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Face processing in 8-month-old infants: evidence for configural and analytical processing

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Abstract

Two experiments examined whether 8-month-old infants process faces (photos in Experiment 1, schematic faces in Experiment 2) analytically by processing facial features independently of the facial context or configurally by processing the features in conjunction with the facial context. Infants were habituated to two faces and looking time was measured. After habituation they were tested with a habituation face, a switch face, or a novel face. In the switch faces, single features of the habituation faces were switched. The results showed that the infants processed facial features of photographs of faces configurally whereas they processed features of schematic faces (eyes, nose, facial contour) analytically. Thus, although infants have access to both processing modes, for real looking faces they use the configural mode.

Keywords: Face; Processing; Infant

1. Introduction

Adults are experts at recognizing faces. They identify faces quickly and exactly without any effort. Numerous studies have shown that adults' exceptional face recognition performance can be attributed to configural processing—processing the relations among the facial features (e.g., Diamond & Carey, 1986; Farah, Tanaka, & Drain, 1995; Farah, Wilson, Drain, & Tanaka, 1998; Freire, Lee, & Symons, 2000; Tanaka & Farah, 1993). On the other hand, a great deal of evidence suggests that individual features also provide an important source of information for face processing (e.g., Bruyer & Coget, 1987; Macho & Leder, 1998; Schwarzer & Massaro, 2001), and most recent studies are concerned with the question of whether and how both configural and featural information are processed in face recognition (e.g., Collishaw & Hole, 2000; Leder & Bruce, 2000; Schwaninger, Lobmaier, & Collishaw, 2002; Searcy & Bartlett, 1996; Tanaka & Sengco, 1997). Thus, the mature system for face processing in adults operates with different modes of configural and featural processing and can be understood as the result of years of experience of differentiating upright faces. However, even infants show an impressive ability to recognize faces. The question arises, therefore, as to whether the different modes of face processing are a result of development and experience or whether they can be observed even in the first months of life. So far, several studies have shown that infants process configural information in faces and that they respond to different internal sections of faces (Cohen & Cashon, 2001; Mondloch et al., 1999; Pascalis, de Haan, Nelson, & de Schoenen, 1998; Slater, Quinn, Hayes, & Brown, 2000; Slater et al., 2000). However, until now it is still unclear just to what extent a purely featural processing mode, similar to that observed in the adult face processing system, is also involved in the infant face processing system. In the present study, therefore, we investigated how infants process single facial features such as the eyes, nose, mouth, and facial contour. We studied whether infants process them with or without the influence of the facial context.

2. Research on the different modes of face processing in adults

As mentioned above, the information adults use to perceive, store, and recognize faces is of both configural

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and featural character. According to Maurer, Le Grand, and Mondloch (2002), configural processing can be divided into three types: (1) sensitivity to first-order relations i.e., seeing that a stimulus is a face because the features are arranged with two eyes above a nose, which is above a mouth; (2) holistic processing i.e., glueing together the features into a gestalt; and (3) sensitivity to second-order relations i.e., perceiving the specific distances among the features. Previous research has shown that adults process all of these three types of configural information. They have a remarkable ability to detect faces amongst a sample of other visual stimuli on the basis of first-order relations (Moscovitch, Winocur, & Behrmann, 1997). Studies using event-related potentials and functional magnetic resonance imaging have identified the neuronal correlates of detecting a face (Bentin, McCarthy, Perez, Puce, & Allison, 1996; Bentin, Sagiv, Mecklinger, Friederici, & von Cramon, 2002; Rossion et al., 2000). These measures are affected much more by variations that influence sensitivity to first-order relations than by variations that affect sensitivity to second-order relations (e.g., Gauthier, Skudlarski, Gore, & Anderson, 2000).

When adults detect the first-order relations of a face, they tend to process the face as a gestalt which makes it harder to process individual features. This effect was demonstrated by the "composite face effect" (e.g., Young, Hellaway, & Hay, 1987). Here it was shown that the top half of a face can be recognized correctly when it is presented in isolation, but that recognition is significantly slower when the top half is combined with the bottom half of a different face. However, this effect was only found when the two halves were aligned so as to create the impression of a new facial gestalt, and not when the two face halves were misaligned. Holistic processing of faces has also been demonstrated by the "part-whole recognition effect" (Farah et al., 1998; Tanaka & Farah, 1993). The authors showed that adults are more accurate in recognizing the identity of a feature when it is presented in the context of the whole face than when it is presented as an isolated feature. No such advantage was found for the processing of scrambled or inverted faces and houses. As shown by Young et al. (1987), holistic processing seems to occur not only among the internal features but also between the internal features and external contour, making it difficult to realize that the internal features of two faces are the same when they are presented in different external contours.

