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# Converging evidence of configural processing of faces in high-functioning adults with autism spectrum disorders

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There is conflicting evidence about whether individuals with autism spectrum disorder (ASD) demonstrate configural processing of faces. We examined two types of configural processing of unfamiliar faces in high-functioning adults with ASD: Holistic processing (processing a face as a gestalt percept) and processing of second-order relations (the spatial relations among facial features, e.g., distance between two eyes). Compared to age- and IQ-matched typical adults, 17 adults with ASD demonstrated normal holistic processing (as demonstrated by the composite face effect), normal sensitivity to second-order relations in upright faces, and the expected disruption of sensitivity to second-order relations in inverted faces. They were also normal in using the internal features and shape of the external contour to make same/different judgements about facial identity. The results provide converging evidence of configural processing of unfamiliar faces in high-functioning adults with ASD, and bring into question the generalizability of previous reports of abnormal face processing in individuals with ASD.

Individuals with autism spectrum disorder (ASD) do not always show typical face processing. For example, adults typically show a face inversion effect: Inversion disrupts the recognition of faces more than other visual stimuli such as aeroplanes and houses (Yin, 1969). Individuals with ASD are worse than typical individuals at face recognition (e.g., Behrmann et al., 2006), and also tend to show a much smaller inversion effect (e.g., Hobson, Ouston, & Lee, 1998; Langdell, 1978; Tantam, Monaghan, Nicholson, & Stirling, 1989). Atypical face processing by individuals with ASD is further

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suggested by recent neuroimaging evidence indicating that, when viewing faces, individuals with ASD show less activation in areas typically associated with face processing, such as the fusiform gyrus (Dalton et al., 2005; Grelotti et al., 2005; Hubl et al., 2003; Kanwisher, McDermott, & Chun, 1997; Pierce, Muller, Ambrose, Allen, & Courchesne, 2001; but see also Pierce, Haist, Sedaghat, & Courchesne, 2004).

However, the source of the difficulty in face processing in individuals with ASD is unclear. One hypothesis is that individuals with ASD have deficits in configural processing, which refers to processing the spatial organization of faces (Maurer, Le Grand, & Mondloch, 2002). The importance of configural processing in face perception is demonstrated by a greater disruption of configural processing than featural processing (processing the shapes of individual features) when faces are inverted (e.g., Farah, Wilson, Drain, & Tanaka, 1998; Mondloch, Le Grand, & Maurer, 2002; Rhodes, Brake, & Atkinson, 1993). Configural processing can be divided into: (1) Processing first-order relations (i.e., the same basic configuration shared by all faces of having two eyes above a nose above a mouth), (2) holistic processing (gluing together the features to form a gestalt), and (3) processing of second-order relations (metric differences among individuals in the spatial relations among the features, such as the spacing between two eyes; Maurer et al., 2002).

Holistic processing of faces has been studied in detail in typically developing individuals, and more recently in individuals with ASD. Young, Hellawell, and Hay (1987) first demonstrated that typical adults are slower to recognize that two top halves of a face are the same when they are fused with the bottom halves of two different faces, a phenomenon now known as the composite face effect. Adults' accuracy increases when the two halves are misaligned, thereby disrupting holistic processing. The interference from information in the irrelevant half of the fused face implies that intact faces are processed holistically. This effect has been demonstrated in typically developing children as young as 4 and 6 years old, who show an effect at least as strong as that shown by adults tested in the same studies (Carey & Diamond, 1994; De Heering, Houthuys, & Rossion, 2007; Mondloch, Pathman, de Schonen, Le Grand & Maurer, 2007).

These findings suggest that holistic processing develops fairly early. However, Teunisse and de Gelder (2003) found that high-functioning adolescents (16–24 years) with ASD did not show the composite face effect like the adult control group. Typical adults were much faster at correctly choosing the target face's upper half from two composite faces when the composites were misaligned versus aligned. Although the group with ASD demonstrated a trend in the same direction, the difference in reaction times between aligned versus misaligned conditions was not significant (and there was also no difference in accuracy). However, they showed an adult-like inversion effect in a forced-choice recognition task, with greater accuracy and faster reaction times when faces were presented upright than inverted. This result suggests that individuals with ASD may not process faces holistically, and that a simple demonstration of an inversion effect is not sufficient to demonstrate that individuals with ASD have normal configural processing.

Joseph and Tanaka (2003) used the part/whole method (Tanaka & Farah, 1993) to demonstrate that children with autism show normal holistic processing under some conditions. With this method, holistic processing is inferred from the finding that adults recognize parts of a face (e.g., Bob's nose) better in the studied context (e.g., in Bob's face) than when it is presented in isolation. Developmentally, children as young as 4–6 years of age demonstrate a whole/part advantage of similar magnitude to that found in adults, a finding that is consistent with the findings using the composite face paradigm (Pellicano & Rhodes, 2003; Pellicano, Rhodes, & Peters, 2006; Tanaka, Kay, Grinnell, Stansfield, & Szechter, 1998).

However, Joseph and Tanaka (2003) found that whereas typically developing 10-year-olds showed the whole/part advantage when asked to recognize the eyes or, on separate trials, the mouth of a target individual, children with autism only showed the whole/part advantage when recognizing the mouth. Thus, when recognition depends on the mouth region of the face, children with autism appear to show normal holistic processing. However, when recognizing the eyes, children with autism were worse than the typically developing group, both when the eyes were presented in isolation and in the whole face. The lack of a whole/part advantage suggests some disruption of holistic processing, and is consistent with evidence that individuals with ASD may attend to the eyes less or attend to the mouth more than typically developing children (e.g., Dalton et al., 2005; Klin, Jones, Schultz, Volkmar, & Cohen, 2002; Langdell, 1978; Pelphrey, Sasson, Reznick, Goldman, & Piven, 2002).

Another type of configural processing is sensitivity to second-order relations, which are the metric differences in the spatial relations among features (e.g., spacing between two eyes) that can be used to distinguish individual facial identities. Sensitivity to second-order relations appears to develop more slowly than featural processing, as evidenced by the finding that 10-year-olds show adult-like abilities when discriminating faces based on changes to feature shapes but worse performance than adults when discriminating faces based on changes to the spacing of the features (Mondloch et al., 2002). Furthermore, Le Grand, Mondloch, Maurer, and Brent (2003) have demonstrated that individuals deprived of early visual input to the right hemisphere due to a congenital cataract in the left eye have poor sensitivity to second-order relations, a result indicating the importance of early experience in developing sensitivity to second-order relations in faces. Previous studies have also suggested that processing of second-order relations is disrupted with inversion, more than the processing of featural information, a pattern indirectly suggesting a role of experience in the development of skill in processing second-order relations (e.g., Collishaw & Hole, 2000; Freire, Lee, & Symons, 2000; Leder & Bruce, 2000; Leder & Carbon, 2006; Mondloch et al., 2002; Rhodes, Hayward, & Winkler, 2006; but see Riesenhuber, Jarudi, Gilad, & Sinha, 2004; Sekuler, Gaspar, Gold, & Bennett, 2004; Yovel & Kanwisher, 2004).

Rouse, Donnelly, Hadwin, and Brown (2004) argue that children with autism are sensitive to second-order relations, as measured by the Thatcher illusion. The Thatcher illusion is created by taking the eyes and mouth of a face and inverting them, creating a striking difference from the original face (Thompson, 1980). This manipulation is much harder to detect when the face is inverted (so that the eyes and mouth are now seen in their original orientation) compared to when the face is seen upright (Bartlett & Searcy, 1993; Lewis & Johnston, 1997). Moreover, the manipulated face looks grotesque when viewed upright but not inverted. Although the Thatcher illusion demonstrates the disruption of face processing when a face is inverted, whether the Thatcher illusion is a direct test of sensitivity to second-order relations is open for debate. Infants as young as 6 months old are sensitive to the difference between normal and Thatcherized faces (Bertin & Bhatt, 2004). Six-year-olds (the youngest age tested), like adults, report that an upright Thatcherized face is grotesque (Donnelly & Hadwin, 2003), but they are less accurate than adults in discriminating changes in facial identity based on differences in the spacing of features (that are within natural limits) and do not show an adult-like pattern of inversion (Mondloch et al., 2002). The different results may arise because inverting the eyes and mouth, as is done in the Thatcher illusion, may disrupt more than sensitivity to second-order relations. The fact that adults are still affected by the Thatcher illusion when presented with just the eyes and mouth suggests that typical configural processing is not necessary to perceive the Thatcher illusion (Boutsen & Humphreys, 2003).

