

Locally oriented perception with intact global processing among adolescents with high-functioning autism: evidence from multiple paradigms

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Background: According to predictions from the Weak Central Coherence (WCC) theory for perceptual processing, persons with autism should display a tendency to focus on minute details rather than on a more general picture (Frith & Happé, 1994). However, the evidence for this theory is not consistent with findings of an enhanced detection of local targets (Plaisted, O'Riordan, & Baron-Cohen, 1998b; Plaisted, Swettenham, & Rees, 1999), but a typical global bias (Mottron, Burack, Stauder, & Robaey, 1999; Ozonoff, Strayer, McMahon, & Filloux, 1994). **Method:** Adolescents with high-functioning autism and CA- (approximately 15 years) and IQ- (approximately 105–110) matched typically developing adolescents were administered a series of global–local visual tasks, including a traditional task of hierarchical processing, three tasks of configural processing, and a disembedding task that involved rapid perceptual processing. **Results:** No group differences were found on either the traditional task of hierarchical processing or on tasks of configural processing. However, group differences were found on the disembedding task as the search for embedded, in relation to isolated stimuli, was slower for the typically developing adolescents but similar for the participants with autism. **Conclusions:** These findings are consistent with other reports of superior performance in detecting embedded figures (Jolliffe & Baron-Cohen, 1997; Shah & Frith, 1983), but typical performance in global and configural processing (Mottron, Burack et al., 1999; Ozonoff et al., 1994) among persons with high-functioning autism. Thus, the notions of local bias and global impairment that are part of WCC may need to be reexamined. **Key-words:** Asperger's disorder, autistic disorder, neuropsychology, perception, visuo-spatial functioning.

The WCC theory (Frith, 1989; Frith & Happé, 1994; Happé, 1999) was developed to account for anecdotal and clinical evidence that persons with autism focused on the details in a scene rather than on the larger context and gist in the environment. According to this framework, details are perceived and retained at the expense of global or contextual understanding. This is consistent with evidence that persons with autism display relatively enhanced performance on embedded figures tasks (Jolliffe & Baron-Cohen, 1997; Shah & Frith, 1983), the Block Design component of the Wechsler IQ tests (Shah & Frith, 1993; Tymchuk, Simmons, & Neafsey, 1977), and in copying impossible figures (Mottron, Belleville, & Ménard, 1999). One research approach that is in keeping with this account of autism entails the use of experimental tasks that involve hierarchical stimuli (e.g., large shapes or letters composed of smaller shapes or letters) to probe the perceptual processes associated with seeing the details versus the larger configuration. Global processing measures on these tasks are thus viewed as an index of central coherence, whereas local processing measures are seen as antithetical to efficient coherent processing. The evidence from these tasks is mixed as persons

with autism show the expected enhanced local processing or impaired global processing under certain conditions (Plaisted et al., 1999, experiment 2; Rinehart, Bradshaw, Moss, Brereton, & Tonge, 2000), but not under others (e.g., Mottron, Burack et al., 1999; Ozonoff et al., 1994; Plaisted et al., 1999, experiment 1). These inconsistent findings suggest that the constructs of global and local processing may not map as directly onto the WCC theory as researchers initially assumed.

In the present study, we examined global and local visual processing in persons with autism in several different ways in order to identify those features of global and local processing that apply. Accordingly, we compared performance on a traditional *hierarchical letter detection* task, several *configural grouping* tasks, and a *disembedding* task. In the traditional hierarchical task, visual targets can appear unpredictably at either the local or the global level; in the configural tasks, visual targets can only be detected after local features have been combined into a larger gestalt (Mottron, Burack et al., 1999); and, in the disembedding task, visual targets can only be detected by ignoring larger configurations which are formally task-irrelevant but are processed

involuntarily by typical participants (Jolliffe & Baron-Cohen, 1997). These tasks differ in several ways from one another with regard to processing. Whereas classic hierarchical letter detection requires skill in dividing or switching attention between levels for optimal performance, the configural grouping tasks require that participants ignore display elements at the local level in order to see the target at the global level, and the disembedding task requires that participants ignore larger configurations in order to see targets at the local level.

The performances of high-functioning adolescents with autism and typically developing participants matched on age, gender, and IQ were compared on all of the tasks. Weak Central Coherence theory provided conflicting notions for a priori predictions with regard to which of these global-local tasks should reveal the greatest differences in performance between typically developing persons and those with autism. If persons with autism are simply impaired in the ability to form mental representations of the global level of structure, as the original description of the theory implies (Frith, 1989; Frith & Happé, 1994), then the group of persons should show impairments in detecting global targets in both the hierarchical letter detection tasks and the configural grouping tasks. Disembedding performance should be enhanced for persons with autism because of their insensitivity to the global level of structure. However, several other patterns of possible results would prompt a reconsideration of this 'strong' version of the WCC theory. For example, persons with autism may simply exhibit a built-in preference or bias for the local level of structure, with no deficit in processing the global level. In this case, group differences would be expected only in the hierarchical letter detection task, in which targets are equally likely at both levels and so their preference would reveal itself in relatively better local target detection. Finally, the 'local bias' in autism may be one in which persons with autism are better able than typically developing persons to ignore task-irrelevant global information. In this case, the groups would not be expected to differ on the hierarchical letter detection task, in which targets at both levels are always relevant. They would also not differ in the configural grouping tasks, in which the global level alone is task relevant. In this scenario, they would differ only on the disembedding task as the persons with autism should be better able than typically developing persons to ignore the global level of structure.

