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Evidence of the Face Inversion Effect in 4-Month-Old Infants

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This study tested the presence of the face inversion effect in 4-month-old infants using habituation to criterion followed by a novelty preference paradigm. Results of Experiment 1 confirmed previous findings, showing that when 1 single photograph of a face is presented in the habituation phase and when infants are required to recognize the same photograph, no differences in recognition performance with upright and inverted faces are found. However, Experiment 2 showed that, when infants are habituated to a face shown in a variety of poses and are required to recognize a new pose of the same face, infants' recognition performances were higher for upright than for inverted faces. Overall, results indicate that, under some experimental conditions, 4-month-olds process faces differently according to whether faces are presented upright or inverted.

It has long been known that human faces are extremely difficult to recognize when seen upside down. This inversion effect is not restricted to faces but is much greater

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with faces than with other stimuli usually viewed in a specific orientation, such as landscapes, houses, or animals (Scapinello & Yarmey, 1970; Yin, 1969; for reviews, see Rossion & Gauthier, 2002; Valentine, 1988). The face inversion effect is thus defined as a disproportionate impairment of face recognition as compared to object recognition induced by inversion (Yin, 1969).

Many studies provide evidence that a crucial role in determining the face inversion effect is played by a difference in the encoding strategy for processing upright and inverted faces (Diamond & Carey, 1986; Farah, 1990, 2000; Rhodes, Carey, Byatt, & Proffitt, 1998). In the literature there is no consensus about the nature of this difference (e.g., Maurer, Le Grand, & Mondloch, 2002). Some authors claim that individual face recognition would rely on configural, second-order relational properties, that is, on the distinctive spatial relations among the constituent facial features that define the specific configuration of an individual face (Diamond & Carey, 1986). Other authors suggest that upright face stimuli are represented holistically rather than featurally, resulting in a relatively undecomposed representation of the whole face rather than its parts (Farah, Wilson, Drain, & Tanaka, 1998; Tanaka & Farah, 1993). It is beyond the purposes of this article to go into the ongoing debate about holistic or configural processes thoroughly. Although there is no agreement about terminology and definitions, overall literature about adults converges to suggest that the mode of visual processing used for upright faces differs from that commonly employed for objects. Furthermore, the distinctive characteristics of this mode of visual processing appear to be of fundamental importance in inducing the face inversion effect because they are more likely to be adversely affected by stimulus inversion than is the encoding of relatively isolated elements (e.g., Diamond & Carey, 1986; Sergent, 1984).

Evidence also clearly shows that the face inversion effect reflects extensive experience with faces. Behavioral studies with adults show that nonface objects may be processed in a manner analogous to that employed with faces, provided that participants are required to discriminate between visually similar exemplars and to acquire sufficient expertise in the task. Indeed, an inversion effect comparable with that obtained with faces was found for the recognition of dogs when dog experts were tested (Diamond & Carey, 1986) and for the recognition of handwriting with experts in this domain (Bruyer & Crispeels, 1992). In addition, a cortical region localized in the superior temporal sulcus, called the face fusiform area, which is highly active during face processing, is also activated with nonface stimuli that share a common spatial structure, but only when adult participants are extensively trained with them (Gauthier, Tarr, Anderson, Skudlarsky, & Gore, 1999).

Assuming that the face inversion effect results from the combined actions of configural or holistic processing and experience with faces, we now examine whether these two factors are able to exert an influence in 4-month-olds' visual processing to understand whether the presence of the face inversion effect is plausible at this age. A number of studies provide evidence for organized perceptual representations in young infants (e.g., Quinn, & Eimas, 1996). At 3 months of age it has been shown that line segments are perceived or discriminated better when in the presence of a contextual frame than when they are presented in isolation (i.e., pattern–line effect; Quinn & Eimas, 1986). The presence of this effect is taken as evidence that the perception of visual patterns does not proceed solely by processing simple featural information but rather involves the use of more complex configural information (Enns & Printzmetal, 1984). Furthermore, it has been demonstrated that emergent configural aspects of a simple geometric stimulus are not only perceived and represented by 3- to 4-month-old infants but endowed with a kind of functional priority over the local components (Ghim & Eimas, 1988; Quinn & Eimas, 1986).

Using more complex stimuli, namely line drawings rather than simple geometric arrays, Younger and Cohen (1986) showed that 4-month-olds process the features of a line drawing independently, whereas 7- and 10-month-olds are able to process the correlations among the different features. However, recent evidence provided by Cohen and colleagues (Cashon & Cohen, 2002, 2003) revealed that, in a similar task, the ability to perceive correlations among internal and external features of a human face emerges earlier, at 4 months of age. This finding is consistent with previous evidence indicating that at about the same age the right hemisphere appears more capable than the left of processing faces (de Schonen & Mathivet, 1990) and more capable of processing configural second-order relations than local features within both faces and simple geometric patterns (Deruelle & de Schonen, 1991, 1995, 1998; de Schonen & Mathivet, 1989). Overall, literature about this topic suggests that infants process visual patterns according to their constituent elements or their configuration, depending on the complexity of the stimuli and the age of the infants. However, by 4 months of age, it seems that face stimuli can be processed in a configural manner (Cashon & Cohen, 2003; Deruelle & de Schonen, 1998).

Regarding the effect of experience with faces in the first months of life, first it seems that some attentional biases present at birth would ensure that newborns are repeatedly exposed to faces, therefore biasing the input to the cortical circuits with this class of stimuli (Johnson & Morton, 1991; see also Simion, Macchi Cassia, Turati, & Valenza, 2003). Second, face recognition abilities seem to start to develop as early as a few days from birth both in the case of the mother's face (Bushnell, Sai, & Mullin, 1989; Field, Cohen, Garcia, & Greenberg, 1984; Pascalis, de Schonen, Morton, Deruelle, & Fabre-Grenet, 1995) and in the case of a stranger's face (Pascalis & de Schonen, 1994). Three-month-old infants are able to recognize a face presented through different poses, demonstrating the ability to learn some physiognomic aspects of the face that remain invariant across variations in perspective (Pascalis, de Haan, Nelson, & de Schonen, 1998). Moreover, as it could be predicted from a theoretical scenario by de Schonen and Mathivet (1989), recent evidence shows that deprivation of patterned visual input from birth until 2 to 6 months of age in patients affected by bilateral congenital cataracts produces a deficit in face processing (Geldart, Mondloch, Maurer, de Schonen, & Brent, 2002) and configural face processing (Le Grand, Mondloch, Maurer, & Brent, 2001) that persists even after years, suggesting that visual experience in the first months of life plays a crucial role for normal development of face configural processing abilities.

