The Self in Infancy: Theory and Research
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CHAPTER 17

Intermodal Origins of Self-Perception

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Introduction

The self is certainly the first and one of the most intriguing sources of stimulation that the infant encounters. We create a diversity of rich and varied types of stimulation to all the sensory systems through our actions in the context of a changing environment. The infant moves her hands to her face and mouth; sees and feels her body moving and hears her own vocalizations; and at the same time sees, hears, and feels people and other objects moving around her. Through our exploratory activities, we discover properties and affordances of objects and events in our environment, and at the same time and in the same way, our sensory systems specify the nature of our own actions and properties of the self.

> Information about the self accompanies information about the environment, and the two are inseparable. Egoreception accompanies exteroception, like the other side of a coin. Perception has two poles, the subjective and the objective, and information is available to specify both. One perceives the environment and coperceives oneself (J.J. Gibson, 1979, p. 126).

In the quote above, Gibson (1979) points out the reciprocal nature of exploring the self and the environment. He suggests that when we look at our environment, we perceive objects and events, and at the same time we obtain information about the position and motion of our head, body, arms, and hands. When we walk, optical information (flow patterns) specifies our changing position in space and at the same time the unchanging positions of objects and surfaces in the environment. We perceive ourself in relation to the environment. In this manner, knowledge of the self and the world develops hand in hand.

What are the origins of our unique abilities for self-reflection, possession of a self-concept, and understanding of self as both subject and object? It is suggested here that the self-understanding of adults develops from the perceptual experiences

of infancy. The action systems of the infant interact with the environment to create at first a preconceptual and then a more explicit and accessible basis of knowledge about the self. This chapter will focus on the development of two kinds of knowledge about the self in early infancy: intermodal information relating one's seen and felt motions, and featural information about one's visual appearance. Knowledge about these aspects of self derive from different sources of information and thus may develop separately, but in an interrelated manner. The provocative question of, when do infants know that the stimulation from the self specifies the self, will also be explored in the context of the infant's increasing sensitivity to these two sources of information.

History

Accounts of the nature and development of self-perception abound. They are characterized by diverse taxonomies, differing theoretical perspectives, and divergent empirical approaches. James (1890) distinguished between two primary aspects of the self: the existential self, or "I," and the empirical self, or "me." This distinction persists in our current thinking. The "I" is considered the "knower," the agent of action, the self as subject, and is experienced through four kinds of awareness: agency, distinctness, continuity in time, and ability to reflect on the self. The "me" is considered to be the self as object, the sum of all one's parts, including material, social, and spiritual aspects (see reviews by Butterworth, 1990; Damon & Hart, 1982, 1988; Harter, 1983). Along similar lines, Rochat (in press) has recently described the "I" as the "situated self," stemming from perception of the self as a separate entity in the environment, and the "me" as the "identified self," entailing conceptual knowledge about the self.

How does this self-knowledge develop? Baldwin (1902), Freud (1922), and, more recently, Mahler and Furer (1968) describe the infant as lacking the capacity for self-awareness and born into an adualistic state of fusion with the environment. Piaget (1954, 1967) also espoused this view and described the "adualistic confusion" as characterizing much of the first year of life. Infants, according to Piaget, experience no distinction between the self and the not-self. Not until the age of 8 or 9 months do they come to gradually differentiate themselves from other objects and events in the environment.

In contrast with these traditional views, there is now a resurgence of interest in the early origins of self-perception in infancy. Recently, a number of investigators have rejected the adualistic view and have posited that infants are capable of differentiating some aspects of self during the first days of life (e.g., Butterworth, 1990, 1992; Gibson, 1993; Lewis, 1979; Meltzoff, 1990; Neisser,

1988, 1993; Rochat, in press; Samuels, 1986). For example, Rochat (in press) proposes that the perception of self as a separate and causal agent ("situated self") develops in the first months of life and is a developmental precursor to the conceptual self ("identified self"). The Gibsons (E.J., 1969; J.J., 1966; 1979) provide one of the most well-developed accounts of the origins and development of self-perception, which is based on perceptual experience. Their ecological view rejects the notion of early fusion with the environment and emphasizes the interdependence between perception of the self and perception of the world (as conveyed by the quote above). All the senses have both a propriospecific (specifying self) and an exterospecific (specifying other) function. Thus, the act of perceiving entails both self-perception and perception of the environment at the same time. This enables infants to directly perceive a differentiated self from the beginning. According to this view, the infant comes into the world prepared to detect invariant information specifying the self through all the senses. For example, vision provides powerful information for the self through changes in the optic array that result from one's motion. Posture and locomotion are controlled through vision, even in young infants (see Butterworth, 1990, for a review).

