Child Development, January/February 2006, Volume 77, Number 1, Pages 234 – 243

Recognizing the Face of Johnny, Suzy, and Me: Insensitivity to the Spacing Among Features at 4 Years of Age

Catherine J. Mondloch
Brock University

Anishka Leis and Daphne Maurer
McMaster University

Four-year-olds were tested for their ability to use differences in the spacing among features to recognize familiar faces. They were given a storybook depicting multiple views of 2 children. They returned to the laboratory 2 weeks later and used a "magic wand" to play a computer game that tested their ability to recognize the familiarized faces and their own face based on the spacing of features. Children performed at chance levels. Follow-up studies confirmed that they had attended to internal facial features and validated the stimuli. The results contrast with studies showing some sensitivity to the spacing of features in infants and preschool children; multiple mechanisms of face processing may make use of spatial relations and develop at different rates.

Adults are experts at recognizing facial identity: they can recognize thousands of faces, including, at least for a short time, ones they encounter briefly in the course of a laboratory experiment (see Bruce & Young, 1998, for a review). Their expertise is associated with particular neural correlates: the N170 in ERP studies (Bentin, Allison, Puce, Perez, & McCarthy, 1996; Rossion et al., 2000) and increased activity in the fusiform face area in fMRI studies (Aguire, Singh, & D'Esposito, 1999; Haxby, Gobbini, Furey, Ishai, Schouten, & Pietrini, 2001; McCarthy, Puce, Belger, & Allison, 1999). Behavioral studies have shown that, unlike other objects with which they do not have expertise, adults process faces holistically; they glue the features into a gestalt representation that allows them to see the face as a whole. To recognize individual faces, they use the shape of individual features (e.g., eyes, mouth, and chin, *featural processing*) and the spacing of facial features (e.g., the distance between the eyes, a type of configural processing called *second-order relational processing*) (for a review, see Maurer, Le Grand, & Mondloch, 2002). Many of these skills are degraded if the face is not presented in its canonical, upright orientation.

Despite the early emergence of some face processing skills, adultlike expertise is not achieved until some time during adolescence: recognition of faces in a study set increases dramatically between 7 and 11 years of age, but even 14-year-olds make more errors than adults (Carey, Diamond, & Woods, 1980). Even in matching tasks, which eliminate memory demands, performance improves dramatically between 4 and 11 years of age (Bruce et al., 2000; see also De Sonneville et al., 2002). Children's immaturity on behavioral tasks is consistent with findings that the N170 has a smaller amplitude and a longer latency in children than in adults, even in mid-adolescence (Taylor, McCarthy, Saliba, & Degiovanni, 1999). In addition, fMRI studies have shown that the fusiform face area does not respond more to faces than to objects until around 10 years of age; in younger children, face-preferential activity is seen only in occipital regions (Aylward, Park, Field, Parsons, Richards, Cramer, & Meltzoff, 2005; Gathers, Bhatt, Corbly, Farley, & Joseph, 2004). Even in older children (10 – 14-year-olds), the fusiform face area is not as selectively activated by faces as in adults (Aylward et al., 2005) and face-preferential activity is distributed more widely in both the left and right hemispheres (Passarotti, Paul, Bussiere, Buxton, Wong, & Stiles, 2003).

Experiment 1 formed the undergraduate honours thesis of Anishka Leis at McMaster University and a preliminary version of the findings was presented at the 2005 meeting of the Society for Research in Child Development, Atlanta.

This research was funded by an NSERC Discovery Grant to D. Maurer and a Research Capacity & Development Grant (NSERC) to C. Mondloch.

We are grateful to Catherine Best and Mark Strauss for providing background images for the computer game and suggesting the use of a magical wand. Sarah Giddy (McMaster) and Rebecca Woodall (Brock) tested the participants in Experiments 2a and 2b, respectively.

Anishka Leis is now at Department of Psychology, University of Toronto, Toronto.

Correspondence concerning this article should be addressed to Cathy Mondloch, Department of Psychology, Brock University, 500 Glenridge Avenue, St. Catharines, Ontario, Canada L2S 3A1. Electronic mail may be sent to cmondloch@brocku.ca.

 0009-3920/2006/7701-0016

There is both direct and indirect evidence that children's poor performance on face recognition tasks can be attributed largely to immature sensitivity to second-order relations. The indirect evidence is that children perform like adults on measures of other aspects of face processing. For example, when asked to make same/different judgments about pairs of faces that differ only in the shape of the external contour, 6-year-olds are as accurate as adults. They are nearly adultlike when making same/different judgments about pairs of faces that differ only in the shape of internal features (eyes and mouth), with no statistical difference by 10 years of age (Mondloch, Le Grand, & Maurer, 2002; see also Freire & Lee, 2001). In addition, holistic processing is mature by 4–6 years of age, whether measured by the composite face effect (Carey & Diamond, 1994; Mondloch, Pathman, Le Grand, & Maurer, submitted) or the whole/part advantage (Pellicano & Rhodes, 2003; Tanaka, Kay, Grinnell, Stansfield, & Szechter, 1998).