In sum, the overall pattern of results seems convincing in indicating that the two major factors commonly invoked to explain the face inversion effect appear to be operative by 4 months of age: (a) Infants are sensitive to configural information embedded in simple visual patterns and in faces, and (b) the extensive visual experience with faces that characterizes infants' normal development affects face processing very early in life. Based on these points, a question should be raised: Is the face inversion effect already present at 4 months of age?

Current literature on face processing abilities in childhood provides evidence indicating that 4-year-olds are able to recognize faces in a holistic (Tanaka, Kay, Grinnell, Stansfield, & Szechter, 1998) or configural manner (Carey & Diamond, 1994; Freire & Lee, 2001) and that signs of an inversion effect might already be present in 3- to 5-year-old children (Pascalis, Demont, de Haan, & Campbell, 2001; Sangrigoli & de Schonen, 2004). Nevertheless, when only literature concerning childhood is considered, face processing abilities still appear to undergo a protracted development that results in the face inversion effect only after at least 3 years of extensive visual experience with this class of stimuli (see also Brace et al., 2001).

However, although data are not fully consistent, studies using completely different techniques observed that face processing is orientation specific and affected by stimulus inversion also in infancy, inducing some authors to propose that sensitivity to facial orientation might develop in an inverted-U fashion (Slater, Quinn, Hayes, & Brown, 2000). For instance, newborns' visual preference for attractive faces is dependent on the upright orientation of the stimuli because it disappears when the stimuli are presented inverted (Slater, Quinn, et al., 2000). Moreover, neural correlates of the inversion effect were reported in infancy, although not entirely comparable with those obtained with adults. More specifically, an ERP study conducted with 6-month-old infants revealed that upright faces demonstrated a greater amplitude negativity than inverted faces (Webb & Nelson, 2001). In addition, with infants 6 months of age, de Haan, Pascalis, and Johnson (2002) observed an event related potential (ERP) component (P400) whose amplitude was modulated by inversion. However, the relations between these phenomena and the recognition competencies for individual faces usually investigated in adults and older infants are not easy to understand.

Within the infancy literature, evidence more directly linked to the effect of face inversion in individual face recognition was first provided by Fagan (1972). Using a fixed familiarization procedure, Fagan showed that 5- to 6-month-old infants were able to discriminate upright but not inverted faces. On the contrary, 4-month-olds were not even able to discriminate between two upright-oriented faces. More recently, Cohen and Cashon (2001) found that 7-month-old infants treated as a novel face a new combination of internal and external features of previously seen familiar faces. The same combination of features was, however, treated as familiar when the stimuli were presented inverted. These findings were interpreted as demonstrating that 7-month-old infants process an upright face as a configuration but an inverted face as a collection of features (Cohen & Cashon, 2001). Such differential response to upright versus inverted faces did not emerge at 4 months of age when infants recognized as novel the combination of familiar internal and external features both in the case of upright and inverted faces (Cashon & Cohen, 2002, 2003). Together, these findings seem to suggest that, at 4 months of age, configural processing emerges for both upright and inverted faces without, however, producing a face inversion effect.

Nevertheless, it is important to note that the studies by Cohen and colleagues focused attention exclusively on the correlations between outer and inner features. However, the inner part of the face per se contains most probably sufficient cues to support 4-month-old infants' face recognition. Evidence reveals that newborn infants use information about internal facial features in making preferences based on attractiveness (Slater, Bremner, et al., 2000). Thirty-five- to 40-day-old infants are able to discriminate their mother from a stranger even when the whole line between face and hair is masked by a scarf, thus relying mostly on the inner portion of the face (Bartrip, Morton, & de Schonen, 2001). Following familiarization to unfamiliar faces, similar results have been obtained at 1, 3, and 6 months of age (de Haan, Johnson, Maurer, & Perrett, 2001; Pascalis et al., 1998). Moreover, on the basis of the results observed by Deruelle and de Schonen (1998), it is plausible that, at least from 4 months onward, the spatial relations among inner features play a relevant role in mediating infants' capacity to perform individual face recognition.

Using photographs of faces in which hair was masked by a shower cap, this study is aimed at testing the presence of the face inversion effect at 4 months of age, when configural processing and experience with faces have already started exerting their influence on face processing. It is possible that, at this age, visual experience with faces is still predominantly multioriented rather than mono-oriented. Also, it is possible that at this age experience with faces is not yet sufficient to assure that recognition is primarily driven by configural information. If this were the case, no differences should be found in infants' ability to recognize a face in the upright or inverted orientation. On the contrary, experience with faces might be already sufficient and face configural processing might be stable enough to assure that face recognition processes are sensitive to orientation, so that upright face recognition is enhanced as compared to inverted face recognition. Experiment 1 was designed to assess the face inversion effect when 4-month-old infants are habituated with a unique three-quarter view of a face. In Experiment 2, detection of perceptual invariances in the inner portion of a face was examined by habituating infants to a face in different poses and testing their ability to recognize the face in a new pose.

EXPERIMENT 1

The purpose of Experiment 1 was to test whether 4-month-old infants' recognition abilities are sensitive to face inversion. Following habituation to one single upright or inverted photograph of the inner portion of a face in a three-quarter pose, infants were presented with the familiar photograph paired with a photograph of a novel face in the same three-quarter pose. No modifications in the orientation of the stimuli between the habituation and the test phase were made. It was predicted that, if infants are sensitive to face inversion, they will be able to discriminate and recognize the upright face stimuli, but they will not differentiate inverted faces. Conversely, a similar recognition performance for upright and inverted faces would provide evidence in favor of the idea that, at 4 months of age, face recognition processes are not orientation specific.

