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Holistic and part-based face recognition in children with autism

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Background: There is substantial evidence that children with autism are impaired in face recognition. Although many researchers have suggested that this impairment derives from a failure of holistic face processing and a tendency to represent and encode faces on a part-by-part basis, this hypothesis has not been tested directly. **Method:** Holistic face processing was assessed by comparing children's ability to recognize a face part (eyes, nose, or mouth) in the context of the whole face in which it was learned with their ability to recognize the same face part in isolation. **Results:** In Study 1, as expected, typically developing 9-year-olds ($n = 27$) and 11-year-olds ($n = 30$) were significantly better at recognizing face parts presented in the whole than in the part test condition, and this effect was limited to upright faces and not found for inverted faces. Consistent with prior findings, typically developing children were most accurate when face recognition depended on the eyes. In Study 2, high-functioning children with autism ($n = 22$) evidenced a whole-test advantage for mouths only, and were markedly deficient when face recognition depended on the eyes. Their pattern of performance diverged from age- and IQ-matched comparison participants ($n = 20$), who performed similarly to the typically developing children in Study 1. **Conclusions:** These findings suggest that face recognition abnormalities in autism are not fully explained by an impairment of holistic face processing, and that there is an unusual significance accorded to the mouth region when children with autism process information from people's faces. **Keywords:** Autistic disorder, face perception, social cognition. **Abbreviations:** ADI-R: Autism Diagnostic Interview – Revised; FFA: Fusiform Face Area.

Marked deficits in reciprocal social interaction and communication skills are defining features of autism (APA, 1994). One of the most productive areas in recent autism research has focused on better defining the social-communicative deficits that characterize the syndrome (Mundy & Sigman, 1989; Volkmar, Grossman, Klin, & Carter, 1997). A number of studies have examined attention to faces and face processing abilities in children with autism, especially given the crucial social importance of faces as a means of personal identification and a medium of communication among humans (Ellis, 1990). These studies have demonstrated that inattention to faces is a developmentally primary symptom of autism that is apparent in infancy (Osterling & Dawson, 1994; Osterling, Dawson, & Munson, 2002; Swettenham et al., 1998), and that children with autism are abnormally delayed in early, face-related social milestones, such as looking to another person's face to reference that person's reactions or to share their own experience of objects and events (Joseph & Tager-Flusberg, 1997; Mundy, Sigman, & Kasari, 1993). Such findings raise the possibility that abnormalities in the perception of faces and their communicative signals are implicated in the profound social impairment that characterizes autism. In fact, a number of experimental studies, reviewed below, have not only provided evidence that children with autism are deficient in their face processing abilities, but have also suggested that they view and represent faces differently from non-autistic children. In particular, it has been frequently speculated that individuals with autism are impaired in normative, holistic face recognition processes, and instead rely to an abnormal degree on feature- or part-based face encoding and recognition strategies. The goal of the present studies was to evaluate this hypothesis by directly comparing children's ability to learn and recognize whole faces with their ability to learn and recognize the individual parts of those same faces.

Holistic face recognition in normally developing children

Faces are remarkably homogenous as a class of visual stimuli in that they share a highly similar structure, always consisting of the same set of parts (e.g., eyes, nose, mouth) in the same basic configuration (e.g., nose centered below the eyes and above the mouth). Yet, despite this basic similarity, most people can easily recognize and discriminate among hundreds of faces. The ease with which humans are able to distinguish between faces has been widely argued to depend on holistic perceptual and encoding processes (Bartlett & Searcy, 1993; Bradshaw & Wallace, 1971; Diamond & Carey, 1986; Farah, Tanaka, & Drain, 1995; Rhodes, 1988;

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Sergent, 1984). Accordingly, the features of a face are seen and represented not simply as component parts, but in relation to the overall facial template or configuration. Sensitivity to configural information in faces would thus significantly augment one's ability to individuate faces (beyond what would be possible on the basis of knowledge of the individual parts alone) by specifying the multiple relationships between the constituent parts and the whole that help to define the uniqueness of any given face. The notion that face recognition is more dependent on holistic processing than are most other forms of object recognition has received indirect support from the robust finding of a 'face inversion effect.' That is, stimulus inversion has been found to disproportionately impair encoding and recognition of faces relative to a wide range of other stimuli classes, such as houses, airplanes, and landscapes (Diamond & Carey, 1986; Yin, 1969). The inordinately negative effect of inversion on face recognition is thought to operate by disrupting the expected spatial configuration to which holistic face processes are tuned, necessitating the use of feature-based recognition strategies that are less sensitive to inversion, and are more efficient for identifying non-face objects than faces (Carey & Diamond, 1977, 1994; McKone, Martini, & Nakayama, 2001; Farah et al., 1995).

Early developmental research on children's face processing skills documented a significant improvement in face recognition between the ages of 5 and 12 (Blaney & Winograd, 1978; Carey; 1981; Carey, Diamond, & Woods, 1980; Flin, 1980; Goldstein & Chance, 1964). An issue of initial debate in the field was whether these age-related improvements might be attributed to the emergence of holistic face processing abilities that were lacking in younger children (Carey & Diamond, 1977; Carey et al., 1980). In a seminal study, Carey and Diamond (1977) first hypothesized that children shift from using primarily featural or part-based representations for remembering faces to more holistic encoding processes. In support of this hypothesis, Carey and Diamond demonstrated that the presentation of faces in inverted orientation had the same disproportionately negative effect on face recognition in 10-year-olds as was previously observed in adults (Yin, 1969). In contrast, they found that inversion did not impair face recognition any more than it impaired house recognition in 6- and 8-year-olds. The absence of an inversion effect in the younger children led Carey and Diamond to conclude that they were not yet representing faces holistically, but were instead encoding and recognizing them in terms of isolated details or parts (e.g., bushy eyebrows).

