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The inversion effect in infancy: The role of internal and external features

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Abstract

The present work examined the role of inner and outer features in infants' failure to recognize inverted faces and in their recognition of upright ones (the "inversion effect"). The first study established that the inversion effect is present in infants as young as 5 months; study 2 and study 3 demonstrated a developmental shift in the basis of this effect between 5 and 7 months. In the second study, 7- and 9-month-olds, but not 5-month-olds, could recognize a face that had its external features inverted but its internal ones upright. In the third study, 7- and 9-month-olds, but not 5-month-olds, could recognize upright faces as long as their internal features remained the same, even when the external features were new. Taken together, these studies suggest that the importance of internal features for face recognition increases between 5 and 7 months.

Keywords

infants; inversion effect; face perception

Face recognition is a remarkable human achievement that is crucial for social development. Faces are highly salient and biologically significant stimuli. As a species, humans appear primed to prefer faces, or face-like stimuli, from birth (Fantz, 1964; Goren, Sarty, & Wu, 1975). For example, newborns prefer faces to patterns and prefer a face-like structure made up of three blobs, arranged as two 'eyes' above a 'mouth,' to other arrangements of the same elements (Simion, Valenza, Macchi Cassia, Turati, & Umilta, 2002; Turati, Simion, Milani, & Umilta, 2002; Valenza, Simion, Macchi Cassia, & Umilta, 1996). Young infants are also able to recognize individual faces, preferring their mother's face to that of a stranger in the first few days of life (Bushnell, 2003; Bushnell, Sai, & Mullen, 1989; Johnson & Morton, 1991; Pascalis, deSchonen, Morton, Deruelle, & Fabre-Grenet, 1995).

In adults, face recognition is considered to be primarily dependent on configural or holistic processing, focusing more on the relation between facial features (eyes, nose, mouth, chin, ears, hairline, etc.) than the individual features themselves (Maurer, Le Grand, & Mondloch, 2002), see also (Carey & Diamond, 1994; Farah, Wilson, Drain, & Tanaka, 1998; Moscovich & Moscovich, 2000; Moscovich, Winocur, & Behrmann, 1997). Three different types of configurational information figure prominently in face perception: (1) first order relations, which refer to cardinal top-down ordering of features shared by all faces – eyes above nose

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above mouth, (2) holistic – referring to a perceptual integration across the whole, where the face is perceived as a single gestalt that is not de-composed into its parts, and (3) second order relations– having to do with the distances between features (Maurer et al., 2002). First-order information is used in distinguishing faces from other stimuli, whereas holistic and/or second-order information is used in distinguishing one face from another.

The importance of configural information in face processing is often demonstrated by showing how detrimental disruptions of configuration are to face recognition. The most common manipulation used to disrupt configural processing is inversion, that is, a 180 degree rotation. Inversion, though it leaves all features intact, disrupts configural processing and impairs 'faceness' and thus recognition (Maurer et al., 2002). Faces are thought to depend more on configural processing than many other stimuli, since inversion impairs face recognition to a greater extent than it does recognition of other stimuli, such as houses, cars, etc (Yin, 1969).

There is some evidence, albeit inconsistent, that inversion can disrupt face recognition in infants as young as 4-months of age. Turati and colleagues (Turati, Sangrigoli, Ruel, & de Schonen, 2004) examined the face-inversion effect at this age in two studies where infants would have to rely solely on internal features to distinguish familiar from new faces (outer features were masked by a shower cap). In the first study, they were habituated to a face (in ¾ pose) that was either upright or inverted; on test, the familiar face was paired with a novel one in the same pose and orientation. Infants recognized the familiar faces equally well in both conditions. There was no evidence of the inversion effect (since inversion did not impair performance). However, evidence of the effect was obtained in the second study, where the task was made more complex by presenting faces in a variety of poses in the habituation phase. Photos were presented either upright or inverted for habituation, and then in either the same or opposite orientation on test. Here, infants recognized faces that were in upright orientation in both phases (habituation and test) but recognition was impaired when the faces were inverted during either habituation and/or test.

Although Turati's results suggest that the inversion effect can be found at 4-months (Turati et al., 2004), the effect appears to be fragile at this age. For example, (Cashon & Cohen, 2003; Cohen & Cashon, 2001) failed to find an inversion effect at this age in a study using composites made up of the internal features of one familiar face and the external features of another. In this study, 4-month-olds treated the composites similarly (as 'new'), whether they were upright or inverted; however, by 7-months, infants responded differentially to the two orientations (see (Schwarzer & Zauner, 2003) for comparable findings at 8-months). These results, together with those of (Fagan, 1972), who found that 5- to 6-month-olds recognized upright but not inverted faces, and (Rose, Jankowski, & Feldman, 2002), who found that 7-month-olds recognized faces when they were upright but not rotated (160° or 200°), suggest that the inversion effect is consolidated some time between 5 and 7 months.

