Journal of Autism and Developmental Disorders, Vol. 36, No. 1, January 2006 (© 2005)
DOI 10.1007/s10803-005-0045-2

Global–Local Visual Processing in High Functioning Children with Autism: Structural vs. Implicit Task Biases

Grace Iarocci,[1,7] Jacob A. Burack,[2,3] David I. Shore,[2,4] Laurent Mottron,[3,5] and James T. Enns[6]

Global–local processing was examined in high-functioning children with autism and in groups of typically developing children. In experiment 1, the effects of structural bias were tested by comparing visual search that favored access to either local or global targets. The children with autism were not unusually sensitive to either level of visual structure. In experiment 2 a structural global bias was pitted against an implicit task bias favoring the local level. Children with autism were least sensitive to the structural global bias but showed greater sensitivity to the implicit task bias. This suggests that autism is associated with differences in the executive control processes used to guide attention to either the global or local level, and strategies may be more "data driven".

KEY WORDS: Global and local perception; visual search; attentional bias.

The sensory world is sufficiently complex and dynamic so that biological organisms must tune themselves selectively to only relevant features of the world if they are to have any hope of responding appropriately in real time. Some of this tuning was accomplished over the history of a species (evolution), other aspects of it are accomplished during an individual's lifetime (development), and still other aspects of selective tuning are accomplished on a moment-to-moment basis in response to changing environmental conditions (learning). In everyday situations, all three of these factors likely contribute to the ongoing perceptual processing of an organism, making them difficult to disentangle through simple observation. In the present study, we sought to disentangle two of these aspects of perceptual tuning in the context of the larger question of how children with autism differ from typically developing children in their approach to the visual world.

Our first bias of interest concerned the tendency for human visual experience to focus initially on the more global or gist-related aspects of a scene before attention is focused on the more local or detailed features of the scene (Navon, 1977). This bias seems to be ubiquitous in humans and likely reflects evolutionary forces that favored attention to meaningful objects and events over attention to the specific shapes, colors, and motion features that were used to convey those objects and events. Thus, evolution

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[1] Department of Psychology, Simon Fraser University, V5A 1S6, Burnaby, BC, Canada.
[2] Department of Educational Psychology, McGill University, Montreal, Quebec, Canada.
[3] Clinique spécialisée des Troubles Envahissants du Développement, Hôpital Rivière-des-Prairies, Montreal, Quebec, Canada.
[4] Department of Psychology, Neuroscience and Behavior, McMaster University, Hamilton, Ontario, Canada.
[5] Département de Psychiatrie, Université de Montréal, Montreal, Quebec, Canada.
[6] Department of Psychology, University of British Columbia, Vancouver, BC, Canada.
[7] Correspondence should be addressed to: Grace Iarocci, Department of Psychology, Simon Fraser University, 8888 University Drive, V5A 1S6, Burnaby, BC, Canada; Tel: +1-604-268-6668; Fax: +1-604-291-3427; e-mail: giarocci@sfu.ca

rewarded humans for being concerned with the message rather than the medium used to deliver that message (Ahissar & Hochstein, 2002; Pylyshyn, 1998).

The second bias of interest concerned sensitivity to the particular spatial–temporal arrangement of a given environment. This kind of tuning is critical since it directly influences the ability of individuals to learn and therefore benefit from the particular circumstances in which they find themselves. Those who incorporate what they have learned quickly and effectively into their behavior will be better prepared for survival by adapting quickly to changes in the immediate environment.

The dissociation of these two biases may be especially useful to understanding the perceptual experiences of individuals with autism because they correspond to two different theoretical views on how autism differs from typical development. According to the Weak Central Coherence (WCC) theory of autism, there are structural differences between the perceptual process of persons with and without autism. In this framework, the persons with autism naturally perceive objects in terms of their parts and are therefore not hindered by the additional operation of separating the local elements from the contextual background that is ordinarily required (Frith, 1989; Frith & Happé, 1994; Happé, 2005). A disturbance in the ability to integrate local parts into a perceptual representation in which both of these levels are accessible is thought to underlie the atypical performance on complex visual-spatial tasks such as the Block Design subtest of the Wechsler Scales (Shah & Frith, 1993) and the Embedded Figures Test (Jolliffe & Baron-Cohen, 1997).

An alternate view is that persons with autism do not have structural differences in processing global and local levels of visual structure, but rather that their atypicalities derive from different executive strategies that serve to coordinate global and local level processing in a given task. Support for this view is based on reports that the performance of persons with autism on global–local RT tasks is comparable to that of their MA matched typically developing peers under certain conditions (Mottron, Burack, Stauder, & Robaey, 1999; Ozonoff, Strayer, & McMahon, 1994; Plaisted, Swettenham, & Rees, 1999). However, the tasks used to assess spatial-attention often differ from one another in many ways. Traditional hierarchical letter detection tasks require skill in dividing or *switching attention between levels*, configural grouping tasks require the ability *to ignore local display elements* in order to see the target at the global level, and disembedding tasks require the ability to *ignore larger configurations* in order to see targets at the local level. In a previous study, we compared the performance of high functioning adolescents with autism and their IQ matched peers on each of these three types of global–local tasks, and found that the persons with autism displayed an enhanced ability to prioritize analysis at the local level when the task required it (Mottron, Burack, Iarocci, Belleville, & Enns, 2003). From this perspective, the distinguishing characteristic of autism may be the different manner in which some information is voluntarily selected in a top-down way at the expense of other information (Mottron, Dawson, Soulieres, Hubert, & Burack, this issue).