Research in the areas of perceptual and cognitive development has proliferated in recent years and has shaped our view of the infant's developing sense of self. It suggests that young infants have a growing awareness of self across the first months of life. Body awareness is demonstrated through patterns of tactual exploration and self-directed behavior in neonates; they systematically explore their own bodies and anticipate the arrival of their hand to their mouth by mouth opening (e.g., Rochat, Blass, & Hoffmeyer, 1988; see Butterworth, 1990, for a review). Even neonates show imitation of facial expressions, demonstrating an intermodal representational system for the body (Meltzoff & Moore, 1977; 1983). Furthermore, young infants correct their imitative responses to gradually approximate the gestures of the model, suggesting that they have access to proprioceptive information (Meltzoff & Moore, 1994). Visually guided reaching is present in neonates (Hofsten, 1980), and young infants can adapt the trajectory of their reach to catch a moving object (Hofsten, 1983) and show anticipatory hand-shaping when reaching for objects of different sizes (Bower, Broughton, & Moore, 1970). Young infants detect the contingency between their leg motion and that of an attached mobile (Rovee-Collier & Fagen, 1981) and quickly narrow down their response to the one limb that is attached to the mobile (Rovee & Rovee, 1969). Infants also use visual information to adapt their posture (e.g., Bertenthal & Bai, 1989; Butterworth & Hicks, 1977; Lee & Aronson, 1974), and even neonates are able to compensate for different gravitational forces when moving their limbs (Van der Meer, 1993). Preliminary results also indicate that 1-month-old infants distinguish between a touch on the cheek by their own hand

versus a touch by that of another object and show a rooting response only to objects other than the self (Rochat, in press). Furthermore, by 1 to 2 months of age, looming objects elicit avoidance reactions (Ball & Tronick, 1971; Nanez, 1988; Yonas, Pettersen, & Lockman, 1977).

These abilities show an impressive awareness of the body in space and time. They demonstrate how infants adjust their actions to environmental change, and they support Gibson's ecological view that exploration involves perception of both the world and the self at the same time, and in the same way. These converging findings are consistent with the view that infants perceive the self as a separate entity in the first months of life and are capable of both accommodating to changes in the environment and acting as agents of change on the environment. The evidence for this conclusion is robust and comes from a variety of domains that tap different response systems and utilize different procedures. However, the evidence is also indirect and therefore must be viewed as a working hypothesis at present.

Overview and Definition of "Self"

This chapter explores the intermodal bases for self-perception in early infancy. I will review evidence from a series of studies conducted in our lab that suggests that infants make important strides toward perceiving and understanding the self, even during the first half year of life. Early experience serves to establish a foundation of knowledge about the self that is an antecedent to later self-awareness and self-understanding. The view of self articulated here is consistent with that developed by the Gibsons. A central tenant of this view is that self-knowledge is rooted in the perceptual experiences of infancy. Further, the infant is seen as a differentiated entity from the start, capable of perceiving the self and the environment in relation to one another through detecting invariant relations. Self-perception provides the basis for knowledge about the self and for the development of a conceptual understanding of the self. The perceptual and conceptual modes of experiencing the self are viewed along a continuum. This has been succinctly pointed out before: "To perceive the environment and to conceive it are different in degree, not in kind. One is continuous with the other" (Gibson, 1979, p. 258). "Just as perceiving and conceiving the environment are different in degree but not in kind, so are perceiving and conceiving oneself" (Grene, 1993, p. 117). Thus, as Grene suggests, the conceptual understanding of self emerges from the perceptual experiences of infancy.

