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Development of Visual Self-Recognition in Infancy

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This research investigated the development of visual self-recognition in infancy. Prior research has investigated infants' self-perception in mirror or live video stimulation in which visual–proprioceptive contingency is available. No research, however, has addressed the young infants' ability to recognize his or her own face on the basis of featural information. Infants of 2, 3, 5, and 8 months of age viewed video films of their own face side by side with that of a peer. The faces were presented under both moving and still conditions. Results indicated that by the age of 3 months, infants discriminated the self from the peer and demonstrated a significant visual preference for the face of the peer. This suggests that infants already are familiar with their own visual appearance by 3 months of age. Given that most infants had received at least daily exposure to their mirror image, it was hypothesized that featural recognition of the self developed through mirror exposure. It was further suggested that viewing one's face in the context of the contingency provided by the mirror serves as a basis for perceiving the face as belonging to the self.

The self is probably the first and one of the most important sources of stimulation the infant encounters. However, we know little about the origins of knowledge about the self. How and when does the infant come to recognize the stimulation from the self as belonging to or specifying the self? Currently, there is no good or complete answer to this question. Rather, a number of theories and views abound (Butterworth, 1990; Damon & Hart, 1982; Harter, 1983; James, 1890/1963; Neisser, 1988, 1993; Piaget, 1929/1967, 1954). The Gibsons (E. J. Gibson, 1969; J. J. Gibson, 1966, 1979/1986) provided one of the most comprehensive accounts of the origins of self-perception. According to J. J. Gibson (1979/1986), perceiving the environment also entails perceiving the self. The two are reciprocal. For example,

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when we walk through the environment, we perceive objects and events, and simultaneously, we perceive our own position and motion in relation to them. All the senses are designed to pick up information about the self and about the world at the same time. This enables infants to perceive a differentiated self from the beginning. This view contrasts with the more traditional adualistic view that the infant is born into a state of fusion with the environment and must gradually learn to distinguish between the self and other objects and events across the first year of life (e.g., Mahler & Furer, 1968; Piaget, 1929/1967, 1954).

Bahrick (1995) presented a view of the origins of self-perception consistent with J. J. Gibson's (1979/1986) perspective. The self is seen as a differentiated entity from the beginning and consists of an integrated system of knowledge about many aspects. They include the self as a unique and separate entity, as having a particular visual appearance and distinctive voice, a way of moving, as being a causal agent, and a social being of a particular gender, to name a few. Through development there is progressive differentiation and elaboration of different aspects of self. Development of these aspects may progress at different rates, yet knowledge in one domain influences that in another. There also are many sources of information about the self. Two important sources that may be detected early in infancy include our distinctive visual appearance and the visual–proprioceptive contingency provided by our physical motions. We receive proprioceptive information from the muscles, joints, and vestibular system that tells us how our body is moving, and at the same time we can see the visual consequences of this motion. This perfect intermodal visual–proprioceptive relation uniquely specifies the self. For example, even at birth, we can see and feel our hand moving simultaneously.

Recently, research and theory on the development of the perceptual bases of self has mushroomed (e.g., E. J. Gibson, 1993, 1995; Lewis, 1995: Neisser, 1993, 1995; Rochat, 1995; Rochat & Morgan, 1995a; Schmuckler, 1995, in press; Van der Meer & Van der Weel, 1995). Much of the research on infants' growing awareness of their own bodies and their ability to adjust their actions to environmental change also provide evidence of early self-knowledge. For example, neonates and very young infants systematically explore their own bodies, show coordinated hand–mouth movements, and anticipate the arrival of their hand to their mouth by mouth opening (e.g., Butterworth & Hopkins, 1988; Rochat, Blass, & Hoffmeyer, 1988). They also engage in visually guided reaching (Hofsten, 1980) and adapt the trajectory of their reach to a moving target (Hofsten, 1983). Imitation of facial expressions is accomplished by neonates (Meltzoff & Moore, 1977, 1983), suggesting an intermodal representational system for the body, and infants gradually can refine their imitative responses to look more and more like the gesture modeled (Meltzoff & Moore, 1994). Infants also use visual information to adapt their posture (e.g., Bertenthal & Bai, 1989; Butterworth & Hicks, 1977; Lee & Aronson, 1974) and respond with avoidance reactions to looming objects (Ball & Tronick, 1971; Nanez, 1988; Yonas, Pettersen, & Lockman, 1979). They quickly detect the contingency between their own leg movements and the motion of an attached mobile (e.g., Rovee-Collier & Fagen, 1981), and rapidly narrow their responding to the limb that is connected to the mobile (Rovee & Rovee, 1969). These diverse findings converge to demonstrate that young infants are capable of appropriate physical accommodations to changes in the environment and can act as an agent of change on the environment. They are consistent with J. J. Gibson's (1979/1986) view that infants pick up information specifying the self as a separate entity from the beginning. According to some recent views (e.g., Butterworth, 1992; E. J. Gibson, 1995; Neisser, 1988, 1995; Rochat, 1995) the perceptual bases of self-knowledge may develop even in the first weeks of life through actions such as those described previously and may serve as a precursor to conceptual understanding of the self. Conceptual understanding develops later, and according to Neisser (1995) it emerges only in the second year after children acquire language and the ability to represent their own permanent characteristics. Others, however, have argued that the difference between perceptual and conceptual knowledge of self may be one of degree, not kind (Bahrick, 1995; Grene, 1993). There is no clear demarcation between the two, and infants may possess perceptual knowledge of the self in one domain and conceptual knowledge in another.

