided attention instructions the individuals with autism did not show the same global advantage and global interference effects demonstrated by the control participants. Instead, they made more errors to global targets than to local targets (i.e., there was a local advantage), and responded more slowly when a local form was incongruent with a global target, compared with when a global form was incongruent with a local target (i.e., there was local interference).

There are some important issues concerning the Navon task itself, and in particular the nature of the compound stimuli used in the task. First, many factors involved in the creation and presentation of these stimuli render their global aspects more or less easy to discriminate than their local elements (see Kimchi, 1992, for a review). These factors include the sparsity with which the local elements are placed across the visual field, the visual angle subtended by the compound stimulus, its location within the visual field relative to the point of fixation, and whether the onset of the stimulus is abrupt or gradual. Clearly, arriving at absolute conclusions regarding differences between local and global processing requires great caution. A second issue concerning compound stimuli relates to the role of the local elements in defining the global form. In the Embedded Figures and Block Design tasks it is the form of the local elements, and not just their location, that determines the global form. For the compound stimuli used in the Navon task, however, it is only the spatial locations of the local elements that define the overall form (e.g., it would not matter if a large H was created from small Xs or small Os, provided they were positioned appropriately). Indeed, the utility of compound stimuli hinges on the fact that the form of the local and global aspects can be manipulated independently of each other. Given the fundamentally different relationship between local and global information in these different situations, it is not entirely clear that the local–global distinction investigated with the Navon task is the same distinction referred to in the context of the Embedded Figures and Block Design tasks.

Finally, there is another issue concerning the nature of compound stimuli, and this is pursued in the present study. Because the global form is more extended spatially than each local element, there is a confound between the local–global distinction and the spatial extent of the corresponding forms. Therefore, differences observed between global and local processes, and the interactions between them, might reflect issues to do with the control of the spread of visual attention.

Autism has been associated with deficits in visual attention (see Allen & Courchesne, 2001, for a review). Employing simple visual detection and identification tasks, often modelled on Posner's cueing task (see, for examples, Posner & Cohen, 1984; Posner, Walker, Friedrich, & Rafal, 1984), researchers have proposed deficits in several aspects of visual attention. Individuals with autism, especially those for whom there is evidence of parietal abnormality, are believed to show a relatively narrow spread of attention, as if their attentional spotlight is habitually zoomed-in (Townsend & Courchesne, 1994). In addition, they appear to experience difficulty disengaging from a currently attended stimulus (Casey, Gordon, Mannheim, & Rumsey, 1993; Townsend, Courchesne, & Egaas, 1996; Wainwright-Sharp & Bryson, 1993) and are then relatively slow to redirect attention, with the degree of slowing being associated with the extent of cerebellar abnormality (Harris, Courchesne, Townsend, Carper, & Lord, 1999; Townsend et al., 1999; Townsend, Courchesne et al., 1996; Townsend, Harris, & Courchesne, 1996). Importantly, as Allen and Courchesne point out, individuals with autism are able to redirect visual attention; it is only the fluency with which they can do this that is problematic.

Although the authors know of no studies of autism that have directly examined the possibility of a deficit in adjusting the spread of visual attention, it is this aspect of attention that maps on to the distinction between local and global forms. In view of the assumed overfocused nature of visual attention in autism, any deficit in changing the spread of attention would likely be restricted to broadening it. Indeed, a selective deficit in broadening visual attention would provide another way of understanding the results reported by Plaisted et al. (1999). Thus, such a deficit would only be expected to reveal itself when autistic participants find themselves having to zoom-out to respond to the global aspect of a compound stimulus. It seems reasonable to argue that this would only happen with divided attention instructions, which fail to specify how attention should be set in anticipation of a stimulus. This would leave open the possibility that on a proportion of trials attention would be spatially focused when a target appeared at the global level. On this account, the same deficit would not be apparent with selective attention instructions, which indicate in advance how attention should be spread, thus ensuring that participants should not find themselves spatially overfocused when a global target appears.