Here, the self is considered to be a constellation of perceptions, beliefs, and knowledge about different aspects, including the self as a differentiated entity: as having a unique identity that persists through time and space, as having a

particular visual appearance, a way of moving, sound of one's voice, odor and taste, being a causal agent, a social being and of a certain gender, to name some aspects. Other investigators recently have also emphasized the diverse set of phenomena that fall under the umbrella of "self." Samuels (1986) identified 11 potential bases for self-perception in infancy, including body boundaries, perceptual invariants, and social contingencies. Certainly the diversity of topics represented in this volume attests to the multifaceted nature of our concept of the self, as well as to the resurgence of interest in the topic.

Neisser (1988) distinguishes between five kinds of self-knowledge, each based on different sources of information, including the "ecological" and "interpersonal" selves, both based on perceptions; the "extended" self, based on memory; the "private" self, based on conscious experience and feelings; and the "conceptual" self, based on beliefs and assumptions. Thus, Neisser has differentiated aspects of "the self" according to the type of information accessed, that is, perceiving, remembering, experiencing/feeling, or conceiving. According to Neisser (1993, p.3), "each kind specifies a different aspect of the individual and thus implicitly defines a different sort of self." I find it more useful, however, to view the self as having many related aspects or domains defined by content. These domains or aspects cut across the five kinds of self described by Neisser (1993). For example, the sound of my voice, the appearance of my face, or the contingency that specifies I am an agent of action are all aspects that are perceived, remembered, experienced, and conceived. What is perceived today becomes remembered or conceived tomorrow. Given this view and the assumption that perception and conception lie along a continuum, it is likely that knowledge of different aspects of the self develops at different rates. Thus, at one time, the infant may posses only perceptual information about one aspect (e.g., appearance of the face) and a conceptual understanding of another (e.g., I cause things to happen in the world). If the distinction between perception and conception is one of degree, there can be no clear boundary between them, and the point where conceptual understanding begins and perceptual knowledge leaves off cannot be uniformly defined or clearly demarcated. It is therefore not surprising that studies with different procedures and content areas yield divergent criteria and ages of onset for conceptual knowledge of self.

To summarize the view presented here, the development of self-knowledge begins with the perceptual experiences of infancy. There is but one self with many facets. Exploration in infancy leads to the progressive elaboration of different aspects of self, including differentiation of aspects of both the "I" (perceptual) and then the "me" (conceptual) within a given domain. Development of knowledge about various aspects of self may proceed at different rates, in different ways, and on the basis of different sources of information. Yet the overall effect is the

evolution of a coordinated system of knowledge. This is seen as a gradual process of differentiation of both relatively distinct yet interrelated processes, where knowledge in one domain may inform exploration in another, and differentiation of some aspects precedes and facilitates differentiation of others. Knowledge about the self, of course, also evolves in the context of our general knowledge about the world, and is both influenced by and influences the attainment of general developmental milestones. Much research lies ahead before these processes are identified and their interrelations delineated. This chapter reports a first step in this direction. My focus is on the development of two different and interrelated bases for self-knowledge: visual information about the self and contingent feedback from self-motion. The "visual self" includes what is commonly referred to as one's appearance. It consists of all the visual characteristics of the face and body that distinguish us from others, that is, "what I look like." The "contingent self" entails the perception of a relation between one's own actions and their consequences, which in this case is the resulting visual stimulation. This is an intermodal relation between vision and proprioception. It is also an important basis for perceiving causality and the self as an agent of change in the environment. Before reviewing research on these two topics, let us put this in the context of prior research on self-recognition in children and toddlers.