Early research on the development of self focused on mirror self-recognition in toddlers and emphasized the conceptual basis of self-understanding. Using a paradigm developed by Gallup (1970), toddlers are placed in front of the mirror with a rouge spot on their nose. The age at which the child first attempts to wipe off the spot is taken as the onset of self-recognition. This behavior typically emerges between 15 and 20 months of age (e.g., Amsterdam, 1972; Lewis & Brooks-Gunn, 1979; Loveland, 1987; Schulman & Kaplowitz, 1977) and is inferred to indicate self-recognition on the basis of featural and contingency information provided by the mirror. It is assumed that the child possesses an objective representation of the self against which the mirror image is compared. This procedure, however, provides a particularly strict test of self-recognition because it entails understanding the reflecting properties of mirrors (Loveland, 1986), possessing the motivation to remove a rouge spot, and an explicit and conceptual understanding of self.

Because the mirror provides both contingency and featural information for self, the rouge spot studies have not addressed the separate contributions of each. A review of the literature suggests that sensitivity to contingency emerges prior to sensitivity to featural knowledge of self; however, the estimated ages of emergence vary considerably from one study to the next (see reviews by Butterworth, 1992; Damon & Hart, 1988; Harter, 1983). Lewis and Brooks-Gunn (1979) tested mirror recognition on the basis of contingency while controlling featural information by showing infants a live video image of the self paired with a prerecorded image of self. Discrimination between the two images was found by 9 months of age (also see Amsterdam & Greenberg, 1977). Papoušek and Papoušek (1974), however, found discrimination of a live image of self from a prerecorded one by the age of 5 months, suggesting much earlier evidence of sensitivity to contingency for self. Discrimination of self from another infant on the basis of featural information alone, however, was not found until 15 months (Lewis & Brooks-Gunn, 1979; see also Butterworth, 1990). At this age, infants first discriminated a prerecorded film of the self from that of another child.

Bahrick and Watson (1985) separated contingency information from featural information and assessed self-recognition on the basis of contingency alone using more strict controls for featural information. In the prior studies, the face created a potential confound of differential eye contact and eye motion in contingent and noncontingent displays because the live or mirror display provides constant eye contact. Papoušek & Papoušek (1974) partially addressed this problem by using video controls. We avoided this problem entirely by using infant legs as the display of self. Further, all infants were fitted with yellow booties to minimize featural differences between infants' legs. Results indicated that 5-month-olds discriminated a live film of their own legs moving from a film of another infant's legs moving. Further, featural differences among infants' legs were eliminated completely in another condition in which infants viewed a live and a prerecorded film of their own legs moving, and they again showed robust discrimination. In both conditions, infants preferred to watch the noncontingent–prerecorded film over the contingent–live film (consistent with findings of Papoušek & Papoušek, 1974). They showed this preference even when a bib occluded their view of their own legs. Thus, infants detect the intermodal relation between the proprioceptive experience of their legs moving and the visual display of that motion. Subsequent studies replicated this effect in 5-month-olds, demonstrating that it occurs for arm and hand movement (Schmuckler, in press) and that infants also discriminate various orientations of their own live body motion from one another (Rochat & Morgan, 1995b). It is clear that by 5 months of age, infants detect the contingent relation between their own body motion and the visual consequences of that motion. One of the earliest bases of self-recognition, thus, appears to be the contingency between feeling one's body motion and seeing the consequences of that motion. This information is available to infants from birth onward as they explore their own body visually and haptically.

In contrast, we know very little about the infant's knowledge and discrimination of themselves on the basis of featural information. At what point do they recognize their own face and discriminate it from that of another infant? When and how does this information come to specify the self? Information for the appearance of one's face is primarily available in reflecting surfaces. Most parents report exposing their infants to the mirror at least daily by the age of 2 months (see the Experiment 2, Results and Discussion section of this article). Research using the rouge spot technique estimates that the age of self-recognition emerges between 15 and 20 months when toddlers have a more explicit understanding of the featural self (see reviews by Anderson, 1984; Butterworth, 1995; Cicchetti, Beeghly, Carlson, & Toth, 1990; Damon & Hart, 1982; and Harter, 1983), and findings of Lewis and Brooks-Gunn (1979) also are consistent. However, given the strict criteria of self-recognition used in the rouge spot studies and the fact that infants show a perceptual understanding of self on the basis of other information at a much younger age, it seemed likely that evidence of featural understanding of the self would be evident much earlier.

Further, the ability to discriminate faces also is present very early in infancy. Young infants show excellent discrimination of both moving and static faces, including that of their mother from an unfamiliar woman (Barrera & Maurer, 1981b; Bushnell, 1982); between unfamiliar faces of the same gender (Barrera & Maurer 1981a; Fagan, 1976); and among the faces of a man, woman, child, or baby (Bahrick, Soutollo Netto, & Hernandez-Reif, (1996); Fagan, 1972; Walker-Andrews, Bahrick, Raglioni, & Diaz, 1991). However, no research has yet assessed whether the infant can recognize his or her own face and discriminate it from that of another infant. The ability to recognize one's own face on the basis of its features is a precursor to visual self-recognition and self-knowledge.