The primary issue in the design of this study of different forms of global-local processing was the comparison of the performance on tasks with quite similar visual characteristics but widely varying processing demands. This would provide the best opportunity to examine the extent to which aspects of global-local processing differ among high-functioning adolescents with autism and appropriate comparison groups of peers.

Hierarchical letter task

In the classic hierarchical letter detection task, the participant is asked to indicate whether one or the other of two target letters is present in a display that consists of a compound letter (a large letter made up of smaller letters). The appearance of the target at the global (large letter) or the local (small letter) level in any display is not predictable, so that optimal performance is dependent on the preparation to detect letters at either level in each display. One of the most robust findings of this task is that the level of target detection that is most efficient depends on the overall visual angle of the compound letter (Kinchla & Wolfe, 1979; Lamb & Robertson, 1990). Global target letters are detected most quickly and accurately when the visual angle is relatively small, and local target letters are best detected when the visual angle is large. In this study, we tested letters at three visual angles in order to identify any differences in global and local processing that could be associated with autism.

Configural grouping tasks

In each task in this part of the study, participants were required to combine details into larger configurations.

Fragmented letter task. If persons with autism are less efficient in forming representations of larger configurations or are more likely to focus on elementary display fragments, the identification of letters that are formed with connected lines and uniform brightness should be easier than the identification of the same letters formed from fragments of shapes.

Silhouette identification task. Pictures of common objects are easier to identify in the form of line drawings than in the form of silhouettes (Humphreys & Riddoch, 1987). If autism is associated with an excessive focus on detail, then removal of this detail in the silhouette condition might actually benefit the picture identification of those with autism. Alternatively, if persons with autism represent objects primarily in terms of their features, then removing much of this detail in a silhouette drawing will actually impair their ability to identify these pictures.

Long- and short-range grouping task. Visual grouping at the local and global level can be assessed by detection of targets in a visual search task that involves grouping elements across either a short distance or a long one (Enns & Kingstone, 1995). By selectively increasing the difficulty of grouping at one of these levels but not the other, grouping efficiency can be assessed in a way that is not confounded by general differences in task difficulty (Burack, Enns, Iarocci, & Randolph, 2000). The visual search data

from typically developing children and adults indicates that long-range grouping is more difficult and develops later in life than short-range grouping (Burack et al., 2000). Specific difficulties with grouping at the global level among persons with autism should be revealed in this kind of search task.

Disembedding task

If individuals with autism are likely to ignore the global configuration in a display, especially when it is irrelevant to the task at hand, then they may show improved performance in the embedded condition relative to typically developing persons. In contrast, typically developing persons are better able to identify a letter when it is presented in isolation than when it is embedded within the context of a larger, task-irrelevant configuration, even when the larger configuration is made up of multiple versions of the same letter.

Method

Participants

Twelve high-functioning children and adolescents with autism and 12 typically functioning children and adolescents were tested on each task, except for the grouping task in which only 10 typically developing children were included. The participants in both groups were generally the same across all the tasks, and were matched for each task on manual laterality (Oldfield, 1971), gender, CA, and IQ (Wechsler Intelligence Scale for Children or the Wechsler Adult Intelligence Scale-Revised).

For the hierarchical letter detection task, the segmentation task, and the disembedding task, the age range for the participants with autism (11 male) was 10 to 21 years (mean = 15.75 years, SD = 3.77) and for those without autism (11 male) it was 11 to 21 years (mean = 15.17 years, SD = 3.54). The mean IQ for the participants with autism was 109.83 (SD = 8.49) and for the typically developing persons was 107.5 (SD = 9.13). On the silhouette task, the age range for the individuals with autism (12 males) was 9 to 22 years (mean = 14.92 years, SD = 3.82) and for the typically developing persons (12 males) it was 11 to 19 years (mean = 15.33 years, SD = 2.71). The mean IQ for the participants with autism was 109.58 (SD = 14.67) and for the typically developing persons it was 107.92 (SD = 9.71). In the long- and short-range grouping task, the age range for the children and adolescents with autism was 10 to 22 years (mean = 16.08, SD = 3.4) and for those without autism it was 11 to 19 years (mean = 15.42, SD = 2.7). The mean Full Scale IQ for the individuals with autism was 109.58 (SD = 8.8) and for the typically developing persons it was 105.42 (SD = 11.2).

The children and adolescents with autism met the criteria for diagnoses based on the ADI (Autism Diagnosis Interview) or the ADI-R (Autism Diagnosis Interview-Revised; Lord et al., 1989; Lord, Rutter, & Le Couteur, 1994; Lord, Storoschuck, Rutter, & Pickles

1993). The ADI interviews were administered by a trained clinician with a .90 reliability concordance with the scales' trainers. The diagnoses based on the ADI-R were consistent with subsequent diagnoses based on the ADOS-G, module 3 or 4 (Lord, Rutter, & Di Lavore, 1997). All of the adolescents with autism were able to communicate verbally, and to read and write. At the time of testing, none of the participants were taking medication or showed signs of gross neurological or medical abnormalities. All participants displayed normal or corrected-to-normal vision.

General procedure

For the hierarchization, segmentation, disembedding, and silhouette tasks, the stimuli were presented with the Instep* program on a SVGA monitor connected to a Pentium 100 computer with 2 response buttons in a room in which the level of illumination was controlled. The distance between the subjects' eyes and the screen was 1 meter. A chin rest and chair height adjustment were used to ensure that the eye level of each subject was at the midpoint of the screen. In these tasks, the stimuli were presented for 200 ms with inter-stimulus intervals that varied randomly from 2200 to 2500 ms. Random intervals were used to prevent a response routine that might lead to false alarms. For these tasks, the criterion for exclusion of a participant from any given task was the rejection of more than 25% of the responses within any condition due to incorrect responding, failure to respond, RTs less than 200 ms, or RTs more than 2 standard deviations above the mean.