Studies of Self-recognition

In the past, systematic studies of the development of self have primarily focused on the development of self-recognition in toddlers and young children, using behavior in from of the mirror as an index of self-recognition. In a paradigm originated by Gallup (1970) for use with primates, the child's nose is unobtrusively marked with a rouge spot, and the child is placed in front of the mirror. The age at which children first show mark-directed behavior and attempt to wipe off the spot has been considered the onset of self-recognition. It is assumed that this behavior reflects the existence of a mental representation of self against which the mirror image is compared. Mark-directed behavior typically emerges sometime between 15 and 20 months and is typical by about 2 years of age (Amsterdam, 1972; Johnson, 1982; Lewis & Brooks-Gunn, 1979; Loveland, 1987; Schulman & Kaplowitz, 1977; see Anderson, 1984; Cicchetti, Beeghly, Carlson, & Toth, 1990; Damon & Hart, 1982; and Harter, 1983, for reviews). The attempt to wipe off the rouge spot is inferred to indicate self-recognition on the basis of featural and contingency information. It entails an understanding that the self has stable features that do not include a rouge spot on the nose. It may reflect some degree of conceptual understanding of self (the "me") rather than

perceptual knowledge of self (the "I"). Furthermore, this ability is delayed in children who are mentally retarded (e.g., Mans, Cicchetti, & Stroufe, 1978), which indicates its association with cognitive development. Nevertheless, it appears that the rouge-spot task provides a stringent test of self-recognition, given its reliance on a number of complex abilities that must also undergo development. For example, the infant's understanding of the properties of reflecting surfaces develops with age (Loveland, 1986), and the response system used to index self-recognition (mark-directed behavior) may also develop with age and is thus not well suited for use in testing young infants.

Prior to the time when toddlers demonstrate self-recognition by their behavior in the rouge-spot mirror task, researchers have observed a progression of diverse behaviors in front of the mirror or video image of self, with varying consistency across studies (see reviews by Damon & Hart, 1982, 1988; and Harter, 1983). Dixon (1957) postulated four stages of behavior in front of mirrors, including: 1) interest in the mother's reflection but not their own (4 months); 2) social behavior toward their mirror image (5–7 months); 3) distinguishing their own image from that of another infant (7–12 months); and 4) avoidance of their image. Amsterdam (1972) and Schulman and Kaplowitz (1977) also found a social stage, and Amsterdam noted an avoidant stage (13–24 months).

Because the mirror provides both featural and contingency information for self, Lewis and Brooks-Gunn (1979) attempted to separate these sources of information using video images of the self. They tested recognition on the basis of mirror contingency while controlling for featural information by showing a live video image of self paired with a prerecorded image of self. Discrimination between the two types of images was found at 9 months (see also Amsterdam & Greenberg, 1977). However, it was not until 15 months that infants were able to discriminate a prerecorded film of themselves from that of another child, indicating their ability to use featural information for self-recognition in the absence of contingency. The authors hypothesized that contingency information is an important basis of self-recognition and that self-knowledge develops in four stages: 1) an attraction to faces of infants; 2) recognition of self through contingency; 3) recognition of one's permanent features; and 4) self defined by categorical features independent of contingency.

Butterworth (1992) succinctly summarized the literature in this area and delineated five stages of responding to mirror and video images of self, similar to those proposed by Lewis and Brooks-Gunn: 1) attraction to images of others (0–3 months); 2) contingency detection (3–8 months); 3) awareness of the self as a permanent object (8–12 months); 4) differentiation of the infant's own image from that of others (12–15 months); and finally 5) facial feature recognition (15 months–2 years). Other investigators have focused on delineating the relation

between mirror behavior and stages of cognitive development. For example, Bertenthal & Fisher (1978) found a predictable sequence of five behaviors in infants between the ages of 6 and 24 months that correlated with object concept development: touching one's image, using the mirror to locate a hat attached to self, locating a toy, succeeding in the rouge-spot task (at stage 6 of object concept development), and finally naming one's image. However, Loveland (1986) describes the changes in children's behavior in front of the mirror as reflecting a developing understanding of the nature and properties of reflecting surfaces. That is, the mirror is a special tool for mediated perception, whose affordances take years to discover. This word of caution is well taken and highlights the importance of using convergent approaches in exploring complex phenomenon such as the development of knowledge about the self.