Thus, in this study infants were shown films of their own face side by side with that of another infant of the same age. Infants of 5 and 8 months were selected for the first study because self-recognition on the basis of contingency information had been shown at 5 months (Bahrick & Watson, 1985; Schmuckler, in press). Consistent with the direction of visual preferences observed previously (Bahrick & Watson, 1985; Papoušek & Papoušek, 1974; Rochat & Morgan, 1995b; Schmuckler, in press), it was hypothesized that if infants recognized their own face as familiar, they would look preferentially to the peer's face, showing a novelty preference.

EXPERIMENT 1

In this study, infants viewed a prerecorded video film of their own face alongside that of a peer under both a moving and a still presentation. Although most face perception studies have been conducted with still faces, movement provides the opportunity for abstracting invariant relations specifying the unique appearance of an object (e.g., E. J. Gibson, 1969; Kellman & Spelke, 1983; Owsley, 1983). Thus, the configuration of the facial features may be easier to perceive while moving. Further, the faces were presented in a different orientation on each trial, providing a number of views of the face.

Method

Participants. Thirty-two 8-month-olds (M = 248 days, SD = 9.6) and twenty-four 5-month-olds (M = 162 days, SD = 5.9) participated. The data of nine additional 8-month-olds were rejected from the study: six for excessive fussiness, two for experimenter error, and one for side bias (see Procedure section for details regarding criteria for side bias). Data for an additional six 5-month-olds were collected and rejected from the study: three for excessive fussiness and three for experimenter error. Further, any participant who had an identical twin also was excluded from the study. All infants in this and the subsequent study were normal, healthy, full-term infants (at least 37 weeks gestation) with no complications during delivery. The sample was primarily middle class and from diverse ethnic backgrounds. Parents were selected for having at least 12 years of education.

Video displays. Color video films were made of the infants' faces (head, neck, and shoulder area) measuring approximately 23 × 18 cm. To standardize clothing and irrelevant aspects of appearance, all infants were fitted with a yellow bib for filming and were filmed against a black background. Each face was videotaped in four different orientations for 1 min each: facing center and looking straight ahead (C), facing 45° to the left side (L), 45° to the right side (R), and facing center, looking up, approximately 45° (U). During the filming session, an interesting wind-up toy was held in front of the infant, positioned so as to elicit attention in each of the four orientations. Thus, although the infant's orientation was constrained, the infants produced natural head, eye, and upper body movements, typical of exploring an interesting object.

Apparatus. Infants were seated in an infant seat facing two 19-in. (Panasonic BT–S1900N) video monitors, approximately 55 cm away. A set of colored Christmas tree lights and a mechanical toy dog were positioned between them and were used to attract attention to center prior to each trial. The video monitors were surrounded by black posterboard with three apertures through which observers could monitor infant visual fixations. The visual displays were videotaped with a Panasonic WV 3170 color video camera. They were displayed through an edit controller (Panasonic VHS NV–A500) and two switch boxes connected to two Panasonic video decks (NV–8500 and AG–6300). This allowed the experimenter to present either image on either monitor without the time or noise resulting from switching video cassettes.

A trained observer who was unaware of the participant's condition (moving vs. still) and unaware of the lateral positions of the films of self versus peer, monitored infant visual fixations from an aperture between the two video screens. She held a set of buttons connected to a Rustrak strip chart recorder and depressed one button while the participant fixated the left-hand screen and another while the participant fixated the right-hand screen.

Procedure. Prior to participating in the study, parents completed a questionnaire that assessed the amount of mirror exposure the infant had received. The infants' faces then were videotaped in the testing room for 4 min, 1 min in each of four orientations (C, R, L, U). Following a 10-min break, during which the infant was entertained in an adjacent waiting room, the test session began.

Each infant received a visual preference test with his or her own face side by side with that of an age-matched peer under both a moving and a still condition. In the moving condition, infants received four 30-sec trials of the self and peer faces side by side. On each trial both the self and peer were shown in the same general orientation, moving naturally as they did while observing the interesting toy. Each of the four different orientations was shown across the four trials, one on each trial. The lateral positions of the displays of the self versus the peer alternated across the four trials. In the still condition, infants received four 15-sec trials of the self and peer displays side by side. These trials were 15 sec long because static images recruit less attention than moving images and pilot participants seemed restless during longer (30 sec) exposures to static displays. The particular static images presented were selected from the moving videos of each infant and were chosen to be good representations of each orientation. As in the moving condition, a different one of the four orientations was shown on each trial and the lateral positions of the self and peer images alternated across the four trials. Figure 1 displays an example of the displays received for the still condition by one 8-month-old, showing each of the four orientations.

The order of conditions was counterbalanced across infants such that half of the participants at each age received the still condition first and the moving second, and the other half received the opposite order. Further, half the infants in each of these groups was shown their own image on the right screen first and that of the peer on the left, whereas the other half received the opposite arrangement. Two orders for orientation also were chosen and were counterbalanced across infants such that half of the participants within each of these groups received each order (C, L, R, U or U, R, L, C) across the four trials of each condition.

A yoked-control procedure was used for pairing each infant's display with that of an age-matched peer. That is, each infant served as the novel peer display for the next infant of the same age who was tested. This randomized differences in appearance and movement of faces across face pairs and allowed infants to view a face that was very similar in appearance or dissimilar to their own with equal likelihood.