Still other findings point to atypical functioning of both basic and executive processes. For example, Bertone, Mottron, Jelenic, & Faubert (2003) found both enhanced and diminished motion perception among young adults with autism as compared to IQ matched young adults without autism. The persons with autism showed superior abilities to discriminate the orientation of simple, luminance-defined (first-order) gratings but inferior abilities to discriminate more complex, texture-defined (second-order) gratings on the same visuo-spatial static task. These findings suggest that the perceptual peaks of persons with may stem from dissociations within low-level visual processes in addition to the higher order modulation of these basic processes (Bertone, Mottron, Jelenic, & Faubert, 2003; Castelli, Frith, & Happé, 2002).

The present study was designed to examine whether children with and without autism would differ in their structural visual biases (structural organization of a visual image) or in the way they respond to the implicit expectancy demands (spatio-temporal contingencies) of a task to focus on the global or the local level. Alternatively, the groups may differ with regard to both structural and expectancy biases. In Experiment 1 we began by examining whether there were any differences in structural biases between children with autism and typically developing comparison children by comparing their visual search in three different tasks. In a *control* condition, participants searched for target items that could differ from distractor items at either the local level of structure, the global level, or at both levels. In this task, the typical finding of a global advantage in search is expected because of the tendency for humans to see the "forest" before the "trees." In the *local hard* condition, stimulus factors were introduced to make search for targets at the local level particularly difficult. In the *global hard* condition, similar factors were varied to make search for targets at the global level especially inefficient. These more extreme conditions were tested to make sure that any possible group differences observed in the *control* condition were not simply derivative of group differences in overall task difficulty. Any autism-specific difference in local or global processing at the level of structural biases should be apparent both when the task was generally easy and when it was generally hard.

Our approach in Experiment 2 was to directly pit the common bias for global processing against an implicit expectancy bias to focus on the local level. The implicit bias was accomplished by varying the probability that targets would appear at the local level from being very low to being very likely (Austen & Enns, 2000, 2003; Gratton, Coles, & Donchin, 1992).

The children with autism were chosen from a period in development (8–10 years of age) when the emergence of sensitivity to implicit expectancy bias is in transition among typically developing children (Iarocci, Burack, & Shore, in prep). This is in keeping with the notion that the identification of group differences is most likely during and immediately following periods of developmental transition (Burack, Iarocci, Bowler, & Mottron, 2002).

EXPERIMENT 1

A visual search task similar to the one developed by Enns and Kingstone (1995) and adapted by Burack, Enns, Iarocci, and Randolph (2000) to study typical development during the school years was used to examine global–local processing in children with autism. The design of these stimuli is illustrated in Fig. 1a and a sample search display is shown in Fig. 1b. Each display item consists of four dots, arranged in two neighboring pairs. Only a short distance separates the dots within a pair and so their spatial relation is referred to as *local* (only short range grouping is required). A larger distance separates the dots in different pairs and so their spatial relation is referred to as *global* (longer range grouping is required). In this search task, a target is defined as any pair of dots within an item that are not vertically aligned (i.e., tilted). The target pattern can appear independently at the local, global, or even at both levels (dual target). Participants simply try to detect the presence of a target in each display and when they do they indicate whether it lies to the left or right of the center of the display using a spatially corresponding key press. One valuable methodological feature of this task is that target detection at either the local or the global level is not confounded with general task difficulty (for a review, see Burack *et al.*, 2000).

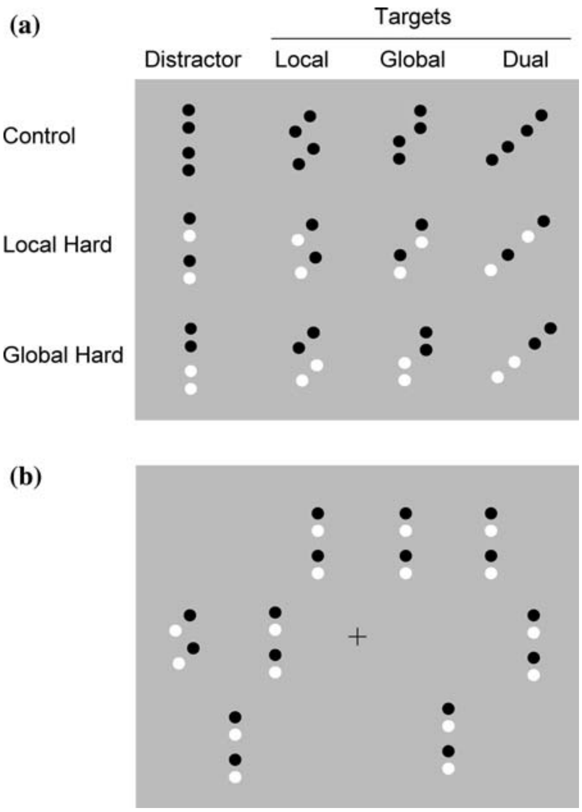

Fig. 1. (a) Targets and distractors used in the visual search tasks of Experiment 1. (b) An example search display in Experiment 1, showing a local target on the left side of an eight-item display in the Local hard condition.

Burack *et al.* (2000) tested the ability to search in three different conditions. In the *control* condition, all dots were the same contrast relative to the background. In the *local hard* condition, each pair of dots consisted one white and one black dot, thereby reducing the degree to which the local dots were perceptually grouped. In the *global hard* condition each dot in a pair was the same contrast but one of the dot pairs was white and one was black dot, thereby reducing the degree to which global dots were perceptually grouped. Across these three conditions, search efficiency was tested over the entire range of search difficulty (i.e., from pop-out to slow serial search), ensuring that any conclusions regarding perceptual access to global–local structure was not confounded by differences in task difficulty. Across the range of task difficulty, there were large improvements between 6 and 8 years of age in search rate for global targets, whereas the efficiency of the search for local targets was fairly constant across the ages of 6–20 years. This finding was interpreted as support for the hypothesis that dissociable processes are involved in perceptual grouping at local and global levels.