However, subsequent developmental research employing a variety of methods has not supported Carey and Diamond's (1977) original conclusion. For example, Flin (1985) argued that floor effects for the 6-year-olds in the upright condition of Carey and Diamond's face recognition task may have obscured a possible inversion effect. Using a more sensitive d' measure to assess inversion effects in an old-new face recognition paradigm, Flin showed that children from the age of 7 to 16 were consistently better at recognizing upright than upside down faces. Additional studies using contrast stimuli other than inverted faces have suggested that younger children process faces holistically. For example, Baenniger (1994) compared recognition of normal intact faces with recognition of scrambled faces in 8- and 11-year-olds and adults, reasoning that if the younger participants processed faces in terms of their constituent parts, they would do no worse in a condition in which the spatial locations and relations among face parts were rearranged. Baenninger found that all groups were equally impaired in the scrambled condition relative to performance in the intact condition. Using a procedure developed by Young, Hellawell, and Hay (1987), Carey and Diamond (1994) compared children's recognition of the top half of composite faces (in which the top of one familiar face and the bottom of another familiar face were aligned) with recognition of the top half of non-composite faces (in which the two face halves were unaligned). They found that 6-year-olds, like older children and adults, were slower in the composite condition, suggesting that even young children process two different face halves as a unified whole. Similarly, Freire and Lee (2001) found that children as young as 4 years of age were able to recognize a target face from among distractor faces that shared the same features (eyes, nose, and mouth), but differed on the spacing between the features, suggesting an ability to process configural information from faces in these young children.

Recently, Tanaka and colleagues (Tanaka, Kay, Grinnell, Stansfield, & Szechter, 1998) assessed holistic face recognition in children using a method that specifically operationalized the distinction between whole and part face processing (Tanaka & Farah, 1993). Children were presented with a sample face stimulus that was identified by name (e.g., 'This is Tom'). After an exposure of 5 seconds, one of two types of test trials followed immediately. In the whole-face test condition, children were presented with the sample face and a foil face, which differed from the sample by only one feature (eyes, nose, or mouth), and were asked 'Which is Tom?' Alternately, in the isolated-part test condition, children were presented with one feature from the target face and a foil feature, and were asked, for example, 'Which is Tom's nose?' The logic of the whole–part method is that if upright faces are encoded holistically, individual features of a previously learned face will be recognized more readily in the context of the whole face than when seen in isolation. Using this approach with 6-, 8-, and 10-year-olds, Tanaka et al. (1998, Exp. 3) observed a whole-face test advantage for upright faces, but not inverted faces, across the three age groups. Further, although recognition of upright faces improved with age, the magnitude of the whole-face advantage (relative to isolated-parts performance) was consistent across age groups. These findings provided further evidence that young children process faces holistically, and are susceptible to the disruptive effect of stimulus inversion on face processing.

Face recognition in autism

There is already substantial evidence that individuals with autism encode and remember faces in abnormal ways. In a pioneering study, Langdell (1978) tested the ability of children with autism to recognize the faces of their peers from partial cues depicting either the eye or mouth region of the face. Langdell found that both younger and older children with autism were significantly better than comparison groups in recognizing faces on the basis of an isolated view of the mouth region, and that the younger children with autism were significantly worse than comparison groups in using eye cues to identify faces. Moreover, within-subjects comparisons showed that the younger children with autism were better at identifying peers' faces from mouth cues than from eye cues, and that the older children with autism performed similarly in the two conditions. In contrast, both younger and older non-autistic participants with cognitive impairment were significantly better at identifying faces from eye cues than from mouth cues. This latter finding is consistent with results from several other studies showing better discrimination and recognition of eyes than mouths in samples of normal individuals (Goldstein & Mackenberg, 1966; McKelvie, 1976; Sergent, 1984; Tanaka & Farah, 1993; Walker-Smith, 1978), highlighting the unusualness of the relative proficiency at mouth recognition found in children with autism. In addition, Langdell also found that older children with autism recognized inverted faces significantly better than did comparison participants, and with a degree of accuracy approaching their performance in the upright, partial cue conditions, again suggesting atypical, possibly feature-based, face recognition strategies in children with autism. In a subsequent study, Hobson, Ouston, and Lee (1988) also demonstrated that older adolescents with autism were significantly better than controls at recognizing inverted faces, which they were able to identify as well as upright faces.

A number of researchers have reported that individuals with autism are impaired in face identity recognition (Boucher & Lewis, 1992; Braverman, Fein, Lucci, & Waterhouse, 1989; Davies, Bishop, Manstead, & Tantam, 1994; de Gelder, Vroomen, & van der Heide, 1991; Hauck, Fein, Maltby, Waterhouse, & Feinstein, 1998; Klin, Sparrow, de Bildt, Cicchetti, Cohen, & Volkmar, 1999; Korkman, Kirk, & Kemp, 1998; Ozonoff, Pennington, & Rogers, 1990; Tantam, Monaghan, Nicholson, & Stirling, 1989). Although several studies (Boucher & Lewis, 1992; Braverman et al., 1989; Hauck et al., 1998; Klin et al., 1999; Ozonoff et al., 1990) have indicated that these deficits do not apply to nonfacial control stimuli, at least one study (Davies et al., 1994) demonstrated a more general impairment also affecting the processing of complex non-face stimuli. From among studies supporting a face-specific, visual processing deficit in autism, Boucher and Lewis (1992, Exp. 2) found that children with autism were impaired in recognizing faces but not houses relative to a comparison group. However, it may be argued that the houses used in the Boucher and Lewis experiment were not optimal as control stimuli in that, unlike faces, they did not share a canonical shape and configuration of features, and could be easily discriminated and remembered in terms of salient parts or features. Davies et al. (1994) compared children's ability to recognize faces across changes in expression and viewing angle to their ability to recognize patterns among different arrays of geometric stimuli (each composed of several small circles, triangles, and squares). They found that high-functioning children with autism were equally impaired in both tasks relative to comparison participants, suggesting impaired perception of the configural properties of both face and non-face stimuli.

Additional evidence of abnormal face processing in autism comes from brain imaging research. Functional neuroimaging studies have consistently demonstrated that perception of faces in normal individuals evokes activity in an area of ventral temporal cortex known as the 'fusiform face area' (FFA; Haxby et al., 1994; Kanwisher, McDermott, & Chun, 1997; Puce, Allison, Gore, & McCarthy, 1995). Several researchers conducting functional MRI studies of individuals with autism spectrum disorders (Critchley et al., 2000; Pierce, Muller, Ambrose, Allen, & Courchesne, 2001; Schultz et al., 2000) have reported abnormally weak FFA activation during face viewing tasks. Schultz et al. (2000) found that individuals with autism and Asperger disorder exhibited heightened activation of the inferior temporal gyri during a face discrimination task, which was the same pattern of activation that normal participants exhibited during a non-face object discrimination task. The authors interpreted these results as suggesting that individuals with autism spectrum disorders use feature-based visual processing strategies that are normally used to discriminate among objects, such as chairs and cars, to discriminate among faces as well as non-face objects.

