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Face Perception in High-Functioning Autistic Adults: Evidence for Superior Processing of Face Parts, Not for a Configural Face-Processing Deficit

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Configural processing in autism was studied in Experiment 1 by using the face inversion effect. A normal inversion effect was observed in the participants with autism, suggesting intact configural face processing. A priming paradigm using partial or complete faces served in Experiment 2 to assess both local and configural face processing. Overall, normal priming effects were found in participants with autism, irrespective of whether the partial face primes were intuitive face parts (i.e., eyes, nose, etc.) or arbitrary segments. An exception, however, was that participants with autism showed magnified priming with single face parts relative to typically developing control participants. The present findings argue for intact configural processing in autism along with an enhanced processing for individual face parts. The face-processing peculiarities known to characterize autism are discussed on the basis of these results and past congruent results with nonsocial stimuli.

Keywords: autism, configuration, face perception, inversion, peaks of ability, visual processing

It has been hypothesized that deficits in processing faces underlie the social difficulties observed in the autistic spectrum (Hobson, Ouston, & Lee, 1988; Langdell, 1978). Various face-processing impairments have been reported in this population. For example, high-functioning individuals with autism and Asperger's syndrome perform worse than their matched controls in the recognition of face identity across changes of facial expressions or orientation (Davies, Bishop, Manstead, & Tantam, 1994). Low-functioning individuals with autism also experience difficulties matching faces according to age and gender (Hobson et al., 1988). They are impaired on facial expression matching (Braverman, Fein, Lucci, & Waterhouse, 1989) and when detecting an incongruent face relative to typical controls (Tantam, Monaghan, Nicholson, & Stirling, 1989). The poor performance of low-functioning individuals with autism is also observed in the immediate recognition of unfamiliar faces, whereas that of nonfacial stimuli is preserved (buildings: Boucher & Lewis, 1992; shoes: Gepner, de Gelder, & de Shonen, 1996). The delayed recognition of previously seen faces also reveals a face memory deficit in low-functioning individuals with autism (Hauck, Fein, Waterhouse, & Feinstein, 1995).

Functional MRI investigations of face processing in autism have provided evidence for an absence of activation of the fusiform face area in face discrimination tasks, whereas typical individuals show maximum activation in this region (Schultz et al., 2000). Indeed, Schultz et al. observed an activation of the inferior temporal gyrus, a region implicated in object recognition in typical individuals, when individuals with autism were looking at faces. Pierce, Muller, Ambrose, Allen, and Courchesne (2001), though replicating the absence of typical fusiform face area activation, emphasized that the loci of maximal activation were not restricted to the inferior temporal regions and extended to individual-specific neural sites in persons with autism. However, the possibility that these atypical patterns of activation result from atypical attentional strategies during the task, rather than a perceptual deficit, has been raised (Hadjikhani et al., 2004).

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These behavioral and neuroanatomical activation peculiarities have led to the hypothesis that individuals with autism show a deficit in processing faces configurally and rely instead on part-based encoding (Boucher & Lewis, 1992; Davies et al., 1994; Tantam et al., 1989). This would be consistent with preferential focus on face parts (e.g., mouths), evident in face recognition (Langdell, 1978) or observation (Klin, Jones, Schultz, Volkmar, & Cohen, 2002) tasks. It would also be coherent with activation of the cerebral regions implicated in part-based object processing during face discrimination tasks (Schultz et al., 2000).

However, this possibility generalizes the hypotheses initially formulated for nonsocial pattern perception among individuals with autism, who show a perceptual bias toward local aspects of information. This bias is assumed to result from a deficit in the perception of global configurations and has been theorized as the weak central coherence (WCC) model (Frith, 1989/2003). Findings of detail-focused perception (Jolliffe & Baron-Cohen, 1997; Plaisted, Sweettenham, & Rees, 1999), but with intact global processing (Mottron, Burack, Iarocci, Belleville, & Enns, 2003; Mottron, Peretz, & Ménard, 2000; Plaisted, 2001), have led to the revision of the WCC model and the proposition of the enhanced perceptual functioning (EPF) model (Mottron & Burack, 2001; for an updated version, see Mottron, Dawson, Soulières, Hubert, & Burack, 2006), which proposes that perceptual operations in general, from feature extraction up to and including pattern recognition, are enhanced in autism.

With respect to social material, the possibility of superior part-based processing without configural impairment predicted by the EPF model has not yet been assessed. In the first experiment, the configural processing of whole faces was investigated through the face inversion effect (FIE). In the second experiment, the possibility of a greater emphasis on the processing of face parts was assessed through a face priming paradigm.

Experiment 1: FIE

Recognition of faces has been shown to rely preferentially on the configural information contained in faces (Diamond & Carey, 1986). Face inversion disturbs the processing of configural information (Mondloch, Le Grand, & Maurer, 2002; Searcy & Bartlett, 1996), thereby explaining the decrease in recognition performance evident with inverted faces (the FIE). Thus, individuals with autism performed at a higher level than did their matched controls in the recognition of inverted faces, whereas they performed similarly or at an inferior level in the upright condition (Hobson et al., 1988; Langdell, 1978) and did not show the typical advantage with an upright versus inverted presentation of face stimuli as compared with matched controls (Tantam et al., 1989; see Experiment 2).

The results from FIE paradigms have been repeatedly reported as a demonstration for a configural face-processing deficit in autism. However, a recent study by Joseph and Tanaka (2003) questioned these conclusions. These authors briefly presented a target face, followed by two contiguous faces or face parts (Tanaka & Farah, 1993). In the whole face condition, one of the faces was identical to the target, and the other differed from the target by a single facial part. In the isolated part condition, two face parts were presented after the target face, one belonging to the target face, and the other belonging to another face. Individuals with and without autism did not differ in the recognition of upright face parts when these were presented in their facial context instead of in isolation. In addition, the whole-face advantage disappeared for both groups in the inverted condition. The superior recognition of face parts presented within a facial context was attributed to a holistic encoding of upright faces, a type of encoding that is prevented by inversion. Joseph and Tanaka concluded that the face-processing anomalies in autism cannot be entirely explained by a failure to process the configural information contained in faces.

In Experiment 1, the FIE was reexamined by using a two-choice, match-to-sample task. Nonface stimuli, Greebles, were also used as the control condition, in order to address the issue of the specificity of the autistic deficit, if any. Only the control group was expected to show the typical inversion effect for faces. Both groups were expected to show no inversion effect for Greebles (Rossion et al., 2000).

Method

Participants

Participants with autism. Sixteen adolescents and adults with autism and normal intelligence were randomly recruited from the database of the Rivière-des-Prairies' specialized autism clinic. *Diagnostic and Statistical Manual of Mental Disorders—Fourth Edition* (American Psychiatric Association, 1994) retrospective diagnoses of autism were obtained through the Autism Diagnostic Interview—Revised (Lord, Rutter, & Le Couteur, 1994) for all autistic participants, except 1 who received an in-depth file assessment. Resulting scores were higher than cutoff for all participants but 1 who was subthreshold in the social area (participant: 7; cutoff: 10). He was included in the study because he scored clearly above the Autism Diagnostic Observation Schedule Social plus Communication score cutoff (participant: 13; cutoff: 10). Current diagnoses were confirmed in all but 3 participants through direct observation by using the Autism Diagnostic Observation Schedule—Generic (ADOS–G; Lord, Rutter, & Dilavore, 1997). ADOS–G scores were above cutoff for all these participants, except 1 who was subthreshold in the social (participant: 5; cutoff: 6) and communication (participant: 2; cutoff: 3) areas. He was included because he scored above the Autism Diagnostic Interview cutoff (social: participant = 24, cutoff = 10; communication: participant = 16, cutoff = 8). Three participants who did not receive an ADOS–G received an in-depth clinical assessment through direct observation. Fourteen participants were right-handed and 2 were left-handed. Intellectual functioning was assessed by using the verbal and nonverbal scores of one of the Wechsler Intelligence scales (Wechsler Adult Intelligence Scale—Third Edition: Wechsler, 1997; Wechsler Intelligence Scale for Children—Third Edition: Wechsler, 1991; Wechsler Adult Intelligence Scale—Revised: Wechsler, 1981; Wechsler Intelligence Scale for Children—Revised: Wechsler, 1974). One participant with Pervasive Developmental Disorder received Raven Matrices (Raven, 1938/1996) in place of a Wechsler scale. All participants with autism were students or employed in regular jobs and were living at home or independently at the time of the study.