Only a few studies have empirically tested self-perception in infants younger than 9 months using videos or other visual representations of self. Bennett, Smith, and Loboschefski (1992) recently found that 5-month-olds could discriminate a photo of their own face from those of same-aged peers following preexposure to a moving video display of a peer, but not following preexposure to the self. Papousek and Papousek (1974) found that 5-month-olds discriminated a live video image of self from a prerecorded image of self. Infants showed preferential visual fixation of the noncontingent, prerecorded display. In a subsequent study (Field, 1979), 3-month-olds responded differently to a contingent mirror image of self and a noncontingent presentation of a peer. They looked more to the self, but smiled and vocalized more to the peer. Although both of these studies suggest that discrimination of contingent information elicited by the self emerges in early infancy, both had procedural confounds that made interpretation difficult. First, by recording the noncontingent video film of self under different conditions from that of the contingent film, one introduces the possibility that amount of body motion displayed by infants in the different conditions may have differed and then served as a basis of discrimination. Second, the use of the face creates a potential confound of differential eye contact and eye motion in contingent and noncontingent displays because the mirror image provides constant eye contact. Papousek and Papousek (1974) attempted to separate eye contact and contingency by using video controls. They did find an effect of eye contact; however, the overall effect of contingency was still evident. Bahrick and Watson (1985) conducted a study with 5-month-olds to determine whether they could in fact discriminate a video film of self from that of another infant on the basis of contingency alone, using a method that eliminated the above confounds. This research is discussed in detail in the next section.

The research reviewed here has revealed a developmental progression of infants' behavior in front of the mirror, leading to evidence of self-recognition in the rouge-spot studies by the age of 15 months. The understanding that the mirror image

signifies the self is implicit in the child's meaningful response of attempting to remove the rouge spot using the mirror reflection as a guide. However, one must be cautious in making cross-age comparisons about psychological phenomenon on the basis of a response system that may also undergo development (e.g., see Porges, 1979). The fact that children under the age of 15 months fail to wipe off a rouge spot reflected in the mirror does not necessarily mean that they fail to perceive the image as specifying the self or as related to the self. It may reflect their developing awareness of the properties of reflecting surfaces or a development in the child's motivation to remove a spot on the nose, for example. Further, it should be noted that control conditions assessing the ability of younger children to attempt to wipe off a spot that was directly visible on the self or on another person were not typically included in these studies. Consequently, it appears that this measure is more appropriate for toddlers and young children; therefore, the age onset of self-recognition has been overestimated. Assessing the "meaning" of stimulation to the infant is a difficult task and requires innovative research designs and convergent methods. By using other measures more appropriate for young infants, the origins of self-perception and self-recognition can be more effectively examined at younger ages. Two sets of studies are described in the next sections that answer many of the methodological concerns raised here.

Investigations of "The Contingent Self"

The perception of a contingency between one's behavior and its effects on something in the environment is an extremely important accomplishment. It defines the infant's early orientation toward the world with respect to effectiveness and competence, on the one hand, and helplessness, on the other. It forms the basis for the infant's sense of self as an agent of action in the environment. Research has demonstrated that young infants are competent perceivers of contingencies. For example, they detect the relation between leg kicks, sucking, or vocalization and various forms of auditory and visual stimulation including lights, tones, and the movements of a crib mobile (e.g., DeCasper & Fifer, 1980; Kalnins & Bruner, 1973; Rovee-Collier & Fagen, 1981; Siqueland & DeLucia, 1969; Watson & Ramey, 1972). They are also sensitive to social contingencies (e.g., Murray & Trevarthan, 1985). However, these types of contingencies differ from those provided by mirror or video stimulation. The former are imperfectly related to the baby's behavior. When the infant engages in a social interaction (e.g., the infant smiles, the mother smiles) the infant's behavior has only a moderate probability of eliciting the mother's behavior, and the mother's behavior occurs with a certain probability in the absence of the infant's behavior (see Watson,

1985). Although easily detected by the infant, these kinds of contingent relations are far from perfect. Furthermore, when the infant turns on a light display by kicking his leg (e.g., Watson, 1979), the onset of the visual display is contingent on the frequency of the infant's behavior, but the direction, intensity, and duration of motion does not covary with the light display. When the infant moves his leg, causing an attached crib mobile to move, his behavior is conjugately related to the movement of the mobile. Neither provides stimulation that is perfectly isomorphic with the infant's behavior like that of mirror or video stimulation.