In summary, there is substantial evidence suggesting that individuals with autism are deficient in face recognition abilities and engage in atypical face recognition strategies. A number of investigators (Boucher & Lewis, 1992; Davies et al., 1994; Miyashita, 1988; Tantam et al., 1989) have appealed to the notion that autistic individuals are impaired in holistic face processing and instead rely to an abnormal degree on part-by-part encoding strategies. However, the hypothesis that individuals with autism are relatively deficient in processing the wholes as compared to the parts of faces has not been tested directly. In particular, we do not know if feature-based face processing in autism, such as the apparent focus on the mouth region suggested by Langdell (1978), occurs as a result of a failure of holistic perceptual processes, or as a result of other possible processing abnormalities.

In the present studies, we compared whole and part face recognition processes in typically developing children and children with autism using the whole–part method of Tanaka and Farah (1993). The reasoning behind this method is that if the individual features of a face are processed holistically, they will be recognized more readily when seen in the context of the whole face in which they were learned than when seen in isolation. However, any holistic processing advantage obtained for upright faces would not be expected for inverted faces. We predicted that children with autism, in contrast to typically developing children and an age- and IQ-matched non-autistic comparison group, would not evidence holistic processing of faces, and would not exhibit the normative pattern of better eye than mouth recognition.

Study 1: Typically developing children

Method

Participants. Participants were 27 nine-year-old ($M = 9;4$, $SD = 0;4$) and 30 eleven-year-old ($M = 11;3$, $SD = 0;4$) typically developing children enrolled in a suburban public school system in the Boston metropolitan area.

Materials. Face stimuli were constructed following Tanaka et al. (1998, Exp. 3). High-quality, grayscale digital face portraits were taken from a large group of children who were in the same age range as the participants, but from another school district, and whose parents gave written permission to use the images in research. All original face images were recorded with a neutral expression. Adobe Photoshop graphics software was used to make 12 target faces (6 boys and 6 girls) from the face outline of one child, the eyes of a second child, the nose of a third child, and the mouth of another child. Three foil faces were made for each of the 12 target faces by replacing either the eyes, nose, or mouth of the target face with the eyes, nose, or mouth of a new face from an unused photo. The use of composites for all whole face stimuli assured that target and foil faces would be equated for the naturalness of their appearance. The whole face stimuli were cropped to 3 inches in width and approximately 4 inches in length (maintaining the original proportions of the face outline). Part face stimuli for target and foil faces were made in Photoshop by cropping each feature (eyes, nose, or mouth) using the rectangular marquee tool, thereby eliminating the remainder of the face stimulus and maintaining the original position of the feature (e.g., mouth toward the bottom) on the canvas. Figure 1 shows sample whole and part face stimuli.

In addition to the test stimuli, a set of whole–part training stimuli were made using graphic grayscale images of common non-face objects (e.g., a sailboat for which either the sail or hull served as the part version).

Procedure. Participants were tested individually. All stimuli were presented on a 17-inch touch screen computer monitor programmed to make a beep sound at touchdown for all responses, whether correct or incorrect. Children were seated facing the computer monitor at a viewing distance of approximately 30 inches and with eye level at center screen. Stimulus presentation was programmed using SuperLab Pro 2.0 software.

The training procedure consisted of three parts. The first part acquainted children with (non-face) whole–part stimuli and their presentation. Pointing toward the fixation star at center screen, the experimenter stated, 'You are going to see a picture here. After each picture, you have to pick the one that is the same. Now look at this picture.' The sample appeared for 3.5 seconds at center screen, and was then replaced by the same sample stimulus appearing side-by-side with a foil stimulus from the same object category. The child was instructed, 'Now touch the one that is the same.' This portion of the training consisted of 12 trials alternating between whole and part object recognition. Children were praised for their correct responses. If a child erred, the experimenter provided corrective feedback by repeating the trial and demonstrating the correct touch screen response. The second part of the training proceeded with 10 additional non-face object recognition trials in which no further instructions or feedback were given in order to confirm the child understood the task. All participants in Experiment 1 completed this portion of the training without error. The final part of the training served as an introduction to the test procedure. Children were told, 'Now we are going to be remembering faces.' Two whole face recognition trials proceeded, with the first in upright orientation and the second in inverted orientation. For the latter, children were forewarned, 'Sometimes the faces will be upside down.'

At the beginning of the test procedure, children were told, 'Now it is going to be just like before. You will see a face in the middle of the screen (experimenter points), and then you will see a face here and here (experimenter points to left and right of center screen). You have to touch the one that is the same. Only one is the same.'

For each trial, a whole face stimulus was presented on the touch screen monitor for 3.5 seconds, followed immediately by a two-choice recognition test. In the whole-face test condition, children saw the original (target) face and a foil face differing by one feature. The whole faces appeared side by side, separated by approximately .75 inches of space. In the isolated-part test condition, only the feature (eyes, nose, or mouth) on which the target and foil faces differed were presented. The isolated parts appeared in the same position on the screen as they occupied within the target and foil whole faces. The computer was programmed to record any