The study reported here examined if visual attention in autism tends to be spatially overfocused and if there is an associated deficit in broadening the spread of attention. In doing so it avoided the troublesome issues identified with the Navon task. A version of the crosshairs judgement task developed by Mack and Rock (1998) was utilised instead. This employs simple stimuli (i.e., a fine vertical line and a fine horizontal line bisecting each other) and appears to be completed most easily when visual attention is spatially distributed to a particular degree. Therefore, as participants respond to a stimulus it can be assumed that the spread of their attention covers a particular region of space. Mack and Rock presented a crosshair and required participants to judge, as quickly as possible, whether the vertical or horizontal line was the longer of the two. Because the differences in length were always relatively small and a speeded response was required, Mack and Rock assumed that a decision could not be reached easily by focusing attention on the end points of each line in turn, but instead required that attention be spread so as to cover the area occupied by the crosshair as a whole. In the present study the overall dimensions of the crosshairs were varied to exert control over the spatial spread of attention. The two sizes chosen took account of the retinal angle subtended by the local and global forms in Plaisted et al.'s study. However, rather than attempt to match the size of the smaller crosshair to the absolute value to which visual attention is overfocused in autism (which is not known), it was decided simply to arrange for the smaller crosshair to be larger than the local forms used successfully by Plaisted et al. (1999) to contrast local and global processing. In this way it was clear that if the individuals in the present study adopted the same narrow focus of attention that allowed participants in the Plaisted et al. study to respond differentially to local and global forms, then they should respond more quickly to the smaller of the two crosshairs since this is closer in size to the local forms used by Plaisted et al.

Two crosshairs were presented on each trial, separated by a brief interval, and for each one a decision was required about which line was longest. The sizes of the two crosshairs were selected independently of each other and could be either small or large. If autism is associated with a tendency to overfocus attention within a restricted region of space, then individuals with autism, compared to controls, should respond to the smaller crosshairs with relatively greater speed and accuracy than to the larger crosshairs. This should be particularly apparent in their responses to the first of the two crosshairs on each trial because a relatively long intertrial interval (at least 5 s) ensured they would not be influenced by the attentional set required for the second crosshair of the preceding trial. For this reason, responses to the first crosshair on each trial were analysed to test the proposal that visual attention in autism tends to be habitually overfocused. If autism is also associated with a deficit in redistributing attention from a narrow focus to a wider distribution (i.e., zooming-out is slow), then individuals with autism, relative to controls, should experience difficulty responding to a large second crosshair when this is preceded by a small crosshair (rather than a large crosshair), especially if the time interval between successive crosshairs is relatively brief. They should experience less difficulty dealing with a change in crosshair size when a small second crosshair is preceded by a large crosshair (rather than a small crosshair).

A group of autistic individuals and a group of ability-matched typically developing children (TD) were recruited for the study. A second ability-matched control group with moderate learning disabilities in the absence of autism (MLD) was also recruited. This group was labelled as moderately learning disabled on the basis of information held by the education authorities which led them to statement the children as such.[1]

Method

Participants

Autistic group. Twenty-one individuals with autism were recruited from two special schools. They had been diagnosed as autistic by mental health professionals using established criteria given in DSM-IV (1994). Eight participants did not contribute results for data analysis either because they could not understand the verbal instructions ($N = 5$) or because they were unable to sustain their attention for the duration of the task ($N = 3$). Thus, 13 participants (1 female, 12 males) were included in the final analysis. Descriptive information about all the participants is given in Table 1.

Moderate Learning Disabilities group. Fifteen participants (6 females, 9 males) with moderate learning disabilities were recruited from a specialist school for children with learning disabilities. None of these participants had any symptoms suggesting autism, ADD, ADHD, or Aspergers.

Typically Developing group. Fifteen typically developing children (8 females, 7 males) were recruited from a state primary school. None had a history of any symptoms associated with autism, ADD, ADHD, or Aspergers.

English was the first language of all participants. Using the Ishihara test all participants were screened for colour blindness. The few participants ($N = 5$) who were not familiar with their numbers were screened for colour blindness using a series of questions regarding the colours of objects in the room. In addition, all participants were screened for motor problems that would have made it difficult for them to close two small push buttons with their index fingers. In an attempt to ensure that the MLD and TD groups performed at equivalent levels to the autistic group in the baseline conditions of the experimental task, all three groups were matched according to their performance on Raven's Coloured Progressive Matrices (RCPM) (Raven, Court, & Raven, 1983) and the British Picture Vocabulary Scale (BPVS) (Dunn, Dunn, Whetton, & Burley, 1997) (see Table 1). These two tests were designed to accommodate individuals with limited spoken language. Submitting the RCPM raw scores to analysis of variance (ANOVA) failed to reveal a significant effect of Group ($F(2, 40) = .11$, $p = .89$) and Newman-Keuls pairwise comparisons failed to reveal any significant differences among the groups. Submitting the BPVS raw scores to ANOVA failed to reveal a significant effect of Group ($F(2, 40) = .08, p = .92$) and Newman-Keuls pairwise comparisons again failed to reveal a significant difference among the groups.