Since all faces share the same first-order relations, recognition of individual faces requires the encoding of more subtle variations such as the encoding of second-order relations. As shown by Haig (1984), adults can detect variations in the spatial distances among internal features as small as one minute of visual angle. It could be demonstrated by several studies that the manipulation of second-order relations has almost no effect on information about single facial features and that this holds true for vice versa too (Barton, Keenan, & Bass, 2001; Freire et al., 2000; Le Grand, Mondloch, Maurer, & Brent, 2001; Leder & Bruce, 2000). However, the authors found that inverting faces reduces accuracy and increases reaction times much more when adults discriminate faces that differ in second-order relations than when they discriminate faces that differ in featural information only. Such findings indicate that separate mechanisms are involved in second-order relational processing as opposed to featural processing of individual faces.

The fact that featural processing (e.g., the processing of a single facial feature independently of the facial context, also called analytical, componential, or piecemeal processing) is also involved in face recognition is well documented. Tanaka and Farah (1993) have shown that individual features can be recognized with moderate accuracy, even when presented in isolation or in the context of a scrambled face. Tanaka and Sengco (1997) also acknowledge the influence of individual facial parts for face processing. They demonstrated that adults performed above chance when recognizing face parts presented in isolation, indicating that the individual face parts were encoded independently of the other features and their configuration. Even so, the authors emphasized the interaction between featural and configural information of the face because their results also showed that the alteration of facial configurations interfered with the retrieval of facial features, whereas this was not the case with inverted faces or non-face stimuli. Macho and Leder (1998) and Campbell, Schwarzer, and Massaro (2001) used mathematical models to investigate whether face recognition depends on featural or holistic processes. In Campbell, Schwarzer and Massaro's task (2001), participants were shown faces which varied in the features of the eyes and mouth and were asked to identify them as one of two familiar faces. The results were then evaluated and compared to fit featural or holistic models. It was shown that the results could best be described by a featural processing model. The model predicts that subjects encode single facial features independently and then combine them in a second multiplicative operation. Independent encoding of features is more consistent with featural processing than holistic processing. In a similiar task, Macho and Leder (1998) varied the width of the nose, the size of the mouth and the eye distance of their photographic stimuli, and participants decided which of two faces the photos resembled most. To disencourage the reliance on detailed feature information and therefore featural processing, a poor quality condition was also included in which blurred photos were shown. Despite this, the results were also in line with a featural processing model.

Thus, previous research has shown that both the configural and the featural route of processing are important for face recognition in adults. Collishaw and Hole (2000) provide evidence that these routes exist independently of one another (see also Schwaninger et al., 2002). However, it is still unclear whether the processing of features and configuration actually takes place separately in the course of normal face recognition. Evidence for interactive processing has been provided by Sergent (1984) and by Tanaka and Sengco (1997). To what extent these important featural and configural routes of face processing can already be accessed during the first year of life will be described in the following paragraph.

3. Configural and featural face processing in infancy

In the following section, we will describe to what extent infants process configural and featural information of faces. Firstly, according to the literature on adults' configural face processing mentioned above, we will describe whether and how infants show the three types of configural processing, i.e., sensitivity to first-order relations, processing of holistic information, and sensitivity to second-order relations as perceiving the specific distances among the features.

Several studies showed that newborns already prefer to look at a face-like pattern that has face-like first-order relations than at a scrambled face or other visual stimuli (Goren, Sarty, & Wu, 1975; Johnson, Dziurawiec, Ellis, & Morton, 1991; Johnson & Morton, 1991; Mondloch et al., 1999; Valenza, Simion, Macchi Cassia, & Umilta, 1996). For example, Simion, Farroni, Macchi Cassia, Turati, and Dalla Barba (2002) reported that newborns discriminate schematic faces that consist of small elements arranged in either a face-like or a non-face-like configuration, tending to prefer the face-like pattern (Simion et al., 2002). Also, it could be observed that the orienting responses in newborns are stronger to face-like than other kinds of stimuli, suggesting that a kind of stored representation drives attention to faces (Macchi Cassia, Simion, & Umilta, 2001). Simion, Valenza, and Umilta (1998) demonstrated that the preference for faces can be evoked by a face-like arrangement of internal blobs presented within a contour. They showed that even a square contour and not only a head-shaped contour, is sufficient to produce the preference for the face-like arrangement of the internal blobs. Taken together, these findings and others indicate that from the very beginning of life a sensitivity to first-order relations in faces exists.