Two criteria were established for including the participant's data. First, it was required that at least six of the eight trials be completed to have sufficient data for analyses. Second, to ensure that the participant had noticed both visual displays and had the opportunity to actively choose between them, infants were required to fixate both visual displays during the first two trials of each block. The infant's data were excluded if they devoted less than 3% of the total fixation time to one of the displays.

Results

Infants spent an average of 61% of the available time (120 sec) looking at the moving displays and 60% of the available time (60 sec) looking at the still displays. At 8 months, they fixated the moving displays for 68.7 sec (SD = 25.2) and the still

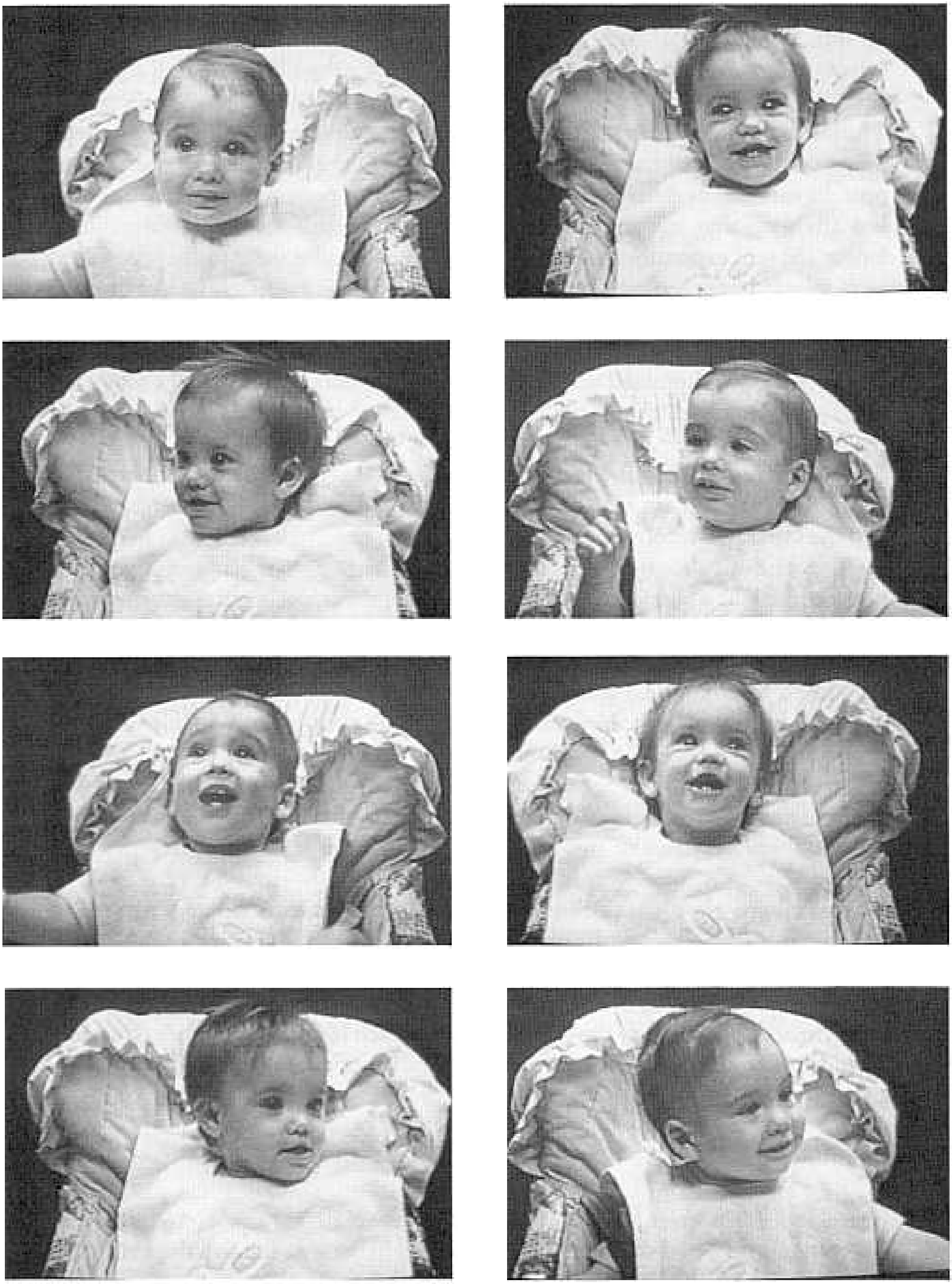

FIGURE 1 Photograph of the visual displays of self and peer in four orientations

displays for 32.5 sec (SD = 10.8). At 5 months, infants fixated the moving displays for 77.5 sec (SD = 29.0) and the still displays for 39.0 sec (SD = 14.2).

Data were expressed in terms of the proportion of total looking time (PTLT) infants spent fixating the novel peer's face. Looking proportions for all eight trials were averaged for each participant. This overall proportion also was broken down in two ways: as a function of block (the first four trials vs. the second four trials) and as a function of condition (the four moving trials vs. the four still trials). Recall that both block and condition were within-subjects factors; however, they were crossed such that for half the participants Block 1 contained the moving trials and Block 2 the still trials, whereas the other half received the reverse arrangement. Consequently, these two factors could not be entered into the same analysis and the overall means could only be broken down according to one of these factors at a time. A secondary observer monitored infant visual fixations for 22 of the 56 participants (eleven 8-month-olds and eleven 5-month-olds). Interobserver reliability was calculated by correlating the PTLTs for the primary and the secondary observers across the eight trials for each infant and averaging across infants. The average correlation was .95.