For the grouping task, a Macintosh computer, running VScope software (Enns & Rensink, 1991), was used to generate the displays and collect the data.

Hierarchical letter task

The stimuli were similar to those used by Lamb, Robertson, and Knight (1990) and consisted of computer-generated white block-letter global patterns of H, S, A, and E formed from smaller local patterns of the same letters, all presented on a black background. The global letters were made up of local letters within a rectangular 5 × 5 matrix with a height to width ratio of 1.58 to 1. Three different sizes of stimuli were used in order to correspond to three distinct visual angles. The smallest stimuli subtended visual angles of 1.37 × 2.17 degrees for global letters and .28 × .45 degrees for local letters, the intermediate stimuli subtended visual angles of 2.74 × 4.34 degrees for global letters and .51 × .91 degrees for local letters, and the largest stimuli subtended visual angles of 5.48 × 8.64 degrees for global letters and 1.03 × 1.60 degrees for local letters. Examples of the stimuli are presented in Figures 1a and 1b.

In the stimulus presentations, the letters H and S were the target letters, and A and E were the distracter letters. Each stimulus presentation consisted of one target and one distracter letter for a total of four stimulus conditions; global H–local A, global S–local E, global A–local H, global E–local S. A block of 80 trials, with 20 trials of each of the 4 stimulus conditions, was presented for each of the 3 visual angle sizes. The order of presentation of stimulus displays was determined by a randomization procedure that included a check to

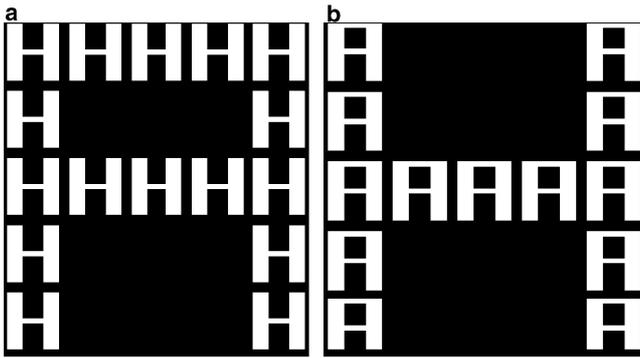


Figure 1 Example of hierarchical stimuli used in visual angles task (1a: local target and 1b: global target)

ensure that the same display did not appear in two consecutive trials. This order of presentation was the same for all subjects, but the order of blocks was counterbalanced across participants.

The participants were initially presented with a printout of the four stimuli and were asked to describe the stimuli. They were corrected until they succeeded (e.g., ‘An A made of H’s’ or ‘H’s forming an A’), and the task was administered after 10 successive correct responses. The participants were told to press one response button when an H appeared on the screen and another when an S appeared (i.e., left button for H and right button for S or right button for H and left button for S). They were informed that only one of the targets could appear at one time, and one would appear in every trial. The left or right response for H and S was counterbalanced across participants, but was the same across blocks for each participant.

Configural grouping tasks

Fragmented letter task. The stimuli were H’s and S’s that were presented in the middle of the screen with intact or segmented lines. The letters subtended visual angles of 8.64 × 5.48 degrees. The 4 conditions included intact line H, intact line S, segmented line H, and segmented line S. Examples of the stimuli are presented in Figures 2a and 2b. The number of stimuli in each condition, the order of presentation, the sequence of the presentation of the stimuli, the training trials, the in-

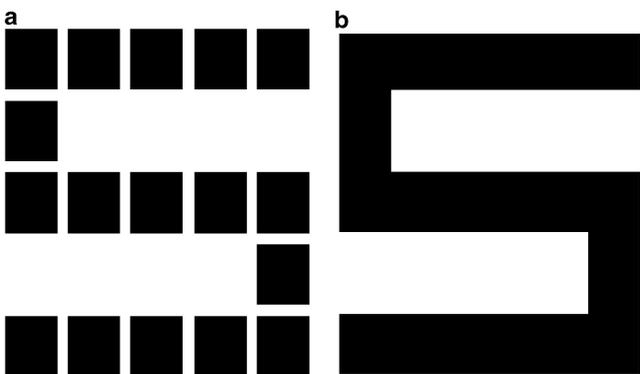


Figure 2 Example of stimuli used in fragmented letter task (2a: fragmented target and 2b: plain target)

structions, and the positioning of the response buttons were all the same as in the hierarchical letter task.

Silhouette identification task. This task was based on Humphreys and Riddoch’s (1987) silhouette task, and involved 24 black and white line drawings that were initially selected from Snodgrass and Wandervart’s (1980) drawings. Twelve were drawings of real objects (e.g., boat) and the other twelve were non-objects made up of parts of two real objects (e.g., a pistol with a trumpet as the barrel) that were recognizable either from their internal features or from their outline. Twenty-four silhouette figures were created by darkening the internal features of each of the line drawings. The stimuli were divided into two sets (A and B) of 12 real objects and 12 non-objects. Thus, Set A included 12 line drawings and their corresponding silhouettes, and Set B included the remaining 12 drawings and their corresponding silhouettes. For each real object, a chimera was included in the other set. For example, if a boat was included as a real object in set A, a boat with an airplane propeller was included as a chimera in Set B. A pretest analysis revealed that the two sets were similar with regard to level of difficulty for identifying the object. Examples of the stimuli are depicted in Figures 3a, 3b, 3c, and 3d.