To what extent infants process faces holistically as a gestalt was studied by Cohen and Cashon (2001). Using the so-called "switch-design" the authors contrasted holistic processing with featural processing. First, they habituated the infants to two adult female faces. Then the infants were tested with a familiar habituation face, a "switched" face and a novel face. The "switched" face was a composite of the two habituation faces, consisting of the internal features of one face and the external features of the other face. One half of the infants saw the faces in an upright and the other half in an inverted orientation. The authors found that the infants in the upright condition looked longer at the switched test face than the familiar test face. In the inverted condition, however, the infants did not look longer at the switched test face. They only looked longer at the novel test face. Cohen and Cashon (2001) reasoned that because all the features of the switched face are familiar to the infants after habituation, if they do not look longer at the switched face than at the familiar face, they must be responding to one or more independent features. On the other hand, if they look longer at the switched face it must be because they are responding to the fact that the switched features were presented in another facial context. The authors concluded that 7-month-old infants process the whole face when the face is upright, but process independent features when the face is inverted (see also Younger, 1992). Cohen and Cashon (2000) also ran this study with 4-month-olds and again found similar holistic processing. Moreover, holistic processing could be observed even when inverted faces were presented. Thus, it seems that young infants, in particular, process faces holistically. However, because Cohen and Cashon (2000, 2001) combined all the internal features with the external features, it is not clear from their study if the infants were also combining the internal features as a whole as has been shown in adults (Young et al., 1987). It is possible that, in Cohen and Cashon's study, the infants combined only some subsets of internal and external features.

Another study carried out by Slater et al. (2000) on infants' understanding of facial attractiveness can also be interpreted with reference to the question of holistic processing and featural processing. Slater et al. were interested in whether there is an inborn preference for attractive faces over unattractive faces. They showed newborns different pairs of one attractive and one unattractive face in a preferential looking task. It was found that the babies preferred the attractive faces when the stimuli were presented in an upright position, but not when these were inverted. One interpretation of this data is that newborns' understanding of attractive faces depends on some kind of holistic information in faces. Because this holistic information is lost when the faces are inverted, the newborns did not respond to the attractive faces in this changed orientation. Thus, the previous studies all suggest that infants are sensitive to holistic information in faces from the first months onwards.

Referring to the sensitivity to second-order relations as perceiving the specific distances among the features, no infant study has isolated the effect of second-order relations and featural information on face processing so far. One finding that could tap the processing of second-order relations is that newborn infants distinguish between two-dimensional depictions of faces on the basis of all the internal features. It has been shown that they prefer to look at attractive faces on the basis of internal features only (Slater et al., 2000). This differentiation between the different internal features of two individual faces may be due to infants' sensitivity to different features in conjunction with different second-order relations. However, until now it is unclear whether infants respond to differences in second-order relations only.

Taken together, previous studies on infants' face processing suggest that young infants process faces on the basis of the two types of configural information, i.e., first-order relations and holistic information in faces. To what extent featural processing also influences infants' face processing is described in the following section.

Until now featural face processing in infancy could only be shown in a rather indirect way. For example, Deruelle and de Schoenen (1991) studied featural and configural face processing in infancy by taking the influence of the hemispheric specialization into account. In this study 4–9-month old infants were tested using the method of divided visual field presentation and required to discriminate between two patterns, which were either symmetrical and face-like or arbitrary and non-symmetrical, and were identical apart from the shape of one of their components. The results showed that the left hemisphere and the right hemisphere were equally efficient at discriminating between the components of an arbitrary asymmetrical pattern, but that when the pattern resembled a frontal view of a schematic face, the discrimination was carried out by the left hemisphere alone. This and related findings suggest that from the age of four months onwards, the left hemisphere has an advantage in the attending to and processing of shapes of the local components (analytical processing) and the right hemisphere has an advantage in the attending to and processing of information about the spatial arrangement of the components within a face (configural processing). The latter conclusion is confirmed by the finding that the right hemisphere was able to recognize a frontal view of the mother's face more efficiently than the left hemisphere, and that the recognition of the mother's face was not based on its outer contour (De Schoenen, Gil de Diaz, & Mathivet, 1986; De Schoenen & Mathivet, 1990). Thus, the analytical and configural modes of processing seem to exist in infancy, each of which seems to be controlled more efficiently by one hemisphere.