The present study is concerned with understanding more about the emergence, development, and basis of the inversion effect during the middle of the first year, a period of dramatic change in face processing (Scott & Nelson, 2006). Because adults often use internal features (eyes, nose, mouth) to distinguish between upright faces, most studies of the inversion effect have focused on these, to the exclusion of external ones (hair, chin, ears, shape of the head). Indeed, in many such studies, the external features are either absent or masked (Mondloch, Le Grand, & Maurer, 2002). However, because infants and young children are more likely than adults to rely on external features, masking them may underestimate infant abilities. For example, in the first week of life, infants can recognize their mother's face, but fail to do so if the outer contour of the face and head are masked by a scarf (Pascalis & deSchonen, 1994; Pascalis et al., 1995). Similar findings were recently reported for newborns, who recognized faces better from their outer features than their inner ones (Turati, Cassia, Simion, & Leo, 2006). This reliance on external aspects of the face remains strong through middle childhood. For example, 5-to 9-year-olds are more accurate using external than internal features in identifying classmates (Campbell et al., 1999), in recognizing newly familiar faces (Want, Pascalis, Coleman, & Blades, 2003) and in identifying famous personalities (Campbell & Tuck, 1995). The pronounced role that external features play in recognition of upright faces from infancy through middle childhood would lead one to anticipate that they may play a significant role in the inversion effect found during the same period.

The present report examines the development of the inversion effect in the middle of the first year of life (at 5, 7, and 9 months), and the role of inner and outer facial features in this effect. In each of three studies, infants were initially familiarized to a photo of a face in an upright, frontal pose. During familiarization, this photo was repeatedly paired with different novel faces in the same pose. Trials continued until the infants met a criterion of consistent preference for the novel face. An advantage of this procedure is that it allows us to be certain that the information had been sufficiently well encoded by all infants to enable them to consistently recognize the familiar face in an upright orientation and distinguish it from a variety of novel ones.

The three studies differed in the test trials that followed familiarization. In Study 1, we examined infants' ability to recognize the familiar face in a new pose (¾ view), a transformation that preserves configuration, and when it was inverted (rotated 180°), a transformation that destroys configuration. In Study 2, we examined the role of internal and external features in the inversion effect by assessing the extent to which infant face recognition was disrupted when one but not the other was inverted on test (following (Moscovich & Moscovich, 2000;Moscovich et al., 1997). In Study 3, which was designed to address issues about infants' utilization of external features raised in Study 2, we examined the relative importance of internal and external features in infants' recognition of upright faces.

Study 1: The Presence of the Inversion Effect in Infancy

In a prior study (Rose et al., 2002), which examined developmental change in configural processing from 7- to 12-months, we found an inversion effect in 7- month-olds, they could recognize upright faces but not those rotated to near inversion (160° or 210°). In that study, infants were familiarized to infant faces presented in an upright, frontal pose. On test, they were presented with the familiar and a novel face, both rotate in the horizontal plane (¾ pose) or both rotated in the vertical plane (160° or 210°). Infants recognized the face in the first condition (which preserved configuration) but not in the second (which disrupted configuration). Thus, by 7 months, inversion hampered recognition.

The present study extends this earlier work downwards, to determine the extent to which younger infants are configural processors, and upwards, to determine whether there are developmental changes in the strength of this effect. This was done by contrasting infants' response to an inverted face (180° rotation) with their response to an upright face in ¾ pose. Infants were tested at three ages – 5, 7, and 9 months, ages bracketing a time of major change in configural processing (Scott & Nelson, 2006).

Method

Design—There were two groups of infants. Both received the same familiarization, in which an upright face (in frontal pose) was paired with a series of novel faces, in the same pose, until the infants recognized the familiar face (as evidenced by having developed a stable preference for the novel one). Then one group was tested for their ability to recognize the familiar face in a new pose (by presenting trials in which the familiar face was paired with novel ones, both in ¾ pose) and the other group was tested for their ability to recognize the familiar face when it was inverted (by pairing the familiar faces with novel ones (both in frontal pose, but rotated 180°).

Participants—There were 132 infants in the final sample: 44 5-month-olds (*M* = 19.2 weeks, *SD* = 2.11; 49% male), 44 7-month-olds (*M* = 27.0 weeks, *SD* = 1.62; 48% male), and 44 9-month-olds (*M* = 38.8 weeks, *SD*= 2.5; 51% male), with 22 per group at each age. A further 14 infants were excluded at 5 months (all due to fussiness/sleepiness), 11 infants at 7 months (10 due to fussiness/sleepiness, 1 due to experimenter error), and 8 infants at 9 months (6 due to fussiness/sleepiness, 2 due to experimenter error).

The participants were healthy, full-term infants from predominately middle class families. Maternal education averaged 14.1 years (*SD* = 2.0); the ethnic distribution was 39% Caucasian, 26% Hispanic, and 35% African-American.

Apparatus—A 3-sided testing booth, constructed from black fabric, measured 1.2 m on each side and 1.5 m across the front. Centered in the side of the booth facing the infant was a display panel, which pivoted back and forth to allow the observer, seated behind, to position faces. The observer monitored infant’s looks through a 7 mm peephole centered between the stimuli. Two 40-watt lights illuminated the faces and the infant's face.