Matching the groups on the basis of their RCPM and BPVS scores meant that the chronological ages of the children in the autistic and MLD groups, though comparable themselves, were higher than the chronological ages of the TD children. Referring the RCPM and BPVS scores to age-based norms confirmed the comparability of the autistic and MLD groups. The ranges for Raven's IQ were 71–125, 71–100, and 102–130, for the autistic, MLD, and TD groups, respectively.[2]

The ranges for verbal IQ based on the BPVS were 40–93, 49–85, and 95–133, for the autistic, MLD, and TD

[1] The authorities providing access to the children were unable to divulge information from their case notes, and were unable to provide information about individual IQs.

[2] The normative information available for translating RCPM scores to a measure of IQ is limited. This meant that in the case of the oldest participant in the autistic group it was possible to derive only a rough approximation by extrapolating from the available information. Although somewhat unreliable in this particular case, the estimate of Raven's IQ for this participant was in the middle of the range for the group.

Table 1 Means, standard deviations (SDs), and ranges for chronological age (CA), Raven's Coloured Progressive Matrices (RCPM) score, and the British Picture Vocabulary Scale (BPVS) score for the Autistic, Moderately Learning Disabled (MLD) and Typically Developing (TD) groups

Group	*N*	CA (yrs:mths)	RCPM score	BPVS score
Autistic	13			
mean		10:03	26.00	58.62
SD		2:07	6.34	18.40
range		7:06–15:03	14–35	15–84
MLD	15			
mean		9:05	25.20	59.13
SD		0:05	5.88	13.63
range		9:01–10:06	16–33	31–85
TD	15			
mean		5:03	26.07	60.73
SD		0:07	4.18	12.03
range		4:11–6:08	19–34	40–83

groups, respectively. It will be seen from these values that the autistic and MLD groups have overlapping ranges that contrast with those of the TD group. It will also be seen that the verbal IQs for the autistic and MLD groups are in a lower range than their Raven's IQs. The children in the MLD group were recruited after the data for the autistic group had been collected, and their recruitment was intended to mirror the discrepancy in IQ scores observed for the autistic group.

Materials

The experiment was run using SuperLab Pro 1.74 on an iBook Macintosh computer with a 15-inch colour screen set for high resolution (800×600). Two remote 4 mm push buttons, one red and one black, were mounted 30 cm apart on a flat wooden surface and interfaced with the computer keyboard.

Four different crosshairs were created using the ClarisWorks 4.0 drawing package. Each crosshair portrayed a red horizontal line and a black vertical line bisecting each other. Two of these crosshairs were small, with the two lines measuring 2.6 mm and 4.5 mm (approximately corresponding to 0.2 and 0.4 degrees of visual angle given a viewing distance of 70 cm). For one of these small crosshairs the red horizontal line was the longer of the two lines, whereas for the other crosshair the black vertical line was the longer of the two. Two larger versions of these crosshairs had lines of length 2.7 cm and 4.3 cm (approximately corresponding to 2.1 and 3.5 degrees of visual angle). All lines were 1 mm thick.

A set of 32 high-resolution colour images were taken off the Web for presentation between trials. These images were an assortment of cartoon characters, complex mosaic-like patterns, and brightly coloured vehicles (cars, trucks, trains). They were chosen to map on to the known interests of the participants and were presented between trials in order to help sustain their commitment to the task.

Design and procedure

Each trial involved the successive presentation of two crosshairs located in the centre of the screen, and participants had to respond as quickly as possible to each one in turn. With two different sizes of crosshair, there were four possible size transitions between the two events on each trial, namely, large–large, small–small, large–small, small–large. For each of these trial types there were a further four possible transition types according to which line in each crosshair was longest, namely, vertical–vertical, horizontal–horizontal, vertical–horizontal, horizontal–vertical. These various permutations yielded 16 different trial types and each participant completed two blocks of 16 trials, with the trials in each block presented in a random order determined afresh for each participant.