Findings on infants' processing of facial expression also suggest that infants do not operate with the configural processing mode only (Kestenbaum & Nelson, 1990). The authors examined the degree to which 7-month-old infants were able to discriminate facial expressions of happiness from fear and anger in upright and inverted orientations. If the task required the categorization of facial expressions over changing identities—in other words, if the task required more than focusing on one single feature—infants were able to discriminate the expressions only when the faces were shown upright. However, if discrimination was possible on the basis of one single feature, infants were able to discriminate the facial expressions in both upright and inverted orientations. Here, the processing mode was not affected by the inversion of the faces. Therefore, when young infants process facial expressions they seem to be able to do this on the basis of single features and also on the basis of more configural information.

Thus, whereas numerous studies exist showing young infants' configural processing of faces there are only very few studies that explore featural processing in infancy. Moreover, the few studies on hemispheric specialization and facial expressions that test for this only provide evidence for facial feature processing in infancy indirectly. Until now there is no direct evidence that infants show the purely featural processing of faces observed in adults. It is clear from the studies by Slater et al. (2000), and Simion et al. (2002) that, in general, young infants do not have difficulty distinguishing internal features of faces. However, it is unclear whether the features are processed interactively as a configuration, or analytically as individual features without the context of the whole face. To clarify this point in our own studies we used the switch design (Cohen & Cashon, 2001) and manipulated single features (eyes, and mouth in Experiment 1, and eyes, nose, mouth, and facial contour in Experiment 2). This made it possible to examine to what extent these facial features were processed in conjunction with the whole face (holistically as one type of configural processing) or as independent single features (analytically). To avoid analytical processing being hindered by low visual acuity, we studied older infants, namely 8-month-olds. In Experiment 1 we used photos of real faces as stimuli, and in Experiment 2 we used schematically drawn faces.

4. Experiment 1

4.1. Design

The study was based on the "switch design" (Cohen & Cashon, 2001) which consists of presenting two different stimuli for habituation followed in the test phase by a stimulus that combines the features of the familiar stimuli. This design enabled us to determine whether infants were processing single facial features independently of the context of the face (analytically) or in conjunction with the context of the face (holistically):

During the habituation phase infants were presented with the face of a woman and the face of a man. The faces were shown one after another in random order. The subsequent test phase consisted of three conditions (switch face, novel face, and familiar face conditions). In the switch test condition, the infants were shown a ‘‘switch’’ face where one feature of one of the habituation faces (either the eyes or mouth) had been replaced by the corresponding feature from the other habituation face e.g., the female face now had the man’s eyes. If the infants processed the eyes or mouth independently of all the other features of the face during the habituation phase, we did not expect them to dishabituate to the switch face in the test phase since the features of the switch face were already familiar to them. If however, the infants processed the eyes or mouth in conjunction with the other facial features, holistically, we expected the infants to dishabituate to the switch faces. In the novel face condition, a further group of infants also received the female and male habituation faces in the habituation phase but instead of a switch face they were shown a completely new face in the test phase. In this case we expected the children to dishabituate to the test face. To rule out the possibility that looking times increase in the test phase due to natural fluctuation, infants in the familiar face condition were shown one of the habituation faces (female or male face) again after habituation in the test phase. In this condition, an increase in looking time in the test phase was not expected.

4.2. Participants

Ninty-seven 8-month-old full-term infants ($M = 8$ months, 12 days, $SD = 8.3$) participated in the experiment. An additional nine infants were excluded from the final sample due to fussiness, interference on the part of the mother or experimentor error. The sample of infants contained approximately equal numbers of males and females (51 boys, 46 girls). Infants were randomly assigned to the following conditions: 25 to the switch eyes, 25 to the switch mouth, 22 to the familiar face, and 25 to the novel face. The names of children were obtained from births published in the local newspapers, and families were contacted by letter and telephone. Parents were professionals, craftsmen and office workers.

4.3. Stimuli

The stimuli consisted of the faces depicted in Table 1, each 11.4 cm × 11.4 cm in size. The two habituation faces and the novel face were taken from the face data base of the Max-Planck-Institute for Biological Cybernetics in Tübingen, Germany. This data base consists of 200 laser scans (Cyberware^{TM}) of 200 heads of young adults. As shown in Table 1, a female and a male face served as habituation faces. The switch faces were constructed by using a 3-D morphing software developed by Blanz and Vetter (1999). In two switch faces one feature of the female face (eyes or mouth) had been replaced by the corresponding feature from the male habituation face, in two further switch faces one feature of the male face (eyes or mouth) had been replaced by the corresponding feature from the female habituation face.