Method

Participants. Fourteen 4-month-olds (M = 123.71 days, SD = 6.35; 7 girls and 7 boys) were tested. They were full-term healthy infants with no known history of medical problems. Five additional infants were not included in the final sample because of fussing or crying. Contact letters were sent inviting parents and their infants to participate. Parents interested in the study were further informed and gave their written consent.

Stimuli. A set of black-and-white photographs of the faces of 6 Caucasian women (23–32 years old) was used as stimuli (see Figure 1). Faces were photographed in a three-quarter pose with a neutral expression under the same lighting conditions and against the same gray background. A shower cap masked hair and other external facial features (i.e., outer contour, hair, and hairline), so that recognition had to rely mostly on the inner part of the face. Also, models were asked not to wear glasses or jewelry, and other minor distinctive details (e.g., blemishes or pimples) were digitally removed. Each photograph once presented on the video screen subtended a visual angle of about 14° (width) and 24° (height) and was presented at a viewing distance of 79 cm. The luminance of all photographs was about 56 lux. The same photographs could be presented upright or inverted, so upright and inverted faces were identical except for the orientation. The six faces were paired into three invariable pairs matched for complexion, eye darkness, and global head contour.

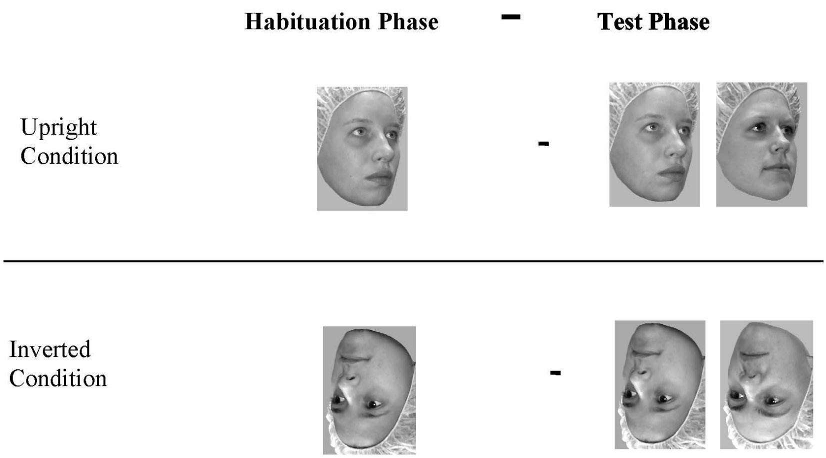

FIGURE 1 Examples of the face stimuli used in Experiment 1.

Apparatus. Babies were placed in an infant seat located in the middle of an 80 cm × 100 cm experimental chamber. Parents were asked not to influence the baby (e.g., by talking). Stimuli were displayed on a television monitor oriented horizontally and reflected by a one-way mirror screen placed above the video screen at a 45° angle. Opposite to the infant and behind the one-way mirror screen a video camera recorded the infant's face and looking behavior. The infants, sitting in front of the one-way mirror screen, could see only the stimuli displayed. Infant's eyes were aligned with a central multicolored star that was used to attract the infant's gaze at the start of both the habituation and preference test phases. The distance between the two testing faces was 17 cm (about 12°). Plain curtains were drawn on both sides of the infant to prevent interference from irrelevant stimuli.

Procedure. Infants were administered two consecutive experimental sessions, each composed of a habituation and a test phase. In each session a single photograph of a female face in a three-quarter pose was presented for habituation, followed by a test phase in which the familiar photograph was paired with a photograph of a novel face in a three-quarter pose. In one session face stimuli were presented upright both in the habituation and in the test phase, and in the other session stimuli were presented inverted in both phases. The order of the two sessions was counterbalanced between participants (upright orientation followed by inverted orientation or vice versa). Faces used in one session were never presented in the second session to the same infant.

As soon as the infant was apparently at ease and his or her gaze was properly aligned with a central fixation point (multicolored star), the experimenter started the habituation phase by pressing a key on the computer keyboard. An infant control habituation procedure was used (Horowitz, Paden, Bhana, & Self, 1972). The same photograph of a face was projected in the middle of the screen. Each stimulus remained on the screen until the infant looked at it and was immediately removed by the experimenter (by pressing a key on the keyboard) as soon as the infant looked away for at least 1 sec. This procedure was repeated until the end of the habituation phase. The habituation phase ended automatically when, from the fourth fixation on, the sum of any three consecutive fixations was 50% or less than the total of the first three (Horowitz et al., 1972). No limits were imposed to the maximum number of trials for reaching habituation.

After the habituation phase, each infant was given two 20-sec paired presentations of the test stimuli. During each 20-sec presentation, infants were simultaneously presented with the same familiar photograph and a novel face in the same pose as the familiar face. The two paired stimuli were always shown in both left and right positions, the position being reversed from Presentation 1 to Presentation 2. The initial left–right order of presentation was counterbalanced across participants. As mentioned earlier, the orientation of the face in the test phase was identical to the habituation phase but changed from one session to the other. The familiarization stimulus within each pair of faces was counterbalanced between participants.

All testing sessions were videotaped. Videotapes of eye movements in the preference test phases were subsequently codified frame by frame. The mean estimate of reliability between the two blind and independent observers, calculated on 20% of testing sessions, was .90 (Pearson correlation; range = .84–.94), so the recording procedure has to be considered reliable.

Results

Preliminary statistical analyses showed no significant effect or interactions involving gender. As a consequence, data were collapsed across this factor. All infants reached the habituation criterion. A paired-sample t test comparing total fixation times to reach the habituation criterion in the first and second experimental sessions was not significant ($M = 56.1$ sec, $SE = 9.22$, vs. $M = 49.79$ sec, $SE = 8.6$), $t(13) = 0.78$, $p = .45$, two-tailed. The same data were entered in a second paired-sample t test to compare looking times in the upright and inverted sessions of the habituation phase ($M = 59.04$ sec, $SE = 11.00$, vs. $M = 46.85$ sec, $SE = 5.8$), $t(13) = 1.61$, $p = .13$, two-tailed. The comparison was not significant.