Table 1 displays the looking proportions for infants at each age for each condition. To assess whether infants were able to discriminate their own face from that of the peer, single-sample t tests against the chance value of .50 were conducted on the PTLTs to the peer for each age separately.[1] For the moving and still trials combined (Trials 1–8), both the 8- and the 5-month-olds showed a significant looking preference for the peer's face, $t(31) = 3.30$, $p < .005$ and $t(23) = 2.58$, $p < .02$, respectively. A total of 27 of the thirty-two 8-month-olds ($p < .01$) and 16 of the twenty-four 5-month-olds ($p < .1$) showed this preference. Infants also showed a significant preference for the peer on the first block of trials (Trials 1–4), irrespective of condition, at both ages, $t(31) = 3.16$, $p < .005$; $t(23) = 2.95$, $p < .01$, respectively, but not on the second block of trials (all ps > .1). Infants may have been somewhat bored and restless by the second block of trials.

Furthermore, results were analyzed separately for the moving and the still conditions irrespective of trial block. For the moving condition, both the 8- and 5-month-olds showed a significant looking preference for the peer, $t(31) = 2.28$, $p < .05$ and $t(23) = 3.21$, $p < .005$, respectively; whereas for the still condition, only the 8-month-olds showed a significant looking preference for the peer, $t(31) = 2.50$, $p < .02$. A more fine-grained analysis revealed that the 5-month-olds did show a significant looking preference for the still image of the peer during the first block of trials, $t(11) = 2.19$, $p = .05$, but not during the second block of trials. This may be because infants were more bored by the second block of trials, and discrimination of the still faces may have been more difficult.

[1]The looking proportions were evaluated with single-sample t tests against the expected proportion of .50 because the time spent looking to the side-by-side displays of peer versus self are interdependent and cannot directly be compared with one another in statistical analyses.

TABLE 1
Experiment 1: Proportion of Total Looking Time to the Face of the Peer as a Function of Age and Condition

Age	*Block 1*	*Block 2*	*Moving*	*Still*	*Total*
5 months[a]					
M	.56	.54	.57	.53	.55
SD	.11	.12	.10	.12	.09
t	2.95**	1.52	3.21***	1.39	2.58**
8 months[b]					
M	.56	.53	.55	.55	.55
SD	.11	.11	.12	.11	.08
t	3.16***	1.67	2.28*	2.50*	3.32***

[a]$n = 24$. [b]$n = 32$.

*$p < .05$, two-tailed. **$p < .01$, two-tailed. ***$p < .005$, two-tailed.

Further analyses assessed the effects of secondary variables. To determine whether infants performed differently as a function of age, condition, or condition order, a three-way analysis of variance (ANOVA) was conducted on PTLTs with age, condition (moving, still), and condition order (moving first, still second, vs. still first, moving second) as main factors, with repeated measures on the second factor. Results indicated no significant main effects or interactions (all *p*s > .10). Evidence of side preferences was assessed by calculating the PTLT to the right side regardless of the stimulus display. *T* tests indicated that this proportion did not differ from chance at 8 or 5 months, $t(31) = .26$, $p > .1$ and $t(23) = 1.72$, $p > .05$, respectively, when scores of both blocks were averaged. When Blocks 1 and 2 were examined separately, however, a significant preference for the right side emerged in Block 1 for the 5-month-olds, $t(23) = 2.56$, $p < .02$. Given that the side of peer and self images was counterbalanced, this side bias cannot account for the main findings of the preference for the image of the peer in that condition. Furthermore, a three-way ANOVA with age, block (1 vs. 2), and condition order (moving–still vs. still–moving) revealed no significant main effects or interactions. Finally, a three-way ANOVA with age, gender, and orientation order (CLRU vs. URLC) also revealed no significant main effects or interactions.

Discussion

These findings demonstrate that 5- and 8-month-old infants already are able to recognize their own face as familiar and discriminate it from that of another infant of the same age. Both the older and younger infants showed evidence of discrimination. When the faces were moving, infants of both ages distinguished their own face from that of the peer. When the faces were static, older infants showed discrimination. Younger infants discriminated the static faces during the first block of trials.

Discrimination of the self from the peer must be based on familiarity with featural information provided by the face. Because all films were prerecorded, no motion contingency was available, as would be the case for mirror images. Further, although discrimination was robust in the moving condition, movement was not necessary for discrimination. Discrimination was evident even in the static condition in which only featural information differentiated the faces from one another. In sum, even by 5 months of age, infants already are sufficiently familiar with the visual appearance of their own face to distinguish it from that of another infant of the same age.

On what basis might infants have learned about their own visual appearance? One important basis for familiarity with the features of one's own face is mirror exposure. Results of a questionnaire completed by the parents of our participants indicated that all but 4 of the infants received daily exposure to their own faces in the mirror. Three of those 4 received at least weekly exposure to their mirror images and only one parent of a 5-month-old reported no mirror exposure at all. Thus, infants' familiarity with their own features most likely originated from mirror exposure.

Further, results of this study indicated that infants demonstrated their familiarity with their own faces by looking preferentially to the novel face of the peer. Both the older and younger infants showed this pattern. When the faces were moving, infants of both ages showed significant preferences for the peer face. The direction of this preference is consistent with prior findings of self-perception on the basis of contingency information for infants of this age (Bahrick & Watson, 1985; Rochat & Morgan, 1995b; Schmuckler, in press). Apparently by 5 months of age, infants are more interested in watching the face of a peer than their own face.