In contrast, there is direct evidence that children's processing of second-order relations is immature: they make significantly more errors than adults when asked to make same/different judgments about pairs of faces that differ only in the spacing of features, and do so at every age we tested between age 6 and age 14 (Mondloch, Dobson, Parsons, & Maurer, 2004; Mondloch, Le Grand, & Maurer, 2003; Mondloch et al., 2002). The poorer performance persists even when memory demands are eliminated by presenting the two faces simultaneously, at least at 8 years of age (the only age tested with the simplified task) (Mondloch et al., 2004). Nonetheless, even 6-year-olds' accuracy is above chance levels in making same/different judgments about upright faces differing only in the spacing of their features ($M = 0.69$ correct vs. 0.82 correct for adults tested with the same task; Mondloch et al., 2002). In addition, like adults, 7-year-old children remember distinctive faces better than typical faces, when faces are made distinctive by manipulating either features (e.g., bushy eyebrows) or their spacing (e.g. mouth up) (Gilchrist & McKone, 2003), and inverting the face eliminates the advantage only for the faces made distinctive by the spatial manipulation.

The purpose of the studies reported here was to investigate whether 4-year-old children can use second-order relations when asked to recognize an individual face. In designing our study, we were very careful to avoid the problem of underestimating children's abilities due to task demands. A study by Brace et al. (2001) highlights the importance of designing child-friendly procedures. They used face inversion as a measure of configural face processing. The *inversion effect* (poorer accuracy for inverted than for upright faces) provides indirect evidence of adults' reliance on second-order relations for face recognition because inversion disrupts adults' ability to discriminate faces that differ only in the spacing of facial features more than it disrupts their ability to discriminate faces that differ only in the shape of individual features (Freire, Lee, & Symons, 2000; Mondloch et al., 2002). Although several studies have reported the lack of inversion effect for children younger than 10 years of age (Carey & Diamond, 1994, 1977; Carey et al., 1980), Brace et al. found an adultlike inversion effect in children as young as 5–6 years of age. They attribute their finding of an inversion effect in such young children to having avoided floor effects on upright trials by using a child-friendly method: they tested children in the context of a story in which children were invited to rescue a boy from a "wicked witch"; children were asked to recognize only one child's face that was presented among a different set of foils on each trial; and there were very few test trials (three upright and three inverted); they measured reaction time in addition to accuracy. Their results provide indirect evidence of sensitivity to second-order relations in 6-year-old children, a conclusion that is consistent with other studies (e.g., Mondloch et al., 2002). However, they did not find an inversion cost in the youngest group tested, 2–4-year-olds.

Like Brace et al. (2001), we attempted to make our procedure very child friendly: children were asked to recognize only three faces, one of which was their own, and they were asked to recognize those faces in the context of a computerized game in which they used a "magic wand" to put children on a bus or train during a trip to the zoo. Unlike Brace et al., in Experiment 1 we tested children's sensitivity to second-order relations directly by presenting each target face beside a foil that differed only in the spacing of facial features. We also familiarized participants with the two target faces over a 2-week period by providing them with a storybook depicting these two children on a visit to the farm. To encourage attention to second-order relations, we varied the appearance of facial features by presenting the faces of the two children in the storybook from different points of view and with a variety of emotional expressions. We included control trials in which the foil was the face of another child and in which the foil had a different external contour, to verify that the child was "playing the game." Although adults rely more on internal facial features than on external features (e.g., hair) when recognizing familiar faces (Ellis, Shepherd, & Davies, 1979), children younger than 7 years of age rely more on external features (Campbell & Tuck, 1995; Campbell, Walker, & Baron-Cohen, 1995). Thus, we expected children to perform well on the control trials, providing confirmation that they understood the task.

Experiment 2 consisted of two follow-up studies. Experiment 2a was designed to verify that 4-year-olds tested with this method are sensitive to some characteristics of internal facial features. We presented each target face beside a foil that differed in the shape and color of the eyes and mouth. In Experiment 2b we asked adults to rate all of the faces presented in Experiments 1 and 2a on a scale of distinctiveness. We did this to rule out the possibility that children were successful on the featural task because we had inadvertently made that task easier by making manipulated faces in the featural task more distinctive than the manipulated faces in the spacing task—at least to adults. Although adult ratings do not allow inferences about perceptions of distinctiveness by 4-year-old children, they do provide a manipulation check.

Experiment 1

Method

Participants

Twelve 4-year-old children (+3 months; half of them females; mean age = 4.15 years; range = 4.03–4.22 years) participated in this study. All participants were Caucasian and were recruited from a database of children whose parents had volunteered them at birth for participation in later studies.