The previous studies examining the effect of inversion, the composite effect, and the whole/part advantage, suggest that individuals with ASD do not process faces configurally as typically developing individuals do. Behrmann and colleagues (2006) recently found that a group of individuals with ASD, who were slower than a neurotypical control group when making same/different judgements of facial identity, also demonstrated abnormal configural processing in nonface tasks, such as a local bias when discriminating hierarchical letters (unlike the control group). The authors conclude that the difficulty experienced by individuals with ASD in processing faces may stem from a general difficulty integrating the local elements of a stimulus into a whole.

However, recent findings suggest that face processing, and in particular configural processing, may not be abnormal in individuals with ASD. For example, Homer and Rutherford (2004) found that individuals with ASD do process faces holistically, at least under some circumstances. When the authors used a delayed matching task with relatively short presentation times of the face stimuli (750 ms) that would encourage holistic processing (Celani, Battacchi, & Arcidiacono, 1999; Hole, 1994), they found that individuals with ASD perceived emotional expressions categorically as did their age-, gender-, and IQ-matched control group. Therefore, task demands that encouraged holistic processing aided in the correct perception of emotional expressions. This finding is surprising considering many studies that report atypical processing of emotional expressions in individuals with ASD (e.g., Adolphs, Sears, & Piven, 2001; Ogai et al., 2003; Weeks & Hobson, 1987), and it suggests that previous studies that used longer presentation times may have underestimated the ability of individuals with autism to demonstrate holistic processing. Lahaie and colleagues (2006) recently demonstrated a face inversion effect in individuals with ASD, citing differences in difficulty of the task, number of trials involved, and stimulus duration as possible sources for previous contradictory reports. Indeed, Behrmann and colleagues (2006) cautioned that their demonstration of abnormal configural processing in individuals with autism relied on reaction time data collected from trials with unlimited viewing time of the stimuli, and encouraged using a paradigm that utilizes short stimulus presentations and accuracy data to complement their findings.

Given the conflicting reports of face processing by individuals with ASD, the present study measured multiple aspects of face processing in the same cohort in order to gain a clearer understanding of the face processing capabilities of individuals with ASD: Two measures of configural processing (holistic processing and sensitivity to second-order relations), two measures of face processing that do not rely on configural information (changes in the shape of internal features and of the external contour), and the impact of inversion on the processing of second-order relations versus features and contours.

## EXPERIMENT 1: THE COMPOSITE FACE EFFECT—A MEASURE OF HOLISTIC PROCESSING

Joseph and Tanaka (2003) reported that children with autism were worse than typically developing children at discriminating between different eyes, and showed a whole/part advantage only when recognizing the mouth and not when recognizing the eyes, unlike typically developing children. The differential use of the eye region versus the mouth region in individuals with

ASD compared to typically developing individuals has been reported with other paradigms. Individuals with ASD look less at people's eyes than typical individuals (e.g., Dalton et al., 2005; Pelphrey et al., 2002), they do not use the eyes as cues in social interactions (e.g., Baron-Cohen, Campbell, Karmiloff-Smith, Grant, & Walker, 1995; Joseph & Tager-Flusberg, 1997), and in some conditions they attend preferentially to the mouth region of the face (Klin et al., 2002; Langdell, 1978). If individuals with ASD in fact spend a greater amount of time attending to the mouth region of a face, and/or attend less to the eye region of the face, they may demonstrate varying degrees of holistic processing of faces due to differences in experience-based expertise, depending on whether the task requires observers to attend to the eye region or the mouth region of the face.

Experiment 1 examined this hypothesis for the first time using the composite face effect. Although typical adults show a composite effect regardless of whether the task involves matching the top halves or the bottom halves of faces (Young et al., 1987), the comparison has not been made in individuals with autism. We designed a task suitable for individuals with ASD and measured the composite effect when the task required matching top halves to when it required matching bottom halves of composite faces. Two control groups were used: A group of 24 undergraduate students (Experiment 1a), in order to verify the validity of the paradigm we modified from Le Grand, Mondloch, Maurer, and Brent (2004), and an age-, gender-, and IQ-matched control group to compare directly to the performance of individuals with ASD (Experiment 1b).

## EXPERIMENT 1A: UNDERGRADUATE CONTROL GROUP

## Method

### *Participants*

Participants were 24 Caucasian undergraduate students (12 male) with normal or corrected-to-normal vision, at McMaster University. All participants gave written consent to participate prior to testing, and received course credit for an undergraduate psychology course or $10 for their participation.

### *Apparatus*

The stimuli were presented on a 22 inch computer monitor (screen size = 47.0 cm $\times$ 30.0 cm; 25.2$^\circ$ $\times$ 16.7$^\circ$ of visual angle from a viewing distance of

100 cm), controlled by a Power Mac G4 Cube computer on Mac OS 9.1 software, using Cedrus Superlab Software.

### Stimuli

All stimuli were presented in the centre of the screen located 100 cm from the observer.

*Practice stimuli—composite face task.* In order to ensure that participants in all groups would understand the task, training trials were created using simple shapes and colours. Oval shapes, roughly the same size as the face stimuli, were created with different colours on the top and bottom halves (7 cm $\times$ 9.7 cm; 4.00° $\times$ 5.54° of visual angle from a viewing distance of 100 cm; see Figure 1). The colours used were red, green, blue, and black. In the halves only condition, only the top or bottom halves were shown (7 cm $\times$ 5 cm; 4.00° $\times$ 2.86°). In the misaligned condition, the top and bottom halves were misaligned by a half-width, performed by shifting the top half of the oval to the left by 1.7 cm (roughly a quarter of the width of the oval) and the bottom half to the right by 1.7 cm (10.4 cm $\times$ 9.7 cm; 5.93° $\times$ 5.54° from 100 cm). In the aligned condition, the top and bottom halves were aligned.

In addition, four faces of Caucasian women were used to create a practice set of faces for the composite face task. To encourage processing of the facial features, the women were wearing surgical caps to hide their hair and hairline, and a cape to hide their clothing, so that only their faces were shown. Greyscale digitized images were split horizontally across the middle of the nose, and then recombined with either their original half or one other half. In the halves only condition, only the top or bottom halves were shown (8.5 cm $\times$ 6.3 cm; 4.86° $\times$ 3.60° from 100 cm). In the misaligned condition, the top and bottom halves were misaligned by shifting the top half of the face to the left by 1.7 cm (a quarter of the width of the face) and the bottom half to the right by 1.7 cm, so that the top and bottom halves were displaced by half of the width of the faces (12.7 cm $\times$ 12.7 cm; 7.24° $\times$ 7.24° from 100 cm). In the aligned condition, the top and bottom halves were aligned (8.5 cm $\times$ 12.7 cm; 4.86° $\times$ 7.24° from 100 cm).

*Test stimuli.* The test stimuli were the same stimuli used in the composite face task created by Le Grand et al. (2004). Le Grand and colleagues created composite faces by splitting greyscale digitized images of adult Caucasian faces in half horizontally across the middle of the nose, and then recombining the faces using the top and bottom halves of different individuals. Ninety-six composite faces were used to make 48 pairs for the top halves task (half of the pairs had the same top halves; bottom halves

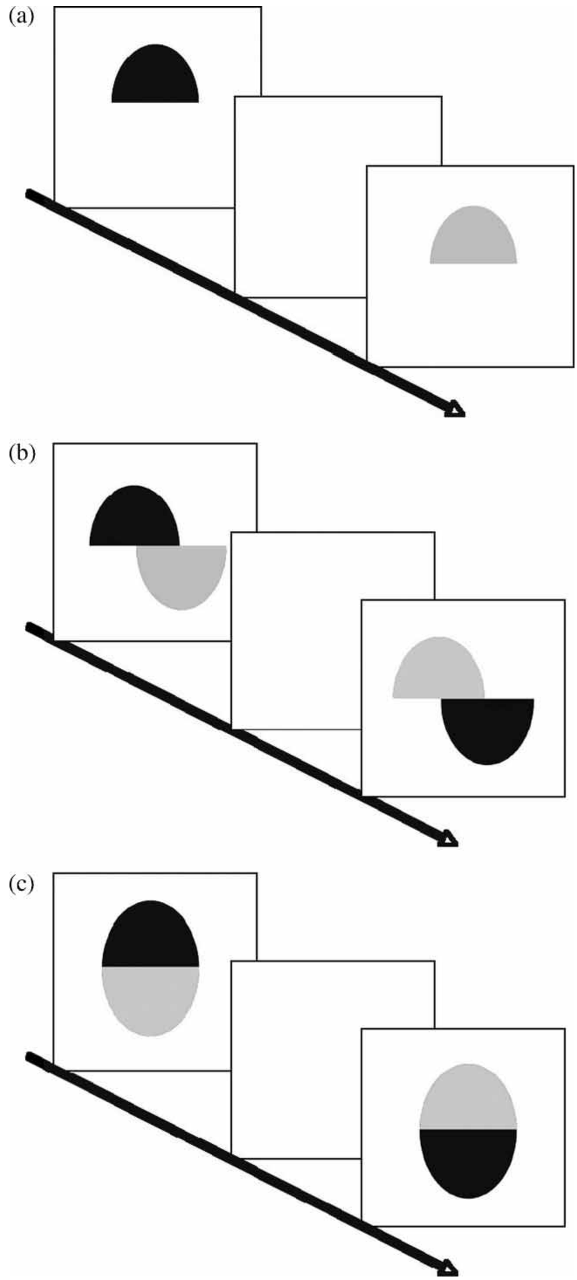



**Figure 1.** Examples of trials with oval stimuli: (a) Halves only condition, (b) misaligned condition, (c) aligned condition.