Visual search by 8-year old participants diagnosed with autism was compared to search by typically developing children who were matched either on the basis of non-verbal or verbal mental age. Any group differences in search could thus be attributed to autism and not to more general developmental delays in either non-verbal or verbal functioning.

Method

Participants

Twelve high-functioning children with autism (10 male) were matched individually to typically developing children on both their verbal and their non-verbal mental age. The verbal mental age (VMA) of children with autism was assessed with the Peabody Picture Vocabulary Test (PPVT-R) (Dunn & Dunn, 1981). Non-verbal mental age (NVMA) was assessed with the Ravens Colored Progressive Matrices (sets A, Ab, and B) (Raven, Court, & Raven, 1990). Each of the typically developing children was selected because their chronological age (CA) was similar to either the NVMA or VMA of a child with autism. Four of the typically developing children served as comparisons in *both* groups. Table 1 shows the mean and standard deviation of chronological age (CA), VMA, and NVMA for the children with autism, along with the CA of the two comparison groups of typically developing children. As Mottron (2004) demonstrated that PPVT and RPM both overestimate crystallized intelligence as measured by the Wechsler Scales, this matching strategy provides a conservative test in case of the finding of equivalent or superior performance by the children with autism.

The children with autism were recruited from public and private organizations and the typically developing children from public schools. All children with autism were classified according to the criteria for current and retrospective diagnoses based on the Autism Diagnosis Interview-Revised (ADI-R) (Lord, Rutter, & Lecouteur, 1994) and the DSM-IV criteria for autism.

Table 1. Mean, Standard Deviation, and Range of Chronological, Non-Verbal, and Verbal Mental Age of Participants in Experiment 1

Group	N	Statistic	CA	NVMA	VMA
Autism	12	*M*	95	118	97
		SD	16	23	32
		Range	71–121	77–144	54–151
TD-NVMA	12	*M*	112		
		SD	17		
		Range	77–136		
TD-VMA	12	*M*	97		
		SD	27		
		Range	61–136		

Note: CA, chronological age (months); TD-NVMA, typically developing, non-verbal mental age (months); TD-VMA, typically developing, verbal mental age (months).

Stimuli and Apparatus

A Macintosh computer, running VScope software (Enns & Rensink, 1992), generated the displays and collected the data. The visual items used in the displays are shown in Fig. 1a. The target item differed from the non-target (distractor) items only in that some of the dots were not oriented vertically with respect to one another (i.e., the dots formed a tilted line). All items were comprised of two pairs of dots (four dots in total), that could be all the same contrast level (i.e., black, 0% pixels lit) with respect to the medium gray background (50% of pixels lit), or two of the dots were white (100% pixels lit) and two were black (0% pixels lit). Three search conditions differed in terms of the relative difficulty of detecting the tilted target item. In the *control* condition, only black items were used, giving local tilt (tilt within a pair of dots) and global tilt (tilt between pairs of dots in an item) equivalent signal strength. In the *local* hard condition the dots within each pair were opposite in contrast (one black, one white), making the detection of tilt at a local level more difficult than at the global level. Finally, in the *global hard* condition the dots within each pair were identical in contrast (both black or white), but the pairs differed in contrast (one black, one white), making the detection of tilt at the global level more difficult.

Each item subtended 1.25 degrees of retinal visual angle, with each individual dot subtending 0.20 degrees. The center-to-center distance between dots within a pair was 0.30 and for dots in different pairs it was 0.75 degrees. On each trial, 2, 8, or 18 items were distributed randomly on an imaginary 6×4 grid subtending 21×14 degrees. Each item was randomly jittered in its grid location by ±0–0.25 degrees to prevent influences on search from item colinearity.

Procedure

The participants performed the search task with their eyes 50 cm from the computer screen. They were required to detect a target item with a tilt in either the dots within a pair (local), the dots between pairs (global), or a tilt at both levels (dual). The target appeared along with 1, 7, or 17 other vertically oriented items (see Fig. 1b). A target item was present in each display; the participants' task was to indicate whether it was present to the left or right of the center of the display by pressing a spatially corresponding key. The targets were equally distributed on the right and left side of the computer screen.

Prior to the formal testing, drawings of each of the three types of possible targets were shown to the participants and they were asked to identify the tilted dots (targets) by tracing them with their fingers. The experimenter referred to these targets as the "sleepy" ones. Once the experimenter was assured that the participant could correctly identify and distinguish the tilted dots (targets) from the vertically oriented dots (distractors), a set of 10 practice trials was initiated. The participants were instructed to maintain fixation at the center of the screen. The experimenter explained that only one target (an item with tilted dots) would appear on the left or right side of the screen and the participants were to press the corresponding response key as soon as they saw the "sleepy" item.

The participants were administered 3 sets of 40 test trials in each of the search conditions in counterbalanced order. Each trial began with a fixation symbol shown for 500 ms, followed by the search display that remained visible until the participant responded. A key press was followed by a feedback symbol (plus for a correct response, minus for an incorrect response or 0 for no response), that served as the fixation point for the next trial. The experimenter monitored the participants' performance to ensure that errors remained below ten percent. Any participant whose error rate exceeded 10% overall was excluded from the analysis. Trials were counted as errors if the participant failed to respond within 5 seconds.