A novelty preference score (percentage) was calculated for each infant in each experimental session. Looking time at the novel face during the two test presentations was divided by the total fixation time over the two presentations toward both the novel and familiar face. The obtained score was multiplied by 100. Novelty preference scores were then compared to the 50% chance value by means of one-sample t tests in the upright and the inverted session. The novelty score was significantly higher than chance level in both the upright session ($M = 55.48$, $SE = 0.02$), $t(13) = 2.31$, $p < .04$, two-tailed, and the inverted session ($M = 55.74$, $SE = 0.03$), $t(13) = 2.18$, $p < .05$, two-tailed. In addition, the mean novelty preference scores did not differ significantly in the upright and inverted sessions, paired-sample $t(13) = –0.06$, $p > .95$, two-tailed. A paired-sample t test was also run to compare the overall amount of looking time at both test stimuli in the upright ($M = 23.57$, $SE = 2.61$) and inverted ($M = 18.70$, $SE = 8.90$) sessions. The difference was not significant, $t(13) = 1.60$, $p > .13$.

Discussion

In Experiment 1 one single photograph of a face, in a three-quarter pose, was repeatedly presented in the habituation phase. In the test phase, infants had to recognize the face relying on the same photograph to which they were habituated. Results show that, within these experimental conditions, no differences in infants' recognition performance with upright and inverted faces are observed. On the basis of these findings, it seems that 4-month-old infants are capable of recognizing an inverted face as well as a face in the upright orientation. Therefore, as could be expected from previous data (Cashon & Cohen, 2002, 2003), no sensitivity to face orientation is observed in 4-month-olds.

However, before accepting this conclusion, it is worthwhile to remember that adults are not unable to recognize inverted faces: Their performance is poorer with inverted than with upright faces; that is, response accuracy is lower and reaction times longer (Scapinello & Yarmey, 1970; Valentine, 1988; Yin, 1969). In the same vein, it might be possible that infants are able to recognize both upright and inverted faces when the task they have to accomplish does not require attending to and processing complex perceptual information. On the contrary, increasing the complexity of the perceptual information provided by the stimuli might increase the difference in the capacity to recognize faces in the canonical versus inverted orientation. In other words, we reasoned that a more complex recognition task might be necessary to point out a gap between infants' recognition performances with upright and inverted faces.

Consistent with this hypothesis, Kestenbaum and Nelson (1990) reported that when 7-month-old infants were habituated to a single face posing happiness, they were able to recognize and discriminate this emotional expression from fear and anger, regardless of the orientation of the stimuli. On the contrary, when different faces posed the same expression, infants manifested the capacity to recognize the similarity of happy faces over changing identities only when the stimuli were presented upright but not when they were inverted. In this latter case, infants failed to recover either to a novel model posing the familiar expression or to novel emotional expressions. The authors concluded that the ability to recognize emotional expressions across different identities results from attending to the invariant orientation-specific configuration of features. Conversely, the ability to discriminate emotional expressions produced by a single face may rely on a featural basis; thus, inverting the stimuli does not disrupt the recognition process.

Therefore, it is possible that 4-month-old infants might be sensitive to face orientation when tested using a more complex task that taps infants' capacity to detect and recognize perceptual invariances contained in the inner face part. Because of the familiarity with upright faces, infants might have developed cognitive skills for this class of stimuli that are still not available for other classes of stimuli, namely inverted faces. As first pointed out by Gibson (1969): "New objects belonging to a class of objects having very familiar distinctive feature should be more easily discriminated one from another than an equivalent set of objects from an unfamiliar class" (p. 105). Experiment 2 was designed to test this possibility with upright and inverted faces.

EXPERIMENT 2

Experiment 2 tested the presence of a sensitivity to face orientation in 4-month-olds by examining infants' ability to detect, extract, and recognize perceptual invariances embedded in the inner portion of upright and inverted faces across viewpoints. It has been demonstrated that adults are worse at identifying an inverted than an upright face under changes of view or perspective (Hill, Schyns, & Akamatsu, 1997; Marotta, McKeeff, & Behrmann, 2002; Moses, Ullman, & Edelman, 1996). In infancy, the capacity to recognize the invariant aspects of an upright face across poses was originally demonstrated by Fagan (1976) in 7-month-old infants, and subsequently replicated by Cohen and Strauss (1979) in 30-week-old but not 18- and 24-week-old infants. More recently, it has been shown that the ability to recognize an upright face across poses emerges at about 3 months of age (Pascalis et al., 1998). However, to our knowledge, no studies have investigated this capacity comparing infants' recognition performance with upright and inverted faces.

In this experiment, following habituation with photographs of the same face represented through different poses, 4-month-old infants were presented with the familiar face in a novel pose paired with a novel face in the same pose. Four different experimental situations were tested. Faces could be (a) upright in both habituation and test phases, (b) inverted in both habituation and test phases, (c) upright in the habituation phase and inverted in the test phase, and (d) inverted in the habituation phase and upright in the test phase. As for the first two situations, one possibility is that infants will recognize the stimulus to which they have been habituated independent of its upright or inverted orientation. This finding would support the notion that similar processes mediate recognition of upright and inverted faces.

Conversely, if infants will not preserve the ability to recognize faces when they are presented inverted, results would suggest the presence of a difference in the way infants process visual stimuli that favors upright faces, despite their short experience with faces at this age.

If infants show no inversion effect in the second condition, good recognition performances in the last two conditions will confirm the total independence between face processing and face orientation, whereas bad recognition performances will show that a change between the habituation and the test phase only makes recognition difficult. In case infants exhibit an inversion effect in the second condition, the last two conditions will tell whether it is easier to transfer information from inverted to upright faces or from upright to inverted faces.

Finally, infants were presented with both female and male faces. Given that during the first 4 months of life infants included in the sample have been interacting more with female than with male individuals (Quinn, Yahr, Kuhn, Slater, & Pascalis, 2002), it was predicted that the inversion effect might emerge with female but not with male faces.