Comparison participants. Sixteen individuals with typical development were recruited from the clinic's database of control participants. Participants had to be free of any medication, past or present neurological or psychiatric disorders, learning disabilities, and family history of autism and other neuro-developmental or psychiatric disorders. Individuals with autism were individually matched to control participants according to verbal, nonverbal and global IQ, laterality (Oldfield, 1971), and chronological age (see Table 1). Approximately the same number of participants from both groups received each version of intelligence scales in the two groups, and nine autistic–control pairs were also matched according to version of IQ test. All participants had normal or corrected-to-normal vision. This study was approved by the local ethical committee, and participants received financial compensation for their participation.

Table 1
Sociodemographic Characteristics of Autistic and Control Participants in Experiment 1

	Autism			Control		
Variable	*M*	*SD*	Range	*M*	*SD*	Range
Age (years)	20.69	4.67	15–32	20.25	3.55	17–28
Verbal IQ	108.13	11.34	95–132	110.46	8.19	95–125
Nonverbal IQ	104.33	11.02	89–130	107.13	12.22	99–132
FS-IQ	108.69	10.29	93–130	109.63	10.37	92–131
Gender	15 males, 1 female			15 males, 1 female		

Note. FS-IQ = full-scale IQ.

Stimuli

The stimuli consisted of images of faces and Greebles. Fifty-two gray-scale faces (26 female and 26 male Caucasian faces) were created by using IQ Biometrix's FACES LE software, Version 3.0 (1998; http://www.wherify.com or http://www.iqbiometrix.com). Four additional face stimuli (two male and two female) were created for the practice trials. Faces did not share any facial feature, and those that contained skin imperfections and features that were too asymmetrical or too salient were discarded to avoid a local processing bias. The facial expression was neutral, and the apparent age ranged between 18 and 35 years. All face stimuli were edited in Adobe Photoshop 3.0.5 in order to remove skin surfaces exceeding the facial outline (see Figure 1A). Each face measured approximately 6 cm wide × 8 cm high. In each gender set, 26 mismatching face pairs (target + foil) were created. Each face was presented once as a target and once as a foil. To avoid the cerebral lateralization effects observed in face recognition (Ricciardelli, Ro, & Driver, 2002), we aligned the target and foil vertically. The location of the target (above or below) was counterbalanced across trials. The task comprised four blocks (upright female faces, inverted female faces, upright male faces, and inverted male faces) of 26 trials each. The same stimulus pairs were used for upright and inverted orientations.

Greebles

Greebles (see Figure 1B) are three-dimensional, unfamiliar complex objects created by Scott Yu, by using Alias sketch! (Alias Research, Toronto, Ontario, Canada). Fifty-two Greebles (26 "Plok" and 26 "Glip") were selected from the original Greeble sample. Four additional Greebles (2 Plok and 2 Glip) were selected for the practice trials. Trials, target position, and block arrangement were identical as for the face stimuli,

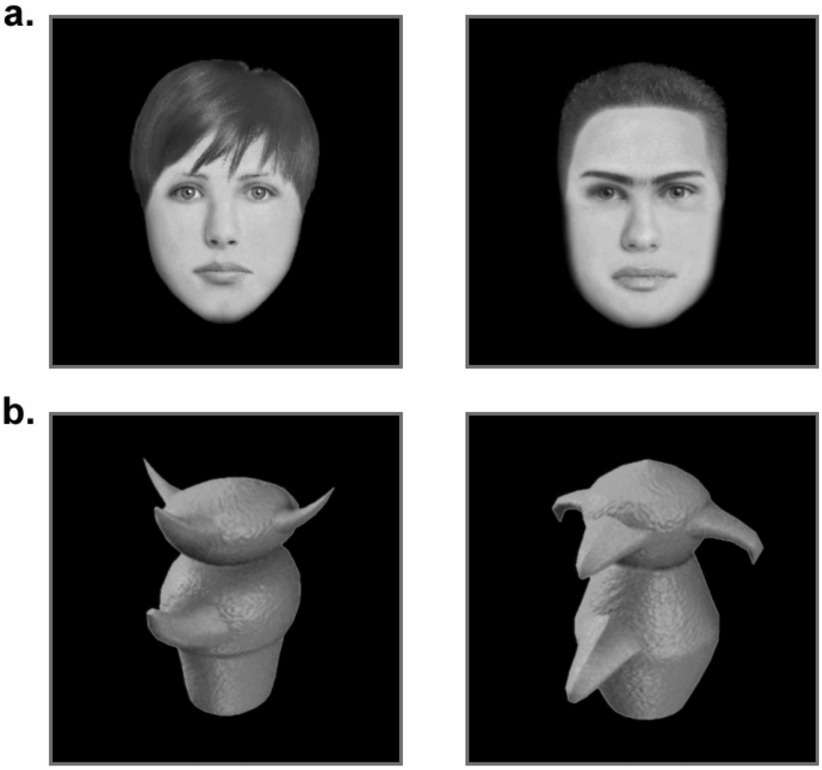

Figure 1. A: Illustration of a male and a female face used in Experiment 1. B: Illustration of a "Plok" and a "Glip" Greeble used in Experiment 1.

resulting in four blocks of 26 trials (upright Plok Greebles, inverted Plok Greebles, upright Glip Greebles, and inverted Glip Greebles).

Apparatus and Procedure

The experiment was run by using Psychlab (Bub & Gum, 1998) on an Apple Macintosh Mac Os 8.6 (processor: Power Mac G4) equipped with a studio-display 17-color monitor (resolution: 1,024 × 768 pixels). All stimuli were presented in grayscale on a black background encompassing the participant's entire visual field.

The experiment consisted of eight blocks of 26 trials. For each stimulus type (face and Greeble), the inverted presentation block was followed immediately by the upright block. This order of block presentation guarantees that familiarization to the task occurred during its easier (upright) part, thereby preventing a possible confound of familiarization with the inversion effect. Face and Greeble genders were alternated in the testing sequence. Pairs of autistic–control participants were randomly assigned to a predetermined testing sequence. Eight different counterbalanced block orders were determined.

A 4-trial practice preceded each 26-trial block in order to familiarize participants with the test condition. During the testing phase, faces within a block were presented in a different random sequence for each participant. In each trial, participants viewed a 500-ms fixation asterisk presented at the center of the screen that was immediately followed by a target face. The target face disappeared after 989 ms, followed by a 24-ms mask (a scrambled Greeble or a scrambled face with the same hair as the target but with novel parts) intended to eliminate any afterimage that may remain of the target. The two faces or Greebles that were to be discriminated were then presented immediately. Participants were instructed to choose which one of the two faces or Greebles presented was identical to the target image viewed before. The stimuli disappeared upon the participant's response. Trials were separated by a delay of 12 ms after the response. Participants were told to work quickly but accurately. They gave their responses by pressing one of two predetermined keys on the computer keyboard (left-handed participants: *2* or *A* key; right-handed participants: minus or plus key).