Measuring Performance

Response times (RT) on trials in which the target location was correctly detected were examined as a function of display size that included the target and all distractors in the display. Because RT functions over display size tend to be linear, it provides two separate measures of response time that correspond to theoretically separable mental processes (Sternberg, 1969; Wolfe, Cave, & Franzel, 1989). One, baseline RT corresponds to the speed of response when there were only two items in the display (indexing the processes of target encoding, response selection and execution). Two, RT slope over display size corresponds to the average increase in RT with each additional display item (indexing the attentional process of distractor rejection). For both measures, the smaller the value, the more efficient is the perceptual examination of the visual target feature (i.e., the detection of an oriented pair of dots).

These two measures were analyzed with 2×3×3 mixed analyses of variance (ANOVA). Group (autism vs. non-verbal or autism vs. verbal) was a between-participant factor, whereas Search Condition (control, local hard, global hard) and Target Type (local, global, dual) were repeated measures. No order effect of conditions was found.

Results

Accuracy

Children in all groups performed the search task very accurately (>90% correct overall). No significant group differences were found in accuracy and the pattern of errors closely followed the pattern of RT data. Specifically, errors tended to be greatest in those conditions in which RT was the largest.

Baseline RT

The mean RT data in the smallest display size (2 items) are shown in Table 2. The ANOVA revealed no effects of Group or interactions involving Group, all Fs < 1.13. However significant interactions of Search Condition×Target Type were found in both analyses, autism vs. non-verbal comparison, $F(4, 88) = 3.92$, $MSE = 10{,}592$, $p < .01$; autism vs. verbal comparison, $F(4, 88) = 3.12$, $MSE = 16{,}348$, $p < .05$. This interaction, shown in Fig. 2a, indicated that RT to local targets was slower in the local hard than in the global hard condition, and conversely, that RT to global targets was slower in the global hard than in the local hard condition for all

Table 2. Mean Baseline RT in Experiment 1

		Target Type		
Group		Local	Global	Dual
Autism	Control	1151	1260	1186
	Local hard	1221	1153	1107
	Global hard	1181	1325	1192
TD-NVMA	Control	916	951	994
	Local hard	1043	1026	984
	Global hard	1065	1064	1044
TD-VMA	Control	1034	1108	1076
	Local hard	1189	1182	1085
	Global hard	1201	1266	1175

Note: TD-NVMA, typically developing, non-verbal mental age (months); TD-VMA, typically developing, verbal mental age (months).

participants. This finding confirmed that our manipulations of contrast between dot pairs had the intended effect in both the local hard and global hard conditions.

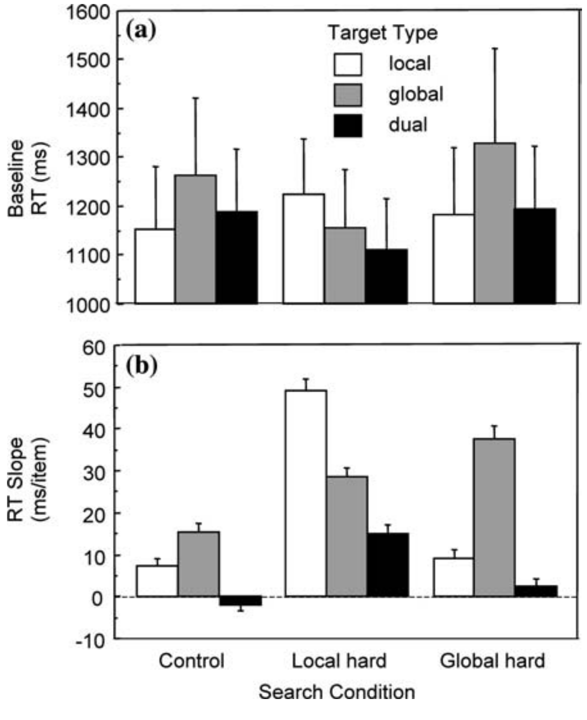

Fig. 2. (a) Mean correct Baseline RT in Experiment 1, showing that the Local hard and Global hard search conditions influence the baseline efficiency of responding to local and global targets. Error bars represent plus/minus one standard error of the mean. (b). Mean correct RT Slopes in Experiment 1, showing that the Local hard and Global hard search conditions influence the efficiency of search for local and global targets. Error bars represent plus/minus one standard error of the mean.

RT Slope (Search Rate)

Mean RT slopes are shown in Table 3. As in the baseline RT measure, significant interactions of Search Condition×Target Type were found in both analyses, autism vs. non-verbal comparison, $F(4, 88) = 30.49$, $MSE = 120$, $p < .001$; autism vs. verbal comparison, $F(4, 88) = 20.46$, $MSE = 140$, $p < .0001$. This interaction, shown in Fig. 2b, indicated that the RT Slope for local targets was larger in the local hard than in the global hard condition, and conversely, that the RT Slope for global targets was larger in the global hard than in the local hard condition. Thus, the manipulation of relative search difficulty between local and global targets was very effective.

Factors involving Group, both main effects and interaction, were not significant with one exception (all other Fs < 1.6). Children with autism were less efficient in searching for local targets than NVMA comparison children, but only in one of the three search conditions, namely, in the Global hard (Local Easy) condition (mean Autism RT slope = 14. 4 ms/item; mean NVMA RT Slope = 2.4 ms/item), $F(4, 88) = 4.23$, $MSE = 120$, $p < .01$. This means that the NVMA children (recall that these are older children) were significantly more efficient in searching in this relatively easy search conditions than were either the children with autism or the VMA comparison children. Most notably, in the more difficult search conditions, children with autism were no less efficient than either of the two comparison groups of children.