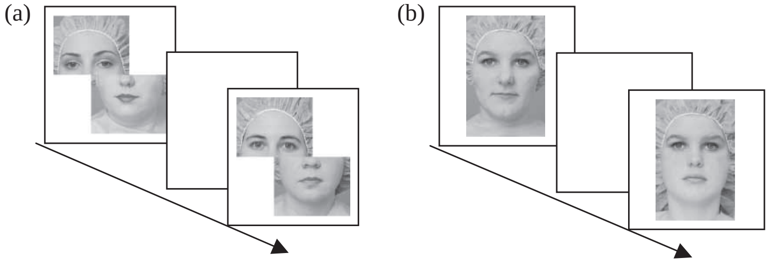



**Figure 2.** Examples of trials from the composite face task: (a) Misaligned condition, (b) aligned condition (Le Grand et al., 2004).

were always different) and 48 pairs for the bottom halves task (half of the pairs had the same bottom halves; top halves were always different).[1] The same set of composite faces was used for the misaligned and aligned conditions. Faces in the misaligned condition were misaligned by shifting the top half to the left by half the width of the face (total size = 14.7 cm × 14 cm; 8.36° × 7.97° of visual angle from a viewing distance of 100 cm), such that the bottom half of the faces remained centred on the screen but the top halves were shifted to the left. The size of the faces in the aligned condition was 9.8 cm × 14 cm (5.60° × 8.36°; see Figure 2). The size of the stimuli was similar to the size of the practice stimuli.

### *Procedure*

This study was approved by the research ethics board of McMaster University. Half of the participants started by matching the top halves of ovals and faces, followed by the task of matching the bottom halves of ovals and faces. The task was always explained using the oval stimuli first, followed by the face stimuli.

### *Procedure for participants who began with top halves*

*Training phase—misaligned condition.* Auditory feedback was given on each trial: A high pitch tone for correct and a low pitch tone for incorrect responses. Observers first performed four halves only practice trials, in which only the top halves of two ovals were shown sequentially. The first stimulus was shown for 1000 ms, followed by a blank screen for 300 ms, and the second stimulus remained on the screen until the participant made a response (see Figure 1a). After the four halves only trials, a picture of an oval with different colours on the top and bottom halves, which were misaligned, was shown on the screen. The participants were told that two such pictures

[1] Le Grand et al. (2004) used only the 48 pairs created for the top halves task in their study.

would be presented sequentially, and that their task was to judge whether the top halves of the two ovals had the same or different colours. Participants completed four misaligned practice trials, in which the first oval was shown for 1000 ms, followed by a blank screen for 300 ms, and then the second oval remained on the screen until the participant made a response. Following the misaligned practice trials, participants saw a maximum of 20 trials of misaligned ovals presented at a faster speed. Each oval was shown for 200 ms separated by an interstimulus interval (ISI) of 300 ms (the same presentation times used later when showing composite faces). Participants continued until they made five consecutive correct responses (see Figure 1b). One participant asked to repeat the practice trials before attempting the faster speed. All participants met the criterion in the first block (maximum 20 trials).

Following the practice block with oval stimuli, participants were asked to make same/different judgements of top halves of faces, presented sequentially. The halves only condition consisted of four trials with a slow presentation time (first face: 1000 ms, ISI: 300 ms; second face: Remains on screen until response) and four trials with a fast presentation time (first face: 200 ms, ISI: 300 ms; second face: Remained on screen until response). Auditory feedback was given on each trial. Participants were required to correctly judge three out of the last four trials to move on to the next phase. If they failed to meet this criterion, the halves only condition was repeated until they met this criterion. Three observers required a repetition of the halves only block before meeting the criterion.

Following the halves only condition, participants completed a practice block of the misaligned condition (eight trials). An example of a misaligned face was shown on the screen and the task of judging whether the top halves of two sequentially presented faces were the same or different was explained. There were two presentation times: Four trials with a slow presentation time (first face: 1000 ms, ISI: 300 ms; second face: Remains on screen until response) and four trials with a fast presentation time (first face: 200 ms, ISI: 300 ms; second face: Remained on screen until response). Auditory feedback was no longer given, because the purpose of the feedback on earlier trials was to ensure that participants understood the task of attending to only the top halves of stimuli, not to train the participants to do well on the composite face task.

*Test phase—misaligned condition.* Participants completed 48 test trials of making same/different judgements of the top halves of misaligned faces (bottom halves were always different). Each face was presented for 200 ms with an ISI of 300 ms (see Figure 2a). There were four practice trials to demonstrate the faster speed. Participants then completed the 48 test trials (correct answer was "same" on 24 trials).

*Training phase—aligned condition.* Following the misaligned condition, participants completed the aligned condition. The practice blocks again began with oval figures. A picture of an oval with the top and bottom halves aligned was shown in the centre of the screen while instructions were given. Afterwards, four practice trials with the top and bottom halves aligned were given (presentation times: first oval = 1000 ms, ISI = 300 ms; second oval = remained on screen until response; Figure 1c). Following the four practice trials, participants repeated the task at a faster presentation time (each oval shown for 200 ms with an ISI of 300 ms) until they met the criterion of five consecutive correct responses, or a maximum of 20 trials (all participants met the criterion within the first 20 trials). Auditory feedback was given on each trial.

Participants then completed a practice block (eight trials) of matching the top halves of aligned faces. There were four trials with a slow presentation time (first face = 1000 ms, ISI = 300 ms; second face remained on screen until response) and four trials with a faster presentation time (first face = 200 ms, ISI = 300 ms; second face remained on screen until response). An aligned face was shown in the centre of the screen during the explanation of the procedure before beginning the practice trials. "Now I'm going to show you pictures in which the top and bottom halves of faces are fused, like this one. Just like before, I want you to only pay attention to the top halves of the faces. Press the top button if you think the top halves of the faces are the same, and press the bottom button if you think the top halves are different." No feedback was given.

*Test phase—aligned condition.* Participants then completed 48 test trials of making same/different judgements of top halves of aligned faces as described by Le Grand et al. (2004). Each face was presented for 200 ms with an ISI of 300 ms (see Figure 2b). There were four practice trials to demonstrate the faster speed. Participants then completed the 48 test trials (correct answer was "same" on 24 trials).

### *Procedure for matching top vs. bottom halves*

The participants who began by matching top halves then repeated the entire procedure described above with the task of matching the bottom halves of ovals and faces (ovals–halves only, ovals–misaligned, practice faces–halves only, practice faces–misaligned, test faces–misaligned, ovals–aligned, practice faces–aligned, test faces–aligned). The other half of the participants performed the task of matching the bottom halves first, followed by the task of matching top halves.

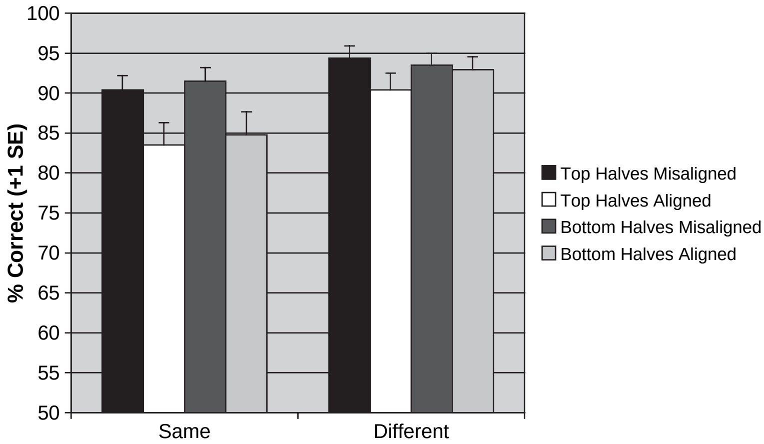



**Figure 3.** Mean accuracy of observers when matching top halves and bottom halves in the misaligned versus aligned conditions (50% correct = at chance).