Results

Data Preparation

From the total sample, 3 autistic participants were excluded, because of distractibility ($n = 2$) or motor tics ($n = 1$) that impeded their ability to participate in the task. Data for correct trials for which response times (RTs) were more than three standard deviations from each subject per condition mean (calculated without the two slowest and the two fastest RTs) were excluded from the analyses (autistic group: 3.2%; control group: 3.5%). Results showed no speed–accuracy trade-off for the autistic and control groups, as verified by the correlations between averaged RTs and errors (*ns*).

Reaction Time Analyses

Statistical analyses were performed on correct reaction times (see Figure 2A). An analysis of variance (ANOVA) for paired samples was conducted, with Group (autistic vs. control) as the between-subjects factor and Stimuli (faces vs. Greebles) and Orientation (upright vs. inverted) as within-subjects factors. Participants with autism tended to display slower reaction times across all conditions, although the ANOVA revealed a nonsignificant effect of group, $F(1, 15) = 3.19$, $p > .09$, $\eta^2 = .175$ (Cohen, 1988). Furthermore, the analysis revealed a significant Stimuli × Orientation interaction, $F(1, 15) = 5.03$, $p < .04$, $\eta^2 = .251$. A breakdown of this interaction revealed a significant inversion effect for faces, taking the form of faster recognition responses to upright than to inverted faces, $F(1, 15) = 36.10$, $p < .00001$, $\eta^2 = .706$; but not for Greebles, $F(1, 15) = 0.708$, $p > .4$, $\eta^2 = .045$. This pattern of results was observed in both the autistic (FIE: 68.85 ms; Greebles inversion effect: 42.65 ms) and control (FIE: 67.05 ms; Greebles inversion effect: −10.3 ms) groups.

Accuracy Analyses

Participants obtained average accuracy scores of above 94% for both groups and all conditions. Error rate analyses revealed a significant Group (autistic vs. control) × Stimuli (faces vs. Greebles) × Orientation (upright vs. inverted) interaction, $F(1, 15) = 6.45$, $p < .025$, $\eta^2 = .301$, indicating that the inversion effect differed across groups in ways that varied according to the type of stimuli (see Figure 2B). A breakdown of this interaction was performed in order to determine the effects of group and orientation separately for each type of stimuli. For faces, this analysis demonstrated a significant Group × Orientation interaction, $F(1, 15) = 4.94$, $p < .045$, $\eta^2 = .248$. Simple effects analysis revealed that participants with autism performed better with upright than inverted faces, $t(15) = 2.19$, $p < .045$, $\eta^2 = .243$. In contrast, face inversion had no effect on accuracy in the control participants, $t(15) = 1.35$, $p > .1$, $\eta^2 = .108$. For Greebles, the interaction of Group × Orientation was not significant, $F(1, 15) = 0.78$, $p > .3$, $\eta^2 = .050$. Only the main effect of group was significant, $F(1, 15) = 9.24$, $p < .008$, $\eta^2 = .381$, which indicated a greater error rate in the control group.

Discussion

The purpose of Experiment 1 was to investigate the nature of the differences that underlie atypical face processing in autism by assessing the FIE. According to several of the previous studies investigating this effect, participants with autism were expected to show a diminished or absent FIE. In contrast to these expectations, a similar FIE was observed in both groups. In addition, autistic participants exhibited a significant cost of face inversion on accuracy that control participants failed to demonstrate. These observations are in keeping with Joseph and Tanaka (2003), who found a typical FIE in autistic participants, whereas the observations are incongruent with the hypothesis that those individuals present a configural face-processing deficit.

The inconsistency of the current findings with those previously documented may be accounted for because previous conclusions were based on error rates only, without examining concurrent RTs. Indeed, differences in the spontaneous inspection time of faces between individuals with and without autism have been documented (Klin et al., 2002). Typical participants spend less time looking at upside-down than at upright faces (van der Geest, Kemner, Verbaten, & Engeland, 2002). In addition, reported error rate differences between upright and inverted face recognition were weak and based on a very small number of trials (Hobson et al., 1988; Langdell, 1978). Another problem is that a floor effect may be responsible for the null inversion effect observed in the autistic group of the Tantam et al. (1989) study. We reduced this confound by diminishing our task complexity. Finally, emotionally

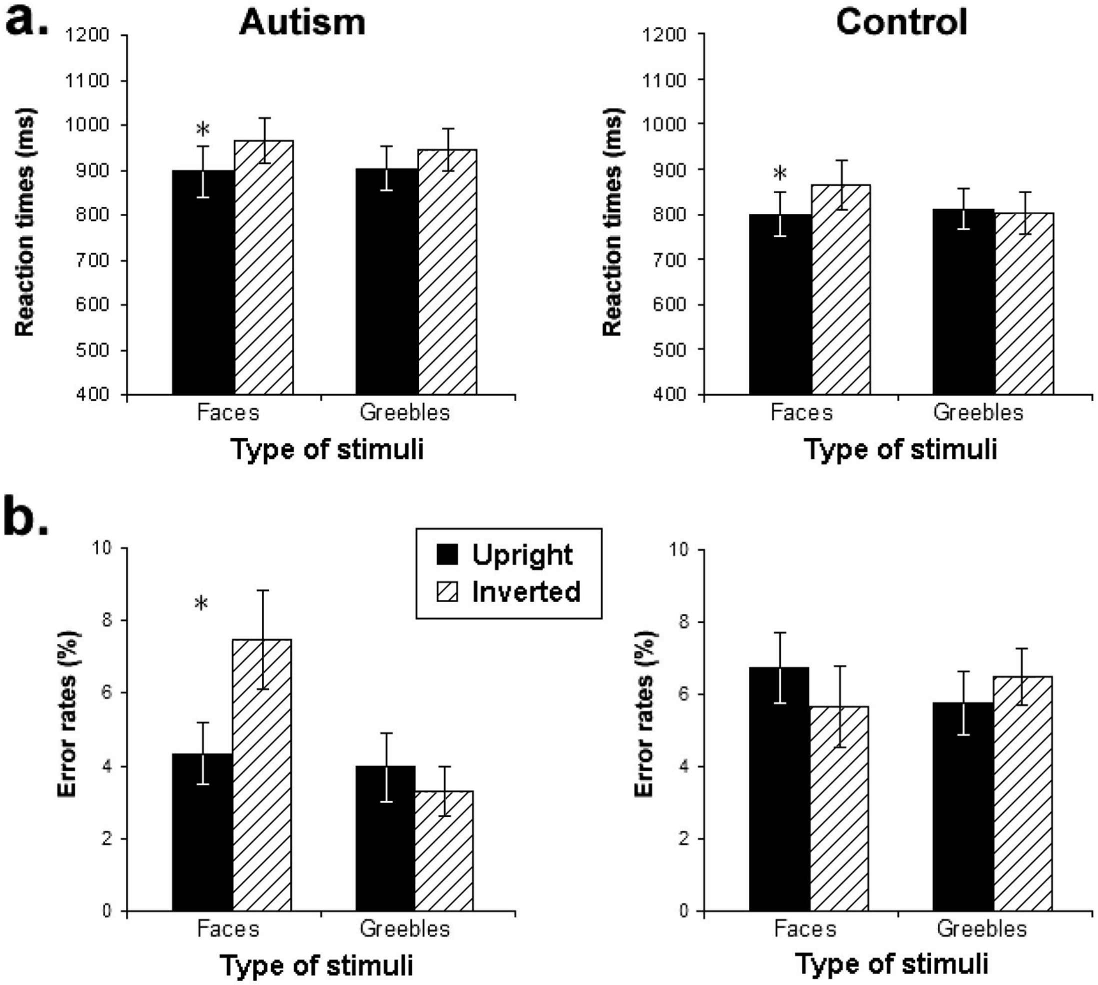

Figure 2. A: Correct reaction times observed in the autistic and control groups in the two-choice match-to-sample task with faces and Greebles, upright and inverted (Experiment 1). B: Error rates observed in the autistic and control groups in the two-choice match-to-sample task with faces and Greebles, upright and inverted (Experiment 1). * For A: Autism and Control, $p < .00001$; for B: Autism, $p < .045$.

neutral face stimuli were used, thus preventing interference of facial emotion with perceptual face processing.