Table 3. Mean RT Slopes in Experiment 1

		Target Type		
Group		Local	Global	Dual
Autism	Control	5.4	13.2	−2.8
	Local hard	44.1	29.1	16.9
	Global hard	14.4	30.5	5.0
TD-NVMA	Control	4.7	9.9	−4.0
	Local hard	49.1	27.4	9.1
	Global hard	2.4	43.6	−1.6
TD-VMA	Control	11.2	22.0	1.3
	Local hard	53.7	28.7	18.6
	Global hard	10.1	37.5	2.8

Note: TD-NVMA, typically developing, non-verbal mental age (months); TD-VMA, typically developing, verbal mental age (months).

Discussion

The main finding was that high-functioning children with autism and typically developing children showed similar patterns when searching for visual targets defined by local (short range) and global (long range) spatial structure. Changes in the sensory properties of the dot pairs (contrast) biased search efficiency in favor of either the local or the global level of structure. Specifically, same contrast dots at the local level and different contrast dots at the global level led to less efficient global target detection. Similarly, same contrast dots at the global level and different contrast dots at the local level led to less efficient local target detection. As such, these data provide no support for the proposal that autism is associated with a general enhancement in the processing of either local elements (Plaisted, O'Riordan, & Baron-Cohen, 1998) or a global deficit in the processing of visual structure (Frith, 1989).

The one group difference that was observed was that the children with autism displayed slower search rates for local targets in the Global hard (Local Easy) condition than their NVMA peers. However, this seemed due more to the exceptionally efficient search for this target among participants in the NVMA comparison group than to inefficient search in children with autism. This interpretation is supported by the finding that the children with autism showed similar search rates to the VMA comparison participants. We note that the NVMA comparison participants were significantly older in chronological age and would therefore expected to be the most efficient searchers (Burack *et al.*, 2000). Thus, the results of Experiment 1 indicate that basic perceptual processes associated with local and global structure appear intact in high-functioning children with autism in an age range in which differences would most likely be found. This is consistent with Mottron *et al.*'s (2003) findings of no differences in search for global and local stimuli when 15.7-year-old high functioning adolescents with autism were compared to 15.2-year-old typically developing adolescents matched on IQ.

EXPERIMENT 2

In Experiment 1, the search task was designed to detect structural biases in global–local perception in the absence of any implicit or explicit directions to attend to a certain level. In Experiment 2, the search task was designed to place into competition a structural bias favoring global processing against an implicit expectancy bias to attend to a certain level of structure. The implicit bias was accomplished by varying the probability (within a block of trials) that targets would appear at the local level from being very low to being very likely (Austen & Enns, 2000, 2003; Gratton *et al.*, 1992).

Method

Participants

A group of 20 high-functioning children with autism, including the 12 children with autism from Experiment 1, were matched to two groups of typically developing children, one on verbal and one on non-verbal mental age. Eight typically developing children served as both VMA and NVMA matches for the group of children with autism. The mean and standard deviation of CA, VMA, and NVMA for the children with autism and for the two comparison groups of typically developing children are displayed in Table 4.

Stimuli and Apparatus

The search items in this experiment are illustrated in Fig. 3a. The distractor items consisted of dots (local level) arranged in a circle (global level), whereas the possible targets in this task consisted of either squares or diamonds. As in Experiment 1, the target item could be present at either the local level (a circular arrangement of either squares or diamonds) or at the global level (a square vs. a diamond arrangement of circular dots).

All items were drawn in black on a white background, in one of 12 possible grid locations (4 rows×3 columns). Each grid location occupied a

Table 4. Mean, Standard Deviation, and Range of Chronological, Non-Verbal, and Verbal Mental Age (in Months) of Participants in Experiment 2

Group	*N*	Statistic	CA	NVMA	VMA
Autism	20	*M*	94	116	89
		SD	16	24	34
		Range	71–121	77–144	51–151
TD-NVMA	20	*M*	101	100	114
		SD	21	25	28
		Range	75–127	77–144	62–163
TD-VMA	20	*M*	93	107	90
		SD	15	25	32
		Range	73–120	60–144	51–153

Note: CA, chronological age (months); TD-NVMA, typically developing, non-verbal mental age (months); TD-VMA, typically developing, verbal mental age (months).

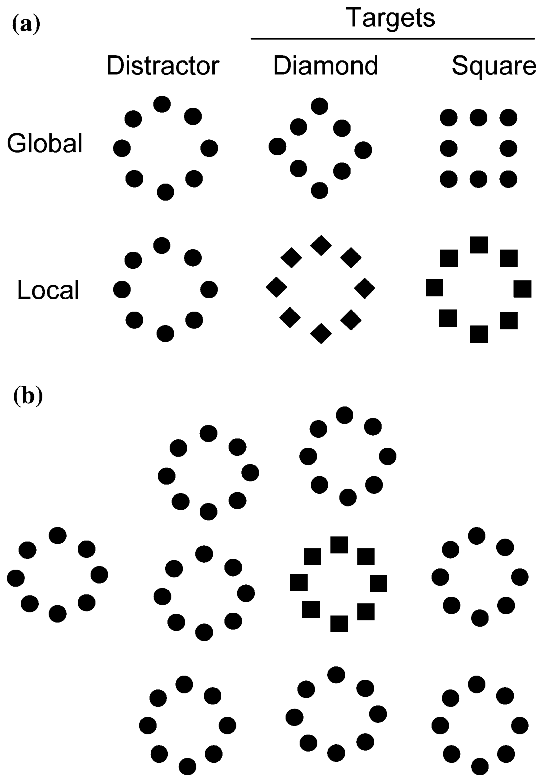

Fig. 3. (a) Targets and distractors used in the visual search tasks of Experiment 2. (b) An example search display in Experiment 2, showing a square target at the local level in a nine-item display.

square of 160 pixels, with local elements subtending 0.25 degrees of visual angle in diameter and global configurations 1.50 degrees of visual angle. On each trial, 1, 2 or 9 items were distributed randomly in the grid. Each item was randomly jittered in its grid location by ±0–0.25 degrees to prevent influences of item colinearity.