## RESULTS

The mean accuracies are presented in Figure 3. In order to minimize the effect of outliers, the median reaction time from each individual was used to calculate group means of reaction times, which are presented in Figure 4. In the current paradigm, when observers were judging whether two top halves of faces were the same or different, the bottom halves were always different. If faces are processed holistically, it should be more difficult to correctly detect that the two top halves are the same when the faces are aligned versus misaligned, because the integrated Gestalt percept of the whole face interferes with any attempts to process only the two top halves (see Figure 2b). Such interference would not be experienced when the faces are misaligned (see Figure 2a). Therefore, holistic processing is inferred by the size of the "composite face effect": Better performance when faces are misaligned than aligned, when the attended halves are the *same*. No effect of alignment would be expected when the attended halves are *different*, because the irrelevant halves contain information that is congruent with the relevant halves. Therefore, as in previous studies of the composite effect (e.g., Le Grand et al., 2004), separate analyses were conducted for *same* versus *different* trials.

*Performance on same trials.* A repeated measures ANOVA was conducted on observers' accuracy and median reaction times on correct same trials, with alignment (misaligned vs. aligned) and attended halves (top vs.

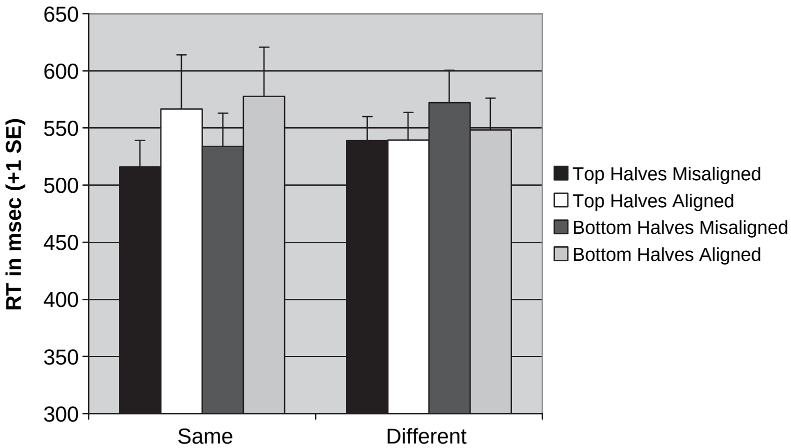



**Figure 4.** Means of observers' median reaction times on correct trials when matching top halves and bottom halves in the misaligned versus aligned conditions.

bottom) as within-subjects variables.[2] There was a main effect of alignment on observer's accuracy, $F(1, 22) = 9.61$, $p < .01$: Observers showed a composite effect by being more accurate on misaligned than aligned trials. The main effect of attended halves was not significant, $F(1, 22) = 0.30$, $p = .57$, nor was the Alignment × Attended halves interaction, $F(1, 22) = 0.06$, $p = .81$. None of the effects were significant in terms of reaction times: Main effect of alignment, $F(1, 22) = 1.93$, $p = .18$; main effect of attended halves, $F(1, 22) = 0.43$, $p = .52$; Alignment × Attended halves interaction, $F(1, 22) = 0.05$, $p = .83$).

*Performance on different trials.* As expected, there were no significant main effects and no significant interactions on either accuracy or reaction times on different trials.

[2] A preliminary repeated measures ANOVA with *order* (top halves first vs. bottom halves first) as a between-subjects variable revealed no main effect of order, $F(1, 22) = 0.00$, $p < .01$, and no significant interaction of order with alignment, $F(1, 22) = 0.07$, $p = .80$, nor attended halves (bottom vs. top), $F(1, 22) = 0.33$, $p = .57$. The three-way interaction of Order × Alignment × Attended halves was significant, $F(1, 22) = 5.04$, $p = .04$. An examination of the means suggested that the composite effect was greater for the second task for all observers. However, because the purpose of this experiment was to determine whether observers would show a composite effect, and not to examine the effect of order, data from both groups were pooled and this variable was dropped from further analyses. Order was also not analysed in Experiment 1b, because neither the main effect of order nor the interactions with order were significant.

## Discussion

Observers were significantly less accurate (mean difference of 6.89% for top halves, 6.71% for bottom halves) in the condition where holistic processing was expected to interfere (i.e., same aligned trials) compared to a condition where no such interference was expected (i.e., same misaligned trials), a difference that demonstrates a composite face effect. Compared to the data from the adult group in Le Grand et al. (2004), on which the procedure was based, the size of the difference is smaller and, unlike Le Grand et al.'s results, it was found only for accuracy and not also for reaction time. The differences suggest that the modifications we made to the paradigm, namely the addition of training trials involving oval stimuli and face stimuli at longer presentation times, may have allowed observers to learn to partially overcome the interference from holistic processing on aligned trials. In addition, the training may have had more effect on aligned trials (where accuracy is normally low) than on misaligned trials (where accuracy is high even without training and approaches ceiling in some subjects). Such differential effects of training would lead to a smaller composite effect on measures of accuracy. In terms of reaction times, the means in the present study ranged from 516 ms to 578 ms, which is faster than the reaction times reported by Le Grand et al. ($M = 815$ ms on same aligned trials and $M = 621$ ms on same misaligned trials). Thus, the addition of practice trials appears to have lowered reaction times such that a floor effect masked any composite effect. Importantly, however, the observers in the present study demonstrated a composite effect in accuracy. Therefore, we used the same paradigm to test individuals with autism and matched control participants recruited from the community.

# EXPERIMENT 1B: ADULTS WITH ASD AND COMMUNITY CONTROL GROUP

## Method

*Participants.* Two groups of adults were tested. The autism group consisted of 17 adults (15 male, mean age = 20.6 years, age range = 17–26 years) with autism spectrum disorders, and an age- and IQ-matched control group consisted of 17 adults (15 male, mean age = 21.6 years, age range = 17–28 years) without any developmental disorders. Demographic information is presented in Table 1, and detailed diagnostic information is presented in Table 2. Participants in the autism group were recruited via referral from a clinical specialist treating autism spectrum disorders. All participants in the ASD group had previously received clinical diagnoses of autism or Asperger Syndrome before entering the study, and one of the authors (MDR)

TABLE 1
Age and IQ scores of participants; standard deviations are shown in parentheses

| *Group* | *Age* | *Verbal IQ* | *Performance IQ* | *Full-scale IQ* |
|---|---|---|---|---|
| Autism | 20.6 yrs (2.7) | 100.9 (18.9) | 95.6 (18.1) | 98.5 (18.6) |
| Control | 21.6 yrs (0.8) | 104.6 (10.3) | 102.9 (15.2) | 104.4 (11.6) |
| | $t(32) = 1.00$, $p = .32$ | $t(32) = 0.72$, $p = .48$ | $t(32) = 1.27$, $p = .21$ | $t(32) = 1.11$, $p = .28$ |

confirmed their diagnoses via two criteria: (1) Autism Diagnostic Interview (ADI-R; Lord, Rutter, & LeCouteur, 1994) and (2) the Autism Diagnostic Observation Schedule (ADOS-G; Lord et al., 2000) Module 4. They were free from other known medical conditions. Participants in the control group were recruited from the community (i.e., nonuniversity students) through newspaper advertisements. Each participant was randomly assigned to match either top halves first or bottom halves first. Four additional adults with autism were recruited for the study but their data are not included in this report for the following reasons: Two participants were excluded because their IQ scores were below 70, and two individuals did not participate beyond the first block because they did not understand the difference between "same" and "different". Participants in both groups received $15 for their participation.

*Procedure.* The procedure was the same as in Experiment 1a. All participants met the two criteria during the training phase before moving on to the testing phase. The criteria were: Obtaining five consecutive correct responses when matching top/bottom halves of misaligned ovals, and being correct on at least three of the last four trials in the face halves only condition.[3]

TABLE 2
Diagnostic scores for the autism group: Mean, standard deviations in parentheses, and range

| *ADI-R* | | | *ADOS* | | |
|---|---|---|---|---|---|
| *Social* | *Commun.* | *Repetitive* | *Commun.* | *Social* | *Repetitive* |
| 23.4 (7.9) | 15.3 (5.3) | 6.4 (2.1) | 6.0 (1.6) | 7.25 (3.3) | 0.9 (1.2) |
| 12–38 | 8–24 | 4–9 | 3–8 | 3–14 | 0–3 |

[3] One individual in the autism group required repetitions in each of the criterion blocks (five blocks of misaligned top ovals, two of misaligned bottom ovals, three of top face halves only, and one of bottom face halves only). Five additional observers in the autism group required a single repetition of one of the criterion blocks. None of the observers in the control group required a block to be repeated in order to meet the criteria.