Each crosshair remained on the screen until the participant pressed one of the two keys to indicate their decision regarding which of the lines was longest. An interstimulus interval (ISI) of 500 ms separated the two crosshairs. The second crosshair was replaced by one of the rich and detailed colour images. This remained on the screen until the participant appeared to be losing interest in it and wanted to proceed with the next trial. The experimenter initiated the next trial by pressing a key on the iBook, whereupon the colour image was replaced by a blank screen for 5 s. At this point the first crosshair of the next trial was presented.

Every participant completed a block of 16 practice trials that were identical to the experimental trials except for the random order of their presentation.

Results

Responses to the first and second crosshairs were analysed separately. In both cases the data were organised with Group as a between-participants factor, and Size, Size Consistency, and Element Consistency as within-participants factors. Group refers to the three populations sampled (i.e., the autistic, MLD, and TD individuals). Size refers to the size of the crosshair being responded to and Size Consistency refers to whether the sizes of the two crosshairs on a trial were the same (small–small, large–large) or different (small–large, large–small). Element Consistency refers to whether it was the same line that was longest in the two crosshairs (vertical–vertical, horizontal–horizontal) or a different line (vertical–horizontal, horizontal–vertical). Because participants had to respond with a different hand according to which line was longest, element consistency involves a repetition of an aspect both of the stimulus and of the response. With regard to responses to the first crosshairs, Size Consistency and Element Consistency were dummy variables since they refer to the nature of crosshairs that had yet to be presented. They were included as factors in the analysis in order to confirm that any effects these two factors had on responses to the second crosshairs were not confounded with differential responding to the first crosshairs.

For every participant, separately for the first and second crosshairs, the number of correct trials (out of 4) and the mean correct RT were determined for each of the 8 ($2 \times 2 \times 2$) conditions created by crossing each of the three within-participants factors. In addition to excluding RTs associated with incorrect responses, RTs below 200 ms or greater than 2.5 SD above the mean correct RT across all trials for a participant were replaced by the participant's average for that condition. In the event, less than 1% of correct RTs were rejected for being either excessively fast or excessively slow. The values for accuracy and speed were submitted to ANOVA and an alpha level of .05 was used for all statistical tests. Data from all three groups were entered into the same ANOVA, which was supplemented by a series of planned comparisons. Results concerning Element Consistency are not reported, partly for the sake of brevity, but also because of the problems of interpretation arising from the fact that this variable incorporates both stimulus and response repetition effects.

Gender, RPCM and BPVS scores as covariates

It has been stated already that there were no significant differences between the three groups of participants in terms of their scores on the RPCM and BPVS tests. Nevertheless, these scores, along with gender, were initially entered as covariates in the ANOVA. It was revealed that collectively the covariates did not have a significant impact on the outcome of the analysis, with values for Rao's R of 1.28 ($p = .21$) and 1.01 ($p = .47$) for the RT and accuracy scores to the first crosshairs, respectively, and 0.74 ($p = .80$) and 1.14 ($p = .32$) for the RT and accuracy scores for the second crosshairs, respectively (all $df = 24, 87$). In light of their insignificance, the covariates were not incorporated in the ANOVAs reported below.

First crosshairs: accuracy

The overall accuracy rates were 91%, 95%, and 95% for the autistic, MLD, and TD groups, respectively. These high rates of accuracy confirm that the task was within the capability of all groups. Table 2 gives the mean number of correct responses to the first crosshair according to its size.

Table 2 The mean number of correct decisions (max. = 4) made by the Autistic, Moderately Learning Disabled (MLD) and Typically Developing (TD) groups to first crosshairs that were small or large (SDs in parentheses)

	Crosshair size	
Group	Small	Large
Autistic	3.71 (0.67)	3.56 (0.80)
MLD	3.80 (0.40)	3.78 (0.42)
TD	3.82 (0.39)	3.77 (0.50)

No main effects or interactions were significant, including the main effect of Group ($F(2, 40) = .90$, $p = .41$). A planned comparison of the autistic group against the MLD and TD groups combined failed to reveal a significant difference ($F(1, 40) = 1.80$, $p = .19$).