Bahrick and Watson (1985) hypothesized that the imperfect contingency tested in these studies specifies to the infant a class of social objects that have potential for interaction. In contrast, the perfect contingency provided by mirror or video stimulation specifies the self, and may serve as an early basis for distinguishing between what is self and what is not self. Stimulation from the mirror provides a perfectly contingent relation between how one moves (proprioception) and the consequent visual stimulation from that motion. The observer can feel his or her own body motions through proprioceptive feedback and can observe the consequent visual stimulation. No object other than the self is capable of providing stimulation that is perfectly correlated with one's felt motions. Consistent with the hypothesis of Lewis and Brooks-Gunn (1979), we suggested that the contingency between visual and proprioceptive information for one's body motion could serve as an important basis for self-perception in early infancy. For example, this kind of information is available each time the infant moves her body; the infant can both see and feel her hand opening and closing. This information is invariant, amodal, and specifies the self (Gibson, J.J., 1966, 1979; E.J., 1969). The proprioceptive-visual contingency is available from birth onward and may potentially provide the basis for one of the earliest forms of self- perception. Perception of this contingency arising from body motion can provide a simple and reliable basis for distinguishing self from not-self.

Bahrick and Watson (1985) assessed the ability of 5-month-old infants to make use of this kind of contingency in distinguishing a video of self from one of another infant. In a series of four experiments, we presented infants with a live video film of their own legs moving (contingent display), side by side with a film of another infant's legs, or a prerecorded film of their own legs (noncontingent displays). All infants were fitted with yellow booties prior to filming, and their legs and feet were portrayed in an inverted position on the screen, much like the infant would experience by looking down at his own legs (see Figure 1).

Infants received four 60-second trials of the contingent and noncontingent displays side by side. The lateral positions of the two displays were counterbalanced across subjects. The design of the study corrected for several confounds inherent in prior video and mirror studies. The problem of differential eye contact between live

versus prerecorded displays or displays of other infants was eliminated by using images of the infant's legs rather than face. Featural differences were minimized across displays of self and other by fitting all infants with yellow booties. The potential for differential amounts of body motion across different types of displays was also eliminated by using a yoked control design. That is, each infant's live film served as the prerecorded film for the next infant. Finally, in other mirror and video studies, the infants had visual access to the motions of their own body; thus, the question of whether infants actually detect proprioceptive information could not be addressed (Field, 1979; Papousek & Papousek, 1974). Visual access permitted detection of an intramodal (rather than intermodal) contingency. That is, a direct comparison between the visual stimulation from the mirror and the visual stimulation from one's body motion could be made. To eliminate this possibility, the infant's direct view of his own body was occluded in Experiments 2–4.

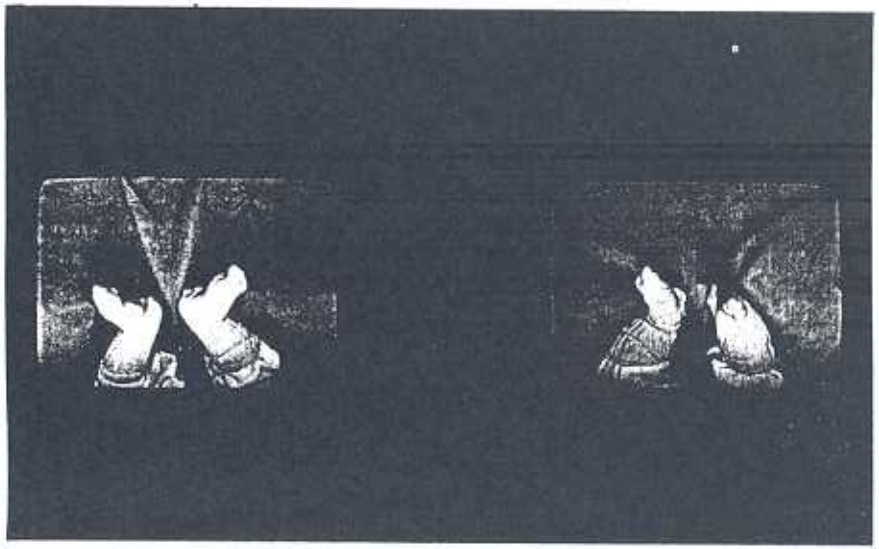

FIGURE 1. An example of the visual displays portraying a live and a prerecorded film of the infant's legs. From Bahrick & Watson (1985).