Materials

Familiarization stimuli. To familiarize participants with the faces of two children, we created a nine-page storybook involving ''Johnny'' and ''Suzy.'' Each page was constructed by using a Canon Power Shot G1 digital camera to take pictures of a felt board (50 × 40 cm) onto which we had pasted the hand-drawn bodies of two children and felt pieces depicting animals, a tractor, etc., to form a farm scene. We also photographed the faces of two 4-year-old Caucasian children, one boy and one girl, from a variety of angles with a number of different expressions (e.g., happy, sad, surprised). Using Adobe Photoshop, we superimposed the faces onto the bodies of the children in the storybook. Finally, we overlaid each page with text that described ''Johnny'' and ''Suzy's'' day at the farm and printed out the storybook onto 8.5 × 11-inch presentation quality paper. Each of the two children's face appeared on six of the nine pages in the storybook; the faces were approximately 3 cm high and were in color.

Test stimuli. On each trial, we presented one of the original, unaltered faces (Johnny, Suzy, or the participant) paired with a foil that was the face of another child (one trial for each original face), the original face with altered external contour (one trial) or the original face with altered spacing of internal features (two trials). A different original picture was presented on each trial to ensure that participants were recognizing a face rather than a particular photograph. Each image contained the child's face and the top of his or her shoulders (see Figure 1).

Spacing manipulation. On the basis of anthropomorphic norms (Farkas, 1994), Mondloch et al. (2002) moved the eyes of an adult female face up or down 1.3 *SD*s, closer together 2.4 *SD*s, or farther apart 3.2 *SD*s; they moved the mouth up or down 0.8 *SD*s. We created the spacing set by moving the features in the 4-year-old faces the same number of standard deviations, except that eyes were moved closer together/farther apart 2.8 *SD*s, the mean of the previous values. We also presented the faces closer to life size: the distance between the chin and the hairline was 130 mm rather than 100 mm as in previous studies. Consequently, we moved the eyes up/down 21 pixels (where 1 pixel = .353 mm) and closer together or farther apart 14 pixels; we moved the mouth up/down 7 pixels. We created two versions of Johnny (eyes out, mouth up; eyes down, mouth down), two versions of Suzy (eyes in, mouth down; eyes up, mouth up), and two versions of each participant's face (eyes in, mouth down and eyes up, mouth up for six children; eyes out, mouth up and eyes down, mouth down for six children).

Contour manipulation. We created the contour set by combining the external contour (hair, ears, and chin) of a different child with the internal features and the clothing of the original image of Johnny, Suzy, or the participant.

Control stimuli consisted of the pictures of other 4-year-old children who participated in the same study.

Procedure

Learning phase. The learning phase began when each child made their first of two visits to the laboratory. During this visit we obtained informed consent and took three pictures of each child's face; children were asked to pose a neutral expression and to look directly at the camera for each picture. We