Method

Participants. The participants were 33 infants (19 boys and 14 girls), with a mean age of 4 months (M = 128.53 days, SD = 10.99). They were full term and did not suffer from any diagnosed medical problems. Nine additional infants were tested but subsequently discarded from the final sample because of fussiness or drowsiness. Infants were randomly assigned to one of two groups (16 to the female faces group, 17 to the male faces group). Contact letters were sent inviting parents and their infants to participate. Parents interested in the study were further informed and gave their written consent.

Stimuli. A set of black-and-white photographs of the faces of 6 Caucasian women (the same as in Experiment 1) and 6 Caucasian men (23–32 years old) were used as stimuli (see Figure 2). Each face was photographed in 12 different poses. Ten photographs were taken with a neutral expression, combining five different points of view (full frontal view, right and left three-quarter, right and left profile) with two different heights of the camera (at the same height as the face and from bottom, which is a point of view that might be frequently experienced by infants). Two additional photographs were taken with faces smiling with teeth visible, in the left and right three-quarter poses. Other characteristics of stimuli were identical to stimuli of Experiment 1 (same gray background, same lighting conditions, same shower cap, neither glasses nor minor distinctive details). The size and the definition of the faces on the screen were the same as in Experiment 1. Brightness and contrast were equated across all photographs. The same photographs could be presented upright or inverted, so upright and inverted faces were identical except for

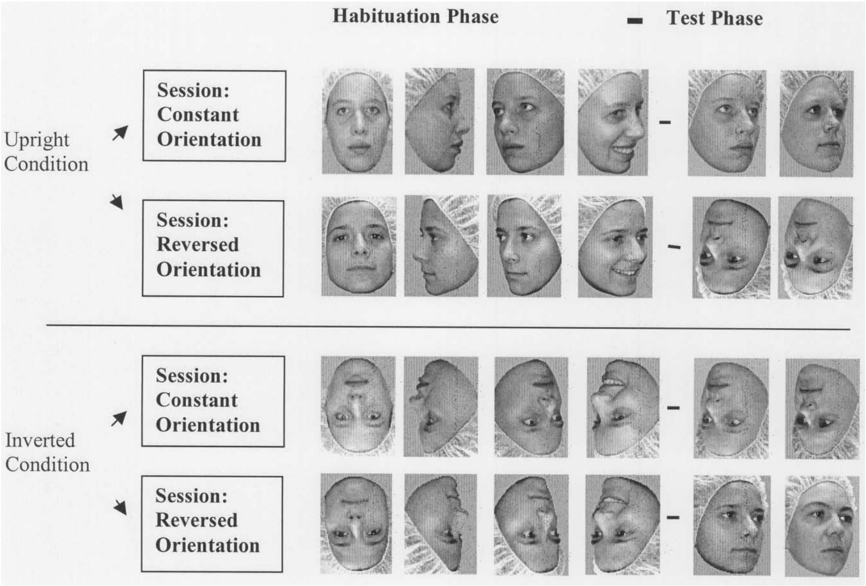

FIGURE 2 Examples of the face stimuli used in Experiment 2.

the orientation. Only six pairs of faces were made with the 12 faces (including the three female pairs of Experiment 1), matched for gender, complexion, eye color, and global head contour.

Apparatus

The apparatus was the same as in Experiment 1.

Procedure

Half of the infants were presented with female faces throughout all testing sessions and phases (female faces group), whereas the other half were shown exclusively male faces (male faces group). Half of the infants belonging to the female faces group and half of those belonging to the male faces group were familiarized with upright faces (upright condition) in both experimental sessions. The other half of the infants were familiarized with inverted faces in both sessions.

Each infant was given two consecutive experimental sessions, each made up of a habituation and a preference test phase. The interval between the two sessions varied from a few seconds to minutes depending on the infant's state. In one session the orientation of the stimuli (upright or inverted) was maintained constant in the habituation and in the test phase (constant orientation), whereas in the other session the orientation of the stimuli in the two phases was reversed (reversed orientation). The order of the two sessions was counterbalanced between participants (constant orientation followed by reversed orientation or vice versa; see Figure 2). Faces used in one session were never presented in the second session to the same infant.

The procedure of habituation and test was the same as in Experiment 1, except for the stimuli that were shown. Several photographs of the same face in different poses were projected in the middle of the screen. Each photograph remained on the screen until the infant looked at it and was immediately removed by the experimenter (pressing a key on the keyboard) as soon as the infant looked away for at least 1 sec (as in Experiment 1). This procedure was repeated with the different photographs of the same face until the end of the habituation phase. The habituation phase ended automatically when the criterion was reached (see Experiment 1). As a consequence, a variable number of different poses of one face was shown during habituation, depending on the number of fixations the infant required to reach the habituation criterion.

After the habituation phase, each infant was given two 20-sec paired presentations of the test stimuli (as in Experiment 1). During each 20-sec presentation, infants were simultaneously presented with the familiar face in a novel three-quarter pose with a neutral expression (i.e., a pose that was not used in the habituation phase) and a novel face in the same pose as the familiar face. The two paired stimuli were always shown in both left and right positions, the position being reversed from Presentation 1 to Presentation 2. The initial left–right order of presentation was counterbalanced across participants. As mentioned earlier, the orientation (constant or reversed) of the stimuli in the test phase, as compared to the habituation phase, was manipulated within participants across the experimental sessions. The familiarization stimulus within each pair of faces was counterbalanced between participants.

All testing sessions were videotaped. Videotapes of eye movements in the preference test phases were subsequently codified frame by frame. The mean estimate of reliability between the two blind and independent observers, calculated on 20% of testing sessions, was .93 (Pearson correlation; range = .86–.95), so the recording procedure has to be considered reliable.