The line drawings from Set A and the silhouettes from Set B were tested in a single session with a one-week interval between the second testing in which the line drawings of Set B were presented with the silhouettes of Set A. This ensured that subjects would not see the silhouette and drawing versions of the same stimulus in the same condition. The stimuli in each session were individually presented on a computer screen, in a random order at a rate of one item per 2200 to 2500 ms. The participants were asked to determine as quickly as possible whether each figure was a real object or not by pressing the appropriate button for either object or non-object.

Long- and short-range grouping task. Participants were required to detect a target item with an oblique orientation among 1, 7, or 13 other vertically oriented items. Targets could be one of three types: long range, short range, or dual. A target item was present in each display, and the participants’ task was simply to indi-

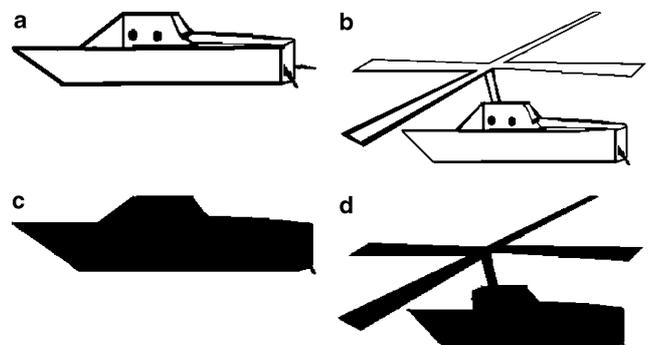


Figure 3 Example of line-drawing and silhouette stimuli used in the silhouette task (a: line-drawing, possible, 3b: line-drawing, impossible, 3c: silhouette, possible, and 3d: silhouette, impossible)

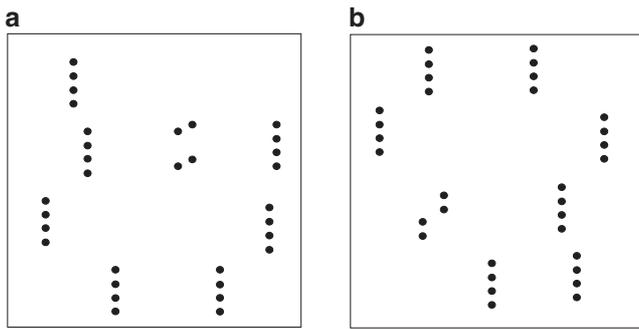


Figure 4 Example of stimuli used in the control condition of the long- and short-range grouping task (4a: long-range and 4b: short-range)

cate with a corresponding key press whether it was present on the left or the right side of the display. Targets were equally distributed on the right and left side of the computer screen.

Each potential search item consisted of four dots. Dot patterns in close spatial proximity to each other were referred to as short range, whereas dot patterns over a greater spatial distance were referred to as long range. Distracters were composed of four dots arrayed in a vertical column. In the Control condition, all dots were drawn in black on a medium gray background (every other pixel was black). In the Local Salient condition, the dots within each pair were of the same contrast (black or white), but the two pairs were opposite in contrast. In the Global Salient condition, the dots within each pair were opposite in contrast (white versus black) to one another. Examples of the visual items used in the displays are shown in Figures 4a and 4b.

The visual angle for each item subtended 1.25 degrees in overall extent, with each individual dot subtending .20 degrees, making the center-to-center distances between dots .30 degrees for short-range items and .75 degrees for long-range items. On each trial, 2, 8, or 14 visual items were distributed randomly on an imaginary 6 × 4 grid subtending 21 × 14 degrees.

Participants were administered 3 sets of 40 experimental trials in each of the 3 conditions (control, local salient, global salient) in counterbalanced order. A set of 10 practice trials preceded each condition in order to ensure that participants understood all aspects of the task. These were repeated if necessary. All conditions were completed for each participant within a single testing session lasting approximately 1 hour, including short breaks between blocks. Each trial began with a fixation symbol that was presented for 500 ms, followed by the search display, which remained visible until the participant responded. A key press was followed by a feedback symbol (+ for a correct response, - for an incorrect response or 0 for no response) that served as the fixation point for the next trial.

Disembedding task

The stimuli were letters H or S that were presented in the middle of the screen either individually or as a pattern of the same letter (all ‘H’s or ‘S’s) that formed a ‘digital 8’. The letters subtended visual angles of

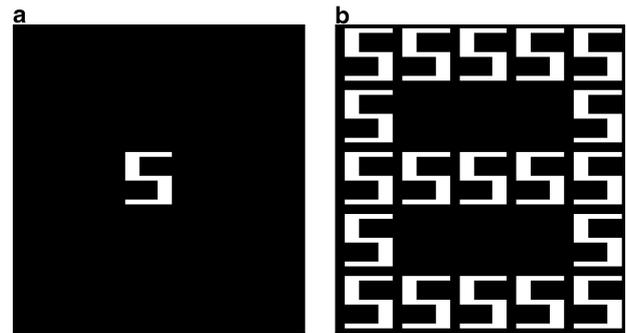


Figure 5 Example of stimuli used in the isolated and embedded task (5a: isolated and 5b: embedded)

1.60 × 1.03 degrees. The number 8 subtended visual angles of 8.64 × 5.48 degrees. The visual items used in the displays are shown in Figures 5a and 5b.

The 4 conditions included H alone, S alone, H in pattern, and S in pattern. The number of stimuli in each condition, the order of presentation, the sequence of the presentation of the stimuli, the training trials, the instructions, and the positioning of the response buttons were all the same as in the hierarchical letter task.