Stimuli—The stimuli for the *familiarization phase* were 20 grey-scale photographs of the faces of 5- to 9-month-old Caucasian infants; all had neutral facial expressions and were photographed in frontal pose, from the shoulders up. Infants wore a standard smock to eliminate distinctive differences in clothing. The photographs (13 cm × 18 cm) subtended a visual angle of about 16° × 23°; paired photos were separated by a visual angle of about 23°. Two of the 20 faces were used as familiar stimuli: for half of the infants one face was used, and for the other half, the other face was used. The remaining 18 stimuli, randomly ordered, served as novel faces; the same ordering of novel faces was repeated for the second 18 trials.

The stimuli for the *test phase* included ¾ and inverted poses of the familiar faces and four additional faces that were drawn from the same pool as the familiarization faces but were new to this phase of the study (novel faces)(see Fig 1).

Procedure—Infants were tested while seated on their parents' lap, approximately 45 cm from the display panel. In the *familiarization phase*, where the familiar face was paired with different novel faces on successive trials, trials began with the first look to either face and ended when the infant had looked at the display for a total of 4 s. The left-right placement of novel and familiar faces was randomized across trials, with the proviso that the novel not appear on the same side on more than two successive trials. To change stimuli, the experimenter, who was hidden from the infant's view, pivoted the display panel back 90 degrees, manually removed and inserted the stimulus plaques, and then closed the panel. Each change of stimuli took 3–5 s. Trials continued until the infant reached criterion -- four out of five consecutive trials having a novelty score ≥ 55%, but less than 100%. The latter proviso compelled some looking to both faces during the criterion run, thereby ensuring active comparison between them. In the event that criterion was not met, a maximum of 36 trials was completed.

In the *test phase*, each group received two stimulus pairings. For one group, each pairing consisted of a familiar and novel face, both inverted (180° rotation). For the other group, each pairing consisted of a familiar and novel face, both in ¾ pose. For both groups, the familiar was presented with a different novel face in each pairing. Each pair was displayed until the infant accrued 8 s of looking time (with the left/right position of targets reversed after the first 4s). Four novel faces were counterbalanced across infants and pairings. The principal measures on test were *Novelty Scores*, which index the percentage of total looking time on test spent looking at the novel stimulus. For each infant, novelty scores were averaged across the two pairings.

Looking times were directly observed and computer recorded, and also video-taped, for reliability scoring. The computer controlled the timing of trials and determined when the criterion was reached, signaling these events with soft tones. The same tester presented stimuli and recorded looks. To avoid bias, several different testers were involved; most were naïve to the hypotheses of the study. Reliability between pairs of observers, which is checked frequently, ranged from $r = .92$ to .98 (for details on reliability, see (Rose, Feldman, & Jankowski, 2001).

Results and Discussion

The effects of gender, familiarization stimulus and ethnicity were examined in preliminary analyses. Because infants have been reported to show better recognition of faces from their own ethnic group (Kelly et al., 2005), it was deemed important to rule out the possibility that the face stimuli here (faces of Caucasian infants) were better recognized by the Caucasian participants. In these analyses, ethnicity was coded as a dichotomy (Caucasian vs. other). Results indicated that there were no effects of gender, ethnicity, or familiar stimulus; thus, the data were collapsed across these three factors in the analyses reported below.

Familiarization—The data from the familiarization phase were analyzed to evaluate age-related differences in speed of processing. As expected, younger infants took more trials to reach criterion than did older infants (at 5, 7, and 9 months, $M = 21.18$, $SD = 11.46$; $M = 14.50$, $SD = 7.49$; $M = 12.00$, $SD = 4.41$, respectively). The results of a 3(age) × 2(group) ANOVA showed a significant main effect for age, $F(1, 126) = 11.00$, $p < .01$, but no difference between groups nor any age × group interaction. The numbers failing to reach criterion ($N = 12$ at 5 months, $N = 2$ at 7 months, and $N = 0$ at 9 months) did not differ across groups.[1]

Test—The novelty scores from test trials are shown in the first panel of Table 1. To determine whether infants recognized the familiar face when shown in ¾ pose or inverted, the mean novelty scores for each group were tested against a chance value of 50%. As indicated by the asterisked values in Table 1, the overall novelty scores were significantly greater than chance at all three ages for the ¾ pose whereas those for the inverted were not significantly above chance at any age. Thus, once they had reached criterion in the learning task, even the youngest infants had abstracted enough information about the face to recognize it when the pose was changed from frontal to ¾, but did not recognize the familiar faces when it was rotated 180 degrees.

These findings were confirmed by the results of a 3 (age) × 2 (group) ANOVA of the novelty scores. There was a significant effect for group, reflecting the higher scores for the ¾ pose than for the inversion, $F(1,120) = 11.21$, $p < .01$, but no significant effect for age, nor any interaction of age with group. Thus, infants' ability to recognize faces was disrupted when they were inverted and that effect was consistent across age.