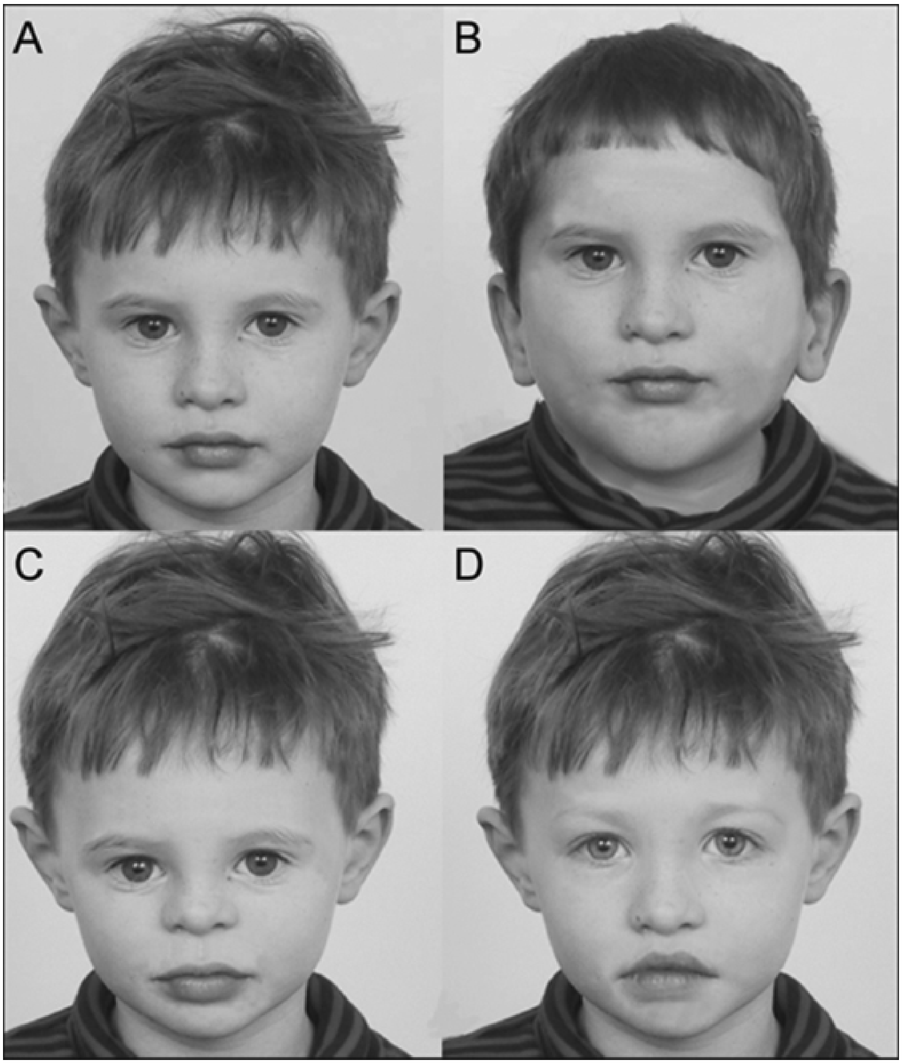

Figure 1. An example of stimuli used during test trials: (A) an original (i.e., unaltered) picture of Johnny and three foils that differ in (B) the shape of the external contour, (C) the spacing among facial features, and (D) the shape and color. Changes in the shape and color of the eyes and mouth provided a measure of featural processing; changes in the spacing of features provided a measure of sensitivity to second-order relations. All faces share the same first-order relations (two eyes above the nose that is above the mouth); individual faces can be distinguished on the basis of second-order relations (the precise spacing among facial features) and differences in the details of features (e.g., color, shape, texture).

then introduced the child to the storybook about Johnny and Suzy. Parents were asked to read the story to their child at least 10 times over a 2-week period. They were given a chart to keep a record of their reading, as well as tips on how to make the book interactive. All parents complied with these instructions.

Test phase. Each child returned to the laboratory 14–20 (mean = 15.6) days after receiving the book and after reading the book at least 10 times. The child sat 60 cm away from a 22-inch computer screen; during the test the experimenter faced the child so as to be blind as to which side of the monitor the "correct" face was on. We began by presenting an array of five pictures, each of which depicted a 4-year-old boy, including Johnny, the participant (if male), and foils. "These are the boys in Mrs. Smith's class. Do you remember Johnny from the farm book? Can you point at Johnny?" If the participant was a boy, the experimenter then said, "Look, you are in the picture too! Can you show me your picture?" The child was then shown an array that consisted of pictures of five girls, including Suzy, the participant (if female), and foils. The experimenter then said, "These are the girls in Mrs. Smith's class. Do you remember Suzy from the storybook? Can you point at Suzy?'' If the participant was a girl, the experimenter added, ''Look, you are in the picture too! Can you show me your picture?'' The purpose of these trials was to verify that the children had in fact read the storybook and were familiar with the faces. Any child who could not correctly identify Johnny and Suzy would have been excluded from the analyses. However, not a single child made an error.

On the first three test trials, the child was shown one of the original faces (Johnny, Suzy, or the child's own face) paired with a face with the same internal features but a different external contour. The background picture consisted of a school bus. The child was told, ''Today is a very special day for Mrs. Smith's class. They get to go on a trip to the zoo! But the bus driver doesn't know what all the kids in the class look like, so maybe you can help the bus driver out.'' Two faces appeared on the screen at this time. ''Look! It's you! And there's another boy/girl who looks a little bit like you. Would you like to go on the trip to the zoo with the other children? Can you use the magic wand to tell the bus driver which kid is you?'' After the child pointed the magic wand to the face he or she thought was his or her own, a new display appeared that consisted of the interior of the bus and a small picture of the child's own face. On this and every subsequent trial, the correct response was placed on the bus (or train). Two additional contour trials followed in which the child was asked to help the bus driver by pointing to Johnny or Suzy. The purpose of these trials was to illustrate to the child that the members of each face pair would be quite similar, but that only one would be the ''real'' person.

The child was then shown a series of four animal pictures (e.g., a monkey, an elephant) and the experimenter continued the story about the trip to the zoo. Then the game continued: ''Look! There's a train ride at the zoo that all the children want to go on. Can you help put the children on the train? This time it's going to be a little bit harder, because Johnny's got a brother in this class and Johnny's brother looks a lot like him. And Suzy has a sister in this class, and Suzy's sister looks a lot like her. So it's going to be hard to tell them apart. So look carefully and try to see if you can tell which one is really Johnny and which one is really Suzy.'' Two faces were then presented on the screen; the faces differed only in the spacing of the facial features. ''Here's Suzy and Suzy's sister. They look a lot alike, but only one of them is really Suzy. Can you wave your magic wand at Suzy to put her on the train?'' When the child waved the magic wand, the experimenter presented a new picture that consisted of a picture of the train overlaid with a small picture of Suzy's face. Johnny and his ''brother'' were presented in the next trial and then the child was told, ''And here's you and another boy/girl who looks a lot like you. Can you put yourself on the train?'' The child was then told that it was time for the children to go home but that the bus driver was sad because he could not remember what the children in the class looked like. A second set of spacing trials then ensued, one for each of the three original faces.

To ensure that the child was still attentive at the end of the procedure, two control trials were included. The child was told, ''Suzy had so much fun on the trip today. Now that it's the end of the day, her mom is coming to pick her up and take her home. Can you help her mom pick out Suzy?'' Two faces were presented side by side on the screen, but this time Suzy was presented next to a completely different girl. The background consisted of a cartoon version of a car. After the child pointed to the face he or she thought belonged to Suzy, Suzy appeared in the passenger side of the car. The same test was then repeated for Johnny. Any child who could not correctly identify these faces would have been excluded from the study. However, not one child made an error.