Results

Preliminary statistical analyses did not indicate main effects or interactions involving gender, hence data were collapsed across this factor. All infants reached the habituation criterion. Infants' total fixation times toward the stimuli in the habituation phase were entered in a 2 (session: first, second) × 2 (group: female faces, male faces) × 2 (condition: upright, inverted) mixed-model analysis of variance

(ANOVA). Session was a within-subjects variable. The ANOVA revealed a significant main effect of condition, $F(1, 29) = 5.87$, $p < .03$, indicating that total fixation time to reach the habituation criterion was greater for upright faces ($M = 74.77$ sec, $SE = 6.46$) than for inverted faces ($M = 52.29$ sec, $SE = 6.65$). The main factor group (female faces vs. male faces) did not reach significance (female faces: $M = 72.69$ sec, $SE = 6.65$; male faces: $M = 54.36$ sec, $SE = 6.46$), $F(1, 29) = 3.907$, $p = .06$. The main effect of session was not found to be significant, indicating that infant fatigue did not influence or compromise data collected in the second experimental session. No significant interactions emerged.

To test whether presentation of continuously different views of a face might have significantly increased habituation time relative to a condition where the same view is repeatedly presented (Experiment 1), habituation times observed in Experiments 1 and 2 were compared by means of *t* tests for independent samples. Mean habituation times to upright faces did not differ significantly in Experiment 2 (session constant orientation, upright condition: $M = 78.80$ sec, $SE = 8.81$) and Experiment 1 ($M = 59.04$ sec, $SE = 11.00$), $t(29) = 1.42$, $p = .17$. Similarly, habituation to inverted faces was not significantly different in Experiment 2 (session constant orientation, inverted condition: $M = 47.83$ sec, $SE = 5.06$) and Experiment 1 ($M = 46.85$ sec, $SE = 5.80$), $t(28) = 0.13$, $p = .89$. So, despite the significant difference in duration of habituation between upright and upside-down faces found in Experiment 2, neither upright habituation times nor inverted habituation times observed in Experiment 2 differed significantly from those observed in Experiment 1.

To examine whether, in the test phase, infants manifested a preference for the novel face, a novelty preference score (percentage) was calculated as in Experiment 1, for each infant in each experimental session. A 2 (group: female faces, male faces) × 2 (condition: upright, inverted) × 2 (session: constant orientation, reversed orientation) mixed-model ANOVA was conducted on the novelty scores. Session was the within-subjects variable. The main effects did not reach statistical significance. The ANOVA produced a significant Condition × Session interaction, $F(1, 29) = 9.738$, $p < .005$ (see Figure 3). Subsequent *t* tests revealed that infants in the upright condition looked significantly longer at the novel face when face orientation was not changed between the habituation and the test phase ($M = 56.82$, $SE = 2.36$) than when the orientation was reversed ($M = 46.94$, $SE = 1.58$), paired-sample *t* test, $t(16) = 3.58$, $p < .003$, two-tailed (see Figure 3). Moreover, when face orientation was held constant, the novel face was looked at significantly longer in the upright than in the inverted condition ($M = 56.82$, $SE = 2.36$ vs. $M = 46.44$, $SE = 3.03$), *t* test for independent samples, $t(31) = 2.72$, $p < .02$, two-tailed (see Figure 3). Both *t* test comparisons are significant even if a corrected alpha level (Bonferroni correction factor, $\alpha = .025$) is used. The Group × Condition × Session interaction did not reach significance, $F(1, 29) = 3.45$, $p = .07$. So, the differential effect of the upright and inverted condition in the two types of experimental sessions (constant orientation, reversed orientation) was not significantly different with female faces (female faces group) and male faces (male faces group).

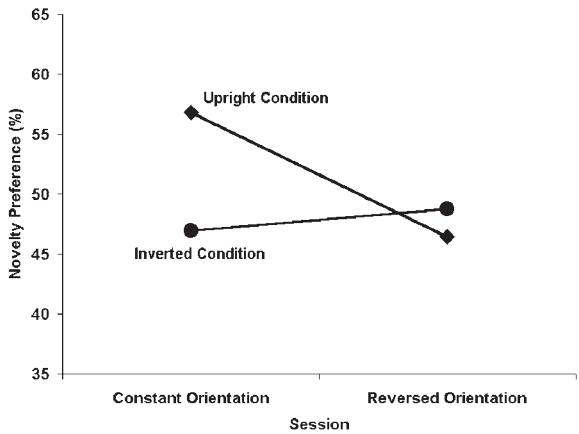

FIGURE 3 Infants' novelty preference as a function of condition (upright and inverted) and session (constant orientation and reversed orientation).

To examine whether novelty preference scores in each of the four main experimental situations (two conditions × two sessions) differed from chance value (50%), one-sample *t* tests were performed. The novelty score was significantly higher than 50% only when children were habituated and tested for recognition with upright faces (constant orientation session, upright condition: $M = 56.82$, $SE = 2.36$), $t(16) = 2.90$, $p < .02$. In the three other cases, the novelty scores were not significantly different from chance: constant orientation, inverted condition ($M = 46.44$, $SE = 3.03$), $t(15) = -1.18$, $p = .25$; reversed orientation, habituation upright/test inverted ($M = 46.94$, $SE = 1.54$), $t(16) = -1.94$, $p = .07$; and habituation inverted/test upright ($M = 48.75$, $SE = 3.01$), $t(15) = -.415$, $p = .68$.

Finally, to test whether infants' total looking times in the test phase differed as a function of the presence of a change in the orientation of the stimuli between the habituation and the test phase, a 2 (session: constant orientation, reversed orientation) × 2 (condition: upright, inverted) mixed-model ANOVA was performed on the raw looking times to both faces presented in the test phase. Session was the within-subjects variable. Neither of the two main effects reached statistical significance. However, the Session × Condition interaction, $F(1, 31) = 6.06$, $p < .03$ (see Figure 4), was significant, indicating that infants' total fixation time in the test phase, in the constant and reversed sessions, varies as a function of whether infants are habituated to an upright or an inverted face.