Experiment 2: Face Priming Paradigm

Although a locally oriented perceptual bias has been proposed to account for the face-processing anomalies observed in autism, no study has yet specifically assessed whether a local bias exists in the face processing of this population. Arguin and Saumier (2004) developed a paradigm that allows an assessment of the contribution of configural and local processing in face recognition by measuring how natural and arbitrary face segments prime face identification. The rationale is that a prime should produce a reduction of face identification latency if it shows a dimension or feature that is specifically processed during face observation. The two factors manipulated were the type of face segmentation performed to construct the primes (natural and arbitrary) and the number of facial segments exposed within the prime (neutral–baseline condition, one, two, three, and four parts).

Natural parts were created by segmenting the faces according to eyes, nose, mouth, and contour (see Figure 3B). A single natural part (e.g., mouth) does not contain any configural information. According to the results of Arguin and Saumier (2004) with typical individuals, a single natural part presented as prime did not affect face identification speed. Adding a second natural part (e.g., mouth) to a previous one (e.g., eyes) adds both local information (the mouth itself) and configural information (distance between eyes and mouth; see Figure 3B). The gain in configural information produced by the addition of a part in the prime grows with the number of parts. With two parts shown in the prime, one spatial relation is specified, whereas three parts specify three pairwise spatial relations. Increasing the number of natural parts has an accelerative gain function, indicating a synergy among face parts, rather than a mere addition of the effect of each part. Supporting this interpretation, the accelerative gain function obtained with natural parts is transformed into a merely additive one in prosopagnosic patients with impaired configural processing (Saumier,

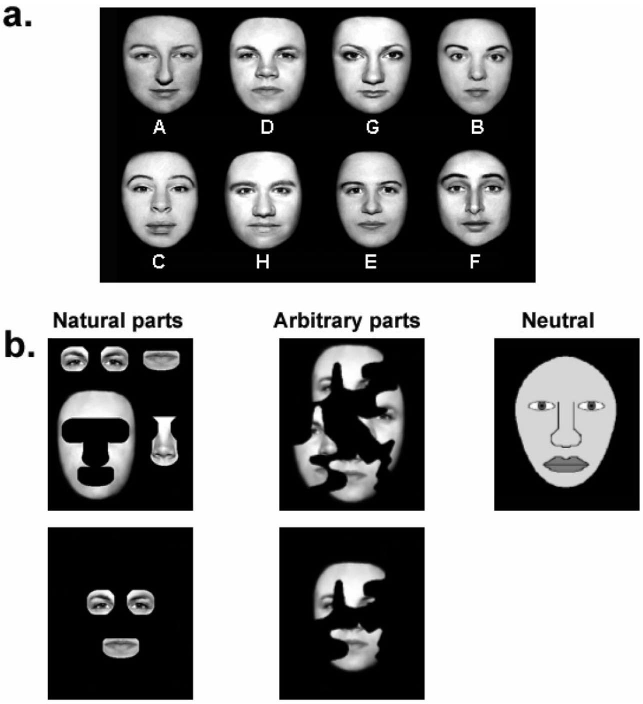

Figure 3. A: The eight faces used in the familiarization phase of Experiment 2. Each face is identified by a specific letter. B: Illustration of the segmentation applied to construct primes made of natural and arbitrary parts (Experiment 2); schematic face used as a neutral–baseline prime (Experiment 2).

Arguin, & Lassonde, 2001) as well as in typical observers when the primes are inverted (Arguin & Saumier, 2004).

Arbitrary parts were created by puzzlelike face segmentations that cut across natural facial parts (see Figure 3B). A single arbitrary part contains partial information about two or more natural face parts and configural information pertaining to the spatial relations between these parts. Adding a second arbitrary part to a previous one provides quantitative, but not qualitative, additional information about the target face, as configural information is already present in each individual arbitrary segment (see Figure 3B). Accordingly, increasing the number of segments in the prime resulted in a linear (or additive) gain function.

Control participants were expected to show a gradual decrease in their RTs as the number of parts in the prime increased. This decrease should follow an accelerating function when the primes are composed of natural face parts. In contrast, the priming function should be linear when the primes are composed of arbitrary facial segments. In addition, the priming effect with single natural face parts should not be significant, in contrast to single arbitrary face parts. Among autistic individuals, increasing the number of natural parts in the prime should result in a linear (or, at least, a less accelerative) gain function if they are impaired in processing configural face information. Increasing the number of arbitrary parts should not affect the linearity of the priming function expected in the control group. Moreover, a locally oriented processing in autism should produce a significant priming effect even for unique natural facial parts.

Method

Participants

Participants with autism. Of 13 participants (see Table 2), 11 were from Experiment 1. Of the 2 participants who participated only in Experiment 2, 1 received a standardized assessment, and 1 received a nonstandardized assessment.

Comparison participants. Five of 13 participants were from Experiment 1.

The proportion of participants receiving a specific version of the Wechsler scales was similar to that in Experiment 1.

Stimuli

Eight faces from the University of Stirling face database (http://pics.psych.stir.ac.uk/) were selected (see Figure 3A). Faces had to be different in their overall facial features while being sufficiently similar not to be easily identified on the basis of any local feature. They were also chosen to be as comparable as possible in terms of age, overall size, skin complexion, and ambient lighting. The selected faces were also as symmetrical as possible with their orientation and eye gaze directed straight toward the viewer. All faces presented a neutral emotional expression. Hair, ears, neck, and skin imperfections were also digitally removed. The position of the major internal facial features was normalized so that each face was identical to the others in this respect. The vertical length of the faces was matched by normalizing the distance between the chin and the midpupil (this distance corresponds to half of the head height of 9.8 cm).

Each face was divided along identical segmentation lines into four distinct components corresponding to natural facial parts: eyes, nose, mouth, and facial contour (see Figure 3B). Each face was also divided along another set of identical segmentation lines into four distinct arbitrary components cutting across the natural facial parts (see Figure 3B). Primes were made of one, two, or three natural or arbitrary face parts, or they constituted a complete face (i.e., four parts). A generic cartoonlike face was also constructed with its drawn parts (eyes, nose, mouth, and facial con-

Table 2
Sociodemographic Characteristics of Autistic and Control Participants in Experiment 2

	Autism			Control		
Variable	*M*	*SD*	Range	*M*	*SD*	Range
Age (years)	21.54	4.91	15–32	21	4.53	15–29
Verbal IQ	111.25	11.12	98–132	110.46	7.49	99–125
Nonverbal IQ	108.17	10.57	89–130	111.08	9.58	98–125
FS-IQ	112.69	9.24	101–130	111.54	6.77	99–127
Gender		13 males			13 males	

Note. FS-IQ = full-scale IQ.

tour) having a height and width that was the average of the parts making up the eight faces described above (see Figure 3B). This generic face served as a neutral prime in the priming phase.

Apparatus and Procedure

The apparatus was the same as for Experiment 1. The entire test period involved two or three phases, depending on whether the participant successfully learned the face sample. In the first phase of the experiment, the participants were shown the entire set of eight faces on the computer screen. One of the first eight letters of the alphabet was typed below each face. Each participant was instructed to study and memorize the face–letter associations displayed during 5 min. Before the familiarization phase began, the participants were told that their memory of the face–letter associations would be tested immediately after the 5-min study period by having them name the correct letter for each face presented individually.