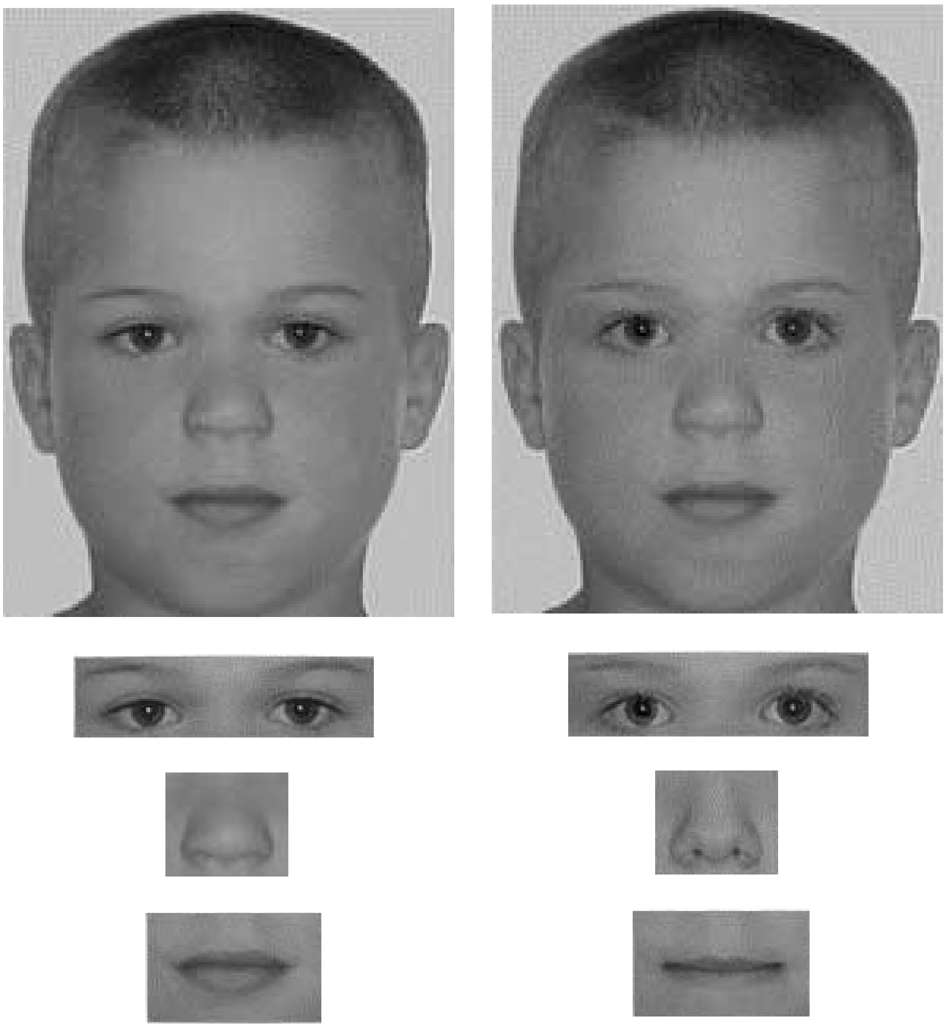

Figure 1 Sample whole (differing on eyes) and part test stimuli. Targets are displayed on left, and foils are displayed on right

touch response within the 3×4 inch perimeter of the target whole and part stimuli as correct. Ambiguous responses to the area between the target and foil stimuli were recorded as incorrect. Children were allowed 8 seconds to respond on the test trials, after which a blank screen appeared for one second, followed by the next sample face stimulus.

Six upright and six inverted faces were presented in the whole-face and isolated-part test conditions for each of the 3 features, yielding a total of 72 trials. In the inverted condition, face stimuli were presented in upside-down orientation in the 3.5 second exposure phase as well as in the subsequent forced-choice recognition test. The set of 6 faces (3 girls and 3 boys) that served as upright stimuli for half the children, served as inverted faces for the other half, and vice versa. The faces were presented in 6 different pseudo-random orders, counterbalanced across participants, with the following constraints: faces were presented in runs of 12 (6 upright, 6 inverted) such that all 12 faces were seen once before any one in the set was seen again; whole-face (W) and isolated-part (P) test trials were distributed evenly throughout the runs (e.g., WPPWWP or PWWPPW); and the target feature (eyes, nose, or mouth) was never the same over more than two consecutive trials. The left and right positions of correct responses were counterbalanced across the 72 test items. Children were not informed on what features the faces differed, and the whole–part nature of the stimuli was never explicitly noted by the experimenter during the training or test procedure.

Testing was administered in 3 blocks of 24 trials. At the end of each block, children were given the opportunity to take a break before continuing. The large majority of participants elected to continue without a break. On the rare occasion that a child did not respond to a test item within the 8 second limit, he or she was told, 'It's okay. You missed that one. Try this one.' If a child appeared reluctant to respond, he or she was told, 'It is okay to make your best guess.' Children's attention to the test stimuli was carefully monitored by the experimenter. On the few occasions that children looked away from the screen before the sample stimulus disappeared, they were told, 'Keep looking so you will remember it.' Similarly, if the child appeared to have chosen a response without scanning the other option, the experimenter said, 'Make sure you look at both faces before you make your choice. Only one of them is the same.' Instructions of this sort were rarely necessary in Experiment 1, and were given regardless of the accuracy of the response.

Results

Table 1 displays the mean number and percentage of trials correct for each age group for each condition. Repeated measures ANOVAs with the factors *orientation* (upright vs. inverted), *test type* (whole vs. part), and *feature* (eyes vs. nose vs. mouth) were conducted for the number of correct responses for each age group. Of main interest was the predicted orientation × test-type interaction, whereby children would perform better in the whole-face than in the isolated-part test condition for upright faces, but not for inverted faces. When all face features were considered, an orientation × test-type interaction was not found for either group, although the expected interaction approached significance in the older group, $F(1, 29) = 3.8, p = .06$. However, an orientation × test-type × feature interaction was found for both 9-year-olds, $F(2, 52) = 11.9$, $p < .001$, and 11-year-olds, $F(2, 58) = 5.2, p < .01$. Analysis of this interaction revealed that both age groups showed the expected whole-face advantage for recognition of eyes and mouths from upright faces, but an isolated-part advantage for noses from upright faces. (See Table 1.) As a result of this divergent pattern of performance across features (the possible cause of which is discussed below), only eyes and mouth trials were included in subsequent analyses.

When only eyes and mouth trials were considered, there was an orientation × test-type interaction for 9-year-olds, $F(1, 26) = 11.4, p < .01$, and 11-year-olds, $F(1, 29) = 12.5, p < .001$, indicating a whole-face advantage for upright but not inverted faces. Accordingly, when faces were upright, 9-year-olds performed significantly better in the whole-face than in the isolated-part condition (75% vs. 62% correct), $t(26) = 3.9$, $p < .001$, but when faces were inverted, their recognition accuracy did not differ significantly between the whole and part conditions (54% vs. 61% correct), $t(26) = 1.6$, n.s. Similarly, 11-year-olds were significantly better at recognizing upright whole faces than upright face parts (80% vs. 70% correct), $t(29) = 2.9$, $p < .01$, but their performance did not differ between the whole and part conditions (58% vs. 63% correct) for inverted faces, $t(29) = 1.6$, n.s.