First crosshairs: reaction time

Table 3 gives the mean correct RTs to the first crosshair according to its size. No main effects or interactions were significant. The factor closest to being significant was the main effect of Group ($F(2, 40) = 1.61$, $p = .21$). A planned comparison revealed that the autistic group were marginally significantly slower than the MLD and TD groups combined ($F(1, 40) = 3.21, p = .08$).

Second crosshairs: accuracy

The overall accuracy rates were 88%, 94%, and 94% for the autistic, MLD, and TD groups, respectively.

Figure 1 shows the average number of correct decisions made by each group of participants to the second crosshair according to the nature of the size transition between the two crosshairs. The autistic group show the most marked fall in accuracy when the sizes of the two crosshairs changed, although, in line with the predictions, this is evident only for the transition from small to large, and not for the transition from large to small.

With regard to the Group, Size Consistency and Size factors, the only effects that were significant were a main effect of Size ($F(1, 40) = 9.53, p < .004$) and the predicted three-way interaction ($F(2, 40) = 5.27$, $p = .0093$). A series of planned comparisons revealed

Table 3 Mean correct RTs (ms) for the Autistic, Moderately Learning Disabled (MLD) and Typically Developing (TD) groups to first crosshairs that were small or large (SDs in parentheses)

	Crosshair size	
Group	Small	Large
Autistic	2152 (945)	2132 (924)
MLD	1727 (706)	1796 (821)
TD	1784 (533)	1746 (572)

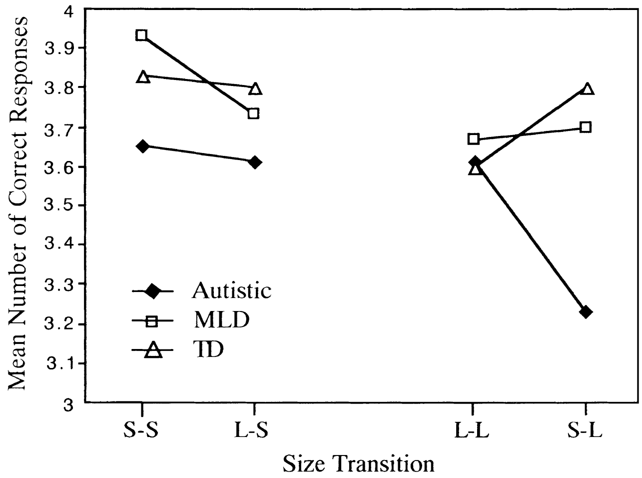

Figure 1 The average number of correct decisions (max. = 4) to the second of two crosshairs made by the Autistic, Moderately Learning Disabled (MLD) and Typically Developing (TD) groups according to the size transition between the crosshairs (L = large and S = small crosshairs)

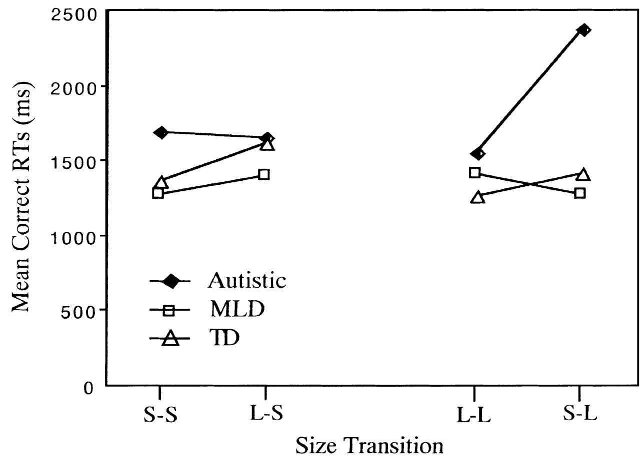

Figure 2 The mean correct RTs to the second of two crosshairs from the Autistic, Moderately Learning Disabled (MLD) and Typically Developing (TD) groups according to the size transition between the crosshairs (L = large and S = small crosshairs)