EXPERIMENT 2

At what age do infants first develop the ability to discriminate their own image from that of another infant? What is the direction of their visual preference when this ability emerges? Bahrick and Watson (1985) hypothesized that prior to 5 months when infants show a visual preference for the display of a peer, there may be an age when infants are first learning about the self and are more interested in looking at the display of the self. Bahrick and Watson (1985, Experiment 4) tested 3-month-olds in a procedure identical to that used for 5-month-olds to assess perception of contingency information specifying the self. Infants received a contingent film of their own legs moving alongside a prerecorded film of a peer's legs. Results indicated no significant visual preference and no overall evidence of discrimination. However, there was a significant bimodal distribution such that some infants showed strong preferences for the self and others showed preferences for the peer. Further, overall 3-month-olds were more interested in the display of the self than 5-month-olds.

These results suggested a period of transition around the age of 3 months from interest in the self to interest in the peer. Therefore, in this study, we tested infants of 2 and 3 months to determine when evidence of discriminating the self from the peer on the basis of featural information might emerge. Further, if discrimination were observed, would infants prefer to look at the display of self over that of the peer?

Method

Participants. Twenty-four infants of 2 months (M = 61.7 days, SD = 7.0), and 24 infants of 3 months (M = 105.7 days, SD = 9.3) participated. The data of eight additional 2-month-olds were collected and rejected from the study: one for equipment failure, one for experimenter error, three for excessive fussiness, two for falling asleep, and one for side bias. The data of six additional 3-month-olds were rejected from the study, three for equipment failure, one for experimenter error, and one for excessive fussiness.

Procedures. The visual displays, apparatus, and procedures were identical to those of the prior study.

Results and Discussion

Infants spent an average of 64% of the available time (120 sec) looking at the moving displays and 87% of the available time (60 sec) looking at the still displays. At 3 months, they fixated the moving displays for 82.15 sec (SD = 21.9) and the still displays for 56.4 sec (SD = 21.2). At 2 months, infants fixated the moving displays for 78.8 sec (SD = 20.4) and the still displays for 48.0 sec (SD = 11.4). The secondary observer monitored visual attention for 12 of the 48 infants (four 2-month-olds and eight 3-month-olds). Interobserver reliability was calculated as before and averaged .97 (SD = .031).

Visual preferences are displayed in Table 2. Fourteen of twenty-three 3-month-olds and 11 of twenty-three 2-month-olds looked more to the peer across the two trial blocks ($p > .1$, both ages; one participant at each age looked equally to both self and peer). Single-sample t tests were conducted on the PTLTs (against .50) to determine whether infants showed evidence of discriminating their own image from that of a peer at either age. Results indicated no evidence of discrimination at either age for PTLTs of the two blocks combined, or for the first block of trials (all $ps >$ .10). However, for the second block of trials, the 3-month-olds showed a significant looking preference for the film of the peer, $t(23) = 2.16, p < .05$. Apparently, given sufficient time, even infants of 3 months also are able to differentiate between their own face and that of another infant and prefer to watch the other infant.

Further analyses showed that it was the still condition that was carrying this effect, $t(11) = 2.39, p < .05$. This seemed surprising at first; however, a two-way ANOVA on the PTLTs to the peer face for the 3-month-olds with condition (moving vs. still) as a within-subjects factor and condition order as a between-subject factor indicated a significant interaction, $F(1, 22) = 6.58, p = .018$, and no main effects. This interaction reflects the fact that infants who received the moving faces first and the still faces second showed greater preferences for the peer in the still condition (M = .61) than infants who received still faces first (M = .48). Perhaps viewing four 30-sec trials of the moving faces first (in Block 1), facilitated differentiation of the features of the still faces in Block 2, whereas receiving still faces in Block 1 did not facilitate differentiation of the moving faces in Block 2.

Further analyses assessed the effects of secondary variables. A three-way ANOVA was conducted on the PTLTs to determine whether infants showed any main effects of age, condition (moving vs. still) or condition order (moving–still vs. still–moving). Results indicated no significant main effects and only one significant interaction, the Condition × Condition Order interaction, $F(1, 44) = 4.67, p = .04$, discussed previously. Effects of side preferences were assessed by examining the PTLT to the right side regardless of the stimulus display as before. *T* tests indicated that this proportion did not differ from chance at 3 months for both blocks averaged, $t(23) = .73, p > .1$; however, at 2 months infants did show a significant preference for the right-hand display overall, $t(23) = 2.24, p < .05$. When Blocks 1 and 2 were examined separately, only the 2-month-olds again showed a significant preference for the right side in Block 1, $t(23) = 2.13, p < .05$. Further, a three-way ANOVA with age, block, and condition order (moving–still vs. still–moving) revealed no significant main effects or interactions. Finally, a three-way ANOVA with age, gender, and orientation order (CLRU vs. URLC) on PTLTs to the peer also revealed no significant main effects or interactions.

TABLE 2
Experiment 2: Proportion of Total Looking Time to the Face of the Peer as a Function of Age and Condition

Age	*Block 1*	*Block 2*	*Moving*	*Still*	*Total*
2 months[a]					
M	.51	.51	.53	.49	.51
SD	.13	.13	.13	.13	.09
t	.33	.46	.96	.30	.69
3 months[b]					
M	.48	.57	.52	.54	.53
SD	.15	.16	.14	.17	.13
t	.51	2.16*	.68	1.23	.94

[a]*n* = 24. [b]*n* = 24.