The same pattern of a whole advantage in the upright condition but no difference between whole and part recognition in the inverted condition was also observed when eyes and mouth trials were analyzed separately. Thus, for 9-year-olds in the upright condition, both eyes and mouths were recognized better when seen in the whole face than in isolation, $t(26) = 2.2, p < .05$ and $t(26) = 2.9$, $p < .01$, respectively. Similarly, for 11-year-olds in the upright condition, both eyes and mouths were recognized better in the whole face than in isolation, $t(29) = 1.9, p < .07$ and $t(29) = 2.6, p < .05$, respectively. In contrast, for both age groups there was no difference between whole and part eye or mouth recognition in the inverted condition. One exception was that, in the inverted condition, 9-year-olds were actually better at recognizing mouths seen in isolation than when seen in the whole face, $t(26) = 2.1, p < .05$.

Additional paired-samples *t*-tests confirmed an orientation (i.e., inversion) effect for recognition of whole faces, but not for recognition of isolated parts. Thus, 9-year-olds were significantly better at recognizing upright whole faces than inverted whole faces (75% vs. 54% correct), $t(26) = 4.9, p < .001$, but did not differ in their recognition accuracy for upright and inverted face parts (62% vs. 61% correct), $t(26) = 0.3$, n.s. Eleven-year-olds were also significantly better at recognizing upright than inverted whole faces (80% vs. 58% correct), $t(29) = 8.2, p < .001$, but did not differ significantly in their recognition of upright and inverted face parts (70% vs. 63% correct), $t(29) = 1.6$, n.s. As can be seen in Table 1, a strong inversion effect was evident whether whole-face recognition depended on the eyes or the mouth.

Analyses comparing children's recognition of eyes to their recognition of mouths did not yield a significant main effect of feature for either age group, but

Table 1 Correct responses for each feature in each condition

	9-year-olds ($n = 27$)			11-year-olds ($n = 30$)		
	Eyes	Mouth	Nose	Eyes	Mouth	Nose
Upright Whole						
M (*SD*[a]	4.8 (1.2)	4.2 (1.6)	3.3 (1.2)	5.1 (1.0)	4.5 (1.1)	4.0 (1.0)
Percentage	80	70	54	86	74	67
Upright Part						
M (*SD*)	4.2 (1.3)	3.3 (1.2)	3.8 (1.1)	4.7 (1.4)	3.7 (1.6)	4.3 (1.1)
Percentage	70	54	64	78	62	71
Inverted Whole						
M (*SD*)	3.5 (1.5)	3.0 (1.4)	3.9 (1.1)	3.5 (1.3)	3.4 (1.1)	3.7 (1.0)
Percentage	58	51	64	58	57	61
Inverted Part						
M (*SD*)	3.5 (1.3)	3.9 (1.4)	3.0 (1.2)	3.8 (1.0)	3.8 (1.4)	3.2 (1.2)
Percentage	59	64	51	63	63	53

[a] Means and percentages are for 6 trials.

did reveal a feature × orientation interaction for both 9-year-olds, $F(1, 26) = 3.9, p < .06$, and 11-year-olds, $F(1, 29) = 8.3$, $p < .01$, such that children were better at recognizing eyes than mouths in the upright condition, but not in the inverted condition. Nine-year-olds were correct on 75% of upright whole and part eyes trials as compared to 62% of mouth trials, $t(26) = 2.5, p < .05$, and 11-year-olds were correct on 82% of upright whole and part eyes trials as compared to 68% of mouth trials, $t(29) = 2.8, p < .01$.

Finally, a mixed-model ANOVA that included age group as a between-subjects factor showed that overall performance was better among 11-year-olds than among 9-year-olds, $F(1, 55) = 3.7$, $p < .06$. However, there was no evidence of an increased holistic advantage in the older group, as would have been reflected in an age × orientation × test type interaction effect.

Discussion

Both 9- and 11-year-old typically developing children exhibited a similar whole face advantage for the recognition of upright face parts. In addition, both groups were significantly better at recognizing upright than inverted whole faces. These findings were consistent with prior evidence that holistic face encoding and recognition processes are operative in school-age children (Flin, 1985; Carey & Diamond, 1994; Freire & Lee, 2001; Tanaka et al., 1998). Further, both groups of children were most accurate when face recognition depended on the eyes, a finding previously documented for adults (e.g., Tanaka & Farah, 1993) and non-autistic children (Langdell, 1978).

An unexpected finding was that nose recognition did not conform to the pattern found for eyes and mouths. If anything, noses were recognized in the reverse pattern, with a part advantage in the upright condition and a whole advantage in the inverted condition. One explanation is that noses are arguably the least salient and informative of the inner face features that were analyzed. Thus, in the upright condition, part performance on noses may have benefited from the effect of directing children's attention to the feature on which the faces differed, whereas in the whole condition this difference was less apparent. Interestingly, inversion may have had the effect of disrupting the normal salience of the eyes and mouth in a way that conferred a holistic processing advantage onto the nose region.

Study 2: Children with autism

Method

Participants. Participants included a group of children with autism and a comparison group of non-autistic children with a history of language impairment and/or language delay. Children were recruited through community sources to participate in a study of social cognition and language functioning. All children with autism met criteria for autism on the Autism Diagnostic Interview – Revised (ADI-R; Lord, Rutter, & LeCouteur, 1994), and their diagnoses were clinically confirmed by a psychologist experienced with autism. IQ was assessed with the Differential Ability Scales (Elliott, 1990). Of an initial 33 children with autism, 11 children were unable to comply and/or attend sufficiently to successfully complete the training procedure (described in Study 1), and were therefore not included in the study. The 11 excluded children were of a mean age of 10;2 and were of significantly lower full scale IQ $(M = 74, SD = 16), t(31) = 2.4, p < .05$, than the 22 children who passed training. The excluded children also had higher levels of symptoms in the ADI-R communication domain $(M = 20.2, SD = 4.6)$, $t(31) = 2.5$, $p < .05$, and marginally higher levels of symptoms in the social domain $(M = 24.6, SD = 4.4), t(31) = 1.7$, $p < .10$, than the children who passed training. The final sample of 22 children with autism included 21 males and 1 female. Participant characteristics are described in Table 2.