that this interaction reflected the fact that the nature of the Size Consistency × Size interaction was different for the autistic group than for the MLD and TD groups. Thus, although the Size Consistency × Size interaction was not different when the MLD and TD groups were compared ($F(1, 40) = 0$), it was different when the autistic group was compared against the TD and MLD groups combined ($F(1, 40) = 10.54$, $p < .002$). For the TD group there was no effect of Size Consistency on responses to second crosshairs that were small ($F(1, 40) = .08, p = .77$) or large ($F(1, 40) = 2.76, p = .10$). Similarly, for the MLD group there was no significant effect of Size Consistency on responses to second crosshairs that were small ($F(1, 40) = 3.05, p = .09$) or large ($F(1, 40) = 0.08$, $p = .78$). In contrast, for the autistic group, although there was no significant effect of Size Consistency on responses to small second crosshairs ($F(1, 40) = 0.10, p = .76$), there was a highly significant effect on responses to large second crosshairs ($F(1, 40) = 8.83, p = .005$), indicating that this group were less accurate when the size transition was from small to large compared with large to large.

Second crosshairs: reaction time

Figure 2 shows the mean correct RTs for each of the three groups in response to the different size transitions across the two crosshairs. The pattern of results mirrors that observed with accuracy, with faster responses being observed in those conditions associated with more accurate performance. Interpretation of the results is not complicated, therefore, by the presence of speed–accuracy trade-off. Once again, the most marked effect appears to be the predicted deterioration in the performance of the autistic group when the size transition between the two crosshairs was from small to large.

With regard to the Group, Size Consistency and Size factors, the effects that were significant included the main effects of Group ($F(2, 40) = 4.18, p = .02$) and Size Consistency ($F(1, 40) = 22.43, p < .0001$), and the Group × Size Consistency ($F(2, 40) = 7.61$, $p < .002$) and Group × Size ($F(2, 40) = 8.63$, $p < .001$) interactions. The Group × Size Consistency × Size interaction also was significant ($F(2, 40) = 10.49, p < .0005$). A series of planned comparisons revealed that this three-way interaction reflected the fact that the nature of the Size Consistency × Size interaction was different for the autistic group than for the MLD and TD groups. Thus, although the Size Consistency × Size interaction did not differ when the MLD and TD groups were compared ($F(1, 40) = .31, p = .58$), it did differ when the autistic group was compared with the TD and MLD groups combined ($F(1, 40) = 20.67, p < .00005$). For the TD group there was an effect of Size Consistency on responses to the second crosshair when this was small ($F(1, 40) = 7.31, p = .01$) but not when it was large ($F(1, 40) = 1.22, p = .28$). For the MLD group there was no significant effect of Size Consistency whether the second crosshair was small ($F(1, 40) = 1.63$, $p = .21$) or large ($F(1, 40) = 1.11$, $p = .30$). In contrast, for the autistic group, although there was no significant effect of Size Consistency on responses to second crosshairs that were small ($F(1, 40) = 0.13$, $p = .72$), there was a highly significant effect on responses to second crosshairs that were large ($F(1, 40) = 35.40, p < .00001$), indicating that this group was slower to respond when the size transition was from small to large rather than from large to large.

Discussion

Participants' responses to the first of each pair of crosshairs provided an indication of the default setting for the spread of their visual attention, and the results were clear. There were no significant differences between the three groups of participants and there was no effect of the size of the first crosshair. The absence of any group differences provides valuable confirmation that the three groups of participants were matched in terms of their capacity to make individual crosshair judgements and not just in terms of their scores on Raven's Progressive Colour Matrices test and the British Picture Vocabulary Scale. The absence of any effect of the size of the first crosshair, and more specifically the absence of any evidence that the autistic group were relatively good at responding to a small crosshair, conflicts with recent claims that autism is associated with a relatively narrow attentional spotlight (Townsend & Courchesne, 1994). Furthermore, a closer look at the behavioural evidence behind these claims reveals it to be rather weak.