The consolidation phase started immediately after the familiarization phase. For this second phase, participants were told that they had to meet two criteria, that is, to be able to correctly and rapidly name each of a random series of 24 face presentations. The participants were not informed at this point that there would be a third test phase. On each trial, participants viewed a 500-ms fixation asterisk presented at the center of the screen, which was immediately followed by the target face. Participants named the letter specifically associated with the face presented in isolation on the computer screen. The target face disappeared immediately when the participant's verbal response activated the voice key connected to the computer. The experimenter then registered the participant's response through the computer keyboard. Both visual and digitally prerecorded auditory feedback giving the correct name for the target on that particular trial were presented by the computer 500 ms after each response. The next trial began 1,000 ms after the feedback presentation. Each participant was required to complete at least one training block of 24 randomly ordered faces (each of the targets appearing three times). This training block was repeated until the participant's performance satisfied the following two conditions: (a) the entire block of 24 face presentations was completed without error, and (b) the RT to name the target was under 1,500 ms for every trial of that block. Each participant was allowed to complete a maximum of 20 blocks. Participants failing to satisfy the two learning criteria after completion of the 20th block did not pursue the third phase of the experiment.

In the third phase of the experiment (priming phase), participants named the previously learned faces, which were primed by facial parts matching the face subsequently presented as the target. On each trial, participants viewed a 500-ms fixation asterisk, followed immediately by a 400-ms prime, then by a 13-ms mask (the outline of the generic face filled in with a checkerboard made of 4 × 4-pixel squares), and the target face presented immediately afterward. The target disappeared when the participant's verbal response activated the voice key connected to the computer. The experimenter then recorded the response through the keyboard. Participants completed four blocks of 120 trials, for a total of 480 trials per subject. Block order was counterbalanced across participants. There were two blocks for each type of facial section used (natural vs. arbitrary facial segmentation). The combinations of prime type (one, two, three, or four part primes and neutral primes; i.e., generic face) and target faces were randomized across blocks. Each target face appeared an equal number of times and with equivalent numbers of each prime type within each block. The eyes, nose, mouth, or contour were shown equally often across trials where a single part of the subsequent target was shown in the prime. Primes made of multiple face parts were constructed by using all the possible combinations of eyes, nose, mouth, and contour an equal number of times across the complete set of eight faces.

Results

Data Preparation

Three participants with autism and 2 control participants were excluded because they failed to reach the learning criteria. Three participants belonging to the autistic group (same participants as in Experiment 1) were excluded because of distractibility or motor tics. To perform analyses on data representative of the processes under study, we discarded trials that failed to activate the voice key (autistic group: 0.9%; control group: 0.7%), correct trials for which RTs were more than three standard deviations from each subject per condition mean (autistic group: 3.8%; control group: 3.9%), and trials on which an error occurred (autistic group: 1%; control group: 2%). Only correct responses were taken into account for the analyses of priming effects.

Priming Effect Analyses

Configural processing of faces. Both groups displayed a gradual decrease in RTs as the number of parts in the prime increased. For each group, there was a main effect of the number of parts presented in the primes: control group, $F(4, 48) = 272.32$, $p < .00001$, $\eta^2 = .958$; autistic group, $F(4, 48) = 188.47$, $p < .00001$, $\eta^2 = .940$. The repeated three-way interaction of Group × Number of Parts × Type of Primes was not significant, $F(4, 48) = 0.48$, $p > .7$, $\eta^2 = .039$. The interaction of Group × Number of Parts was not significant either, $F(4, 48) = 0.72$, $p > .5$, $\eta^2 = .057$, indicating that increasing the number of parts in the prime similarly affected RTs in the two groups (see Figure 4).

The form of the priming effects according to the type and number of parts used were examined through a repeated measures ANOVA based on polynomial contrasts (Kirks, 1968).[1] When natural facial sections were used, 88.3% (control group) and 89.3% (autistic group) of the total variance in RTs was explained by the linear component, 11.6% (control group) and 9.8% (autistic group) were explained by the quadratic component, 0.0% (control group) and 0.8% (autistic group) were explained by the cubic component, and 0.1% (for both groups) was explained by the quartic component. The test for departure from linearity was significant—control group, $F(3, 48) = 23.71$, $p < .00001$, $\eta^2 = .597$; autistic group, $F(3, 48) = 25.25$, $p < .00001$, $\eta^2 = .612$—thereby demonstrating a significant accelerating priming effect, as a function of the number of parts included in the primes for both groups. The contribution of cubic and quartic components was negligible, supporting the absence of irregularities in the curve.

When arbitrary facial segments were used, 96.8% (control group) and 98.2% (autistic group) of the total variance in RTs was explained by the linear component, 3% (control group) and 1.6% (autistic group) were explained by the quadratic component, and 0.1% (for both groups) was explained by the cubic and quartic components. The test for departure from linearity was significant

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[1] Several types of gain functions might characterize the particular pattern of priming effects. We used a repeated measures ANOVA based on polynomial contrasts (Kirks, 1968) that consisted of expressing the intrasubjects variance imputable to the factor Number of Parts, in percentage of explained variance. The percentage of total variance was therefore calculated for each of four different components (linear, quadratic, cubic, and quartic). This procedure aimed to verify whether the priming effect produced by the addition of parts in the prime could best be represented by a linear function or necessitates a higher degree function (quadratic, cubic, or quartic). A linear function is characterized by the absence of any inflexion point in the function (i.e. a straight line). A quadratic (or accelerating) function is characterized by the presence of a unique inflexion point. The quartic and cubic functions are characterized respectively by the presence of two and three inflexion points.

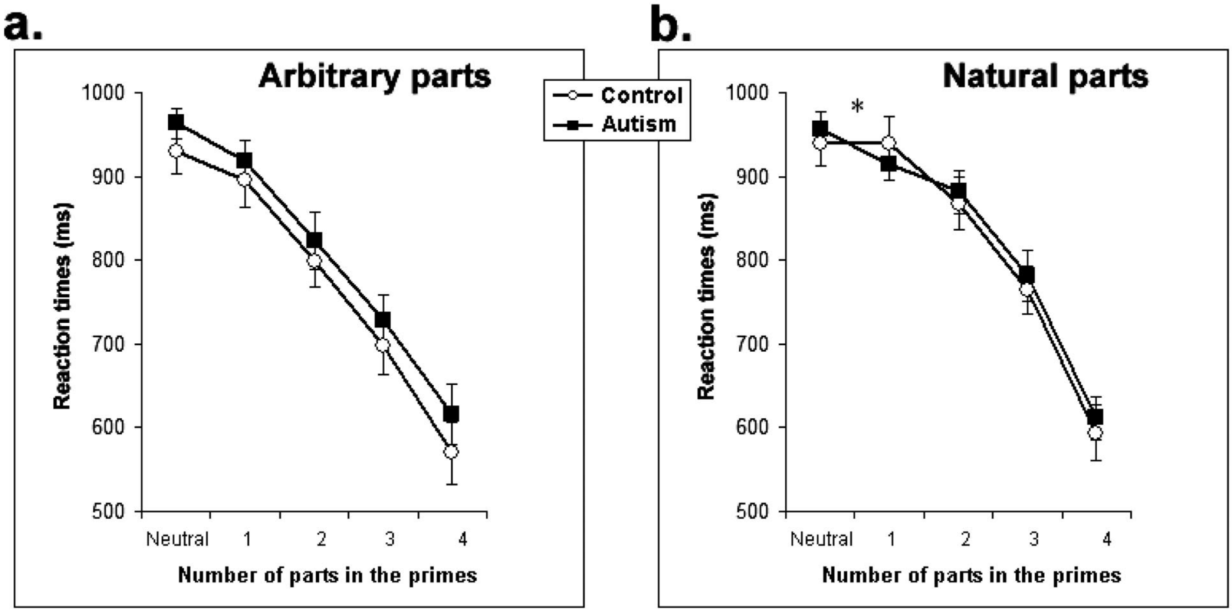

Figure 4. A: Correct reaction times observed for each group as a function of priming conditions with arbitrary face segments primes (Experiment 2). B: Correct reaction times observed for each group as a function of priming conditions with natural facial parts primes (Experiment 2). * $p = .051$.

for the control group, $F(3, 48) = 8.95$, $p < .0001$, $\eta^2 = .359$, but not for the autistic group, $F(3, 48) = 2.17$, $p > .1$, $\eta^2 = .012$. The former demonstrates a significant acceleration of the priming effect with an increasing number of arbitrary segments for normal controls. However, the magnitude of this acceleration was notably weaker than that observed with natural face parts. The contribution of cubic and quartic components was still negligible, supporting the absence of irregularities in the curve.