Study 2: The Role of Internal and External Features in Recognizing Inverted Faces

As noted above, adult expertise in face processing is attributed largely to appreciation of the configuration of its inner features. It is often observed that, when the face is inverted, the

[1]All analyses in the test phase were repeated excluding infants who failed to reach criterion in the continuous familiarization task; the results were not appreciably affected in any of the three studies.

cardinal top-down relation of inner features to one another is destroyed (Maurer et al., 2002). However, when the entire face is inverted, not only is the canonical up-down configuration of inner features destroyed, but the placement of external features (hair, ears, chin, facial contour) is disrupted as well. Adults seem to ignore these latter changes. For them, the inversion effect seems to depend entirely on changes to the internal configuration, given that inverting the internal features alone hampers recognition whereas inverting the external features alone does not (Moscovich et al., 1997). However, in light of evidence that external features are more critical to facial recognition for children than adults (Campbell et al., 1999; Campbell & Walker, 1995; Want et al., 2003) it is possible they may also be more important to the inversion effect seen in infants.

The present study examined the role of internal and external features in the inversion effect at three ages: 5, 7 and 9 months. The familiarization phase was the same as in Study 1, in which one upright face in frontal view was paired with a series of novel upright faces. However, here, for one group, the internal features of the familiar and novel face were inverted on test, that is, rotated 180 degrees (while external features remained upright). For the second group, only the external features of the test faces were inverted (with the internal features remaining upright). If external features are important to the inversion effect in infancy, recognition should be disrupted when they are inverted. Similarly, if internal features are important, then inversion should disrupt recognition.

Method

Participants—There were 132 infants in the final sample: 44 5-month-olds (*M* = 19.8 weeks, *SD* = 2.27; 44% male), 44 7-month-olds (*M* = 28.0 weeks, *S D*= 1.48; 50% male), and 44 9-month-olds (*M* = 39.2 weeks, *SD* = 2.3; 55% male), with 22 per group at each age. A further 12 infants were excluded at 5 months (11 due to fussiness/sleepiness and 1 due to experimenter error), 12 infants at 7 months (10 due to fussiness/sleepiness and 2 due to experimenter error), and 10 infants at 9 months (8 due to fussiness/sleepiness and 2 due to experimenter error).

The participants were healthy, full-term infants from predominately middle class families. Maternal education averaged 14.5 years (*SD* = 2.2); the ethnic distribution was 39% Caucasian, 27% Hispanic, 30% African-American, and 4% Asian.

Design, Apparatus, and Procedure—These aspects of Study 2 are the same as for Study 1. The only difference between studies was in the design of the test stimuli.

Stimuli—The same 20 photos used in the *familiarization phase* of Study 1 were used again here. The stimuli for the *test phase* differed as a function of condition, with internal and external features of familiar and novel faces faces inverted separately. Using Adobe Photoshop, the internal features (eyebrows, eyes, nose, and mouth) were separated from the external ones (hair, forehead, ears, outer cheeks area, and chin). The two sets of features were defined by cutting a circle of radius 85mm, containing the inner features, from each face; the size and shape of the cut was constant across faces. For the ‘internal inverted’ condition, the internal units of the familiar and novel faces were inverted 180°, and then pasted on the original, familiar face. For the ‘external inverted’ condition, the external units were inverted 180° and then pasted over the original (see Fig 2). Differences in skin tone or texture were blended to minimize demarcations between internal and external parts.

Results and Discussion

Since preliminary analyses again showed no effects of gender, ethnicity, or familiarization stimulus, the data were collapsed across these factors.

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Familiarization—The age differences in speed of processing were similar to those observed in Study 1. Again, younger infants took more trials to reach criterion than did older infants (at 5, 7, and 9 months, $M = 22.00$, $SD = 11.30$; $M = 16.18$, $SD = 8.80$; $M = 13.09$, $SD = 5.08$, respectively.) The results of a 3(age) × 2(group) ANOVA showed a significant main effect for age, $F(2,126) = 11.43$, $p < .01$, but no difference between groups nor any age × group interaction. The number of infants failing to reach criterion ($N = 13$ at 5 months and $N = 4$ at 7 months) did not differ across groups.

Test—The novelty scores from the test trials of this study are shown in the second panel of Table 1. Again, the mean novelty scores for each group were tested against a chance value of 50% and those significantly different are asterisked.

Infants of all three ages performed at chance when the internal features were inverted, despite the fact that they could have used the upright external features for recognition. In the other condition, where the external features were inverted and the internal upright, the two older groups recognized the familiar face but the 5-month-olds did not. Thus it appears that younger infants did not make use of the internal features.

These results were supported by an 3(age) × 2(group) ANOVA of the novelty scores, which showed a significant group effect, $F(1,126) = 5.78$, $p < .05$ and a marginally significant age × group interaction, $F(2,126) = 2.86$, $p = .06$. The interaction indicates that the 5-month-olds, unlike the older infants, had difficulty with inversion of the external features as well as the internal ones.