Townsend and Courchesne (1994) required their participants to press a key when a simple visual stimulus appeared in a currently attended spatial location, but to refrain from responding when the stimulus appeared in a different location. They recorded RTs and visually evoked potentials from the scalp. It was observed that their autistic participants for whom there was evidence of damage to parietal cortex were quicker than normal controls when responding to targets appearing at the attended location (though they do not report the results of a statistical test of this specific difference). In light of other evidence to which they refer (i.e., Townsend, Courchesne et al., 1996), showing that these individuals with autism show a bigger difference in RTs to stimuli at attended compared with unattended locations (referred to as a steeper gradient of attention), Townsend and Courchesne attributed these faster responses to the beneficial effects of having a more spatially focused attentional spotlight. They offered no other behavioural evidence to support their claim that the spread of attention was overfocused in this group of participants and it remains a claim that is only weakly supported by the evidence. There are, for example, other interpretations for the autistic group's faster responding to targets at the attended locations. One possibility is that it reflects heightened sensory processing at the fovea rather than heightened attention. In addition, the other evidence Townsend and Courchesne draw support from is not entirely consistent with their claim. For example, they rely heavily on the results of a study reported by Townsend, Courchesne et al. even though this employed a different visual attention task (see Figure 1 in Townsend & Courchesne). Although Townsend, Courchesne et al. did find that individuals with autism for whom there was evidence of parietal damage showed a bigger RT difference to targets at attended versus unattended spatial locations, this group did not respond more quickly than normal controls to targets at attended locations; instead they responded more slowly. In other words, Townsend, Courchesne et al. had not made the observation that was key to the argument put forward by Townsend and Courchesne for a narrow attentional spotlight, even though they had observed a steeper gradient of attention for this group. Finally, it is important to acknowledge that Townsend and Courchesne's claim is based on evidence from individuals with autism for whom there is also evidence of parietal damage and it is possible that a narrow attentional spotlight is associated with parietal damage rather than with autism. In their own study, and in the study by Townsend, Courchesne et al., individuals with autism for whom there was no evidence of parietal damage responded more slowly than normal controls to targets at an attended location. Townsend, Courchesne et al. also observed that this group had the same gradient of attention as normal controls. Therefore, in addition to the lack of internal consistency in the behavioural evidence for their hypothesis, it seems that a narrow attentional spotlight is to be associated with parietal damage rather than with autism.

Returning to the results of the present study, and to the responses to the second of the two crosshairs, individuals with autism were found to be less accurate and slower to respond to a large second crosshair when this was preceded by a small crosshair. This deficiency emerged in comparison with other types of size transition and in comparison with the two control groups. Given that they performed relatively well for all other transition types, it seems that the individuals with autism did not have a general deficit in controlling the spread of their attention or a problem dealing with large stimuli in general. Rather, they had a specific problem dealing with the transition from small to large. In this way the present results support the suggestion that autism is associated with a deficit in broadening the spread of visual attention. Evidence for such a deficit is equally apparent whether the behaviour of the autistic group is contrasted with the behaviour of the typically developing group or with the behaviour of the moderately learning disabled group. The latter two groups displayed a similar pattern of performance to each other, confirming that the distinctive behaviour of the autistic group reflected their autism and not any learning disabilities accompanying this.

A deficiency in broadening the spread of attention could explain why autism might sometimes appear to be associated with an overfocused attentional spotlight. Even if people with autism are not initially overfocused when exposed to a visual stimulus, once they focus on a localised feature they will then find it difficult to zoom out. Hence, whereas typically developing individuals might well be capable of zooming out to switch their attention to the more global aspects of a stimulus, autistic individuals would do this less quickly and less often. The end result would be that they remain focused for a greater proportion of time than is observed with typically developing individuals. The reason such overfocusing was not observed in the responses to the first crosshairs in the present study could hinge on the fact that these crosshairs were preceded by a blank computer screen. Hence, there were no small-scale visual features on which they could zoom in and focus their attention. Perhaps they were zoomed out to a degree that allowed them to attend to the computer screen as a whole and then were as adept as the other groups at zooming in to respond to the large and small crosshairs.

Reference has been made already to claims that individuals with autism experience difficulties disengaging from a currently attended stimulus (Casey et al., 1993; Townsend, Courchesne et al., 1996; Wainwright-Sharp & Bryson, 1993) and then redirecting attention, and that the slowness with which attention is redirected is associated with the extent of cerebellar abnormality (Harris et al., 1999; Townsend et al., 1999; Townsend, Courchesne et al., 1996; Townsend, Harris et al., 1996). These different aspects of the control of visual attention are likely to be interdependent, and there is already evidence that the brain mechanisms subserving them are themselves interdependent (see Allen & Courchesne, 2001). It is possible to envisage how broadening the attentional spotlight might be linked to the disengagement and shifting of attention. As part of the process of redirecting visual attention to a different object the spread of attention might need to be broadened, perhaps sufficiently to embrace the new target. Hence, problems broadening the spread of attention could be reflected in difficulties redirecting attention towards a target in the periphery. Clearly, further work is needed to determine how these various aspects of visual attentional control are linked and whether their interdependence is responsible for the constellation of visual attentional deficits observed in autism.