4.4. Apparatus and procedure

Each infant was tested individually in the laboratory. The infants sat on a seat inside a large neutral-coloured metal sphere facing a computer monitor located 63 cm from the infants’ face on which the facial stimuli were presented. The infants were supported by a parent from behind. The visual angle from infant to stimuli presented

Table 1

Habituation faces (female and male face)	Test faces switch eyes	Test faces switch mouth	Novel face
			
			

on the monitor was approximately 5°. This ensured that the stimuli presented were projected onto the fovea and therefore perceived clearly in their entirety. To prevent parents from influencing their babies' looking times, they were asked to keep their eyes closed and to refrain from talking for the duration of the experiment. A low-light video camera was attached to a peep-hole in the back of the sphere and the entire session was taped on a VCR. Furthermore, infants were viewed by two independent observers hidden from view behind the sphere. The first experimenter observed the infants directly through a peep-hole in the back of the sphere. The second experimenter observed the infants on a television screen. Both experimenters recorded infants' looking times on a microcomputer. The computer also controlled the presentation of the faces. The observers' task was to depress a button for the duration of each fixation. The duration of each trial was under the infants' control. The trial began when the infant looked at the stimulus on the screen and continued until the infant looked away for 1.5 s.

Immediately after these 1.5 s the next stimulus was presented, and the trial began with the infant's first fixation. Fixations recorded by the primary observer were used to control the timing of stimulus presentation. Fixations recorded by the second observer (present in all sessions) were used for reliability. Inter-observer reliability, computed by correlating the fixation times recorded by each observer on each trial was 0.99.

A criterion habituation procedure was used to ensure that each infant received adequate habituation time. In the habituation phase, both habituation faces (female and male faces) were presented but only one habituation face was presented on each trial. The habituation faces were presented randomly until the infant's looking decreased to criterion level. To reach criterion, the infant had to maintain at least a 50% decrease of peak fixation level across three consecutive trials. The peak was defined as the average of the infant's two longest looks, whereby it was not necessary that the two longest looks were sequential. Immediately after the third criterion trial one of the test faces (a familiar face, a switch face (eyes or mouth), or the novel face) was presented to independent samples of infants. The infants were assigned randomly to the test conditions. The use of the female or male face as the familiar test face was balanced out over the babies. A computer tone at the end of the test trial marked the end of the test phase.

4.5. Results and discussion

The fixation data for habituation and test phases are summarized in Table 2.

Preliminary analyses were conducted on the habituation and test data to determine whether male or female infants differed in their performance on the test trials. There was no main effect of sex or interactions of sex with test condition (all $p > 0.05$). Thus, for subsequent analyses, the data were collapsed over this variable. A two-way, mixed-model analysis of variance was used to examine the pattern of looking over trials during the habituation phase. Looking time in the trials (average of the two peak trials and average of the three criterion trials) served as the repeated measure. The between-subject variable was test condition (see Table 2). As expected from the habituation criterion, there was a significant effect for the repeated measure, $F(1,93) = 271.03$, $p < 0.001$, and no significant interaction between the repeated measure and the different conditions, $F(1,93) = 1.73$, $p > 0.05$. However, there were significant differences among the conditions in the peak-criterion levels of looking, $F(1,93) = 2.63$, $p < 0.05$. Thus, looking on the peak trials exceeded looking on the criterion trials similarly for all conditions but absolute levels were different. Therefore, looking times in the different test conditions were analyzed taking looking

Table 2
Summary of the fixation data for the peak habituation trials, the last three habituation trials (criterion trials) and the test trials (Experiment 1)

Test condition	Habituation trials		
	Peak trials	Criterion trials	Test trials
Familiar			
M	16.92	4.53	4.11
SD	9.28	2.37	1.98
Switch eyes			
M	13.59	3.79	5.74
SD	7.65	1.78	4.87
Switch mouth			
M	16.32	4.15	6.75
SD	9.04	2.45	2.99
Novel			
M	20.05	5.57	9.27
SD	8.87	2.67	8.04

Note—The fixation data are reported in seconds.

time level for each condition into account. For this reason, a two-way, mixed-model analysis of variance was run to determine infants' responses to the test trials. Trial (criterion trial and test trial) served as the repeated measure. The between-subject variable was condition (familiar, switch eyes, switch mouth, and novel). The results showed that looking times differed between the criterion habituation trials and the test trial, $F(1,93) = 13.95$, $p < 0.001$, and more importantly, trial interacted significantly with condition, $F(3,93) = 2.64$, $p < 0.05$. Thus, the difference in looking times between criterion trial and test trial differed significantly between the test conditions. To determine whether the eyes and mouth were processed independently or not, it was critical to find out whether the babies dishabituated to the switch faces. For this reason, we computed single t-tests for repeated measures (criterion trials versus test trial) with a Bonferoni correction ($\alpha' = 0.025$) for each condition (switch eyes and switch mouth). The results showed a significant increase in looking time between the criterion trials and the switch mouth and switch eyes trials (switch mouth: $t(24) = -5.36$, $p < 0.001$; switch eyes: $t(24) = -2.37$, $p < 0.02$). Thus, after habituation the infants looked significantly longer at the test face in which the mouth or the eyes had been switched.