*$p < .05$, two-tailed.

Analyses comparing preferences for the face of the peer across all four age groups also were conducted. Figure 2 depicts these preferences for the two blocks combined as well as for each block separately and for the moving and still conditions separately. Results of an ANOVA with Age (2 vs. 3 vs. 5 vs. 8) and Block (1 vs. 2) as main factors indicated no significant main effects of age or block ($ps > .1$) and a significant Age × Block interaction, $F(3, 100) = 2.76, p = .046$. As can be seen from the figure, the 3-month-olds showed greater preferences in Block 2, whereas the older participants show greater preferences in Block 1. This suggests that younger infants require more time to differentiate the faces than older ones. An ANOVA with age (2 vs. 3 vs. 5 vs. 8) and condition (moving vs. still) also was conducted and indicated no main effects or interaction.

We also conducted a phone interview to determine at what age parents began to expose their infants to their own face in the mirror. Parents of the twenty-three 3-week-olds ($M = 22.8$ days, $SD = 5.1$) contacted reported the following frequencies of mirror exposure: several times per day, 17%; at least once per day, 17%; several times per week, 13%; occasionally or rarely 17%; never, 35%. In summary, at 3 weeks of age many infants receive regular mirror exposure (daily, 35%), whereas many others have not yet been explicitly exposed to the mirror at all (35%). Parents were also asked to estimate when they began exposing their child to the mirror image regularly. Of the 11 participants who had received mirror exposure at least several times a week, the age when the infant first was regularly exposed to the mirror was the first or second day of life for 6 infants and on Day 8, 14, 15, 18, and 20 for the remaining infants ($M = 7.8$ days, $SD = 7.5$). Further, results of the mirror questionnaire given to the parents of the infants in our sample revealed that 60% of our 2-month-olds and 83% of our 3-month-olds received daily or more than daily exposure to the mirror. All but one of the remaining participants (a 2-month-old who received no mirror exposure) received exposure at least weekly or several times per week. Thus, although there is substantial variability in age of onset, by 2 or 3 months of age most infants have had regular, daily mirror exposure for some time.

GENERAL DISCUSSION

Results of this research indicate that visual recognition of one's own face on the basis of featural information emerges during the first half-year of life. Such early evidence of visual self-recognition has not been previously documented. One reason for this may be that the use of visual preference as an index of self-recognition is more appropriately matched to the exploratory abilities of young infants and provides a less stringent test of self-recognition than the measures of self-directed behavior used in prior studies. These findings demonstrate that infants are able to discriminate a display of their own face from that of another infant by the age of 3 months. At 3 months, they show an emerging visual preference for the face of the

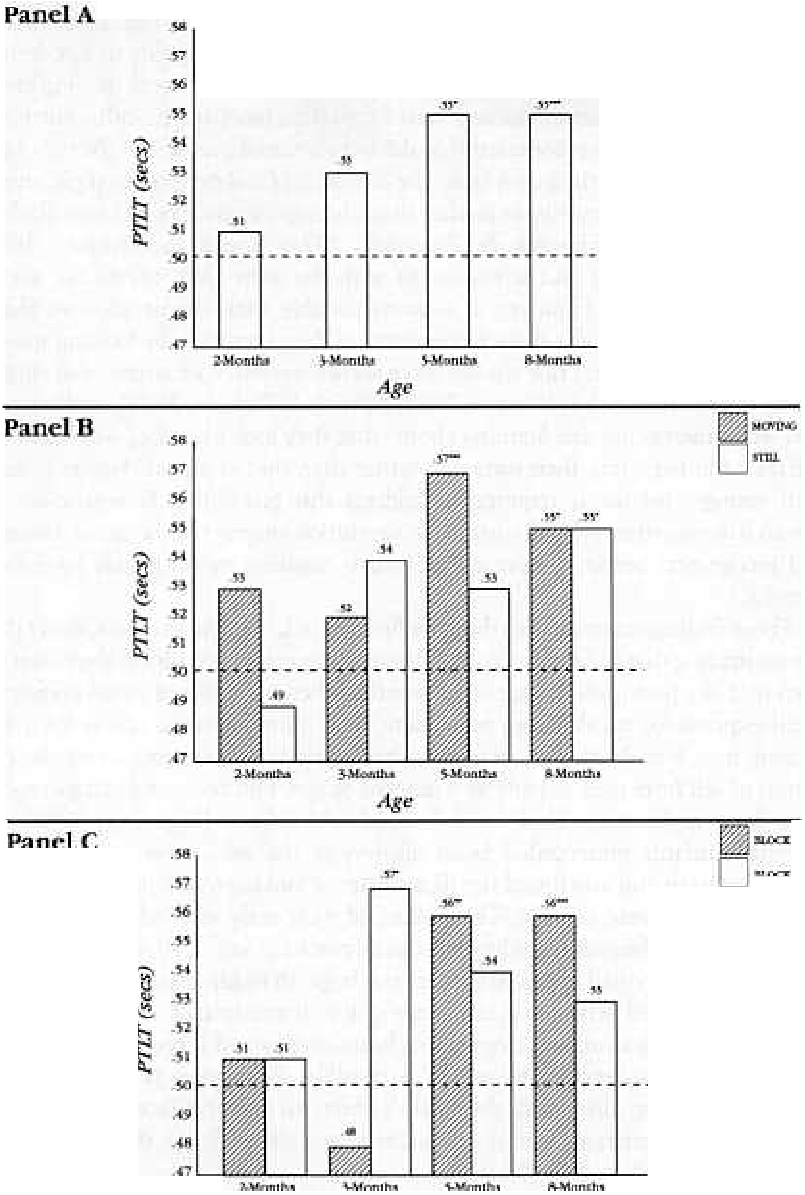

FIGURE 2 Proportion of total looking time (PTLT) to the face of the peer as a function of age for all trials combined (panel a), the moving versus still trials (panel b), and block 1 versus block 2 (panel c)