Study 3: The Role of Internal and External Features in Recognizing Upright Faces

The findings of Study 2 raise the possibility that 7- and 9-month-olds are less attentive to external features than are the 5-month-olds. To determine whether this is the case, we examined the role of internal and external features in distinguishing among upright faces. In an earlier study, we found that 6 ½- month-olds were attentive to subtle changes in inner features (Orlian & Rose, 1997), but we did not look at the role of external features. Moreover, the faces were cartoon-like and thus may have been processed differently from real faces (Schwarzer & Zauner, 2003). The present study used photos of real faces and included manipulations of external as well as internal features.

In the test phase of this study, the intact, upright familiar face was paired with another upright face that had either different internal features or different external ones. When the internal features differed, the external features of the paired test stimuli were the same; when the external features differed, the internal ones were the same.

Method

Participants—There were 132 infants in the final sample: 44 5-month-olds ($M = 19.2$ weeks, $SD= 2.06$; 52% male), 44 7-month-olds ($M = 27.7$ weeks, $SD = 1.61$; 48% male), and 44 9-month-olds ($M = 40.2$ weeks, $SD= 2.1$; 50% male), with 22 per group at each age. A further 10 infants were excluded at 5 months (all due to fussiness/sleepiness), 10 infants at 7 months (due to fussiness/sleepiness), and 8 infants at 9 months (7 due to fussiness/sleepiness and 1 due to experimenter error).

The participants were healthy, full-term infants from predominately middle class families. Maternal education averaged 13.9 years ($SD = 2.8$); the ethnic distribution was 40% Caucasian, 25% Hispanic, 33% African-American, and 2% Asian.

Design, Apparatus, and Procedure—These aspects of Study 3 are the same as for Study 1 and Study 2, except here one group was tested for recognition of the internal features of upright faces and the other was tested for recognition of external features. Again, the only difference between studies was in the design of the test stimuli.

Stimuli—The same 20 photos used in the *familiarization* phase of Study 1 and Study 2 were used once again. The stimuli for the *test phase* included the two familiar faces and four 'novel' ones. The novel faces were created using the familiar faces and two entirely new ones. Using Adobe Photoshop, the internal features of each face (eyebrows, eyes, nose, and mouth) were separated from the external ones (hair, forehead, ears, outer cheeks area, and chin) and re-combined to create four novel test faces -- two that shared the same internal features as the familiar face and two that shared the same external features. Differences in skin tones or texture were blended, to create a natural look for the reconstructed faces. Thus, the 'novel faces' for the two test problems in Group 1 were novel only with respect to the internal features, whereas the novel faces for the two test problems in Group 2 were novel only with respect to the external features (Fig 3).

Results and Discussion

Once again, preliminary analyses indicated that were no effects of gender, ethnicity, or familiarization stimulus on test scores, so the data were collapsed across both factors.

Familiarization—As in Study 1 and Study 2, age was related to speed of processing, with younger infants taking more trials to reach criterion than older ones (at 5, 7, and 9 months, $M = 22.09$, $SD = 10.37$; $M = 16.09$, $SD = 7.24$; $M = 13.55$, $SD = 5.97$, respectively. The results of a 3(age) × 2(group) ANOVA showed a significant main effect for age, $F(1,126) = 12.69$, $p < .01$, but no difference between groups nor any age × group interaction. The number of infants not reaching criterion ($N = 12$, all at 5 months) did not differ across groups.

Test—The novelty scores from the test trials of this study are shown in the third panel of Table 1. Again, the mean novelty scores for each group were tested against a chance value of 50% and those significantly different are asterisked.

As can be seen, infants of all three ages could recognize upright faces on the basis of their external features, but only the two older groups could recognize them on the basis of their internal features.

These results are supported by a 3(age) by (2) group ANOVA of novelty scores, in which there was a significant effect for age, F (1,126) = 3.73, p <.05 and for the interaction of group with age F (2,126) = 2.83, $p < .05$. The interaction effect indicates that, while infants of all three ages can recognize a familiar face on the basis of external features, paying more attention to novel faces that differ from the familiar only in this aspect, only the two older groups infants were able to base their recognition on internal features alone.

General Discussion

The primary focus of the present study was to determine the development of the inversion effect from 5 to 9 months, a time of major change in face processing (Scott & Nelson, 2006) and the extent to which this effect is dependent on internal and external features. The results of Study 1 showed that this effect was present at all three ages tested: 5, 7, and 9 months. After having been familiarized with upright faces, infants of these ages recognized the face in a new ¾ pose (itself an indication of configural processing), but not when it was inverted (rotated 180°). In Study 2, where internal and external features were inverted separately, recognition was disrupted for 5-month-olds when either feature set was inverted, whereas it was disrupted for the two older groups only when the *internal* features were inverted. These findings indicate that basis for the inversion changes with age, with older infants relying more on internal features. The presence of this developmental shift was reinforced by the results of Study 3, where infants of all three ages recognized upright faces on the basis of their external features, but again, only the two older groups recognized them on the basis of their internal features.