A repeated measures ANOVA conducted for each group separately revealed a significant Type of Parts × Number of Parts interaction in both groups: control group, $F(3, 48) = 4.56$, $p < .007$, $\eta^2 = .363$; autistic group, $F(3, 48) = 5.4$, $p < .003$, $\eta^2 = .403$. This interaction was due to a larger acceleration of the priming effect when the primes were composed of natural facial sections (quadratic component: control group: 11.6%; autistic group: 9.8%) than when they were made of arbitrary segments (quadratic component: control group: 3%; autistic group: 1.6%). This result replicates Arguin and Saumier's (2004) findings: For both groups, adding arbitrary parts produced a more linear priming curve than did adding natural parts. The similarity of the priming effect observed in the autistic and the normal control groups does not support the hypothesis of a configural face deficit in autism.

Local bias in face processing. Inspection of the priming functions (see Figure 4B) indicates a greater priming effect in the autistic group with single natural face parts (control group: 0.35 ms; autistic group: 41.82 ms) and arbitrary facial segments (resp.: 34.45 ms and 45.50 ms), suggesting a superior local face processing among participants with autism. Because a difference between groups was predicted for single part primes, the priming effects resulting from exposure to single natural or arbitrary parts were directly compared across groups. Student tests for paired samples showed significantly greater priming with a single natural face part in the participants with autism than in the control participants, $t(12) = 2.17$, $p = .051$, $\eta^2 = .281$, but no significant group difference with single arbitrary segments, $t(12) = 0.54$, $p > .6$, $\eta^2 = .024$.

Differential effect of face regions. The priming effect induced by each type of natural facial section (eye, mouth, nose, or contour) was compared across groups in relation to the a priori hypothesis of a higher reliance on the mouth region in autistic individuals (Klin et al., 2002). The interaction of Type of Facial Part × Group was not significant, $F(4, 48) = 1.17$, $p > .3$, $\eta^2 = .089$. However, post hoc within-group analyses revealed a significant effect of the type of natural part among individuals with autism, $F(4, 48) = 4.23$, $p < .005$, $\eta^2 = .261$. A posteriori comparisons using the Newman–Keuls method indicated a significantly greater magnitude of priming with the eyes than with the mouth, the contour, or the neutral condition ($p < .05$; eyes: 877 ms; nose: 916 ms; mouth: 943 ms; contour: 925 ms; neutral condition: 956 ms).

A Group (autistic vs. control) × Type of Prime (natural vs. arbitrary) × Number of Parts (neutral, one, two, three, or four) repeated measures ANOVA was also conducted on error rates. None of the interactions or main effects was significant (all ps > .05). In addition, the results showed no speed–accuracy trade-off for both the autistic and control groups, as verified by the correlations between average RTs and error rates (*ns*).

Discussion

The contribution of configural and local processing to face recognition was investigated by examining the priming effect produced by natural and arbitrary face segments in a face identification task. Participants with or without autism displayed an identical, accelerating priming function with an increasing number of natural parts in the primes and a weaker acceleration of the priming effect with an increasing number of arbitrary parts in the primes. The similar performances across groups when processing an increasing number of natural and nonnatural facial parts primes indicate that both groups benefited from configural information when processing faces. However, the two groups behaved differently regarding the gain produced by adding one and two parts in the natural parts condition. In the control group, no gain was observed by adding one part to a neutral prime, and the slope then increased abruptly from one part to two parts. In contrast, the gain evident by the autistic group was important between zero and one but remained linear between one and two parts. The fact that an important gain occurred between zero and one in the autism group plausibly diminishes the possible gain produced by the addition of a second natural face part. This limitation did not exist for the comparison group, for which gains began only when adding a second natural part. This may explain why the gain evident between one and two parts is superior to that between zero and one parts in the comparison group but is roughly equivalent in the autistic group. For the remaining part of the curve, the effect of this initial difference between groups disappears. The gain produced by adding configural information (three and four parts) therefore produces the same accelerative function in the two groups. Because of this initial difference in the processing of an isolated natural part, the actual demonstration of configural processing in the two groups remains the accelerative gain function produced by the complete sequence of adding one to four parts.

Typical individuals did not benefit from primes composed of a single natural facial part, consistent with Arguin and Saumier's (2004) findings. In contrast, the superior effect of a single natural facial part on recognition speed observed among participants with autism suggests that this amount of information is sufficient to activate face representations. This finding represents the first direct demonstration of a local bias in face recognition among these individuals, in the form of superior face-part processing.

Participants with autism used the eye region to a greater extent than other facial features. This contrasts with previous findings suggesting a greater degree of attention devoted to the mouth and less attention to eyes (Joseph & Tanaka, 2003; Klin et al., 2002). The fact that these previous findings were obtained by using long exposure durations (3.5 s for Joseph & Tanaka, 2003; counted in seconds for Klin et al., 2002) suggests that mouth preference (or eye avoidance) may rather reflect an attentional strategy. Presenting the face part for 400 ms minimizes only the risk that atypical attentional strategies toward faces (Klin et al., 2002; van der Geest et al., 2002) interfere with the measurement of perceptual processing.

In contrast, the priming effects obtained with natural parts and brief exposure durations reflect the amount of information extracted at the perceptual level. In the present study, the perceptual processing of eyes was superior to other face parts among individuals with autism. This provocative statement reconciles the apparently contradictory findings concerning processing of eyes through a distinction between enhanced perceptual processing of, and atypical attention toward, facial regions. This would also be consistent with van der Geest et al.'s (2002) results showing that the first fixation of children both with and without autism is directed toward the eyes, relative to the mouth region or outside the whole face area.

General Discussion

The integrity of the inversion effect and of the priming functions represent two independent arguments in support of spared configural processing in individuals with autism. The finding of a superior processing of face parts by individuals with autism may have an explanatory power for previous results suggesting an atypical face perception and attention to faces in this group. For example, individuals with autism demonstrate an enhanced reliance on, or a greater scanning of, atypical parts, such as nonfacial features, mouth, and face outline relative to their controls when observing faces (Joseph & Tanaka, 2003; Klin et al., 2002; Langdell, 1978; Pelphrey, Sasson, Reznick, Goldman, & Piven, 2002; Weeks & Hobson, 1987). In contrast, typical individuals direct 70% of their ocular fixations toward the eyes (Walker-Smith, Gale, & Findlay, 1977). An enhanced perception of face parts may modify the typical hierarchy between socially relevant and irrelevant parts, by increasing the amount of information extracted from parts other than the eyes. However, an increase in the amount of information extracted from the eyes by individuals with autism in short time spans may also result in shorter fixations toward the eyes, leading to apparent indifference to eyes in individuals with autism. In addition, atypical responses to emotional expression, independent from perceptual processes, may also be a factor in voluntary avoidance of the eye region.