Comparison group participants were assessed for autistic symptomatology with the ADI-R, and were all well below diagnostic threshold scores in the three symptom domains. Of an initial 23 comparison participants, 3 children were unable to complete the training procedure, and were therefore not included in the study. The 3 excluded children had a mean age of 8;8 and a mean full scale IQ of 79 ($SD = 18$). The final comparison sample of 20 non-autistic children

Table 2 Participant characteristics

	Autism ($n = 22$)	Comparison ($n = 20$)
	M (*SD*), Range	*M* (*SD*), Range
Age	10;11 (2;1), 8;0–14;4	10;9 (1;11), 8;0–14;4
Full scale IQ	91 (22), 57–141	91 (14), 61–117
Verbal IQ	86 (22), 57–133	90 (13), 69–122
Nonverbal IQ	96 (23), 59–153	93 (16), 50–114
ADI-R scores[a]		
Communication	16.8 (3.1), 11–23	1.4 (1.2), 0–3
Social	21.5 (5.1), 10–28	1.7 (1.6), 0–5
Repetitive behaviors	6.8 (3.0), 3–12	0.6 (0.7), 0–2

[a] Higher scores reflect increased symptom severity. Standard diagnostic threshold scores for the communication, social, and repetitive behaviors domains are 8, 10, and 3, respectively.

included 14 males and 6 females. Characteristics of the comparison group are detailed in Table 2. Although the comparison participants were recruited for having a history of language difficulties and/or delay, most of the children did not meet conventional quantitative criteria for specific language impairment on standardized tests, and the group as a whole did not evidence a significant difference between verbal and nonverbal IQ. Independent samples *t*-tests confirmed that the autism group and the non-autistic comparison group were well matched on age and on full scale, verbal, and nonverbal IQ (all *p*-values > .50).

Procedure. The procedure was the same as in Study 1.

Results

Preliminary analyses revealed a pattern of consistently poor performance across nose trials, whether in upright or inverted orientation, or in whole or part test type, for both the autism and comparison groups. Therefore, as in Study 1, nose trials were eliminated from all subsequent analyses.

Results were first analyzed for the groups separately to determine whether they exhibited the same patterns of test-type, orientation, and feature effects that were found for typically developing 9- and 11-year-olds in Study 1. Between-group comparisons were then made to assess whether the differences in pattern of performance identified for the autism group were statistically significant.

Autism group. When eye and mouth trials were analyzed together, there was a significant orientation × test type interaction, $F(1, 21) = 5.4, p < .05$, indicating a whole advantage for upright but not inverted faces among children with autism.

However, when eyes and mouth trials were analyzed separately, this interaction was found to hold for mouths, $F(1, 21) = 4.1, p < .06$, but not for eyes, $F(1, 21) = 0.1$, n.s. Thus, as can be seen in Table 3, children with autism did exhibit the typical pattern of enhanced recognition accuracy when viewing the wholes of upright faces, but this pattern was present mainly for mouth recognition and was significantly diminished for eye recognition. In addition, children with autism demonstrated a strong effect of orientation when whole-face recognition depended on the mouth, with 70% accuracy in the upright condition, as compared to 47% accuracy in the inverted condition, $t(21) = 3.4, p < .01$. In contrast, there was no effect of orientation when face recognition depended on the eyes, with 62% accuracy in the upright whole condition, and 59% accuracy in the inverted whole condition, $t(21) = 0.4$, n.s. Further, in contrast to both groups of typically developing children in Study 1, children with autism were not more proficient in recognizing the eyes (60% correct) than the mouths (64% correct) of upright faces, $t(21) = 0.8$, n.s.

Comparison group. When eye and mouth trials were combined, participants in the non-autistic comparison group did not exhibit a significant orientation × test type interaction, $F(1, 19) = 2.1, p = .16$, but as can be seen in Table 3, the pattern of performance was in a direction favoring whole over part recognition in the upright condition (68% vs. 60% correct), but not in the inverted condition (51% vs. 52% correct). Paired-samples *t*-tests confirmed a near significant effect for upright whole over upright part recognition, $t(19) = 1.9$, $p < .07$, but no difference between whole and part performance in the inverted condition, $t(19) = 0.1$, n.s. Table 3 shows that the whole-over-part advantage for upright faces was similar in magnitude for eyes and mouth trials. Likewise, when other feature-specific effects were considered, the comparison group exhibited patterns of performance that were also similar to those of the typically developing children in Study 1, and that were clearly different from those found in children with autism. Thus, in contrast to the children with autism, the non-autistic group evidenced a strong effect of orientation when whole-face recognition depended on the eyes (76% vs. 53% correct for upright and inverted, respectively), $t(19) = 3.4, p < .01$,

Table 3 Correct responses for each feature in each condition

	Autism ($n = 22$)		Comparison ($n = 20$)	
	Eyes	Mouth	Eyes	Mouth
Upright Whole				
M (*SD*[a])	3.7 (1.7)	4.2 (1.6)	4.6 (1.2)	3.6 (1.2)
Percentage	62	70	76	60
Upright Part				
M (*SD*)	3.5 (1.1)	3.6 (1.4)	4.1 (1.6)	3.1 (1.2)
Percentage	58	59	68	52
Inverted Whole				
M (*SD*)	3.6 (1.1)	2.8 (1.2)	3.2 (1.5)	3.0 (1.3)
Percentage	59	47	53	49
Inverted Part				
M (*SD*)	3.4 (1.2)	3.3 (1.4)	3.1 (1.3)	3.1 (1.3)
Percentage	56	55	52	52

[a] Means and percentages are for 6 trials.