Procedure

Prior to formal testing, the participants were shown drawings of the four possible targets and each was identified as either a "small" or a "big" "square or "diamond." The participants were asked to use their fingers to trace each target type. Once the experimenter was assured that the participant could identify "squares" and "diamonds" in local and global displays, 10 practice trials were initiated. The participants were told that a square or a diamond would be present in every display and they were instructed to indicate a diamond (either small or big) by pressing one key and to indicate a square (either small or big) by pressing the other key.

The main manipulation in this experiment concerned the three conditions of likelihood that the target would be either local or global. In the *global bias* condition, the target was presented at the global level 70% of the time and at the local level 30% of the time. In the *neutral* condition the target was equally likely at the local and global levels, as in Experiment 1. In the *local bias* condition, the target was presented at the local level 70% of the time and at the global level 30% of the time. The order of the biasing conditions was counterbalanced across participants, with the neutral condition being tested second in every case. The participants were not told that the likelihood of the target level varied in these conditions. They were administered 3 sets of 40 experimental trials for each probability level (see Fig. 4).

Measuring Performance

Although display size varied in this experiment, and RT increased linearly with display size, $F(2, 76) = 188.03$, $MSE = 11{,}619$, $p < .001$, the main findings in this experiment did not involve any group differences in either display size or in a Group×Display Size interaction, all Fs < 1.98. This replicates the main finding in Experiment 1 that the overall search efficiency of children with autism does not differ significantly from comparison participants matched for verbal or non-verbal mental age. Accordingly, we did not break down the analysis of correct RT into separate measures of baseline RT and RT slope. Instead, we averaged the RT data over display size, in

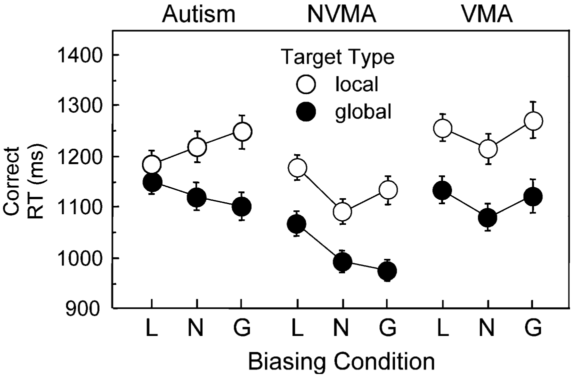

Fig. 4. Mean correct RT in Experiment 2, showing that children with autism are more sensitive than typically developing children to biases in whether the target will occur at the local or global level. L, Local Bias, N, Neutral, G, Global Bias. Error bars represent plus/minus one standard error of the mean.

order to focus on the primary findings concerning target level likelihood. The main dependent measure in this task was therefore mean correct RT.

ANOVAs examined the between-participant factor of Group (autism vs. NVMA, autism vs. VMA) and the repeated measures factors of Bias (Global, Neutral, Local), Target Type (global, local), and Display Size (1, 2, 9). No order effect was found.

Results

Accuracy

The children in all groups performed the search task very accurately ($>92\%$ correct overall). No significant group differences were found in accuracy, and the pattern of errors closely followed the pattern of RT data. The errors tended to be greatest in those conditions in which RT was the largest, ruling out speed-accuracy tradeoffs as the interpretation of RT differences in the analyses that follow.

Correct RT

Mean correct RT is shown in Fig. 4 for each of the three groups of participants. In this graph, the influences from both the biasing conditions and the type of target were evident. However, the nature of the interaction between Bias×Target Type differed in these three groups, $F(2, 116) = 2.57$, $MSE = 11{,}018$, $p < .08$, as did the interaction of Group× Target Type, $F(2, 57) = 3.27$, $MSE = 15{,}203$, $p < .04$.

The children with autism showed the strongest statistical interaction of Bias×Target Type, $F(2, 38) = 7.78$, $MSE = 10{,}893$, $p < .01$, eta-squared = .29, indicating that they were the most sensitive to the Biasing manipulations. Thus, as the likelihood of a global target increased, they were able to respond most rapidly to global targets and, conversely, that as the likelihood of a local target increased they were able to respond to it more rapidly. The children with autism, like all children in this experiment, responded to global targets more rapidly than to local targets, but this main effect of Target Type was smallest in this group (mean RT difference = 89 ms, $F(1, 19) = 40.50$, $MSE = 17{,}729$, $p < .01$).

Typically developing children matched for nonverbal mental age also showed a significant Bias×Target Type interaction, $F(2, 38) = 3.96$, $MSE = 7996$, $p < .03$, eta-squared = .17, but it was not as strong as for the children with autism. In particular, the NVMA group was less able to respond quickly to local targets when they were most likely to occur. Their general tendency to respond more quickly to global than local targets was also stronger for these children than for the children with autism (mean RT difference = 121 ms, $F(1, 19) = 97.28$, $MSE = 13{,}632$, $p < .001$).