## Results

The data were analysed in the same way as in Experiment 1a. The mean accuracies are presented in Figure 5 and the reaction times are presented in Figure 6. A repeated measures ANOVA with group as the between-subjects variable (autism group vs. control group), and alignment (misaligned vs. aligned) and attended halves (top vs. bottom) as within-subjects variables, was conducted on accuracy for same trials. There was a significant main effect of alignment, $F(1, 32) = 13.18$, $p < .01$, with both groups being more accurate on misaligned trials than aligned trials, a difference indicative of a composite effect. No other effects or interactions were significant. The main effect of group approached significance, $F(1, 32) = 3.52$, $p = .07$, but group did not interact with any other variable: Group × Alignment, $F(1, 32) = .38$, $p = .54$, Group × Attended halves, $F(1, 32) = 2.19$, $p = .15$, and Group × Alignment × Attended halves, $F(1, 32) = 2.63$, $p = .12$. If individuals with autism tend to focus on the mouth region of the face more than the eyes relative to typically developing individuals, we would have expected a Group × Attended halves interaction; however, this interaction was not significant. If individuals with autism have weaker holistic processing, we would have expected a Group × Alignment or Group × Alignment × Attended halves interaction; however, neither was significant. Therefore, the composite effect did not differ significantly between the autism group and the control group (see Figure 5). We also examined how many individuals in each group demonstrated the expected composite effect (i.e., better performance on same misaligned trials vs. aligned trials), but no group

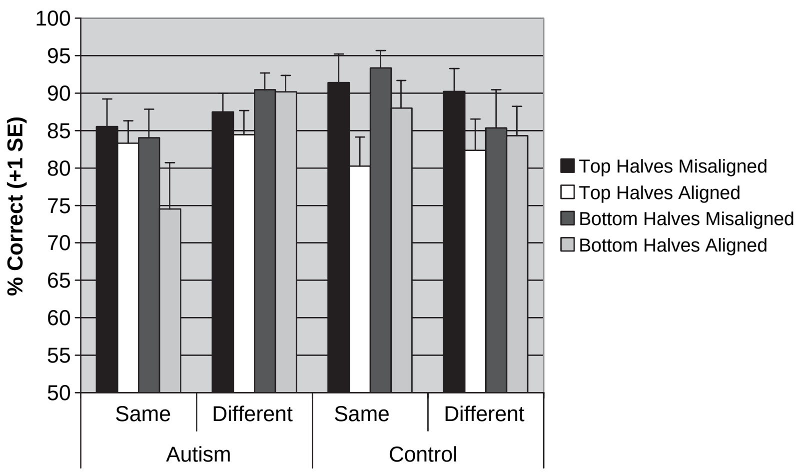



**Figure 5.** Mean accuracy of observers in the autism group versus control group when matching top halves and bottom halves in the misaligned versus aligned conditions (50% correct = at chance).

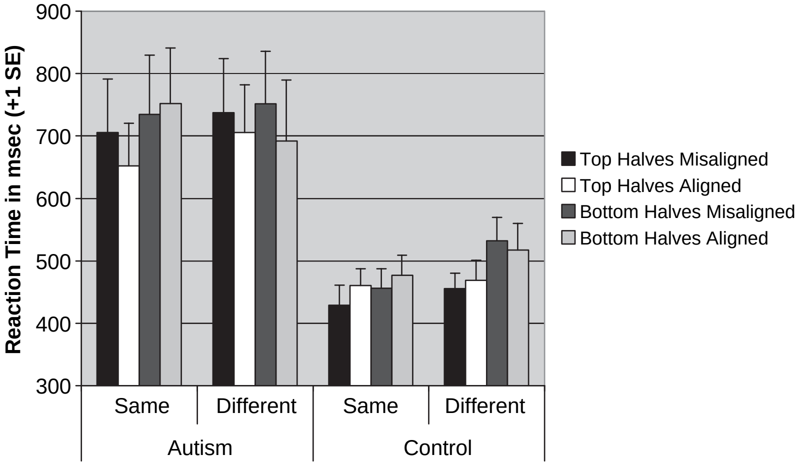



**Figure 6.** Means of observers' (autism group vs. control group) median reaction times on correct trials when matching top halves and bottom halves in the misaligned versus aligned conditions.

differences were apparent for either the task matching top halves, $\chi^2(2) = 4.03$, $p > .10$, and the task matching bottom halves, $\chi^2(2) = 0.86$, $p > .50$ (see Table 3).

An analysis of individual's median reaction times on correct trials showed that the autism group was significantly slower to respond than the control group, $F(1, 32) = 13.46$, $p < .01$. However, no other main effects or interactions were significant, much like the findings in Experiment 1a.

The analysis on different trials revealed no significant effects or interactions on accuracy. As with same trials, reaction time data revealed that the autism group was slower to respond overall than the control group, $F(1, 32) = 9.98$, $p < .01$, but no other effects or interactions were significant.

## Discussion

The results show that high-functioning individuals with autism spectrum disorders can process faces holistically. They were less accurate in recognizing that the two top (or bottom) halves of faces were the same when they were combined with different bottom (or top) halves and they were aligned, compared to their performance when the top and bottom halves were misaligned. The size of the composite effect was similar to that of an age- and IQ-matched control group. Thus, given a relatively large number of trials (48 trials vs. 21 trials used by Teunisse & de Gelder, 2003), an extensive training procedure to explain the task, short presentation times of the face stimuli, and a simple task of responding same or different with a button

TABLE 3
Number of individuals in the autism group and the matched control group who demonstrated a composite effect (i.e., better performance on misaligned same trials vs. aligned same trials) and who did not show a composite effect

| | *Top halves* | | | *Bottom halves* | | |
|---|---|---|---|---|---|---|
| | *Misaligned >aligned* | *Misaligned =aligned* | *Misaligned <aligned* | *Misaligned >aligned* | *Misaligned =aligned* | *Misaligned <aligned* |
| Autism | 9 | 5 | 3 | 11 | 4 | 2 |
| Control | 14 | 1 | 2 | 10 | 3 | 4 |

press, at least some high-functioning adults with ASD demonstrate holistic processing.

Contrary to previous findings, we did not see a significant difference in the performance of individuals with ASD as a function of whether the task required attending to the top versus bottom halves of faces. Inspection of the mean accuracies (Figure 6) shows that the composite effect for the autism group appears larger for the task of matching bottom halves than for the task of matching top halves of faces; however, this difference was not statistically significant. When we examined individual composite effects (i.e., better performance on misaligned same trials than aligned same trials), again, there was no statistical difference between the autism and control groups when attending to top versus bottom halves (see Table 3).

The autism group did differ from the control group in having significantly longer reaction times on both same and different trials. There are several possible explanations for this finding. Recent neuroimaging studies have shown activation of atypical processing pathways in individuals with ASD while they process faces (Dalton et al., 2005; Hubl et al., 2003). Therefore, one interpretation of the slower reaction times in individuals with ASD is that activation of these pathways requires more processing time than the typical visual pathways. However, it is important to note that the viewing time of the faces did not differ in the two groups. Each face was shown on the screen for only 200ms, which is much shorter than in previous studies examining face processing in individuals with ASD. Even with such a short stimulus duration, individuals with ASD were as accurate as the matched control group in making same/different judgements about the identity of the faces and demonstrated holistic processing. Given the current findings, it is difficult to determine whether the slower response times involve more processing time required for face processing per se, or whether it largely reflects slower motor responses and/or cognitive decision-making processes.

To better understand the source of the difference in reaction times, we conducted post hoc analyses on the reaction times to the oval stimuli shown during training. Before observers viewed faces, they first completed a block of misaligned and aligned trials with coloured ovals as stimuli. Observers were required to reach a criterion of five consecutive correct responses before moving on to a block of faces. We performed two separate repeated measures ANOVAs for the first block and second block of the ovals task (matching top halves first and bottom halves second for half of the participants), on individual's median reaction times for the last five correct trials of the training blocks with oval stimuli. As in the analyses with the test stimuli, alignment and attended halves were the within-subjects variables, and group was the between-subjects variable. In both blocks, as expected, the main effect of alignment was not significant, first block: $F(1, 32) = 0.07$, $p = .79$; second block: $F(1, 32) = 1.13$, $p = .30$, indicating that neither the autism group nor the control group showed any composite effect with the oval stimuli. Furthermore, there was no main effect of attended halves and no interactions involving these two variables in either analyses. The only significant effect in both analyses was the main effect of group, first block: $F(1, 32) = 6.13$, $p < .05$; second block: $F(1, 32) = 4.36$, $p < .05$, signifying that the autism group (first block $M = 595$ ms; second block $M = 698$ ms) responded significantly more slowly than the control group (first block $M = 439$ ms; second block $M = 355$ ms) in both blocks. This result suggests that the slow response of the autism group is not limited to processing of faces, and may simply reflect slower decision-making processes and/or slower motor responses. However, because the oval stimuli were introduced to the participants as practice trials, we cannot exclude the possibility that the difference in reaction times when viewing oval stimuli may reflect a difference in how individuals with and without autism approach practice versus test trials, rather than a difference in processing nonface visual stimuli. Nonetheless, accuracy of individuals with autism when making same/different judgements of one half of the face revealed interference from the unattended half of the face, suggesting intact holistic processing of faces.