A deficit in broadening the spatial spread of visual attention could also explain some key aspects of the atypical visual behaviour seen in autism. In particular, it is consistent with the superior performance of individuals with autism on the Embedded Figures Task (Shah & Frith, 1983; Jolliffe & Baron-Cohen, 1997) and the Block Design subtest of the Wechsler intelligence scales (e.g., Shah & Frith, 1993). It is also consistent with their tendency to draw the local elements of a line drawing at an early phase in their copying and with their relative insensitivity to the global structural impossibility of the depicted object (Mottron et al., 1999). In all of these cases the tendency to be overfocused that results from difficulties zooming out would explain the reduced impact of the global aspects of a stimulus. This is a different explanation from weak central coherence because it does not deny that individuals with autism have the capacity to integrate local elements to derive a global form, only that they find it difficult to do so when this requires the spread of attention to be broadened. We have already seen from the selective attention condition of Plaisted et al.'s (1999) study that when the spread of attention does not need to change within a block of trials (and, ipso facto, does not need to change within a trial) individuals with autism behave like normal participants and show the standard global advantage and global interference effects in the Navon task. As Plaisted et al. themselves point out, Weak Central Coherence Theory cannot easily explain their results because with selective attention instructions individuals with autism show the same capability as normal controls to integrate local elements to derive a global form. With regard to their divided attention condition, Plaisted et al. propose that the distinctive behaviour of their autistic participants reflected abnormally high levels of activity in visual channels encoding local features which, in the absence of instructions to prepare for a global target (which they argue would dampen the activity in these channels), would distract them from responding to global forms. We have already indicated in the introduction how a deficit in broadening the spread of attention provides an alternative explanation for Plaisted et al.'s results.[3]

Finally, in an article published after the current study was completed,[4] Rinehart, Bradshaw, Moss, Brereton, and Tonge (2001) examined stimulus transition effects across successive compound stimuli (large digits made up from small digits). They found that high-functioning individuals with autism responded more slowly to a global target that was immediately preceded by a local target, than to a local target that was preceded by a global target. This differential transition effect was not observed in a control group. When describing their results Rinehart et al. focus on the distinction between the status of local and global forms in a hierarchical stimulus rather than on the difference in the spatial extent of these forms. In providing an explanatory framework for the difficulty experienced by the autistic group in shifting between

[3] We are grateful to Kate Plaisted for pointing out that proposing a deficit in broadening the spatial extent of visual attention provides an alternative explanation of Plaisted et al.'s (1999) results.

[4] We are grateful to an anonymous reviewer for drawing our attention to this recent article.

local and global forms, they suggest that it reflects a more general deficit in shifting attentional set. However, they do not make clear why this should be restricted to local–global transitions.[5] If we think about the spatial extent of their local and global forms, instead of the nature of these forms, then the specificity of the transition effect observed by Rinehart et al. is entirely consistent with our findings and with the hypothesis that individuals with autism show a selective deficit in broadening the spread of visual attention. Whether such a deficit is an instance of a more general, possibly executive dysfunction, such as an inability to disengage from an object of attention, remains to be determined.

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[5] In Figure 2 of their paper Rinehart et al. (2001) provide information about the mean RTs associated with local–global and global–local transitions. In a personal communication, Nicole Rinehart has kindly provided information about the mean RTs for the other two transition types and these confirm that the autistic group had a problem that was restricted to local–global transitions. The mean RTs for local–local and global–global transitions were 983 and 990 ms, respectively, for the control group, and 1211 and 1227 ms, respectively, for the autistic group. For the control group these values appear very similar to those associated with the two types of transition involving a change in the level of the target (i.e., local–global and global–local transitions). For the autistic group these values are very similar to the mean RT for global–local transitions but faster than the mean RT for local–global transitions. Thus, it is the local–global transition that is exceptional for this group, yielding a mean RT that is slower than the mean RTs for the other three transition types (which do not differ from each other). This pattern of mean RTs for the autistic group confirms that they did not experience difficulty with both types of change in target level (i.e., local–global and global–local transitions), but only with local–global transitions.

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