peer by the second block of trials, whereas at 5 and 8 months, this discrimination is more robust and is evident in the first block of trials. The ability to discriminate between the faces was evident regardless of whether the faces were moving or still, although discrimination was more robust for moving faces at 5 months. Further, at all ages tested, infants manifested this ability by a visual preference for the display of the peer's face over their own face. The direction of this preference replicates the results of prior self-recognition studies based on contingency perception (Bahrick & Watson, 1985; Papoušek & Papoušek, 1974; Rochat & Morgan, 1995b; Schmuckler, in press) and is consistent with the view that infants are socially oriented by this age. However, it remains possible that infants younger than 2 months potentially might show recognition of their own face by looking more to the self than the peer. Prior studies have shown evidence of attentional shifts in young infants (Bahrick & Watson, 1985; Bahrick & Pickens, 1995), and it may be that when infants are first learning about what they look like, they would be more interested in exploring their own face rather than that of a peer. Future research with younger infants is required to address this possibility. Nevertheless, this research demonstrates that featural self-recognition emerges by the age of 3 months, and recognition becomes more robust and is manifest more quickly by 5 and 8 months.

These findings contrast with the prior findings of Lewis and Brooks-Gunn (1979) demonstrating that infants do not discriminate a prerecorded film of their own face from that of a peer until the age of 15 months, when measures of visual preference, facial expression, vocalization, movement, and imitation were taken for infants ranging from 9 to 24 months of age. Rather, these findings demonstrate discrimination of self from peer as early as 3 months of age. Further, our findings recently have been replicated with 5- and 8-month-old infants (Legerstee, 1996). She presented infants prerecorded facial displays of the self, a peer, and a doll in successive trials and also found significantly more looking to the display of the peer when the faces were moving. The finding of such early featural recognition has implications for theories regarding the development of self. It suggests that knowledge about one's visual appearance does not begin in toddlerhood at the age when mirror self-directed behavior in the rouge task is demonstrated. Rather, familiarity with one's facial features develops throughout infancy and is present long before a full conceptual understanding of self is possible. Perception of one's own face appears to develop along with the infant's ability to perceive faces in general and along with the emerging ability to perceive and differentiate the other diverse sources of stimulation from the self.

How might the infant's ability to distinguish his or her own face from that of a peer have emerged? We suggest that it developed through prior visual experience with the mirror. Parents of all but 2 infants in our sample reported that infants received regular mirror exposure. The mirror allows the infant to become familiar with his or her own facial configuration along with the visual–proprioceptive contingency that specifies self.

When do infants come to understand that the display of their own face viewed in the mirror or video actually specifies the self? This intriguing question cannot be answered by this research. There is no direct test of whether a preverbal child understands "This is me!". It is possible that the infants in our study failed to perceive the video stimulation from their own face as specifying the self. Instead, they may have shown discrimination of self from peer on the basis of novelty. That is, they may have perceived the display of their own face as a familiar one and that of the peer as a novel one and preferred to look at the novel face.

Alternatively, it may be that infants perceive a differentiated self from the beginning (J. J. Gibson, 1979/1986) and that the stimulation in the mirror and video displays is attributed to the self from the start, or in early infancy. The abundance of research demonstrating the infant's ability to adapt his or her own body to environmental change (discussed earlier) supports the view that the self is a differentiated entity even in the first months of life. Further, our perceptual systems provide information about the self and the environment simultaneously (J. J. Gibson, 1979/1986). Infants have a great deal of experience with the visual–proprioceptive contingency provided by observing and feeling their own body motions from birth onward and are sensitive to this contingency, even in video displays (Bahrick & Watson, 1985; Rochat & Morgan, 1995b; Schmuckler, in press). The perfect contingency generated by visual feedback from one's body motions and the proprioceptive experience of those motions is excellent information for self. It specifies the *ecological self* (Neisser, 1988): the existence of a differentiated self, situated in a particular spatial location, with a body that has distinct boundaries. This contingency also is available in mirror stimulation and specifies that the face viewed in the mirror belongs to the self, despite its incongruent spatial location. It is similar to the visual–proprioceptive contingency the infant experiences from birth onward when watching his or her own body move. Therefore, early experience with mirror stimulation and the contingency it provides may enable the infant to attribute the facial configuration seen in the mirror to the self. The early sensitivity to this contingency thus may provide the basis for the emerging awareness that the features viewed in the mirror specify the self. Regardless of when this understanding emerges, there appears to be a growing awareness of one's own appearance during the first half-year of life, and the ability to discriminate one's features from those of a peer is evident in early infancy. This is an important part of the child's developing sense of self and must be addressed by current theories of the development of self-perception.

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