Results

For all tasks, the dependent variables were reaction times (RT) and errors. The RT analyses were based on the means of correct responses. However, responses less than 200 ms or longer than 2 SD above the mean for each participant’s responses (by subject) were eliminated from the analyses. The mean correct RTs for the visual angles task are presented in Table 1, for the segmentation task in Table 2, for the silhouette tasks in Table 3, for the grouping task in Table 4, and for the disembedding task in Table 5. Only analyses on RT will be reported here, as error analyses did not reveal any differences between the groups.

Table 1 Mean correct RT in ms for hierarchical letter detection task

	Local	Global	Difference
Persons with autism			
Small	652	624	+28 faster for global
Medium	603	613	-10 faster for local
Large	602	627	-25 faster for local
Typical subjects			
Small	560	564	-4 faster for local
Medium	562	584	-12 faster for local
Large	565	575	-10 faster for local

Table 2 Mean correct RT in ms for fragmented letter task

	Connected	Fragmented	Difference
Persons with autism	521	530	+9 slower for fragment
Typical subjects	489	494	+5 slower for fragment

Table 3 Mean correct RT in ms for silhouette identification task

	Line	Silhouette	Difference
Persons with autism			
Real	1045	1046	+1 slower for silhouette
Chimera	984	1137	+153 slower for silhouette
Typical subjects			
Real	893	958	+65 slower for silhouette
Chimera	950	1087	+137 slower for silhouette

Table 4 Mean RT slopes in ms/item for long- and short-range grouping task

	Local	Global	Difference
Persons with autism			
Control	5.4	6.8	1.4 ms/item faster on local
Global salient	47.1	20.6	26.6 ms/item faster on global
Local salient	8.6	28.1	19.6 ms/item faster on local
Typical subjects			
Control	1.3	5.2	3.9 ms/item faster on local
Local salient	53.6	22.0	31.6 ms/item faster on global
Global salient	5.5	31.1	25.6 ms/item faster on local

Table 5 Mean correct RT in ms for disembedding task

	Isolated	Embedded	Difference
Persons with autism	575	585	+10 slower for embedded
Typical subjects	513	550	+37 slower for embedded

Hierarchical letter task

A Group (with autism, without autism) × Level (local and global) × Visual Angle (large, medium, small) repeated measures ANOVA with RT as the dependent variable only revealed an interaction of Level × Visual Angle, $F(2, 44) = 3.33, p < .05$. This reflects faster responding to global targets with the small visual angle and to local targets with the large visual angle.

Configural grouping tasks

Fragmented letter task. A Group (with autism, without autism) × Condition (intact line, segmented line) repeated measures ANOVA with RT as the dependent variable revealed neither main effects nor interactions.

Silhouette identification task. A Group (with autism, without autism) × Condition (line drawing, silhouette) repeated measures ANOVA with RT as the dependent variable revealed neither main effects nor interactions.

Long- and short-range grouping task. The mean correct RTs for the two participant groups are shown

in Table 4. The goodness of fit for linear functions across display size was high for the 18 combinations of Group, Target Type and Level Saliency (mean $r^2 = .78$). Accordingly, the data analyses were conducted separately on RT slope (i.e., ms per item) and baseline RT (i.e., y-intercept in ms) of these linear functions. The accuracy data were analysed in the same way.

For the analysis of RT slope, a mixed ANOVA with Group (with autism, without autism), and the within-subject factors of Target Type (local, global, dual) and Level Saliency (control, local-salient, global-salient) revealed main effects of Target Type, $F(2, 40) = 38.73, p < .01$, and Level Saliency, $F(2, 40) = 43.23, p < .01$, as well as a two-way interaction of Target Type × Level Saliency, $F(4, 80) = 43.21, p < .01$. Simple effects tests of the Target Type × Level Saliency interaction indicated that RT slopes in the global-salient condition were larger for local targets (49 ms per item) than for global targets (20 ms per item), $F(1, 80) = 90.25, p < .01$, and that RT slopes in the local-salient condition were larger for global targets (30 ms per item) than for local targets (7 ms per item), $F(1, 80) = 54.68, p < .01$. In the control condition, RT slopes for local and global targets did not differ significantly from one another. These comparisons confirmed that the experimental manipulations had the intended effects on search performance.

For the analysis of baseline RT, a mixed ANOVA with the same factors revealed main effects of Target Type, $F(2, 40) = 31.38, p < .01$, and Level Saliency, $F(2, 40) = 7.43, p < .05$, and a Target Type × Level Saliency interaction, $F(4, 80) = 23.19, p < .01$.

For response accuracy, mixed ANOVAs with the same factors as the RT analyses also revealed main effects of Target Type, $F(2, 40) = 4.11, p < .05$, Level Saliency, $F(2, 40) = 16.33, p < .01$, and a Target Type × Level Saliency interaction, $F(4, 80) = 11.23, p < .01$. The directions of these effects were identical to the RT analyses. In none of these analyses were there significant effects involving group.

Disembedding task

The data on this task were not normally distributed and were, therefore, not amenable to an ANOVA. Therefore, non-parametric analyses were used here. A Wilcoxon signed ranks two-tailed test revealed an effect of embedding for the typically developing participants, Asymp Sig. (2-tailed) (z) = .028, but not for the participants with autism, Asymp Sig. (2-tailed) (z) = .638.