In sum, the results show that after habituation to two faces presented sequentially, 8-month-old infants dishabituate to these faces if the eyes or mouth have been exchanged. This means that the infants responded to the fact that eyes and mouth—both familiar to them—were shown in a different but familiar context. Thus, in 8-month-old infants eyes and mouth were processed holistically, i.e., in conjunction with the facial context. In congruence with previous findings, the use of the configural mode of face processing in infancy was shown again.

Since the purpose of our study was not only to confirm configural processing but also to test more directly for featural processing in infancy, we attempted to facilitate featural processing in the next experiment. To this end, we used schematically drawn faces as stimuli instead of photographs of real faces because in schematic faces the part-based structure is more pronounced than in photos. This in turn might support featural processing more than configural processing. In addition, we not only switched two facial features such as the eyes and mouth but also two further features i.e., the nose and facial contour since it is possible that the independent processing of facial features does not occur with the eyes and mouth but with other facial features.

5. Experiment 2

Using the switch design described above, in Experiment 2, we studied whether 8-month-old infants process the features of schematically drawn faces such as the eyes, nose, mouth and facial contour independently of the context of the face (analytically) or in conjunction with the facial context (holistically as one type of configural processing).

5.1. Participants

165 eight-month-old full-term infants ($M = 8$ months, 15 days, $\text{SD} = 8.7$) participated in the experiment. An additional 12 infants were excluded from the final sample due to fussiness, interference on the part of the mother or experimentor error. The sample of infants contained approximately equal numbers of males and females (83 boys, 82 girls). Infants were randomly assigned to the following conditions: 30 infants to the switch nose, 30 to the switch eyes, 25 to the switch mouth, 30 to the switch facial contour, 25 to the familiar face, and 25 to the novel face. The names of children were obtained from births published in the local newspapers, and families were contacted by letter and telephone. Parents were professionals, craftsmen and office workers.

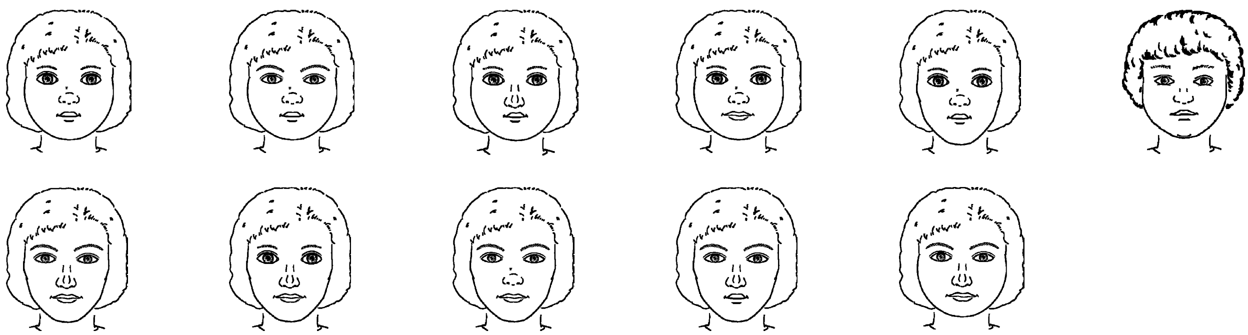
5.2. Stimuli

The faces were schematically drawn by hand and edited electronically using Adobe Photo Shop 6.0. The faces were each 11.4 cm × 11.4 cm in size and are depicted in Table 3. The stimuli consisted of a child habituation face and an adult habituation face, four "switch" faces where one feature of the child face (either the nose, eyes, mouth or facial contour) had been replaced by the corresponding feature from the adult habituation face, four "switch" faces where one feature of the adult face (similarly nose, eyes, mouth or facial contour) had been replaced by the corresponding feature from the child habituation face, and a completely new face.