The findings from Study 2, where inverting the internal features impaired recognition for 7- and 9-month-olds, but inverting the external features did not, are strikingly similar to those reported for adults by Moscovitch and colleagues. These investigators tested normal adults and CK, an individual with visual object agnosia but normal face recognition (Moscovich & Moscovich, 2000;Moscovich et al., 1997). Using photos of the faces of famous people, Moscovich et al., (1997), found that inverting the internal features impaired recognition in both normal adults and in CK (with recognition dropping about 20% in normal controls and 60% in CK). By contrast, inverting the external features had no noticeable effect for either the normal adults or CK. The findings were comparable when the photos contained only the internal or external feature set (Moscovich & Moscovich, 2000).

While older infants more often use and rely on internal features, the findings from Study 3 indicate that they use external ones if the internal features are identical. In this study, when two upright faces had the same internal features, but different external ones, infants based recognition on the external features. Conversely, when the two faces had the same external features but different internal ones, they based recognition on the internal features. By contrast, the 5-month-olds appeared to attend exclusively to external features, and failed to use internal features to recognize the familiar face when the externals of the familiar and novel were the same. This may be the continuation of a tendency to rely on external features present in the newborn period (Turati et al., 2006). These findings are in agreement with work suggesting that the external features play a role in processing upright faces throughout childhood (Campbell et al., 1999;Carey & Diamond, 1994) given that children are easily fooled by external paraphernalia (Carey & Diamond, 1977). External features may remain important, at least in part, because they provide a frame of reference for the relative location of internal features.

From 5- to 9-months, infants come more flexible in their processing, able to utilize either internal or external features, as required. It would appear, then, that the appreciation of the configural information contained in faces deepens over the first year of life, as infants acquire more experience differentiating faces. They become accustomed to seeing the same faces with varying hairstyles and paraphernalia and so learn to rely less on external feature, which are constantly changing, and rely more on internal ones. These data support Turati's contention (Turati et al., 2006) that there is a shift in the relative importance of different sources of information in face recognition over the first year of life. Initially the outer features of the face enjoy an advantage over the inner features. While configural processing is possible even in the newborn period, with newborns showing preferences for attractive faces that are abolished if the stimuli are inverted (Slater, Quinn, Hayes, & Brown, 2000), it is not the preferred mode of processing (Turati et al., 2006). Within the first year of life, there is a shift such that configurational processing gradually becomes predominant and progressively fine-tuned. These findings are in agreement with ERP work showing a developmental change between 4 and 8 months in the P400 response to featural and configural aspects of faces (Scott & Nelson, 2006).

The results of the three studies in the present paper study extend our understanding of the inversion effect in infancy in several ways. First, they show that the effect is found consistently over a large part of the first year, even though external features were intact, rather than masked, as is more common. These findings suggest the effect is very strong, since infants were not able to take advantage of these additional cues for recognition of inverted faces. Second, they show that the inversion effect is present for infant faces, not just the more commonly used adult faces, with which they have had more experience and more time to build a prototype. Third, they show that the inversion effect, which is generally found under conditions where the face is inverted during familiarization and test, holds even when infants have learned the face in a typical, upright orientation but are then required to recognize it after a rotation (see also Turati et al., 2004). It should noted that, although the stimuli were all faces of Caucasian infants, none of the findings varied as a function of infant race, perhaps because the sample was drawn from a multi-ethnic community.

The basis for the inversion effect may lie in the way information is encoded. In a recent study (Gallay, Baudouin, Durand, Lemoine, & Lecuyer, 2006), 4-month-olds were found to scan and encode upright and inverted faces differently. When faces were upright, infants spent more time exploring internal features (mainly in the region of the nose and mouth), shifted their gaze more frequently between internal features, and also shifted their gaze frequently between internal and external features. It seems then that infants use different exploratory strategies to extract information from upright and upside-down faces. In adults, a recent fMRI study revealed that brain activation is different for upright and inverted faces, with there being less activation in the fusiform gyrus (an area important to face processing) when inverted faces were processed (Kanwisher, Tong, & Nakayama, 1998).

In sum, the inversion effect, which appears early in life and depends on configural processing, shows a developmental shift in its dependence on internal and external features between 5 and 7 months, which may reflect differences in encoding strategies.