## EXPERIMENT 2: SENSITIVITY TO SECOND-ORDER RELATIONS

Given the discrepant findings reported in the literature of whether individuals with ASD demonstrate configural processing of faces, we felt it necessary to test different aspects of configural processing in the same individuals with ASD. Experiment 2 was designed to test another type of configural processing: Processing of second-order relations (Maurer et al., 2002). Although Rouse and colleagues (2004) have argued that children with autism are sensitive to second-order relations as measured by the Thatcher illusion, the Thatcher illusion does not provide a sensitive, metric test of sensitivity to second-order relations (see introduction).

Mondloch et al. (2002) developed a paradigm that provides a quantitative measure of sensitivity to second-order relations and allows direct comparison of the processing of second-order relations to the processing of nonconfigural information (feature shapes and face contours). They manipulated a digitized photograph of a young woman's face (named Jane), so that Jane's eyes and mouth were replaced by those of other women (featural set), the position of Jane's eyes and mouth were changed (spacing set), or Jane's internal features were pasted into the outer contour of other women's faces (contour set). Participants were asked to make same/different judgements about the identity of two sequentially presented faces, and the face sets were blocked to encourage different aspects of face processing. The face sets were validated by showing that adults' accuracy is higher for upright than inverted faces, with a small inversion cost for the feature and contour sets and a large inversion cost for the spacing set, as would be expected if it measures sensitivity to second-order relations.

The purpose of Experiment 2 was to examine directly sensitivity to second-order relations in individuals with ASD, using the same stimuli as Mondloch et al. (2002). Mondloch, Dobson, Parson, and Maurer (2004) demonstrated that adults' performance in detecting changes in the spacing set (a measure of sensitivity to second-order relations) was not affected by whether the stimuli were presented sequentially or presented simultaneously side-by-side for an unlimited time, whereas 8-year-olds were slightly more accurate with the paired presentation. Perhaps the greater memory load created by sequential presentation is especially taxing for observers who do not possess adult-like face processing abilities (Schiano, Ehrlich, & Sheridan, 2001). Therefore, we chose to allow individuals with ASD to have unlimited viewing time in a paired presentation for this task, in order to reduce memory demands. If individuals with ASD naturally rely more on a feature-based analysis of faces, as has been suggested by previous research (e.g., Hobson et al., 1988), paired presentation of faces would allow them to use their natural face-processing strategies during the task (Celani et al., 1999), thereby revealing differences in their face processing compared to typically developing individuals. As in Experiment 1, we first tested a control group of 24 undergraduate students to verify that the results were not affected by using paired presentations following participation in Experiment 1 with composite stimuli.

## EXPERIMENT 2A: UNDERGRADUATE CONTROL GROUP

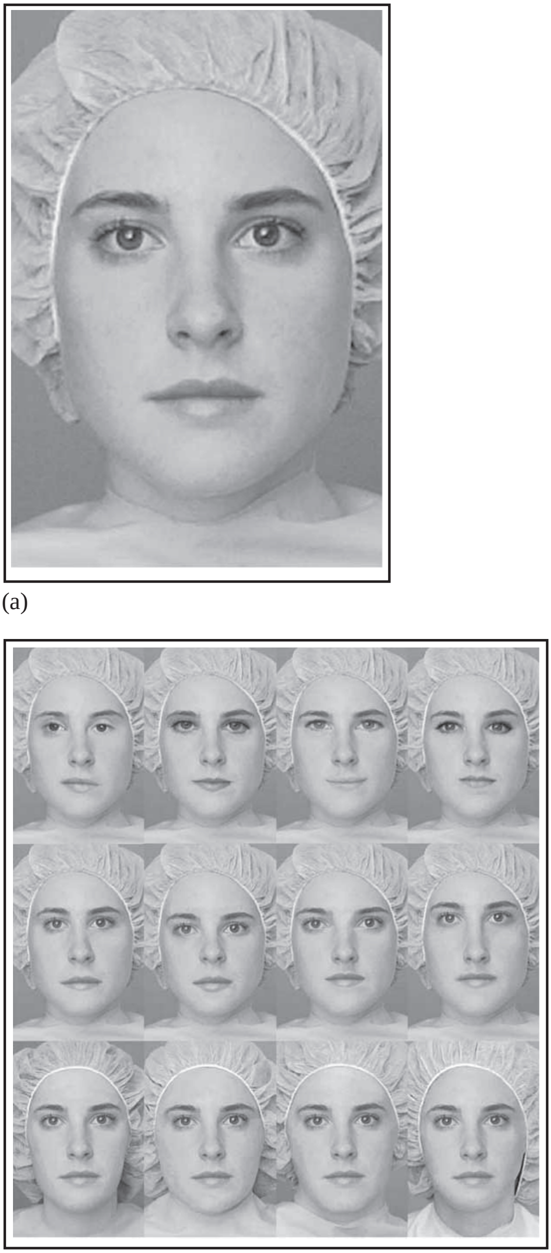
### Method

*Participants.* Participants were the same 24 Caucasian undergraduate students (12 male) as in Experiment 1a.

*Apparatus.* The apparatus was the same as in Experiment 1.

*Stimuli.* The stimuli for testing the processing of featural, spacing, and contour information were created by Mondloch et al. (2002). The stimuli consisted of the face of a Caucasian woman, and 12 altered versions of her face (see Figure 7). There were three sets of four faces: Spacing set, featural set, and contour set. The spacing set was created by moving Jane's eyes 4 mm up (0.23° of visual angle from a viewing distance of 100 cm), down, in, or out, and simultaneously moving the mouth up or down by 2 mm (0.12° from 100 cm). According to anthropomorphic norms (Farkas, 1981), the movements correspond to shifts in Jane's eyes of 1.3 *SD* up or down, of 2.4 *SD* closer together, or of 3.2 *SD* farther apart and shifts of Jane's mouth moved up and down by 0.79 *SD*. Thus, the differences covered most of the variations in spacing among adult female faces in the population, without being so large that the faces appeared deformed or unnatural. The featural set was created by replacing Jane's eyes and mouth with the eyes and mouths of four other women. The contour set was created by pasting Jane's internal features into four other women's faces. A fourth set of faces, referred to as "Jane's cousins", were unaltered male and female Caucasian faces with a neutral facial expression, wearing a surgical cap and cape. This set was included to ensure that individuals with autism had understood the task and were following instructions. All stimuli were 8.4 cm × 8.8 cm (4.80° × 5.03° of visual angle viewed from 100 cm). On each trial two faces were shown simultaneously side-by-side, separated by 2.2 cm (1.26° of visual angle) of blank space.

*Procedure.* Following the composite face task, each participant completed a test of processing spacing, featural, and contour information (Mondloch et al., 2002). All participants performed a block of same/different judgements with upright faces and then with inverted faces. First, a picture of Jane was shown on the screen, followed by the 12 altered versions of Jane's face, called Jane's sisters. Participants were informed that two photos of Jane or her sisters would be appearing side-by-side, and that their task was to judge whether the photos were the same or different, as quickly but as accurately as possible. Each participant received 6 practice trials (2 from each of the spacing, featural, and contour sets) followed by 30 test trials



(a)

(b)

**Figure 7.** Jane (a), and her sisters (b): Top row: Featural set; middle row: Spacing set; bottom row: Contour set (Mondloch et al., 2002).

from each set (first spacing, second featural, third contour set). On each trial two faces were shown side-by-side, and remained on the screen until the participant responded. After the participants completed the 90 test trials, the same procedure was repeated but with inverted stimuli.

Following the inverted faces block, participants completed a block of 30 upright trials with Jane and "her cousins" (i.e. unaltered caucasian male and female faces). On each trial two faces were shown side-by-side until the participant responded whether the faces were the same or different. Participants were instructed to answer as quickly but as accurately as possible.