For each participant, we created two versions of the test in which the positions of the faces were reversed left to right. We then asked a laboratory member other than the experimenter to open randomly one of the two files to ensure that the experimenter was unaware of which side the target face was presented on.

This protocol was approved by the Research Ethics Board at both McMaster University and Brock University.

Results and Discussion

No child made an error on the contour trials or the control trials. In contrast, on the spacing trials 4-year-olds performed at chance levels when asked to find Johnny or Suzy, M correct (on four trials) = 2.08, $t(11) = 0.32$, $p > .2$ and when asked to find their own face, M correct (on two trials) = 1.25, $t(11) = 1.9$, $p = 0.09$ (all tests were one-tailed). Only 4 of the 12 children tested were correct on at least four of the six spacing trials. These data suggest that 4-year-olds are not able to use information about the spacing of facial features to recognize a face's identity, in contrast to 6-year-olds who perform above chance when asked to make same/different judgments about pairs of adult faces that differ in the spacing of facial features by the same amounts used in this experiment

(Mondloch et al., 2002). Four-year-olds performed poorly, despite our efforts to make the task easier for them than the task used for 6-year-olds: we increased face size, presented color photographs rather than black and white, presented the two choices side by side rather than sequentially, made the task more child friendly by providing a magic wand, and used familiar faces. These data suggest that the ability to use second-order relations for facial identity emerges between 4 and 6 years of age and are consistent with the previous report that 4-year-olds do not show an inversion effect, even when tested with a child-oriented method (Brace et al., 2001). To verify that their poor performance can be attributed to immature sensitivity to second-order relations, rather than a failure to attend to the internal facial features at all, in Experiment 2a we tested 12 new children on their ability to recognize Johnny, Suzy, and their own face when the foil face differed only in the shape and color of the internal features (i.e., eyes and mouth). To evaluate whether the success in Experiment 2a might have arisen because the featural changes were especially distinctive, in Experiment 2b, we asked adults to rate the distinctiveness of all the faces that had been shown to the 4-year-olds.

Experiment 2a

Method

The participants consisted of 12 Caucasian 4-year-old children (+3 months; mean age = 4.15 years, range = 4.07–4.25 years), 6 of whom were females. Ten of the children read the storybook at least 10 times; 1 child read the book only 7 times and 1 read the book only 9 times, but their performance did not differ from that of the group. (The child who read the book 7 times did not make any errors on the task.) The procedure was identical to that in Experiment 1 except that the six spacing trials were replaced with featural trials. On each featural trial we paired the original picture with an altered version in which the eyes (including eyebrows) and mouth of the original face were replaced (see Figure 1 for an example). The replacement eyes and mouth were the same horizontal length as the original eyes and mouth; in addition we matched the location of the inner corner of each eye and the center of the upper lip between the original and foil faces to minimize any differences in spacing. The eyes differed in shape and color.

Results and Discussion

No child made an error on control trials and one child made a single error on the contour trials. On the featural trials 4-year-olds performed above chance levels both when asked to find Johnny or Suzy, *M* correct (on four trials) = 3.00, $t(11) = 2.87$, $p < .008$, and when asked to find their own face, *M* correct (on two trials) = 1.5, $t(11) = 2.57$, $p = .01$ (both one-tailed). Nine of the 12 participants were correct on at least four of the six featural trials. These data confirm that 4-year-olds do attend to the internal portions of faces; nonetheless the results of Experiment 1 suggest that they are insensitive to the spacing of those features, at least on recognition tasks. A *t* test comparing number of correct responses across six test trials involving spacing (Experiment 1) versus features (Experiment 2) revealed that children made more correct responses in the featural study ($M = 4.5$) than in the spacing study ($M = 3.3$), $t(22) = 1.98$, $p < .05$, one-tailed.

Experiment 2b

One possible explanation for the better performance of 4-year-olds on featural trials in Experiment 2a than on spacing trials in Experiment 1 is that we inadvertently used stimuli that are inherently easier to discriminate for the featural trials. There is no way to measure the difficulty of two discriminations that lie on different dimensions of variation, but the exquisitely sensitive adult visual system provides a proxy to address the question. In Experiment 2b, we used adult ratings to evaluate whether we had made the featurally altered faces, but not the spatially altered faces, especially distinctive, thus providing an alternative cue to facial identity.

Method

Twelve Caucasian adults (6 males) participated in this study. After obtaining informed consent, each participant sat 60 cm in front of the computer monitor. We showed adults the 26 original (i.e., unaltered) test faces of Johnny, Suzy, and each participant in Experiments 1 and 2a. We also showed them each of the spatially altered versions ($n = 28$) and each of the featurally altered versions ($n = 28$). Stimuli were presented sequentially in a different random order for each participant. Before viewing the stimuli, adults were given the following instructions. *You will see a series of children's faces. Each face will be presented for 3 s. After viewing each face, I would like you to rate it on distinctiveness. A score of 6 means that the face is very distinctive, that the face would stand out if seen in a playground. A score of 0 means that the face is not at all distinctive. A score of 3 means that the face is somewhat distinctive*. Adults provided their ratings verbally and an experimenter entered the values into the computer.