Discussion

We administered a series of global-local tasks, including a traditional task of hierarchical letter

detection, three tasks of configural grouping, and one of disembedding in order to address differences in findings across studies of global–local processing among high-functioning persons with autism. The primary finding was that participants with autism displayed similar RTs in identifying embedded as compared to isolated stimuli on a search task for letters embedded in a larger task-irrelevant configuration, whereas the typically developing adolescents were slower in the identification of embedded figures. Group differences were not found on the other tasks, including a traditional task of hierarchical processing, or on those of configural processing. This is inconsistent with the common assumption that persons with autism display a tendency to focus on minute details rather than on a more general picture (Frith & Happé, 1994) and with earlier findings of a global bias among high-functioning persons with autism (Mottron, Burack et al., 1999).

On the traditional task of hierarchical processing, both groups showed the common patterns of local bias with larger letters and global bias with smaller letters. Concordantly, performance on the configural tasks was similar with regard to the detection of intact and segmented letters, identification of line drawings or silhouettes as either objects or non-objects, and grouping stimuli over varying spatial distances that correspond to global and local levels of processing. Thus, the findings are consistent with some predictions of the global–local version of WCC, especially that processing may be locally biased (Happé, 1999). However, this local bias is not necessarily a consequence of, or even associated with, a global processing deficit.

Positive findings from the disembedding task

The finding of group differences on the disembedding task is consistent with other examples of relatively superior performance in detecting embedded figures among persons with autism (Jolliffe & Baron-Cohen, 1997; Shah & Frith, 1983). These tasks are all similar as they involve a global level that is task-irrelevant. For example, in the disembedding task, participants did not need to consider the global ‘digital 8’ that was formed by the grouping of the target stimuli since this 8-configuration was never used as a target to be detected in that task. This is similar to the classic embedded figures task, in which participants do not formally need to attend to the drawing of, for example, the baby carriage in which triangles are embedded (Witkin, Oltman, Raskin, & Karp, 1971). The lack of formal task-relevance of the global stimuli in these embedded tasks distinguishes them from the classic hierarchical processing task in which the identities of the global stimuli (often letters) are the same as those used as local stimuli (also letters). However, the evidence from this study also extends the findings from the

other embedded tasks since our task involves a timescale on the order of hundreds of milliseconds, whereas the tasks used in the other studies involved response duration of more than 10 seconds. This consistency in the findings between earlier disembedding tasks and the one tested in this study points to the robustness of the effect. Successful disembedding, when it involves the filtering of recognizable stimuli that are momentarily task-irrelevant, seems to be evident among persons with autism in tasks of both early perceptual and later cognitive processes.

Negative findings from the classic hierarchical and configural tasks

The findings from the classic hierarchical and configural tasks reflect another failure to elicit behavioral manifestations of WCC with experimental paradigms of global–local processing (Mottron, Burack et al., 1999; Ozonoff et al., 1994). They are also inconsistent with Rinehart et al.’s (2000) evidence of impaired global processing across levels of congruency among children and adolescents with autism on a selective attention task, but consistent with their findings of typical global advantage in global tasks and typical global interference in local tasks. The findings presented here are also consistent with Plaisted et al.’s (1999) evidence of intact processing on a selective attention task, but not with the finding of a local bias on a divided attention task. The failure to replicate Plaisted et al.’s (1999) finding of group difference on a divided attention task with our grouping task that also involves divided attention may be due to differences in the paradigms. Plaisted et al.’s (1999) task involves identifying the presence versus absence of a designated target, whereas our grouping paradigm requires discrimination based on location of the target on the left or right side of the display. Another source of difference may be that Plaisted et al.’s (1999) task places greater demands on so-called ventral stream processing (the ‘what’ visual system of conscious perception), whereas the present grouping task could be completed using the less consciously accessible dorsal visual stream (the ‘where’ system) (Goodale & Milner, 1992). This might suggest that visual tasks that are more demanding of the ventral stream because they require conscious stimulus identification would be most likely to reveal differences between persons with autism and other populations.

Caution is always warranted in the interpretation of results that reveal no differences among participant groups, since studies are usually designed to minimize the likelihood of concluding a false positive rather than minimizing the likelihood of missing an effect. Perhaps our tasks were simply too insensitive to measure the underlying differences. Several features of the present study, however, indicate that the finding of no differences may be meaningful. One,

each task was designed to be able to index a certain kind of performance, such as faster RT to global targets for stimuli with small visual angles and faster RT to local targets for stimuli with large visual angles. In the long- and short-range grouping tasks, the expected patterns of RT were also found (Burack et al., 2000). The finding of these expected effects indicates that the tasks were able to index the appropriate processes in both groups of participants and that any group differences in these processes would have been detected. Two, group differences were found in the disembedding task in the same context and with virtually the same participant populations as the other tasks. This highlights the need for an interpretation of these group differences that takes into account the subtle task differences between the classic hierarchical and disembedding tasks. One explanation is that the primary difference between the global level of structure that led to response interference among the persons with autism (hierarchical and grouping tasks) and the global level of structure that did not (disembedding task) was that the global level of structure was formally task-irrelevant only in the latter task. Thus, persons with autism appear to be better able than others to ignore some features of the visual array that are unrelated to the task.

Finally, two of our tasks, the silhouette and segmentation tasks, may be insufficiently sensitive to elicit differences among conditions. For example, no differences in performance were found between the silhouette and the line drawing conditions on the silhouette task among typically developing persons, even though the task was useful in observing faster object-decisions on silhouette drawings by H.G.A., a 65-year-old agnosic patient (Humphreys & Riddoch, 1987). Similarly, the failure to find differences in performance across the various conditions of these tasks may be due to either the ease of the tasks, which results in ceiling levels of performance that mask potential differences (O'Riordan & Plaisted, 2001), or to task manipulations that were not sufficiently sensitive to differentiate among levels of ability.