## Results

The mean accuracies are shown in Figure 8. A repeated measures ANOVA was conducted with condition (spacing, featural, or contour changes) and orientation (upright vs. inverted) as within-subjects variables. There was a significant main effect of condition, $F(1, 23) = 49.95$, $p < .01$, a main effect of orientation, $F(1, 23) = 17.86$, $p < .01$, and a significant Condition × Orientation interaction, $F(1, 23) = 5.80$, $p < .01$. In order to further examine this interaction, we calculated the size of the inversion effect by subtracting accuracy on inverted trials from upright trials. Pairwise comparisons with a Bonferroni correction revealed that the inversion effect was larger in the spacing condition (14.6%) than in the featural condition (3.0%), but neither of the inversion effects observed in these two conditions was significantly different from the inversion effect seen in the contour condition (7.3%).

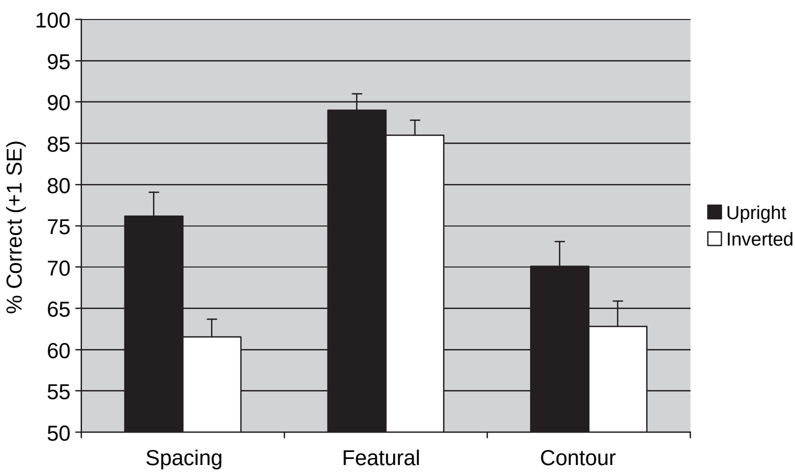



**Figure 8.** Mean accuracy of observers in detecting spacing, featural, and contour changes in upright and inverted faces (50% correct = at chance).

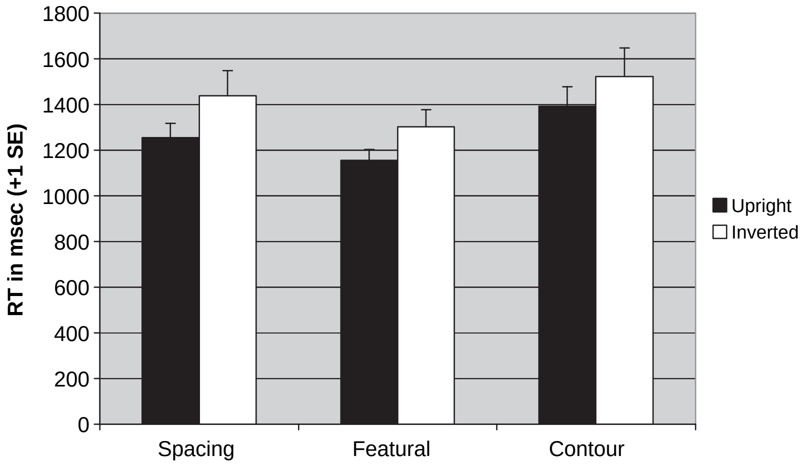



**Figure 9.** Mean of observers' median reaction times in detecting spacing, featural, and contour changes in upright and inverted faces.

Mean reaction times (calculated from individual's median reaction times to reduce the effect of outliers) are shown in Figure 9. A repeated measures ANOVA was conducted with condition (spacing, featural, or contour changes) and orientation (upright vs. inverted) as within-subjects variables. The main effect of condition was significant, $F(1, 23) = 15.14$, $p < .01$ (see Figure 9), and the main effect of orientation was also significant, $F(1, 23) = 4.89$, $p < .05$, reflecting faster reaction times to the upright faces than inverted faces. However, the Condition × Orientation interaction was not significant, $F(1, 23) = 0.35$, $p = .71$.

Participants were highly accurate on the final cousins task, with a mean accuracy of 92.3% correct and a mean reaction time (calculated from individual median reaction times on correct trials) of 1793 ms,[4] suggesting that observers had understood the tasks and were still paying attention at the end of the procedure.

## Discussion

Using paired presentations and unlimited viewing time, typically developing observers demonstrated the expected inversion effect: Better performance when faces were presented upright than inverted. Furthermore, this inversion effect was greater when the changes were made to the spacing of features (14.6%) rather than the feature shapes (3.0%), demonstrating a

[4] One participant did not complete the cousins task due to time constraints.

greater disruption of sensitivity to second-order relations by inversion than sensitivity to featural information. No interaction between the face set and orientation was found in reaction times, ruling out the possibility of a speed–accuracy tradeoff. The finding that observers were also more accurate at detecting featural changes than spacing or contour changes when faces are presented upright (see Figure 9) is consistent with previous findings (Freire et al., 2000; Mondloch et al., 2002). These results verify that the current paradigm successfully taps into three types of processing that are affected differently by inversion: The processing of second-order relations, feature shapes, and contours. Furthermore, the results indicate that the modifications we made to simplify the task do not lead to ceiling effects. Therefore, individuals with ASD as well as age- and IQ-matched controls were tested using the same paradigm.

## EXPERIMENT 2B: ADULTS WITH ASD AND COMMUNITY CONTROL GROUP

### Method

*Participants.* The participants in the autism group and the age- and IQ-matched control group were the same as in Experiment 1.

*Stimuli and procedure.* Stimuli and procedures were the same as in Experiment 2a.

### Results

Mean accuracies of the autism group and community control group are presented in Figure 10. Because our main question was whether individuals with ASD demonstrate configural processing, we first examined whether the two groups differed in how well they detected spacing changes in upright faces. A *t*-test on accuracy revealed no difference in the performance of individuals in the autism group and the control group when making same/different judgements of faces that differed in the spacing of the internal features, $t(32) = 0.21$, $p = .84$. However, the autism group was slower to respond ($M = 2275$ ms) than the control group ($M = 1298$ ms), $t(32) = 3.06$, $p < .01$.

We then examined whether individuals with ASD differed from the control group on other types of face processing, namely the processing of feature shapes and face contours, as well as the effect of inversion on face processing (as in Experiment 2a). A repeated measures ANOVA with group as the between-subjects variable (autism group vs. control group) and two

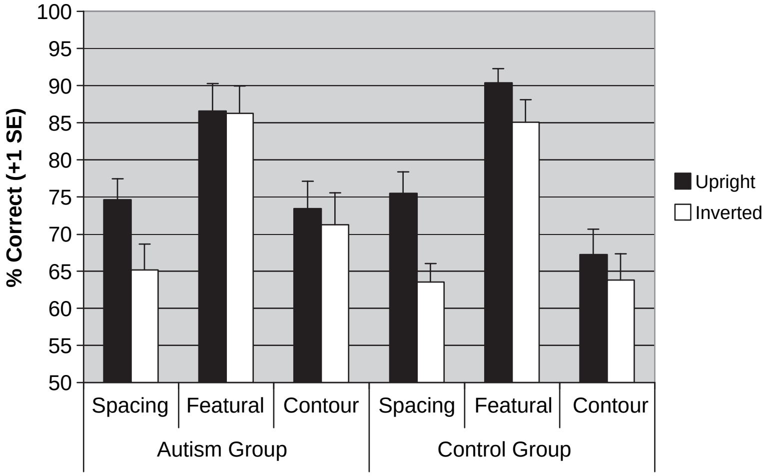



**Figure 10.** Mean accuracy of observers in the autism group versus control group in detecting spacing, featural, and contour changes in upright and inverted faces (50% correct = at chance).

within-subjects variables, condition (spacing, featural, or contour changes) and orientation (upright vs. inverted), was conducted on accuracy. There was a significant main effect of orientation, $F(1, 32) = 19.54$, $p < .01$, as observers in both groups were more accurate in recognizing changes when the faces were presented upright rather than inverted. There was also a significant main effect of condition, $F(1, 32) = 40.95$, $p < .01$, indicating that observers in both groups performed best when recognizing featural changes (see Figure 10). As expected, there was also a significant Condition × Orientation interaction, $F(1, 32) = 4.85$, $p = .01$. However, there was no significant main effect of group, $F(1, 32) = .37$, $p = .55$, and there were no significant interactions involving group: Group × Condition, $F(1, 32) = 1.81$, $p = .17$, Group × Orientation, $F(1, 32) = 1.36$, $p = .25$, and Group × Condition × Orientation, $F(1, 32) = .21$, $p = .81$.