In a pilot study, we examined whether all facial features were equally salient. Here 30 adults judged the similarity between switch faces and habituation faces on a nine point scale from one being "almost identical" to nine being "very dissimilar". The stimulus pairs consisted of all 16 possible comparisons and were created by pairing each switch face with each habituation face; this procedure was repeated in a different random order for a total of 32 judgments by each participant. The similarity ratings for the switch faces and the habituation faces identical to the switch faces on only one feature were compared with the similarity ratings for the switch faces and the other habituation faces (identical to the switch face on the other three features). An analysis of variance of the similarity ratings with faces and features as within-participant factors showed that all three-match comparisons were significantly more similar (3.57 for the

Table 3

Habituation faces (child face/ adult face)	Test faces switch eyes	Test faces switch nose	Test faces switch mouth	Test faces switch facial contour	Novel face



eyes, 2.28 for the nose, 2.06 for the mouth, and 3.42 for the outline) than the one-match comparisons (6.93 for the eyes, 7.87 for the nose, 7.72 for the mouth, and 6.98 for the outline), $F(1, 29) = 537.43$, $p < 0.01$, and that there were no significant differences between the facial features, $F(3, 87) = 2.48$, $p > 0.05$. There is therefore no indication that any one feature is more salient than another. Moreover, a previous study (Schwarzer, 2002) using the same material showed that 2-year-old children did not attend to any one specific feature more than to another, indicating that there was no preference for any of the switch faces.

5.3. Apparatus and procedure

Apparatus and procedure were identical as described in Experiment 1.

5.4. Results and discussion

The fixation data for habituation and test phases are summarized in Table 4.

Table 4
Summary of the fixation data for the peak habituation trials, the last three habituation trials (criterion trials) and the test trials (Experiment 2)

Test condition	Habituation trials		
	Peak trials	Criterion trials	Test trials
Familiar			
M	16.75	4.37	5.71
SD	6.89	1.93	3.77
Switch eyes			
M	17.63	4.70	4.78
SD	8.97	2.31	2.80
Switch nose			
M	14.97	4.09	5.57
SD	6.10	1.56	4.38
Switch mouth			
M	19.40	4.70	8.26
SD	10.97	2.06	7.00
Switch contour			
M	18.03	5.12	5.75
SD	10.28	2.72	5.23
Novel			
M	18.74	4.69	8.50
SD	10.82	2.20	6.11

Note—The fixation data are reported in seconds.

Since preliminary analyses showed that the looking times in the different conditions did not differ between girls and boys (all $p > 0.05$), we collapsed the data. As in Experiment 1, a two-way, mixed-model analysis of variance was run to determine infants' responses to the test trials. Trial (criterion trial and test trial) served as the repeated measure. The between-subject variable was condition (familiar, switch eyes, switch nose, switch mouth, switch facial contour, and novel). The results showed that looking times differed between the criterion habituation trials and the test trial, $F(1, 159) = 23.56$, $p < 0.001$, and that, as in Experiment 1, trial interacted significantly with condition, $F(5, 159) = 2.76$, $p < 0.05$.

To examine the looking times in the four switched conditions further, we computed single *t*-tests for repeated measures with a Bonferoni correction of $\alpha' = 0.013$. Here, the results showed that the differences between criterion trial and switch trial for the features 'eyes', 'nose', and 'facial contour' did not reach the significance level (eyes: $t(29) = -1.76$, $p > 0.05$; nose: $t(29) = -0.14$, $p > 0.05$; facial contour: $t(29) = -0.72$, $p > 0.05$). However, infants looked significantly longer at the test stimulus in which the mouth was switched in comparison to the criterion trials, $t(24) = -2.77$, $p < 0.01$.

To examine whether the non-significant difference between criterion trial and switched trial (i.e. eyes, nose, and facial contour) could be due to the fact that the infants could simply not perceive the difference between the two stimuli, we ran three control studies with 89 eight-month-old infants. In the control studies, we habituated independent samples of infants to one habituation face only (child face or adult face) using the same criteria as in the main experiment. After habituation we presented—using independent samples—the switched faces in which the eyes, nose or facial contour had been switched. Each group of infants received only one type of switched face. Thus, dishabituation to the switch faces would indicate that the infants responded to the difference in the switched faces. As expected, the control studies showed that the infants responded significantly to the switch faces such that they looked significantly longer at the faces with switched eyes, $t(29) = 2.17$, $p < 0.05$, switched nose, $t(27) = -1.99$, $p < 0.05$ and switched facial contour, $t(30) = 2.12$, $p < 0.05$. To rule out the possibility that the infants were able to encode the stimuli more thoroughly in the discrimination control studies than in the main experiment due to longer looking times for the familiar face in the former, mean looking times for the child face during the habituation phase of each switch study and corresponding control study (e.g., for switch eyes and control eyes) were calculated and compared. t-tests for independent samples revealed no significant differences in looking times, $t(48) = -1.22$, $p > 0.05$ for the eye condition, $t(46) = -0.199$, $p > 0.05$ for the nose condition and $t(49) = 1.039$, $p > 0.05$ for the facial contour condition. Thus, discrimination in the control studies could not be attributed to the infants encoding the faces for a greater length of time. In the main experiment therefore, the non-significant result between criterion trials and switched stimuli in the eyes, nose, and facial contour conditions could not be due to the fact that the infants could not perceive the difference between the faces. Instead, this result means that attributes such as the eyes, nose, and facial contour are processed independently of the context of the face (analytically) whereas the mouth is processed in conjunction with the facial context.