Results and Discussion

To compare the distinctiveness of the spatially versus featurally altered foil faces, we calculated the difference between the rating of each manipulated face and the original version. Larger scores indicate that our alterations increased the distinctiveness of a face. For each adult, we then calculated a mean distinctiveness score across the 28 spatially altered faces and across the 28 featurally altered faces. A two-tailed t test revealed that the distinctiveness scores did differ across the two face sets, $t(11) = 6.2$, $p < .0001$. Adults rated the spatially altered faces as more distinct relative to the original versions (mean difference = 1.66, $SE = 0.22$) than the featurally altered faces (mean difference = 0.47, $SE = 0.09$). These ratings eliminate the hypothesis that 4-year-olds performed better when the foils differed from target faces in the shape and color of individual features than in the spacing of features because the featurally altered faces were more distinct than the spatially altered faces. In fact, adults in Experiment 2b indicated that just the opposite was the case. The results from adults do not indicate that 4-year-olds perceived the spatially altered faces as distinctive; they do indicate that 4-year-olds' differential sensitivity to individual features versus their spacing is unlikely to be caused by differences in distinctiveness inherent in the stimuli, at least as judged by the adult visual system.

General Discussion

The results of Experiments 1 and 2 indicate that we have developed a method that is very suitable for testing face processing in preschool children. All but two children read the storybook at least 10 times and several had memorized the book before returning to the laboratory for their second visit. Children enjoyed playing the computer game: two children were excited to have a magic wand like "Harry Potter"; some asked to play the game a second time. Every child correctly identified Johnny and Suzy on the first two trials and on the last two control trials.

As expected based on previous results with 5-year-old children (Campbell et al., 1995), 4-year-olds were very accurate when the foil differed from the target face only in the shape of the external contour. Across the two studies (24 children), only one child made an error on the contour trials. It is of interest to note that although several children remarked, "Hey! That boy (girl) is wearing my clothes," not one child remarked that the foil face was comprised of his or her internal features. Thus, external facial contour and hair are salient stimuli to preschool children.

Although by no means without error, 4-year-olds were able to identify both their own face and the faces of Johnny and Suzy when the foils differed in the shape and color of internal features. In contrast, they performed at chance levels when the foils differed in the spacing of those features despite the fact that the storybook contained six pictures of each child and both facial expression and head orientation were varied across pages, thus ensuring that the appearance of any individual feature varied across pages. Likewise, children were able to recognize a very familiar face—their own face—when the foils differed in the shape and color of features but not when they differed in the spacing of features. Although children see pictures of themselves posing different expressions and taken from different points of view and they see themselves in the mirror while combing their hair or making "funny faces," this experience is insufficient for them to recognize their own face based on second-order relations. We showed children their own pictures from the photographic rather than the mirror perspective, and it is possible that 4-year-olds' accuracy would have increased had we used the mirror perspective. We note, however, that 4-year-olds were able to recognize their own face based on featural and contour cues in the photographic perspective.

Our findings are consistent with several studies showing prolonged development of the neural mechanisms underlying face processing (Aylward et al., 2005; Passarotti et al., 2003; Taylor, Edmonds, McCarthy, & Allison, 2001; Taylor et al., 1999). The finding that the N170 to eyes alone matures more quickly than the N170 to a whole face (Taylor et al., 2001) is consistent with our finding that featural processing emerges before second-order relational processing (see Aylward et al., 2005, for discussion). Furthermore, Aylward et al. (2005) reported that individual differences among children in the extent to which memory for upright faces is better than memory for inverted faces (their measure of configural processing) are associated with differences in the amount of activation in the putative fusiform face area for faces relative to houses. This association led them to conclude that increased specialization of the FFA is related to increases in configural processing over the age range 8–14.

Collectively, these data suggest that the ability to use second-order cues to recognize facial identity emerges between 4 and 6 years of age. The interpretation must take account, however, of three recent studies showing that by 4 years of age there is some sensitivity to second-order relations. The first study (Bhatt, Bertin, Hayden, & Reed, 2005) provides evidence of sensitivity to the spacing among features in 5-month-old infants. After being habituated to a schematic face in which the eyes were moved out and the mouth down, 5-month-olds looked longer at the unaltered face with features in an average location; they failed to do so when the habituation and test stimuli were inverted. We note, however, that Bhatt et al. presented schematic faces; infants may detect differences in the spacing between features defined by clear edges in schematic drawings but not in photographic images or real faces in which the boundaries of features are less clear. The second study (Thompson, Madrid, Westbrook, & Johnston, 2001) provides evidence of sensitivity to second-order relations in infants. In a preferential looking paradigm, 7-month-old infants were shown an unaltered face paired with a face that was either shortened (by deleting a horizontal "slice" of the face between the eyes and mouth) or lengthened (by adding a horizontal "slice" of the face). Infants looked longer at the member of each pair that had proportions closest to the population mean. We note, however, that the manipulation used by Thompson et al. also slightly changed the shape of the external contour. Finally, Pellicano, Rhodes, and Peters (in press) tested children's sensitivity to the spacing of facial features using the whole/part paradigm. The whole/part effect is a measure of holistic processing (Tanaka & Farah, 1993) and refers to the finding that adults and children as young as 4 years of age recognize the features from an individual's face more easily in the context of the whole face (e.g., Larry's nose in Larry's face) than in isolation (Pellicano & Rhodes, 2003; Tanaka et al., 1998). The usual interpretation of the whole/part paradigm is that poor performance in the isolated features condition indicates that faces are processed holistically (i.e., as a gestalt) and that characteristics of individual features are encoded in the context of this gestalt representation (Tanaka & Farah, 2003). Disrupting holistic processing by presenting features in isolation impairs the recognition of features, as does altering the gestalt by changing second-order relations (Tanaka & Sengo, 1997). Pellicano et al. (2003) showed that altering the spacing of facial features in one part of a face also impairs the ability of 4-year-olds to recognize facial features in another part of the face.