Typically developing children matched for verbal mental age did not show a significant Bias×Target Type interaction, $F(2, 38) < 1.0$, $MSE = 14{,}319$, eta-squared = .02. The VMA group also did not show any sensitivity to the Biasing manipulation for either global or local target, both *F*s < 1.0. However, this group showed the greatest difference between RT to global and local targets (mean RT difference = 135 ms, $F(1, 19) = 115.29$, $MSE = 14{,}248$, $p < .001$).

Discussion

Taken together with the results of Experiment 1, which showed that children with autism are equally adept as their typically developing cohorts in accessing targets at either the local or the global level of visual structure in a search task, the findings in Experiment 2 point to an important difference in the way children with autism approach a global–local search task strategically. This disparity in approaches is exemplified by the differences in the patterns of performance between the two groups of typically developing children, that differed chronologically by 8 months. The younger (VMA) group showed both less sensitivity to the biasing manipulation and the larger overall RT difference in responding to global vs. local targets. This difference favored global targets, pointing to a strong task independent bias to favor processing at the global level. In contrast, the older group (NVMA) showed somewhat more sensitivity to the biasing manipulation in the task. This sensitivity to bias was strong for global targets but weak or non-existent for local targets, suggesting that the biasing manipulation was most effective for the level of structure that is most readily accessible to these participants. In contrast, the children with autism showed roughly equivalent sensitivity to biasing manipulations for both global and local targets, while at the same time showing the smallest task independent bias in favor of global targets.

The sensitivity to bias shown by children in this experiment cannot be interpreted as a response bias, as the biasing manipulation did not alter the likelihood of whether one response (square) or the other (diamond) was required, but rather the likelihood that the target (whether square or diamond) would appear in an item at either the global or the local level. Thus, the children with autism were better able than their typically developing peers to overcome any task independent biases to either local or global processing levels and to tune themselves to the implicit demands of the task.

GENERAL DISCUSSION

Conceptual, methodological, and developmental issues were considered in understanding the ways that children with autism approach visual search tasks. At a conceptual level, we hypothesized that children with autism may be either excessively reliant on structural perceptual biases or overly sensitive to the implicit constraints of a visual search task. In order to disentangle these two biases methodologically, we compared performance on two search tasks. In Experiment 1, we manipulated the structural features of the global–local stimulus array and in Experiment 2 we manipulated the probability that the target structure would appear at the global or local level, thereby creating an implicit expectancy bias toward attending to one level or the other. Our main developmental consideration was to assess global–local processing performance when the related attentional biases are thought to be in developmental transition. In addition, comparison groups of typically developing children were selected to address the mental age discrepancy in the verbal and non-verbal abilities of the children with autism.

The main finding was that high-functioning children with autism showed typical processing of global and local visual structure but were more sensitive to the implicit task biases as compared to both a group of typically developing children matched on VMA and another matched on NVMA. With regard to the sensitivity to implicit expectancy biases, the experimental probability manipulation was effective in biasing attention to either the local or global level for all groups. All children appeared to approach the task with a global bias as they generally responded to global targets more rapidly than local targets. However, the children with autism approached the task with a diminished global bias and were most able to tune into and respond to the implicit expectancy changes across the blocks of trials in the search task. Although the performance of the children with autism appeared optimal in terms of their ability to adjust and benefit from the particular circumstances of the task, this pattern of responding to global–local stimuli may reflect more general atypicalities among children with autism. Thus, despite typical abilities to process global–local structures and their constituent elements, children with autism showed different higher-order coordination of attention between global and local levels that may result in atypical perception of objects and events. The findings are particularly compelling as the performance of children with autism differed significantly from that of their VMA and NVMA typically developing peers, minimizing the possibility that the differences are due to immature attention in the children with autism.

Processing the “gist” or global level of a percept appears to be a relatively stable structural bias that may be generalized to various perceptual contexts because it has proven adaptive across many situations (Bruce, Green, & Georgeson, 2003). For example, an observer does not need to process all the information available in their visual field to recognize visual events, but rather must selectively extract the most relevant aspects from the visual array to perform multiple categorizations of the same input (e.g., Schyns & Oliva, 1999). The highest level of the visual image (e.g., the forest) may be the most efficient since all the visual information is contained within the global level of structure. Although the lower-order elements (e.g., trees) may not be actively processed, they are available for further processing if required (Modigliani, Loverlock, & Kirson, 1998). Thus, adopting a “gist” or “essence” approach to processing global–local information prevents the system from getting “bogged down” on minute details or redundancies that do not facilitate the cognitive task of identifying familiar objects or people.

The notion that attention is hierarchically organized is best illustrated in the human’s approach to face processing because faces are processed as integral configurations rather than complex configurations comprised of separable elements. For example, Austen and Enns (2003) assessed whether the efficiency of detecting changes in face identity and expression (sad, happy) is dependent on rich and detailed processing of all visual features of the face or sensitive to task contingencies. In a neutral bias condition, observers were informed that changes in identity or expression were equally likely; in an identity bias condition that 75% of the changes would involve identity and 25% expression; and in an expression bias condition that 25% the changes would involve identity and 75% expression. Austen and Enns (2003) found an "asymmetry in the effects of bias" and concluded that a widely distributed attentional setting (induced by the Identity Bias condition) was the most optimal for face recognition but also benefited the efficient processing of expression, a specific feature of the face. However, a narrowing of attentional distribution (induced by the Expression Bias condition) improved expression detection, but had a large cost on the detection of identity. Thus, Austen and Enns (2003) showed that even while fully attentive to a single object the observer does not uniformly process all of the visual attributes that comprise that object, but rather that processing is selectively achieved through a global attentional setting that both optimally captures essential global and local elements while flexibly attuning to changes in the immediate context.