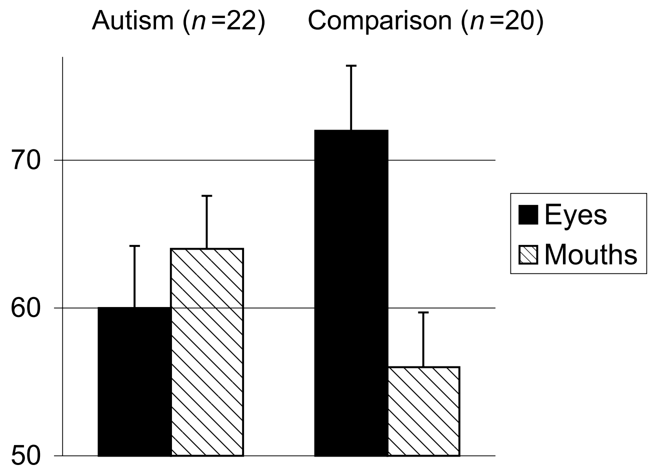

Figure 2 Percentage of correct responses on upright (whole and part) recognition trials

as well as when whole-face recognition depended on the mouth (60% vs. 49% correct), $t(19) = 2.5$, $p < .05$. Further, comparison participants were significantly more proficient at recognizing the eyes (72% correct) than the mouths (56% correct) of upright faces, $t(19) = 2.8$, $p < .02$.

Group comparisons. The purpose of the between-group analyses was to make direct comparisons of feature effects on face recognition in the two groups. First, a mixed-model ANOVA with the factors group, test-type, and feature was conducted for all upright test trials. There was a main effect of test-type, $F(1, 40) = 8.1, p < .01$, with better performance on whole than part test trials across groups. There was no effect of group, F (1, 40) = 0.2, n.s., nor was there a group × test-type interaction, $F(1, 40) = 0.2$, n.s. The only other significant effect was a group × feature interaction, $F(1, 40) = 6.8, p < .02$, reflecting the reverse pattern of performance on eye and mouth trials between the two groups, which is illustrated in Figure 2. Independent samples *t*-tests showed a stronger difference between groups on eye recognition, $t(40) = 1.9, p = .06$, than on mouth recognition, $t(40) = 1.3, p = .10$.

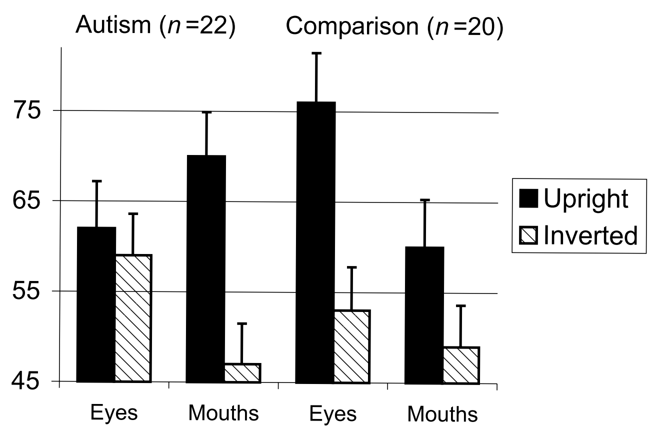

Figure 3 Percentage of correct responses on whole-face recognition trials

A second mixed-model ANOVA with the factors group, orientation, and feature was conducted for whole face trials to assess feature-based differences in the effect of inversion between groups. There was a strong main effect of orientation, $F(1, 40) = 17.6$, $p < .001$, but there was no effect of group, F (1, 40) = 0.001, n.s., nor was there a group × orientation interaction, $F(1, 40) = 0.3$, n.s. However, there was a strong group × orientation × feature interaction, F (1, 40) = 8.1, $p < .01$. As can be seen in Figure 3, this effect mainly reflected the very weak inversion effect for eye recognition in the autistic group as compared to the strong inversion effect for eye recognition in the control group. Difference scores between upright and inverted eye recognition and between upright and inverted mouth recognition were calculated for all participants in order to compare the magnitude of the inversion effect for eyes and for mouths separately between groups. The inversion effect for eye recognition was of significantly larger magnitude in the control group than in the autistic group, t (40) = 2.0, $p = .05$. Although the inversion effect for mouths was stronger in the autistic than in the control group, this group difference did not reach statistical significance, $t(40) = 1.4$, $p = .16$.

Discussion

The goal of this research was to evaluate the processing abnormalities that underlie impaired face recognition in autism. In particular, we examined the hypothesis that children with autism are impaired in holistic face recognition processes, and depend to an unusual degree on part-based encoding and recognition strategies (Boucher & Lewis, 1992; Davies et al., 1994; Miyashita, 1988; Tantam et al., 1989). Our somewhat unexpected finding was that autistic children did evidence holistic face processing, but this was mainly evident when recognition depended on the mouth region of the face. In contrast to their proficiency in processing mouth cues, children with autism were markedly deficient when face identification depended on the eyes. Thus, on the basis of the current findings, the notion of a holistic processing impairment does not fully explain the processing abnormalities in autistic face recognition.

Our most striking finding was that children with autism exhibited a consistent pattern of strength and largely normative performance in mouth-based relative to eye-based face identification. They recognized the mouths of faces as well as typically developing 9-year-olds, and better than an age- and IQ-matched comparison group. Further, when face discrimination depended on differences in the mouth region, they exhibited a whole-over-part advantage and an inversion effect, both of which are associated with normative holistic face processing. In contrast, children with autism were quite poor at eye recognition across all of the conditions that were tested. The pattern of better mouth than eye recognition was the reverse of the pattern of better eye than mouth recognition that was found in our non-autistic participants and in previous studies of normal individuals (Goldstein & Mackenberg, 1966; McKelvie, 1976; Sergent, 1984; Tanaka & Farah, 1993; Walker-Smith, 1978).

The present findings are consistent with those of Langdell (1978) and a more recent study by Klin (2001). Using eye-tracking technology, Klin measured the visual fixations of high-functioning individuals with autism while they were viewing a videotape of several actors involved in a dramatized social situation. Whereas normal individuals attended to the actors' eyes and their gaze cues, the individuals with autism mainly fixated on the mouth of the actor who was speaking. Together, these findings suggest an unusual privileging of the mouth region in autistic face processing. In addition, our finding of significantly impaired eye processing in children with autism is consistent with a wide range of evidence that individuals with autism fail to use other people's eye gaze for social and communicative purposes: for example, to establish shared attention to an object or event (Joseph & Tager-Flusberg, 1997; Mundy, Sigman, Ungerer, & Sherman, 1986); to learn the referents of novel words (Baron-Cohen, Baldwin, & Crowson, 1997); to regulate conversational turn-taking (Mirenda, Donnellan, & Yoder, 1983); to decipher the goals and intentions of another person (Baron-Cohen, Campbell, Karmiloff-Smith, Grant, & Walker, 1995; Phillips, Baron-Cohen, & Rutter, 1992); and to interpret what others may be feeling or thinking (Baron-Cohen et al., 1995; Baron-Cohen, Wheelwright, Hill, Raste, & Plumb, 2001; Baron-Cohen, Wheelwright, & Jolliffe, 1997).