These diverse findings raise the interesting possibility that there may be different face-processing mechanisms that utilize second-order relations and that become sensitive to second-order relations at different rates during development. For example, the spatial alterations made by Bhatt et al. (2005) resulted in features being in locations that were outside normal limits (the eyes were moved out 7 *SD*s and the mouth down 3 *SD*s). The infants in their study may have responded to distinctiveness rather than identity per se. Unpublished results from our own laboratory show that when asked which face is more "weird," 4-year-olds pick a face with the spacing among features altered well beyond normal limits over an undistorted version of the same individual. These results raise the interesting possibility that variability in the spacing among features influences the categorization of stimuli (e.g., good face/poor face) before it influences discrimination within categories (i.e., among typical faces). This same mechanism might also account for Thompson et al.'s (2001) results for faces altered away from prototypical proportions. The results of the study by Pellicano et al. (2003) suggest that mechanisms underlying holistic processing may become sensitive to the spacing among features before mechanisms that explicitly encode facial identity based on differences in the spacing among features.

Future studies are needed to test the above hypothesis, ideally by testing children's sensitivity to the same changes in the spacing of facial features in a variety of experimental paradigms. For example, the eyes of faces could be moved up/down in the *composite face task;* if holistic processing mechanisms are sensitive to second-order relations, then moving the eyes should increase errors when children are asked to make same/different judgments about the bottom halves of faces. Children could then be asked to make distinctiveness judgments about the same face pairs. The same manipulations could be made to the faces of individuals with whom they interact on a daily basis (e.g., a parent, a play mate, a daycare worker) because the mechanisms may be more sensitive to spacing differences in familiar faces (see Carver et al., 2003, for the effect of familiarity on the Nc component of the ERP waveform between 18 and 24 months of age).

References

Aguirre, G. K, Singh, R., & D'Esposito, M. (1999). Stimulus inversion and the responses of face and object-sensitive cortical areas. *Neuroreport*, *10*, 189–194.

Aylward, E. H., Park, J. E., Field, K. M., Parsons, A. C., Richards, T. L., Cramer, S. C., & Meltzoff, A. N. (2005). Brain activation during face perception: Evidence of a developmental change. *Journal of Cognitive Neuroscience*, *17*, 308–319.

Bhatt, R. S., Bertin, E., Hayden, A., & Reed, A. (2005). Face processing in infancy: Developmental changes in the use of different kinds of relational information. *Child Development*, *76*, 169–181.

Bentin, S., Allison, T., Puce, A., Perez, E., & McCarthy, G. (1996). Electrophysiological studies of face perception in humans. *Journal of Cognitive Neuroscience*, *8*, 551–565.

Brace, N. A., Hole, G. J., Kemp, R. I., Pike, G. E., Duuren, M., & Norgate, L. (2001). Developmental changes in the effect of inversion: Using a picture book to investigate face recognition. *Perception*, *30*, 85–94.

Bruce, V., Campbell, R. N., Doherty-Sneddon, G., Import, A., Langton, S., McAuley, S., et al. (2000). Testing face processing skills in children. *British Journal of Developmental Psychology, 18*, 319–333.

Bruce, V., & Young, A. W. (1998). *In the eye of the beholder: The science of face perception*. Oxford, UK: Oxford University Press.

Campbell, R., & Tuck, M. (1995). Recognition of parts of famous-face photographs by children: An experimental note. *Perception*, *24*, 451–456.

Campbell, R., Walker, J., & Baron-Cohen, S. (1995). The development of differential use of inner and outer face features in familiar face identification. *Journal of Experimental Child Psychology, 59*, 196–210.

Carey, S., & Diamond, R. (1977). From piecemeal to configurational representation of faces. *Science*, *195*, 312–313.

Carey, S., & Diamond, R. (1994). Are faces perceived as configurations more by adults than by children? *Visual Cognition*, *1*, 253–274.

Carey, S., Diamond, R., & Woods, B. (1980). Development of face recognition: A maturational component? *Developmental Psychology, 16*, 257–269.