6. General discussion

The aim of the studies was to examine whether infants process faces not only configurally but also use a purely featural processing mode, similar to that of the adult face processing system. Our results demonstrated that 8-month-old infants processed single facial features such as the eyes and mouth in conjunction with the context of the face when the faces were shown as photos i.e., they processed the faces as a configuration. However, if schematically drawn faces were presented they processed single facial features such as the eyes, nose, and facial contour independently of the context of the face, analytically. Only the mouth was processed together with the facial context of the schematic faces. Thus, it seems that infants prefer to process the features of real faces interactively. If, however, the part-structure of faces is more pronounced, as in schematically drawn faces, the influence of the facial context on the processing of single features is reduced and the infants process the features independently of the facial context. Here, the processing of the mouth in schematic faces can be understood as an exception. While processing the mouth, the infants may have activated former experiences of the effects of the mouth in real faces. They may have noticed that changes of the mouth (due to emotional expressions, speaking, etc.) also cause changes of other features, for example the eyes. This in turn may have led the infants to integrate the mouth into the facial context more than the other facial features that do not have such an influence on other features.

The results of our first experiment confirm and extend the results of Cohen and Cashon's (2000, 2001) study on 4- and 7-month-old infants' processing of upright faces. Cohen and Cashon showed that the infants looked longer at a switch face that was a composite of two habituation faces consisting of the internal features of one face and the external features of the other face, and therefore processed both facial sections in connection with each other. Our study, furthermore, demonstrated that infants also process single facial features (the eyes and mouth) in conjunction with the surrounding facial context. The infants were thus sensitive to holistic information in faces involving the mouth and the eyes and some information of the whole face. This kind of sensitivity to holistic information in faces has already been shown in newborns by Slater et al. (2000), where the authors observed a differential response for attractive faces in the upright position but not when they were inverted.

The results of Experiment 1 also confirmed the results of all of the previous studies showing that young infants distinguish the internal features of faces (Quinn, Yahr, Kuhn, Slater, & Pascalis, 2002; Simion et al., 2002; Slater et al., 2000). Since the faces of our experiment had no hair, all of the responses of the infants may be due to the processing of internal features. Our findings extend the previous findings in that they show that even older infants, such as 8-month-olds, do not process the features of real looking faces in isolation of each other but interactively.

Thus, for photographed faces, we could not provide direct evidence for pure analytical processing. This could only be shown in our second experiment where schematically drawn faces were used. Taken together, the results of both experiments suggest that, in principle, 8-month-old infants have access to both the configural and the featural processing modes, but it seems that when real faces are processed they use the configural processing mode. The finding that infants are familiar with both processing modes is in line with the studies on hemispheric specialization (Deruelle & de Schoenen,

1991) and facial expression (Kestenbaum & Nelson, 1990) that examined analytical and configural face processing more indirectly. In both lines of research, analytical as well as configural processing modes could be observed in infants between 4 and 9 months of age. These studies showed that the specific demands of the task and the type of stimuli determined whether the analytical or holistic processing mode predominated.

When comparing the face processing system of infants, as it is understood so far, with that of adults, parallels and differences can be detected. Parallels can be recognized in that the analytical and configural modes of face processing are the two well documented routes in the adult face processing system (see Collishaw & Hole, 2000; Leder & Bruce, 2000; Schwaninger et al., 2002; Searcy & Bartlett, 1996; Tanaka & Sengco, 1997) and that, in principle, even infants have access to these processing modes. Differences between the adult and infant system can be seen in that adults use both ways of processing when they perceive, store or recognize real upright faces whereas in infants the analytical processing mode could only be shown for the processing of schematic faces but not for photos of real faces. It seems that the infants' system of processing faces (usually real faces) shows a bias towards configural processing. This becomes particularly apparent in Cohen and Cashon's study (2000) where 4-month-old infants process even inverted faces configurally. By contrast, the adult system has access to both modes of processing and more importantly, it is able to use the appropriate one or a combination of the two depending on the demands of the specific situation. Thus, although the infant face processing system seems to be equipped with the fundamental processing modes also relevant for the adult face processing system, learning and experience with faces is necessary to apply these adequately.

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