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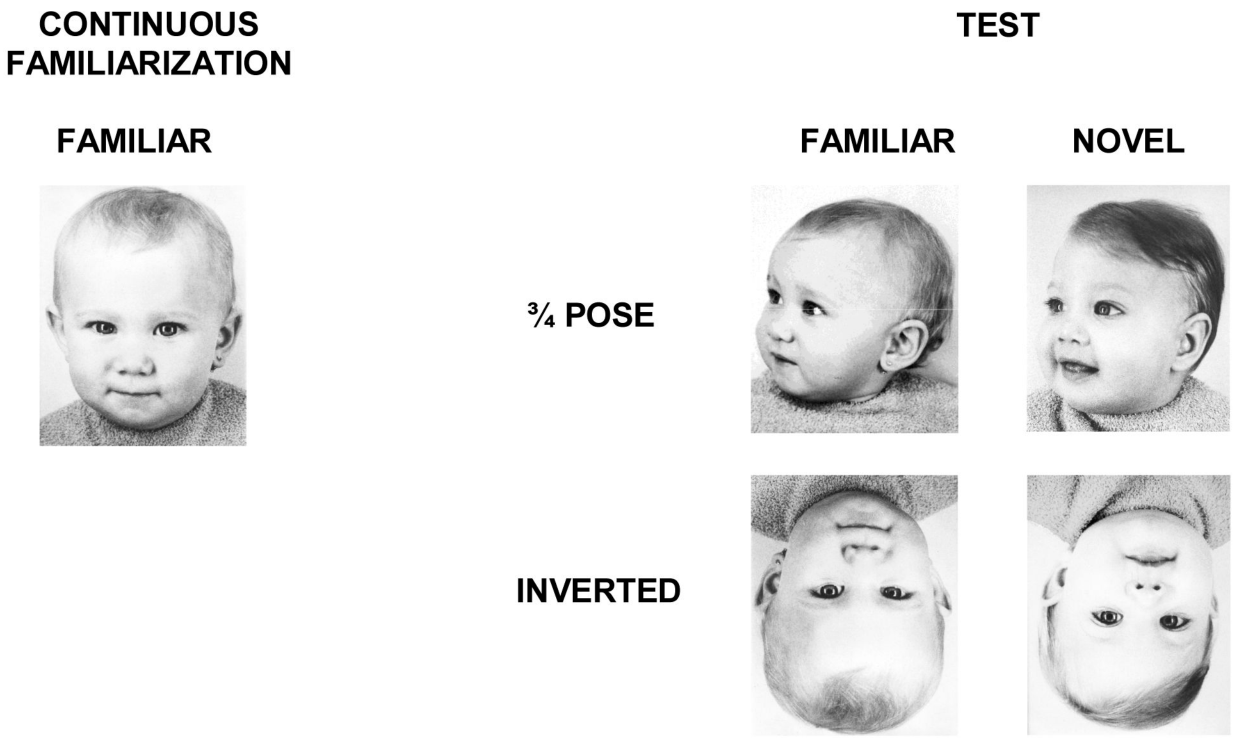

Figure 1.
Sample of faces used in Study 1. Infants were familiarized with an upright face that was paired with a series of novel faces in the same pose, with trials continuing until they demonstrated a preference for the novel face. Infants were then tested for recognition when (a) the familiar face was shown in ¾ pose paired with a novel faces in the same pose and (b) when the familiar face was inverted 180° and paired with a novel inverted face.