The enhanced local processing of faces may also explain why individuals with autism are more disturbed by small variations in the orientation of the stimulus or in its expression during face recognition (Teunisse & de Gelder, 1994) and why their performance in emotion recognition decreases more rapidly than their corresponding typical control group when face parts are gradually suppressed (Hobson et al., 1988). Superior processing of face parts may explain (or be explained by) a preference for high spatial frequencies in matching faces (Deruelle, Rondan, Gepner, & Tardif, 2004). This would render individuals with autism more dependent on local cues and therefore disadvantaged when local cues are reduced or unavailable. A detrimental effect of local precedence on the detection of global targets by individuals with autism has been recently demonstrated in the processing of elementary nonsocial information. Indeed, autistic participants, relative to the control group, were slower and less accurate to respond to a large target when a small target preceded it. In contrast, they were as proficient as their controls when they had to detect a small target preceded by a large target (Mann & Walker, 2003).

A limitation of this study is that the generalization of the current findings to autistic individuals with younger chronological age, lower general intelligence, and neurological comorbidity cannot be taken for granted. In addition, more autistic than nonautistic participants had to be excluded because of distractability and/or motor variables, even if those factors are unlikely to be related to a different face-processing style. Our results would also benefit from a replication using a larger sample size. Consequently, cautious interpretations of results should be made, considering those limiting factors.

The current pattern of findings is strikingly similar to observations pertaining to various types of nonsocial visual and auditory behavioral results in high-functioning individuals with autism. In cognitive tasks involving two different levels of stimuli, such as Navon-type global and local stimuli (Plaisted et al., 1999; Rinehart, Bradshaw, Moss, Brereton, & Tonge, 2000), individuals with autism appear to focus to a greater extent on, or respond more quickly and accurately to, the local aspects of the stimulus array compared with their matched controls. This has been found in visual search tasks (O'Riordan & Plaisted, 2001), in auditory tasks (Mottron et al., 2000), and in disembodying tasks (Jolliffe & Baron-Cohen, 1997; Mottron et al., 2003; Shah & Frith, 1983). In perceptual tasks involving low-level processing mechanisms, high-functioning individuals with autism have shown superior discrimination abilities in the visual (Bertone, Mottron, Jelenic, & Faubert, 2005; Plaisted et al., 1999) and auditory (Bonnel et al., 2003) modalities relative to their controls. Despite these demonstrations of an enhanced local processing, the perception of the global aspect of visual Navon-type stimuli (Mottron, Burack, Stauder, & Robaey, 1999, Experiment 1; Ozonoff, Strayer, McMahon, & Filloux, 1994; Plaisted et al., 1999), of hierarchical auditory stimuli (Mottron et al., 2000), and of the holistic aspects of compound visual stimuli (Mottron et al., 1999, Experiment 2) have consistently been found to be within the average range.

Neuroanatomical or activation findings pertaining to enhanced perceptual functioning in autism are scarce but consistent with the current findings. Hubl et al. (2003) demonstrated a greater activation of the lateral occipital complex among participants with autism than in typical controls in a face-detection and a visual search task with nonsocial geometrical stimuli. The overactivation of this region (typically recruited in object-processing tasks) indicates that autistic individuals rely more on perception when processing social as well as nonsocial perceptual stimuli. This study also demonstrated a greater activation of the frontal eye fields in autistic individuals when performing a facial detection task. This area is typically activated when a feature-based processing strategy is used and is no longer recruited when global or configural processing is needed. Regarding nonsocial information, participants with Pervasive Developmental Disorder performed at a superior level in an embedded figure task while showing a greater activation of the ventral occipito-temporal regions and less activation in prefrontal and parietal cortical areas than did their controls (Ring et al., 1999). This was interpreted as showing a superior reliance on primary and associative visual cortices and on a more locally oriented and figure-ground strategy relative to comparison participants.

Our findings challenge Frith's (1989/2003) theory of WCC in autism, which assumes a global processing impairment, but they remain consistent with the enhanced discrimination hypothesis in Plaisted (2001) and O'Riordan and Plaisted (2001), as well as with the EPF model in Mottron and Burack (2001). Both hypotheses assume a cross-modal and cross-material locally oriented perceptual bias in autism without deficit with respect to global processing or feature integration. This generalized enhanced local processing may represent the consequence from a diminished inhibitory influence of higher order processes on lower order ones (Mottron & Burack, 2001). However, it may also represent a "paradoxical functional facilitation" (Kapur, 1996; for an application to the EPF model, see Bonnel et al., 2003) of an atypical neural network, such as a limitation of its complexity (Bertone, Mottron, Jelenic, & Faubert, 2003) or of the connectivity between regions devoted to high- and low-level processes (Castelli, Frith, Happé, & Frith, 2002; Frith, 1989/2003; Just, Cherkassky, Keller, & Minshew, 2004), although no direct evidence for a primary deficit can be found in the current set of findings.

The main consequences of the current series of findings are twofold. First, they orient the interpretation of atypical behaviors toward faces during the development of children with autism not to a social deficit but to a possible superiority of fine-grained, low-level perception. Second, they suggest that at least a subset of the particularities evident in autism in the processing of social material may be explained by the same types of models as those in use to account for atypical perception of nonsocial material.

References

American Psychiatric Association. (1994). *Diagnostic and statistical manual of mental disorders* (4th ed.). Washington, DC: Author.

Arguin, M., & Saumier, D. (2004). *The analytic and configural mechanisms of visual face recognition revealed by priming*. Manuscript submitted for publication.

Bertone, A., Mottron, L., Jelenic, P., & Faubert, J. (2003). Motion perception in autism: A "complex issue." *Journal of Cognitive Neuroscience, 15,* 218–225.

Bertone, A., Mottron, L., Jelenic, P, & Faubert, J. (2005). Enhanced and diminished visuo-spatial information processing in autism depends on stimulus complexity. *Brain, 128,* 2430–2441.

Bonnel, A., 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.

Boucher, J., & Lewis, V. (1992). Unfamiliar face recognition in relatively able autistic children. *Journal of Child Psychology and Psychiatry, 33,* 843–859.

Braverman, M., Fein, D., Lucci, D., & Waterhouse, L. (1989). Affect comprehension in children with pervasive developmental disorders. *Journal of Autism and Developmental Disorders, 19,* 301–316.

Bub, D., & Gum, T. (1998). Psychlab software (Version 1.0–097) [Computer software]. University of Victoria: Victoria, British Columbia, Canada.

Castelli, F., Frith, C. D., Happé, F., & Frith, U. (2002). Autism, Asperger syndrome and brain mechanisms for the attribution of mental states to animated shapes. *Brain, 125,* 1839–1849.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences.* Hillsdale, NJ: Erlbaum.

Davies, S., Bishop, D., Manstead, A. S., & Tantam, D. (1994). Face perception in children with autism and Asperger syndrome. *Journal of Child Psychology and Psychiatry, 35,* 1033–1057.

Deruelle, C., Rondan, C., Gepner, B., & Tardif, C. (2004). Spatial frequency and face processing in children with autism and Asperger syndrome. *Journal of Autism and Developmental Disorders, 34,* 199–210.

Diamond, R., & Carey, S. (1986). Why faces are and are not special: An effect of expertise. *Journal of Experimental Psychology, 115,* 107–117.

Frith, U. (2003). *Autism: Explaining the enigma*. Oxford, England: Basil Blackwell. (Original work published 1989)

Gauthier, I., & Tarr, M. J. (1997). Becoming a "Greeble" expert: Exploring mechanisms for face recognition. *Vision Research, 37,* 1673–1682.

Gepner, B., de Gelder, B., & de Schonen, S. (1996). Face processing in autism; Evidence for a generalized deficit? *Child Neuropsychology, 2,* 123–139.