Carver, L., Dawson, G., Panagiotides, H., Meltzoff, A. N., McPartland, J., Gray, J., et al. (2003). Age-related differences in neural correlates of face recognition during the toddler and preschool years. *Developmental Psychobiology, 42*, 148–159.

De Sonneville, L. M. J., Verschoor, C. A., Njiokiktjien, C., Op het Veld, V., Toorenaar, N., & Vranken, M. (2002). Facial identity and facial emotions: Speed, accuracy, and processing strategies in children and adults. *Journal of Clinical and Experimental Neuropsychology, 24*, 200–213.

Ellis, H. D., Shepherd, J. W., & Davies, G. M. (1979). Identification of familiar and unfamiliar faces from internal and external features: Some implications for theories of face recognition. *Perception*, *8*, 431–439.

Farkas, L. G. (1994). *Anthropometry of the head and face in medicine* (2nd ed.). New York: Elsevier.

Freire, A., & Lee, K. (2001). Face recognition in 4- to 7-year-olds: Processing of configural, featural, and paraphernalia information. *Journal of Experimental Child Psychology, 80*, 347–371.

Freire, A., Lee, K., & Symons, L. A. (2000). The face-inversion effect as a deficit in the encoding of configural information: Direct evidence. *Perception*, *29*, 159–170.

Gathers, A. D., Bhatt, R., Corbly, C. R., Farley, A. B., & Joseph, J. E. (2004). Developmental shifts in cortical loci for face and object recognition. *Neuroreport*, *15*, 1549–1553.

Gilchrist, A., & McKone, E. (2003). Early maturity of face processing in children: Local and relational distinctiveness effects in 7-year-olds. *Visual Cognition*, *10*, 769–793.

Haxby, J. V., Gobbini, M. I., Furey, M. L., Ishai, A., Schouten, J. L., & Pietrini, P. (2001). Distributed and overlapping representations of faces and objects in ventral temporal cortex. *Science*, *293*, 2425–2430.

Maurer, D., Le Grand, R., & Mondloch, C. J. (2002). The many faces of configural processing. *Trends in Cognitive Science*, *6*, 255–260.

McCarthy, G., Puce, A., Belger, A., & Allison, T. (1999). Electrophysiological studies of human face perception. II: Response properties of face-specific potentials generated in occipitotemporal cortex. *Cerebral Cortex*, *9*, 431–444.

Mondloch, C. J., Dobson, K. S., Parsons, J., & Maurer, D. (2004). Why 8-year-olds can't tell the difference between Steve Martin and Paul Newman: Factors contributing to the slow development of sensitivity to the spacing of facial features. *Journal of Experimental Child Psychology, 89*, 159–181.

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

Mondloch, C. J., Grand, R., & Maurer, D. (2003). Early visual experience is necessary for the development of some—but not all—aspects of face processing. In O. Pascalis & A. Slater (Eds.), *The development of face processing in infancy and early childhood* (pp. 99–117). New York: Nova.

Mondloch, C. J., Pathman, J., Le Grand, R., & Maurer, D. (2003, June). *Can children's insensitivity to spacing among facial features be attributed to immaturity in holistic processing*? Poster presented to the Canadian Society for Brain, Behaviour, and Cognitive Science, Hamilton, Canada.

Passarotti, A. M., Paul, B. M., Bussiere, J. R., Buxton, R. B., Wong, E. C., & Stiles, J. (2003). The development of face and location processing: An fMRI study. *Developmental Science*, *6*, 100–117.

Pellicano, E., & Rhodes, G. (2003). Holistic processing of faces in preschool children and adults. *Psychological Science*, *14*, 618–622.

Pellicano, E., Rhodes, G., & Peters, M. (in press). Are preschoolers sensitive to configural information in faces? *Developmental Science*.

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

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

Tanaka, J. W., & Farah, M. J. (2003). Holistic face recognition. In M. Peterson & G. Rhodes (Eds.), *Analytic and holistic processes in the perception of faces, objects and scenes* (pp. 53 – 91). New York: Oxford University Press.

Tanaka, J. W., Kay, J. B., Grinnell, E., Stansfield, B., & Szechter, T. (1998). Face recognition in young children: When the whole is greater than the sum of its parts. *Visual Cognition*, *5*, 479 – 496.

Tanaka, J. W., & Sengo, J. A. (1997). Features and their configuration in face recognition. *Memory & Cognition*, *25*, 583 – 592.

Taylor, M. J., Edmonds, G. E., McCarthy, G., & Allison, T. (2001). Eyes first! Eye processing develops before face processing in children. *Neuroreport*, *12*, 1671 – 1676.

Taylor, M. J., McCarthy, G., Saliba, E., & Degiovanni, E. (1999). ERP evidence of developmental changes in processing of faces. *Clinical Neurophysiology, 100*, 910 – 915.

Thompson, L. A., Madrid, V., Westbrook, S., & Johnston, V. (2001). Infants attend to second-order relational properties of faces. *Psychological Bulletin & Review, 8*, 769 – 777.