Thus, the tuning of attention to global–local structures may involve two mechanisms that develop at different rates. One, an early developing global attentional setting that generalizes across global–local tasks and a later developing attunement to accommodate to the changing environmental conditions. There is some preliminary evidence for this developmental sequence as the performance of the youngest TD-VMA group in this study was less sensitive to the implicit task biases, yet showed the strongest structural global bias. Thus, the asymmetry in attentional biases may be an integral part of adaptive processing of visual events.

The current findings indicate that, in children with autism, the attentional setting and attunement dimensions of global–local processing may be organized or manifested differently, and the asymmetry between structural and task biases may be attenuated. For example, compared to typically developing children matched on VMA and NVMA, children with autism showed less stability in global bias across search conditions and relied more on prior experience with a particular level of the visual structure (repeated presentations of the target at a specific level) to guide their attentional strategies and set processing priorities. A similar pattern of results was found in a study of the orienting performance of individuals with autism (Ristic *et al.*, 2005). Unlike typically developing individuals who are biased to automatically orient to eye-gaze direction from infancy (Butterworth & Jarrett, 1991; Corkum & Moore, 1995; Hood, Willen, & Driver, 1998) and have difficulty overcoming the bias even in adulthood (Friesen, Ristic, & Kingstone, 2004), individuals with autism did not share the same bias to attend to the social relevance of perceived gaze direction. Rather, they voluntarily attended to eye gaze cues in response to the behavioral contingencies (i.e., high correspondence between the cue and the target) between the eye-gaze direction and stimulus event (Ristic *et al.*, 2005).

The different approach to global–local processing among children with autism may have perceptual consequences by setting priorities to attend to one level of structure over another, although children with and without autism have the same access to global and local visual structures as evidenced in Experiment 1. The pattern of global–local processing observed in the children with autism, and possibly other aspects of selectivity, may be characterized as piecemeal and data driven, whereas the typical processing style is more parsimonious and theory driven. A piecemeal and data driven strategy may be particularly useful for global–local tasks that require rapid and selective tuning of perception on a moment-to-moment basis in response to the immediate background such as extracting an embedded figure from a complex background (Frith & Happe, 1994), determining whether an image is geometrically impossible (Mottron & Belleville, 1993) and recognizing inverted faces (Boucher & Lewis, 1992; Davies, Bishop, & Manstead, 1994; Langdell, 1978).

This part-based system of processing may also explain decrements in the performance of persons with autism on other types of global–local tasks (Behrmann & Avidan, 2005). For example, most individuals attend to the upper eye region of the face – an area that is most informative for identity recognition (Vinette, Gosselin, & Schyns, 2004). However, children with autism demonstrate a bias toward attending to information located in the lower, mouth region, as they spontaneously perform more visual saccades and spend longer fixation times looking at the mouth than the eye region of the face (Dalton *et al.*, 2005; Klin, Jones, Schultz, Volkmar, & Cohen, 2002) and show greater impairment when the mouth is occluded (Langdell, 1978). Similarly, children with ASD are more likely to integrate the mouth features than the eye features in their holistic face representations (Joseph & Tanaka, 2001).

Thus, children with autism who are overly reliant on the spatial–temporal features of a task may learn quickly to selectively tune their perception on a moment-to-moment basis in response to the immediate context, but may be disadvantaged over the course of development when perceptual learning must be consolidated and generalized to different contexts. These strict attunement to task contingencies is not always beneficial as it does not necessarily or consistently inform about subsequent processing priorities across tasks. Conversely, typically developing children who use a parsimonious and theory driven global–local processing strategy may become adept at a variety of visual tasks with experience and practice but are most proficient at face processing because of the highly configural organization of the face and the extensive experience with homogeneous exemplars from birth (Tanaka, 2001).

Perceptual and, more generally, cognitive biases are ubiquitous in humans and, all too often, lead to misperception or fallacies in human judgment (e.g., visual illusions, misattributions of cause and effect, misattributions about the self and other, and hindsight biases) (Ross & Nisbett, 1980; Tversky & Kahneman, 1974). These cognitive biases may be exceedingly difficult to overcome since awareness of the bias does not produce a more accurate perception. Despite these shortcomings, biases in global–local perception appear to reduce the burden of visual processing of the wide range of features available within even one object or visual event.

CONCLUSIONS

Although children with autism are able to "integrate the parts into a coherent whole" and can attend to the global or the local level of a visual structure when called to do so, they may coordinate attention differently between the two levels. This piecemeal strategy of processing may lead to enhanced performance in some contexts wherein structural global biases typically interfere with the task requirements (e.g., embedded figures test) but may impede performance in everyday visual exploration, particularly of objects that are complex and dynamic (e.g., face identity and emotion recognition), as these attentional biases are adaptive mechanisms for managing the overabundance of visual information embedded within any object.

ACKNOWLEDGEMENTS

We thank the students, parents, teachers, and school principals who participated in this study, Dr. Peter Doehring, Director of the Delaware Autistic Program, and Hanna Kovshoff, Tara Flanagan, and Catherine Zygmuntowicz for their invaluable help with data collection. Grace Iarocci's work was supported by a research grant from the Social Sciences and Humanities Research Council of Canada. Jake Burack's work was also supported by a research grant from the Social Sciences and Humanities Research Council of Canada. David Shore thanks the Killam Trust funds (Dalhousie) and the Rotman Research Institute for post-doctoral fellowships. James Enns' work was supported by an NSERC (Canada) Discovery Grant.

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