Weak central coherence and hierarchical processing

The findings suggest possible constraints on interpretations of WCC theory, especially with regard to hierarchical processing. Initially, the construct of 'coherence' within the WCC theory was equated with the global processing of visual and auditory stimuli in hierarchical paradigms (Mottron, Burack et al., 1999; Mottron, Peretz, & Ménard, 2000; Ozonoff et al., 1994; Plaisted et al., 1999). However, the failure to find differences between high-functioning adolescents and their typically developing peers on several, though not all, commonly used measures of hierarchical processing suggests that this aspect of WCC theory does not fully account for the atypicalities of persons with autism.

The theory may need to be refined as different processes are implicated. Based on the behavioral evidence in this paper and elsewhere, processing of the global level of structure in standard hierarchical stimuli appears to be intact among high-functioning persons with autism. However, in support of the global-local extrapolation of WCC, enhanced visual perceptual processing of elementary characteristics is displayed in some discrimination (Plaisted, O'Riordan, & Baron-Cohen, 1998a) and search tasks (Plaisted et al., 1998b). Moreover, the detection of changes in auditory pitch is enhanced in relation to typical global processing (Mottron et al., 2000). Under certain conditions, then, the relation between local and global processing is an atypical bias toward local processing with a local to global interference (Rinehart et al., 2000) and a preference toward detecting local targets in divided attention conditions (Plaisted et al., 1999). For example, the attention required to group stimuli at relatively long spatial ranges was similar for high-functioning children with autism as compared to VMA and NVMA matched children, whereas differences were found in the higher-order coordination of attention between global and local levels (Iarocci, Burack, Shore, Enns, & Porporino, 2001).

The findings across studies are inconsistent with the notion of a global deficit per se, but highlight two types of tasks that may reveal a local bias. The first type includes those of sensory discrimination in which processing of elementary properties of isolated visual information (Plaisted et al., 1998a) or pure sounds (Bonnell et al., 2003) is enhanced. As evidence from these tasks might reflect enhanced processing of psychophysical aspects of perceptual information, Mottron and Burack (2001) propose a notion of generally enhanced low-level perception to account for superior perceptual discrimination and bias toward local aspects of information. In contrast, Plaisted (2001) rejects the notion of local enhancement in favor of enhanced discrimination abilities that are manifested in both perceptual and conceptual processing. Despite the differences in the explanations of the findings from this type of task, the two perspectives share the notion that the basic processing of low-level perceptual properties is atypical among persons with autism, regardless of the integrity of the perception of global aspects.

The second type of task was designed to assess the processing of two different levels of stimuli, such as global and local stimuli in the divided attention condition of a hierarchical task (Plaisted et al., 1999), the targets and distracters in a visual search task (O'Riordan & Plaisted, 2001; O'Riordan, Plaisted, Driver, & Baron-Cohen, 2001), isolated pitch and musical contour stimuli in a hierarchic auditory task (Mottron et al., 2000), and the figure and ground stimuli in the disembedding task used here. Across these tasks, persons with autism appear to focus excessively on the most local aspect of the stimulus

array, or to ignore the irrelevant stimuli at the global level. This may be evident in the narrowing of attention when local processing is chosen when either of the levels can be selected or in a spontaneous focus of attention on local aspects of a stimulus in a copying (Mottron et al., 1999) or embedded figures (Jolliffe & Baron-Cohen, 1997) task when responses occur over a period of several seconds. One focus of future research should be to determine the extent to which the performance on these two types of task are related and provide informative alternatives to the WCC model for understanding perceptual atypicalities among persons with autism.