Hadjikhani, N., Joseph, R. M., Snyder, J., Chabris, C. F., Clark, J., Steele, S., et al. (2004). Activation of the fusiform gyrus when individuals with autism spectrum disorder view faces. *NeuroImage, 22,* 1141–1150.

Hauck, M., Fein, D., Waterhouse, L., & Feinstein, C. (1995). Social initiations by autistic children to adults and other children. *Journal of Autism and Developmental Disorders, 25,* 579–595.

Hobson, R. P., Ouston, J., & Lee, A. (1988). What's in a face? The case of autism. *British Journal of Psychology, 79,* 441–453.

Hubl, D., Bolte, S., Feineis-Matthews, S., Lanfermann, H., Federspiel, A., Strik, W., et al. (2003). Functional imbalance of visual pathways indicates alternative face processing strategies in autism. *Neurology, 61,* 1232–1237.

IQ Biometrix. (1998). FACES (Version 3.0) [Computer software]. Redwood Shores, CA: Wherify Wireless.

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.

Joseph, R. M., & Tanaka, J. (2003). Holistic and part-based face recognition in children with autism. *Journal of Child Psychology and Psychiatry, 44,* 529–542.

Just, M. A., Cherkassky, V. L., Keller, T. A., & Minshew, N. J. (2004). Cortical activation and synchronization during sentence comprehension in high-functioning autism: Evidence of underconnectivity. *Brain, 127,* 1811–1821.

Kapur, N. (1996). Paradoxical functional facilitation in brain-behaviour research. A critical review. *Brain, 119,* 1775–1790.

Kirks, R. E. (1968). *Experimental design: Procedures for the behavioral sciences.* Belmont, CA: Brooks/Cole.

Klin, A., Jones, W., Schultz, R., Volkmar, F., & Cohen, D. (2002). Visual fixation patterns during viewing of naturalistic social situations as predictors of social competence in individuals with autism. *Archives of General Psychiatry, 59,* 809–816.

Langdell, T. (1978). Recognition of faces: An approach to the study of autism. *Journal of Child Psychology and Psychiatry, 19,* 255–268.

Lord, C., Rutter, M., & Dilavore, P. (1997). *Autism Diagnostic Observation Schedule Generic (ADOS-G).* Unpublished manuscript.

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,* 659–685.

Mann, T. A., & Walker, P. (2003). Autism and a deficit in broadening the spread of visual attention. *Journal of Child Psychology and Psychiatry, 44,* 274–284.

Mondloch, C. L., Le Grand, R., & Maurer, D. (2002). Configural face processing develops more slowly than featural face processing. *Perception, 31,* 553–566.

Mottron, L., & Burack, J. (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: Erlbaum.

Mottron, L., Burack, J. A., Iarocci, G., Belleville, S., & Enns, J. T. (2003). Locally oriented perception with intact global processing among adolescents with high-functioning autism: Evidence from multiple paradigms. *Journal of Child Psychology and Psychiatry, 44,* 904–913.

Mottron, L., Burack, J. A., Stauder, J. E., & Robaey, P. (1999). Perceptual processing among high-functioning persons with autism. *Journal of Child Psychology and Psychiatry, 40,* 203–211.

Mottron L., Dawson, M., Soulières, I., Hubert, B., & Burack, J. A. (2006). Enhanced perceptual functioning in autism: An updated model, and eight principles of autistic perception. *Journal of Autism and Developmental Disorders: Perecption in Autisim* [Special issue].

Mottron, L., Peretz, I., & Ménard, E. (2000). Local and global processing of music in high-functioning persons with autism: Beyond central coherence? *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, 54,* 961–979.

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.

Pelphrey, K. A., Sasson, N. J., Reznick, J. S., Goldman, B. D., & Piven, J. (2002). Visual scanning of faces in autism. *Journal of Autism and Developmental Disorders, 32,* 249–261.

Pierce, K., Muller, R. A., Ambrose, J., Allen, G., & Courchesne, E. (2001). Face processing occurs outside the fusiform "face area" in autism: Evidence from functional MRI. *Brain, 124,* 2059–2073.

Plaisted, K. (2001). Reduced generalization in autism: An alternative to weak central coherence. In J. Burack, T. Charman, N. Yirmiya, & P. R. Zelazo (Eds.), *The development of autism: Perspectives from theory and research* (pp. 149–169). Mahwah, NJ: Erlbaum.

Plaisted, K., Sweettenham, 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.

Raven, J. C. (1996). *Progressive matrices: A perceptual test of intelligence.* Oxford, England: Oxford Psychologists Press. (Original work published 1938)

Ricciardelli, P., Ro, T., & Driver, J. (2002). A left visual field advantage in perception of gaze direction. *Neuropsychologia, 40,* 769–777.

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.

Ring, H. A., Baron-Cohen, S., Wheelwright, S., Williams, S. C., Brammer, M., Andrew, C., et al. (1999). Cerebral correlates of preserved cognitive skills in autism: A functional MRI study of embedded figures task performance. *Brain, 122,* 1305–1315.

Rossion, B., Gauthier, I., Tarr, M. J., Despland, P., Bruyer, R., Linotte, S., et al. (2000). The N170 occipito-temporal component is delayed and enhanced to inverted faces but not to inverted objects: An electrophysiological account of face-specific processes in the human brain. *Neuroreport, 11,* 69–74.

Saumier, D., Arguin, M., & Lassonde, M. (2001). Prosopagnosia: A case study involving problems in processing configural information. *Brain and Cognition, 46,* 255–259.

Schultz, R. T., Gauthier, I., Klin, A., Fulbright, R. K., Anderson, A. W., Volkmar, F., et al. (2000). Abnormal ventral temporal cortical activity during face discrimination among individuals with autism and Asperger syndrome. *Archives of General Psychiatry, 57,* 331–340.

Searcy, J. H., & Bartlett, J. C. (1996). Inversion and processing of component and spatial–relational information in faces. *Journal of Experimental Psychology: Human Perception and Performance, 22,* 904–915.

Shah, A., & Frith, U. (1983). An islet of ability in autistic children: A research note. *Journal of Child Psychology and Psychiatry, 24,* 613–620.

Tanaka, J. W., & Farah, M. J. (1993). Parts and wholes in face recognition. *Quarterly Journal of Experimental Psychology, 46,* 225–245.

Tantam, D., Monaghan, L., Nicholson, H., & Stirling, J. (1989). Autistic children's ability to interpret faces: A research note. *Journal of Child Psychology and Psychiatry, 30,* 623–630.

Teunisse, J. P., & de Gelder, B. (1994). Do autistics have a generalized face processing deficit? *International Journal of Neuroscience, 77,* 1–10.

van der Geest, J. N., Kemner, C., Verbaten, M. N., & Engeland, H. (2002). Gaze behavior of children with pervasive developmental disorder toward human faces: A fixation time study. *Journal of Child Psychology and Psychiatry, 43,* 669–778.

Walker-Smith, G. J., Gale, A. G., & Findlay, J. M. (1977). Eye movement strategies involved in face perception. *Perception, 6,* 313–326.

Wechsler, D. (1974). *Wechsler Intelligence Scale for Children—Revised.* New York: Psychological Corporation.

Wechsler, D. (1981). *Wechsler Adult Intelligence Scale—Revised.* New York: Psychological Corporation.

Wechsler, D. A. (1991). *Wechsler Intelligence Scale for Children—Third Edition (WISC–III).* San Antonio, TX: Psychological Corporation.

Wechsler, D. A. (1997). *Wechsler Adult Intelligence Scale—Third Edition (WAIS–III).* San Antonio, TX: Psychological Corporation.

Weeks, S., & Hobson, R. P. (1987). The salience of facial expression for autistic children. *Journal of Child Psychology and Psychiatry, 28,* 137–152.

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