Discussion

Experiment 2 showed that face recognition might be constrained by orientation of the stimuli, with face differentiation only observed among upright-oriented stimuli. Face discrimination was easier between two upright faces than between the

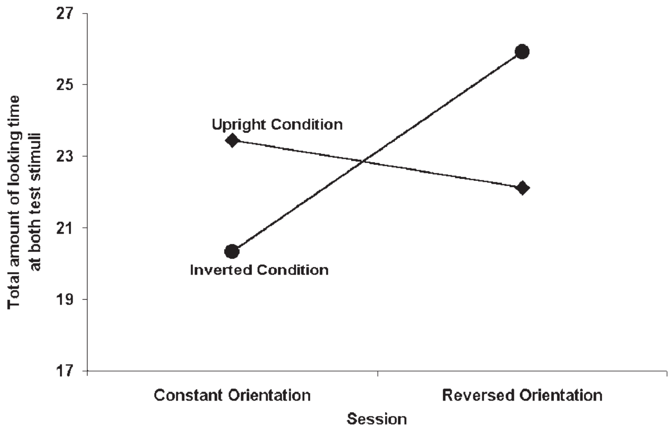

FIGURE 4 Infants' total amount of looking time at both test stimuli as a function of condition (upright and inverted) and session (constant orientation and reversed orientation).

same two faces rotated. The learning conditions of Experiment 2 allowed the development of a representation for upright faces that resulted in recognition when a new photograph of the same face in a different pose was presented. Infants were able to overcome the changes in face appearance induced by modifications of viewpoint. This outcome is in agreement with Pascalis et al.'s (1995) findings, indicating that, by 4 months of age, infants extract some perceptually invariant aspects of the inner portion of an upright face that allow them to recognize the same face when shown in a novel view. What is new in these results is that habituation with multiple views made recognition of inverted faces difficult, so that processing different poses resulted in recognition only when faces were presented upright. When stimuli were presented inverted, performance level was decreased, demonstrating that the familiarity of upright faces affects recognition across views. Based on these findings, it can be concluded that 4-month-old infants are sensitive to usual upright orientation and that, at 4 months of age, infants' discrimination and recognition skills are better and more robust for upright than for inverted faces. It is interesting to note that a discrepancy in the pattern of results obtained with upright and inverted faces was observed also when the overall amount of looking times at both test faces (familiar and novel) in the four main experimental situations (two conditions × two sessions) were examined. Finally, we assumed that given that our 4-month-old participants were more frequently interacting with women than with men, they might show an inversion effect for female faces at an earlier age than for male faces (Quinn et al., 2002). This could emerge in Experiment 2 through a greater inversion effect with female than with male faces. The stimuli gender effect was, however, not significant.

The overall pattern of results of Experiment 2 clearly differ from that found in Experiment 1, given that a difference in infants' performance for upright and inverted faces emerged in Experiment 2 but not in Experiment 1. Different interpretations might be provided to explain this difference. The first possibility is that, by presenting several poses of the same face in the habituation phase, configural processing in infants was in some way encouraged or facilitated. According to this interpretation, maximum reliance on configural rather than part-based information might have induced an inversion effect in Experiment 2. In fact, specific impairment in recognizing faces across different camera angles is a typical characteristic of prosopagnosic patients (Posamentier, 2002; Shuttleworth, Syring, & Allen, 1982), suggesting that this ability requires processing of the configural perceptual information embedded in faces (Farah, 2000; Farah, Rabinowitz, Quinn, & Liu, 2000). However, studies with normal adults only partially support the claim that recognition of unfamiliar faces across view angles favors configural processing. Valentin, Abdi, and Edelman (1999; but see Hill et al., 1997) showed that when adults are forced to generalize recognition across stimulus perspective they use two different procedures according to the size of the rotation between the original and the rotated view. From full face to three-quarters view, the configuration can be generalized and adults can use configural processing. However, when a large rotation is applied (full face to profile), adults perform better if a local mark (e.g., a dark spot on a cheek) is visible on the two views than when no marks are drawn on the face. In our Experiment 2, infants were not habituated with a unique view but with several views of a face from full face to profile; moreover, the view used in the recognition test was not an extremely rotated view but was taken among intermediate rotated views. Therefore, it is not excluded that our young observers might have been able to build a configuration from the different views and transfer it to the tested view. However, although our data are clear in demonstrating that 4-month-old infants are able to extract and recognize some invariant aspects of an upright face across changing poses, they cannot shed light on which type of visual perceptual information (i.e., local or configural) infants utilized to perform this task. Thus, at present, this first interpretation does not appear to have enough support.

A second possibility is that the inversion effect appears only when realistic experience with a face is provided. If this were the case, it is possible that in Experiment 2 the inversion effect emerged because the face was learned through several views, that is, in the most ecological situation. The visual environment constantly offers innumerable images of different faces in a variety of poses, expressions, and lighting conditions. On the contrary, it is difficult to imagine that a face is learned by infants exclusively in a three-quarter view as it happens in Experiment 1. In other words, a poor experienced point of view, like the three-quarter pose, might not give rise to an inversion effect in 4-month-old infants. Future research might adequately challenge this point by testing the presence of the inversion effect when infants are habituated to a face in a single frontal view, which is probably, in the first months of life, among the different views of a face, the most experienced one when close to the viewer and within a good vision range. In fact, Cashon and Cohen (2002, 2003) already demonstrated that no inversion effect is present at 4 months of age when a single photograph of a whole face and head (i.e., with hair) is presented in a single frontal view. However, the possibility remains that a different pattern of results might come out when, as in these experiments, the outer contour of the face is masked by a scarf.

The final and more conservative explanation of the disparity found between Experiments 1 and 2 relies on the added complexity of the recognition task administered in Experiment 2. Contrary to Experiment 1, in which infants had to recognize the same single face image to which they had been habituated, in Experiment 2 babies had to abstract the perceptual commonalities that characterize several different images of a face, recognizing as familiar a novel image of the same face. Suggestive evidence for this interpretation exists in the results of this study. First, no difference in the time to reach habituation for inverted versus upright faces was found for infants in Experiment 1. However, in Experiment 2, infants took longer to reach habituation for upright faces, suggesting that, initially, infants found upright face pictures of the same individual to be more dissimilar than inverted face pictures. This in turn suggests a better perceptual discrimination ability with upright faces. Second, although habituation times for Experiments 1 and 2 did not differ significantly, there certainly appears to be a tendency for the upright faces that suggests habituation might have been more difficult for multiple views.