What might account for apparently intact mouth processing in children with autism? One possibility is that because of a perceptual impairment in processing information from the eyes (Swettenham et al., 2001), or because of an affectively-based aversion to looking at the eyes (Davidson & Irwin, 1999; Hutt & Ounsted, 1966; Trepagnier, 1996, 1998), the mouth region takes on greater significance as the primary medium of communication for autistic children. Experimental and naturalistic observation studies have demonstrated that children with autism are significantly delayed (by several years) in spontaneously following others' shifts of gaze, and that they depend on vocal cues to establish joint attention (DiLavore & Lord, 1995; Leekam, Hunnisett, & Moore, 1998). Indications that a social-communicative milestone as important as joint attention may be established via vocal channels rather than through normative visual channels involving shifts of eye gaze (Leekam et al., 1998; see also Carpenter, Pennington, & Rogers, 2002) provides a compelling developmental explanation of how mouths may come to be experienced as more informative and salient by children with autism. Another possibility is that autistic impairments in language functioning foster an early and enduring tendency to attend to mouths in an effort to disambiguate speech sounds via lip reading, especially when other communicative cues from the eyes are inaccessible.

One limitation of the present study was that one-third of the original sample of children with autism was not included as a result of their inability to complete the experimental training procedure. The excluded children were somewhat younger in age, had a mean IQ that was one standard deviation below that of the children with autism who participated, and had higher levels of communication and social symptoms reported on the ADI-R. Our impression was that the excluded children failed the training because they lacked the attentional abilities and/or motivation required to process and respond to stimuli presented continuously on a computer screen. The relatively high (average-range) IQ of our final autism sample makes it possible that our finding of largely intact mouth processing is limited to more able children with autism. In addition, although differences in symptom levels between included and excluded participants were not necessarily meaningfully (as both groups were well beyond diagnostic thresholds), the lower level of symptoms among children who were included in the final sample is consistent with the hypothesis that attention to mouths represents compensatory social-adaptive strategies that would be expected to be more available and practicable for less severely affected and more able children.

The question of whether there are holistic face processing impairments in autism remains an open one. Using a whole–part face recognition paradigm, Donnelly and Davidoff (1999) recently found that cueing participants to the feature (e.g., eyes, mouth) on which test faces would differ improved overall recognition accuracy and preserved, and in some cases enhanced, a whole-over-part advantage (i.e., holistic processing). They explained this somewhat counterintuitive finding by arguing that holistic face representations are computed in an automatic or mandatory fashion, and that attentional cueing increases the efficiency of input into these computations. In the present study, it is possible that children with autism did not adequately attend to the eye region of the sample faces, contributing to their poor performance on eye recognition. Thus, an assessment of whether attentional cueing enhances face recognition and possibly fosters holistic processing of faces in children with autism certainly seems worthy of investigation. However, it is our expectation that children with autism will not improve substantially in their ability to represent and encode the eye region of faces as a result of attentional cueing. If this were found to be true, it would suggest that holistic face processing is not strictly mandatory, but requires cumulative life experience of attending to and encoding face information, which in the case of the eye region is lacking in most individuals with autism.

Another approach to assessing whether normative holistic face processes are biologically and functionally intact in at least some individuals with autism is to relate patterns of performance on process-oriented behavioral measures with patterns of brain activation elicited by faces in functional neuroimaging studies. Abnormally weak activation of the fusiform face area during face viewing tasks has been reported in several recent functional MRI studies of individuals with autism (Critchley et al., 2000; Pierce et al., 2001; Schultz et al., 2000). For example, Schultz et al. (2000) reported that individuals with autism demonstrated reduced activation in the fusiform gyrus during a simple face discrimination task, and instead showed increased activation of inferotemporal brain regions normally engaged in the perception of non-face objects. Although these findings are important and intriguing, they could be significantly extended if they were related to process-oriented behavioral measures from the same individuals. For example, one possibility would be to correlate behavioral measures of holistic face processing, such as the whole–part procedure used in the present studies, to the degree of fusiform activation elicited by faces in functional neuroimaging. If the two were significantly correlated, this would suggest that the decreased fusiform activation that has been found at the group level is due to a general lack of experience with faces (leading faces to be processed like other objects) rather than to an autism-specific insult to the fusiform brain region.

Our findings suggest several directions for future research. It is possible that the divergence exhibited by children with autism in their ability to identify faces on the basis of mouth cues but not eye cues could extend to other domains of face processing, such as recognition of facial expressions of emotion (Calder, Young, Keane, & Dean, 2000). Baron-Cohen, Wheelwright, and Jolliffe (1997) found that individuals with autism were impaired in identifying basic emotions from the eyes, but not from whole faces, in which mouth cues were available, suggesting that a pattern of mouth-based processing may also characterize emotion recognition in autism. Another possibility is that an impairment in gaze perception (Swettenham et al., 2001) may underlie face processing abnormalities in autism. Although there is evidence that perception of eye gaze direction and perception of identity in faces are functionally and anatomically dissociable in normal individuals (e.g., Hoffman & Haxby, 2000), a primary impairment in gaze perception, as suggested above, could have a variety of deleterious effects on the development of face processing abilities in children with autism. Finally, the possibility that impairments in earlier, lower-level visual processes account for autistic face perception abnormalities needs to be considered (Elgar & Campbell, 2001). Along these lines, two recent studies that measured the ability to detect a set of dots moving coherently within an array of dots moving randomly have reported significantly increased motion coherence thresholds in individuals with autism (Milne et al., 2001; Spencer et al., 2000). Such a disturbance in lower-level, dorsal visual stream processes may conceivably result in, for example, impaired perception of conjugate eye movement (Puce et al., 1998), on which much of the communicative significance of the eyes is based. In this manner, disturbances in earlier, lower-level visual stream processes could interfere with eye gaze perception, significantly altering the nature of developmentally critical inputs from faces in the social environment of children with autism, and leading to the decrements in face recognition that are widely reported in the literature, and the pattern of relatively intact mouth processing found in this and at least one other study (Langdell, 1978).

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