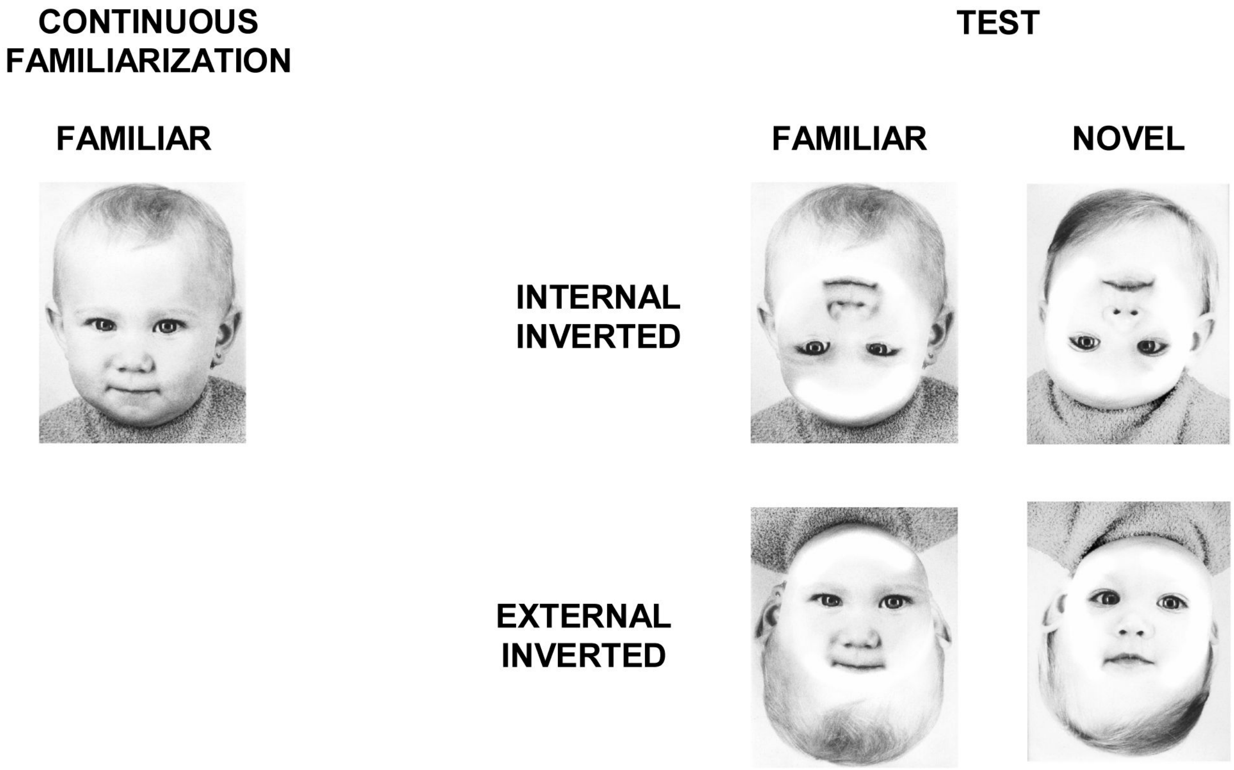

Figure 2.
Sample of faces used in Study 2. After the same familiarization as in Study 1 either (a) the internal features of the familiar face were inverted, and it was paired with an identically treated novel face, or (c) the external features of the familiar face were inverted, and it was paired with an identically treated novel face.

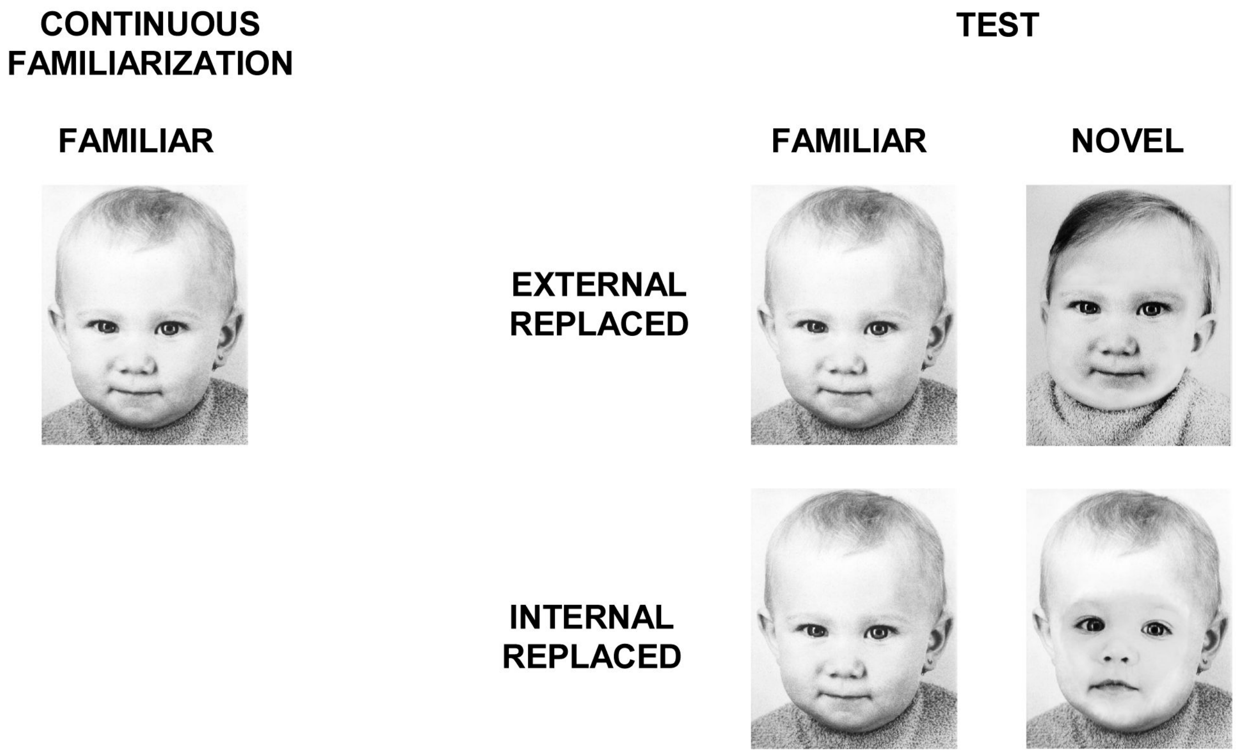

Figure 3.
Sample of faces used in Study 3. After the same familiarization as in Study1, the intact face was paired with a version of itself having (a) the internal features replaced or (b) the external features replaced.

Table 1

Performance (% time looking at novel face) on Test Trials

	5-Month-Olds		7-Month-Olds		9-Month-Olds	
	M	***SD***	***M***	***SD***	***M***	***SD***
Study 1						
¾ Pose	55.87*	12.39	57.70**	9.14	57.42**	7.55
Inversion	50.47	11.15	51.25	13.40	50.83	8.33
Study 2: inverted faces						
External features inverted	49.17	12.05	58.04**	11.79	60.37**	13.05
Internal features inverted	51.08	10.61	50.54	13.51	51.15	9.24
Study 3: upright faces						
External features differ	56.97**	11.67	56.96**	7.52	58.12**	10.81
Internal features differ	47.91	10.15	56.22*	11.54	57.19**	10.28

N = 22 per group at each age

Novelty scores were compared against chance (50%) using t-tests.

* $p < .05$.

** $p < .01$.