Probably as a consequence of the greater experience they have with upright faces, infants have acquired some perceptual information about a face that in some way includes a specific upright orientation of the face configuration. This information might have facilitated the encoding of the relevant perceptual information required by the complex face recognition task administered in Experiment 2. This capacity to abstract the critical perceptual information might be not available in the case of an unfamiliar or atypical class of stimuli, such as inverted faces. In summary, it is possible that the added complexity of the task (Experiment 2) pointed out a gap between infants' performances with upright and inverted faces that did not emerge when the task was easy to deal with (Experiment 1). In other words, in Experiment 1 a sort of floor effect might have hidden differences in face recognition performances.

In any case, this study demonstrates that face recognition capacities in 4-month-old infants, in certain experimental conditions, are sensitive to the orientation of the stimuli. How does this outcome fit with previous infant research on the same topic? Fagan (1972) showed an inversion effect at 5 to 6 months of age that emerged only when infants were presented with realistic face representations (i.e., masks) or when face images were presented after more realistic stimulus material were shown. Moreover, he found that 4-month-old infants did not recognize a face picture either when presented upright oriented or inverted. Several more recent studies (Bartrip et al., 2001; Cashon & Cohen, 2002, 2003; de Haan et al., 2001;

Pascalis & de Schonen, 1994; Pascalis et al., 1998; Pascalis et al., 1995) contradict these earlier outcomes, which may be attributed to the fixed familiarization period employed in the Fagan study.

Discrepancies with evidence obtained by Cashon and Cohen (2002, 2003) appear subtler. As already mentioned, these authors found that 4-month-old infants process both upright and inverted faces in a configural manner and did not find an inversion effect at this age. However, it should be underlined that both the stimuli and the recognition task used in Experiment 2 of this study differ from that employed by Cohen and colleagues. As for the stimuli, to avoid that infants based their recognition response on fairly gross perceptual features heavily related with the outer contour of the face, we used pictures in which hair was masked. This choice also implies that we did not test infant capacity to recognize a correlation between inner and outer facial characteristics, but rather their capacity to recognize perceptual invariances within the inner portion of a face. Moreover, once more note that, in Experiment 2, we did not compare upright and inverted faces in recognition per se. Instead, we studied the differences in the generalization of recognition from one image of a face to other images of the same face. Overall, it seems that 4-month-old infants' face recognition performance is affected by the orientation of the stimuli. However, as we also observed, the effect of inversion emerges only in some experimental conditions that have to do with the processing of the inner, rather than outer, facial features and with the recognition task administered.

GENERAL DISCUSSION

Evidence from this study shows that 4-month-olds' capacity to recognize an inverted face (but not an upright face) with standardized hair contour is impaired when stimuli are learned through different poses, that is, when the opportunity to extract some invariant characteristics of the face is provided by the task (Experiment 2). On the contrary, learning through a unique three-quarter view results in view-specific learning that 4-month-old infants are able to perform both in the upright and in the inverted conditions (Experiment 1). Thus, under some experimental conditions, 4-month-old infants' face recognition abilities are limited by orientation of the stimuli, with differentiation only found among upright-oriented faces.

Is this phenomenon comparable to the face inversion effect observed in older children and adults? Because upright and inverted faces did not differ in terms of brightness, contrast, complexity, and features, differences in 4-month-old infants' ability to discriminate and recognize upright versus inverted faces must strongly lie in the specific orientation of the stimuli. This is certainly an important point in common with the adult face inversion effect.

However, other characteristics of the effect obtained appear to be different from those that define the adult face inversion effect. First of all, we obtained a differential pattern of results in the upright and inverted condition only when infants were required to recognize, across views, the invariant perceptual information contained in the face with standardized hair. In adults this is not a condition necessary to show difficulties in recognizing inverted faces (Scapinello & Yarmey, 1970; Valentine, 1988; Yin, 1969). In addition, it is worthwhile emphasizing that in adults all objects are remembered more poorly when studied and tested inverted than when studied and tested in their canonical orientation, but this effect is much larger for faces than for other objects (Yin, 1969). At the moment, we do not know whether this is also true for 4-month-old infants. Although very important, this is not an easy issue to address because it is very difficult to find proper control stimuli adequate for this age. At the best, control stimuli should be well-experienced objects, they should share a common overall configuration, and they should be discriminable relying on the spatial relation of their inner elements (Gauthier & Nelson, 2001). Unfortunately, it is difficult to find stimuli other than faces that meet all these requirements for a 4-month-old infant. Nevertheless, further research might challenge this relevant and interesting issue.

Finally, an interesting debate would be whether the results obtained reflect the engagement of inherently special-purpose processes or mechanisms, or whether they are a sign of a progressive fine-tuning by expertise of parts of the cortical system for faces. Previous studies demonstrating that some inborn basic predispositions induce newborn infants to orient their gaze more frequently and look longer toward face schema in the upright rather than in the inverted orientation (Goren, Sarty, & Wu, 1975; Johnson, Dziurawiec, Ellis, & Morton, 1991) have been taken as supporting the hypothesis that faces are processed by a domain-specific mechanism that does not require experience to develop and would be present already at birth (Farah et al., 2000). On the contrary, our results favor the idea that the processes involved in learning and recognizing an individual face undergo a complex developmental trajectory of progressive specialization. The differential sensitivity to inversion according to whether the faces were presented under different points of view or only under a unique view does not fit with a preorganized face processing system. A preorganized face processing system should show the same behavior whether a face is presented under only one or several poses. Together with the fact that early temporary visual deprivation impairs recognition of a face (Geldart et al., 2002; Le Grand et al., 2001), the results reported here indicate that experience with faces determines very early in life the developmental trajectory of a tool that will become relatively specific. This increasing specificity also includes a progressive tuning to the familiar, upright orientation that typically characterizes faces.

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