An analysis of median reaction times on correct trials (means shown in Figure 11) revealed a significant main effect of condition, $F(1, 32) = 9.80$, $p < .01$, indicating that observers in the autism group and matched control group were faster to recognize featural changes than spacing changes. The main effect of orientation approached significance, $F(1, 32) = 3.84$, $p = .06$, as observers in both groups were faster in recognizing changes when the faces were presented upright than inverted. There was also a significant Condition × Orientation interaction, $F(1, 32) = 3.84$, $p < .05$. The means in Figure 11 suggest that observers in both groups were equally fast at detecting contour changes upright and inverted, whereas spacing and featural changes were detected faster when presented upright. There was also a significant

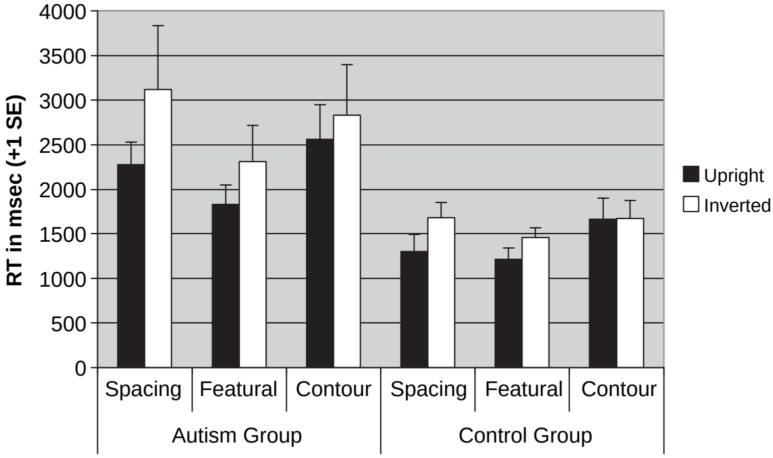



**Figure 11.** Mean of observers' median reaction times in the autism group versus control group when detecting spacing, featural, and contour changes in upright and inverted faces.

main effect of group, $F(1, 32) = 5.93$, $p < .05$, as observers in the autism group were slower to respond overall. However, there were no significant interactions with the variable group: Group × Condition, $F(1, 32) = 2.09$, $p = .13$, Group × Orientation, $F(1, 32) = 0.71$, $p = .41$, and Group × Condition × Orientation, $F(1, 32) = 0.25$, $p = .78$).

Finally, an independent samples *t*-test was conducted on data from the "cousins" task, which was the final task performed by all observers to verify that individuals were still attending to the task and following the instructions. There was no difference in accuracy between the autism group ($M =$ 91.9%, $SE = 2.5\%$) and the control group ($M = 94.7\%$, $SE = 1.9\%$), $t(32) =$ .15, $p = .39$. However, the autism group ($M = 1834$ ms) was overall slower to respond than the control group ($M = 1015$ ms), $t(32) = 4.99$, $p < .05$.

## DISCUSSION

Individuals with autism spectrum disorders performed similarly to an age- and IQ-matched control group in all aspects of face processing tested, other than having consistently longer reaction times. If individuals with ASD have deficits in configural processing, then they should demonstrate difficulty in processing second-order relations of faces. However, the autism group was just as accurate ($M = 74.7\%$, $SE = 2.8\%$) as the control group ($M = 75.5\%$, $SE = 2.9\%$) in detecting changes in the spacing of features in upright faces. Both groups also demonstrated an inversion effect, contrary to earlier reports (e.g., Hobson et al., 1988; Langdell, 1978) but consistent with a more recent report that high-functioning adults with autism demonstrate a face inversion effect (Lahaie et al., 2006). Furthermore, contrary to previous reports (e.g., Hobson et al., 1988; Lahaie et al., 2006) individuals with ASD demonstrated a greater inversion effect to spacing changes than featural or contour changes (9.5% decrement in spacing set vs. 0.4% in featural set and 2.2% in contour set), similar to the matched control group (12.0% decrement in spacing set vs. 5.31% in featural set and 3.4% in contour set). Moreover, on the cousins task, which allowed observers to use all cues to facial identity, individuals with ASD showed accuracy as high as in the control group.

Both groups were also better at detecting featural changes than spacing changes. Although previous studies have reported superior featural processing in individuals with ASD (e.g., Hobson et al., 1988; Lahaie et al., 2006), such an effect was not observed in the present study (86.6% correct by autism group compared to 90.4% correct by control group). Moreover, if individuals with ASD rely on featural processing more than typically developing individuals, they should have also performed better on the inverted featural set. However, a post hoc *t*-test revealed no group difference in accuracy on the inverted featural set, $t(32) = 0.33$, $p = .74$.

Individuals with ASD were slower to respond than the control group in every condition, as was true in Experiment 1, a difference suggesting that these tasks were more difficult for the autism group than the control group. To address the possibility that the ASD group may have been particularly slow to respond to face stimuli, we computed the ratio of the mean reaction times of the ASD group to the matched control group for all tasks[5] to get a measure of the elevation in reaction times in the ASD group. We then compared this elevation for tasks using oval stimuli to tasks using face stimuli. In Experiment 1, the autism group was 1.36 times slower than the matched control group on the first ovals task (matching top halves for half of the participants; bottom halves for the other half) and 1.97 times slower than the matched control group on the second ovals task. On the face tasks, the elevation in reaction times of the autism group ranged from being 1.46 times worse (different trials in the composite face task, Experiment 1b) to 1.81 times worse (the cousins task, Experiment 2) than the matched control group, all within the range observed for the ovals tasks. Therefore, taking into account the variability of reaction times for different tasks, there was no evidence that the autism group was particularly slower than the matched control group when processing face stimuli. Rather, the slower reaction times are likely to reflect more general effects of slower cognitive processing and/or motor responding.

[5] We calculated mean reaction times collapsed across conditions for which there was no main effect of condition in the ANOVAs on reaction time performed in Experiments 1b and 2b.

## GENERAL DISCUSSION

The present study demonstrates that high-functioning adults with ASD demonstrate configural processing of upright faces just as typically developing individuals do. Experiment 1 demonstrated that adults with ASD process faces holistically, as evidenced by greater error rates in judging whether two top (or bottom) halves of faces were the same when the faces were fused with different bottom (top) halves and aligned versus misaligned. Experiment 2 demonstrated that adults with ASD show normal sensitivity to second-order relations in upright faces. Furthermore, like the control group, they experienced a disruption of processing second-order relations when the faces were inverted, whereas the effect of inversion was much smaller when processing featural information. Together, the two experiments provide converging evidence of configural processing of faces in high-functioning adults with ASD.

Activation of the fusiform area has been associated with processing faces in typical adults, but less activation has been shown in individuals with autism during face processing (Hubl et al., 2003; Kanwisher et al., 1997). Therefore, it is surprising that individuals with ASD in our present study performed normally on all measures of face processing, including the measures of configural processing. Of course the possibility remains that there may be other individuals with ASD who do show deficits in face processing, including configural processing. Indeed the group described here has relatively mild social deficits, which could have an effect on face processing. Therefore, it would be interesting to test the same individuals from the current study with fMRI to determine if they had developed compensatory mechanisms that may be used during face perception. For example, Schultz and colleagues (2000) argue that neural activation of individuals with ASD during face processing looks more like typical activation during object recognition, suggesting a more feature-based strategy that is typical of nonface object processing. However, the autism group in the current study behaved much like the matched control group when processing faces as well as oval stimuli. Therefore, rather than using very simple tasks of face perception during an fMRI scan, it would be useful for future research to combine tasks that tap into specific aspects of face processing and measures of the neural correlates underlying task performance.

What the present study cannot address is how face processing develops in individuals with ASD. Individuals with ASD may simply take longer to develop adult-level face processing, but by adulthood they may catch up to typically developing individuals. Much of the atypical face processing that has been demonstrated in individuals with autism involved tests of young children (e.g., Boucher, Lewis, & Collins, 1998). For example, 3- and 4-year-olds with autism demonstrate atypical ERP responses to familiar versus unfamiliar faces (Dawson et al., 2002). Furthermore, data comparing children with autism to typically developing children matched on verbal mental age (whose chronological age is usually much younger than the children with autism), and/or that include children from a wide age range (e.g., Celani et al., 1999; Deruelle, Rondan, Gepner, & Tardif, 2004) are difficult to interpret as configural processing typically does not become adult-like until after age 14 years (Mondloch, Le Grand, & Maurer, 2003). Tracking the developmental trajectory of the many aspects of face processing in individuals with ASD, as has been done with typically developing children, may shed further light on how their brains learn to process faces.

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