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References

- Bonnel, A.C., Mottron, L., Peretz, I., Trudel, M., Gallun, E., & Bonnel, A.M. (2003). Enhanced pitch sensitivity in individuals with autism: A signal detection analysis. *Journal of Cognitive Neuroscience*, *15*, 226–235.
- Burack, J.A., Enns, J.T., Iarocci, G., & Randolph, B. (2000). Age differences in visual search for compound patterns: Long- versus short-range grouping. *Developmental Psychology*, *36*, 731–740.
- Enns, J.T., & Kingstone, A. (1995). Access to global and local properties in visual search for compound stimuli. *Psychological Sciences*, *6*, 283–291.
- Enns, J.T., & Rensink, R.A. (1991). VSearch Color: Full-color visual search experiments on the Macintosh II. *Behavior Research Methods, Instruments, and Computers*, *23*, 265–272.
- Frith, U. (1989). *Autism: Explaining the enigma*. Oxford: Basil Blackwell.
- Frith, U., & Happé, F. (1994). Autism: Beyond 'theory of mind'. *Cognition*, *50*, 115–132.
- Goodale, M.A., & Milner, A.D. (1992). Separate visual pathways for perception and action. *Trends in Cognitive Sciences*, *15*, 20–25.
- Happé, F.G. (1999). Autism: Cognitive deficit or cognitive style? *Trends in Cognitive Sciences*, *3*, 216–222.
- Humphreys, G.W., & Riddoch, M.J. (1987). The fractionation of visual agnosia. In G.W. Humphreys & M.J. Riddoch (Eds.), *Visual object processing: A cognitive neuropsychological approach* (pp. 281–306). Hillsdale, NJ: Lawrence Erlbaum Associates.
- Iarocci, G., Burack, J.A., Shore, D.I., Enns, J.T., & Porporino, M. (2001, April). Global and local processing in autism: Does attention bias perception? Abstract presented at the Society for Research in Child Development in Minnesota.
- Jolliffe, T., & Baron-Cohen, S. (1997). Are people with autism and Asperger syndrome faster than normal on the embedded figures test? *Journal of Child Psychology and Psychiatry*, *38*, 527–534.
- Kinchla, R.A., & Wolfe, J.M. (1979). The order of visual processing: 'Top-down', 'bottom-up', or 'middle-out'. *Perception and Psychophysics*, *25*, 225–231.
- Lamb, M.R., & Robertson, L.C. (1990). The effect of visual angle on global and local reaction times depends on the set of visual angles presented. *Perception and Psychophysics*, *47*, 489–496.
- Lamb, M.R., Robertson, L.C., & Knight, R.T. (1990). Component mechanisms underlying the processing of hierarchically organized patterns: Inferences from patients with unilateral cortical lesions. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *16*, 471–483.
- Lord, C., Rutter, M., Goode, S., Heemsbergen, J., Jordan, H., Mawhood, L., & Schopler, E. (1989). Autism Diagnostic Observation Schedule: A standardized observation of communicative and social behavior. *Journal of Autism and Developmental Disorders*, *19*, 185–212.
- Lord, C., Rutter, M., & Le Couteur, A. (1994). Autism Diagnostic Interview-Revised: A revised version of a diagnostic interview for caregivers of individuals with possible pervasive developmental disorders. *Journal of Autism and Developmental Disorders*, *24*, 659–686.
- Lord, C., Storoschuk, S., Rutter, M., & Pickles, M. (1993). Using the ADI-R to diagnose autism in preschool children. *Infant Mental Health Journal*, *14*, 235–252.
- Lord, C., Rutter, M., & Di Lavore, P. (1997). Autism Diagnosis Observation Schedule – Generic. University of Chicago.
- Mottron, L., Belleville, S., & Ménard, E. (1999). Local bias in autistic subjects as evidenced by graphic tasks: Perceptual hierarchization or working memory deficit? *Journal of Child Psychology and Psychiatry*, *40*, 743–755.
- Mottron, L., & Burack, J.A. (2001). Enhanced perceptual functioning in the development of autism. In J.A. Burack, T. Charman, N. Yirmiya, & P.R. Zelazo (Eds.), *The development of autism: Perspectives from theory and research* (pp. 131–148). Mahwah, NJ: Lawrence Erlbaum Associates.
- Mottron, L., Burack, J., Stauder, J., & Robaey, P. (1999). Perceptual processing among high-function-

- ing persons with autism. *Journal of Child Psychology and Psychiatry*, 40, 203–211.
- Mottron, L., Peretz, I., & Ménard, E. (2000). Local and global processing of music in high-functioning persons with autism. *Journal of Child Psychology and Psychiatry*, 41, 1057–1065.
- Oldfield, R.C. (1971). The assessment and analysis of handedness: The Edinburgh inventory. *Neuropsychologia*, 9, 97–113.
- O’Riordan, M., & Plaisted, K. (2001). Enhanced discrimination in autism. *Quarterly Journal of Experimental Psychology, Section A, Human Experimental Psychology*, 54, 961–979.
- O’Riordan, M.A., Plaisted, K.C., Driver, J., & Baron-Cohen, S. (2001). Superior visual search in autism. *Journal of Experimental Psychology: Human Perception and Performance*, 27, 719–730.
- Ozonoff, S., Strayer, D.L., McMahon, W.M., & Filloux, F. (1994). Executive function abilities in autism and Tourette syndrome: An information processing approach. *Journal of Child Psychology and Psychiatry*, 35, 1015–1032.
- Plaisted, K., O’Riordan, M., & Baron-Cohen, S. (1998a). Enhanced discrimination of novel, highly similar stimuli by adults with autism during a perceptual learning task. *Journal of Child Psychology and Psychiatry*, 39, 765–775.
- Plaisted, K., O’Riordan, M., & Baron-Cohen, S. (1998b). Enhanced visual search for a conjunctive target in autism: A research note. *Journal of Child Psychology and Psychiatry*, 39, 777–783.
- Plaisted, K., Swettenham, J., & Rees, L. (1999). Children with autism show local precedence in a divided attention task and global precedence in a selective attention task. *Journal of Child Psychology and Psychiatry*, 40, 733–742.
- Plaisted, K. (2001). Reduced generalization in autism: An alternative to weak central coherence. In J.A. Burack, T. Charman, N. Yirmiya, & P.R. Zelazo (Eds.), *Development of autism: Perspectives from theory and research* (pp. 149–169). Mahwah, NJ: Lawrence Erlbaum Associates.
- Rinehart, N.J., Bradshaw, J.L., Moss, S.A., Brereton, A.V., & Tonge, B.J. (2000). Atypical interference of local detail on global processing in high-functioning autism and Asperger’s disorder. *Journal of Child Psychology and Psychiatry*, 41, 769–778.
- Shah, A., & Frith, U. (1983) An islet of ability in autistic children: A research note. *Journal of Child Psychology and Psychiatry*, 24, 613–620.
- Shah, A., & Frith, U.J. (1993). Why do autistic individuals show superior performance on the block design task? *Child Psychology and Psychiatry*, 34, 1351–1364.
- Snodgrass, J.G., & Vanderwart, M. (1980). A standardized set of 260 pictures: Norms for name agreement, image agreement, familiarity, and visual complexity. *Journal of Experimental Psychology: Human Learning and Memory*, 6, 174–215.
- Tymchuck, A.J., Simmons, J.Q., & Neafsey, S. (1977). Intellectual characteristics of adolescent childhood psychotics with high verbal ability. *Journal of Mental Deficiency Research*, 21, 133–138.
- Witkin, H., Oltman, P., Raskin, E., & Karp, S. (1971). *A manual for the Embedded Figures Test*. Palo Alto, CA: Consulting Psychologists Press.