In three separate studies, we found that 5-month-old infants showed a significant visual preference for the noncontingent display. In Experiments 1 and 2, where infants saw a live film of their own legs alongside that of another infant's legs, they showed significant preferences ($p < .005$, $p < .001$, respectively)) for the films of the other baby. This occurred even when the infant's view of their own legs was occluded in Experiments 2 and 3. Moreover, in Experiment 3, when featural differences between the contingent and noncontingent displays were eliminated

altogether (by presenting two films of the baby's own legs), infants again showed a robust preference ($p < .001$) for the noncontingent display. That is, they watched a prerecorded film of self more than a live film of self. These findings demonstrated that 5-month-old infants are capable of detecting the perfectly contingent relation between their own body motion and the visual stimulation provided by their live video image. However, they showed more interest in the imperfect contingency provided by a film of another infant's legs. A further study was conducted to assess performance of younger infants in this task. Three-month-old infants viewed a live film of their own legs and a film of another infant's legs side by side, as in Experiment 2. Results, however, indicated no significant preference for one display over the other. Given that 3-month-olds detect contingency under other conditions (e.g., Rovee-Collier & Fagen, 1981; Watson & Ramey, 1972), it seemed unlikely that they failed to detect the contingent relations in this setup. Further analyses revealed a distribution that was significantly bimodal. That is, some infants predominately watched the contingent display of self, whereas others watched the noncontingent display of the other infant. Consistent with other recent findings (Bahrick & Pickens, in press; Hunter & Ames, 1988), it appeared that visual preferences were in transition from familiarity to novelty, yielding a null preference overall. Thus, it may be that 3 months is an age of transition from the infants' preference to explore the perfect contingency generated by their own body motions to the imperfect contingency afforded by social objects. These findings, along with those of Field (1979), which indicate that 3-month-olds look more to their mirror image than to a peer, suggest the possibility that at some point prior to this age, infants may have a general visual preference for the stimulation from self. Together, this research demonstrates that by 5 months, and possibly earlier, infants are sensitive to the intermodal proprioceptive-visual contingency specifying self and self-motion. This ability is viewed as a fundamental basis for knowledge about the self and may underlie early differentiation of self from other.

Rochat (Rochat & Morgan, 1995, this volume) recently extended our investigation of temporal contingency to the domain of spatial contingency. Our research manipulated temporal contingency and held spatial contingency constant across the side-by-side presentations. Rochat and Morgan's work complements ours by manipulating spatial contingency and holding temporal contingency constant across the side-by-side presentations. They presented 3- and 4 1/2-month-old infants with two live films of their own legs side by side. The legs were presented from different perspectives, including an ego versus an observer view, with or without a right/left reversal. In one study, infants saw two ego views of their legs, one normal and the other with a right/left reversal. This caused a discrepancy in the spatial mapping and the direction of movement of the video image, with respect to the infant's legs. Results indicated that infants at both ages

demonstrated a significant preference for the incongruent display with the right/left reversal. This shows a sensitivity to spatial contingency; in particular, the directionality of the leg motion. A further study found no evidence of sensitivity to spatial orientation per se when right/left was not reversed. These results extend those of Bahrick and Watson (1985) by demonstrating that infants detect the visual-proprioceptive contingency generated by their own motion on the basis of spatial as well as temporal information.

A further extension of our research investigated both temporal and spatial contingency and was conducted using films of the infant's' arms and hands (Schmuckler, 1994, this volume). In a study identical to ours except for the body part filmed, Schmuckler presented 5-month-olds with a live display of their own arm and hand alongside a prerecorded film of another infant's moving arm and hand, both presented from the same ego view. Infants showed a significant preference for the noncontingent, prerecorded film. This result replicates both our findings of sensitivity to temporal contingency and the direction of this effect. In a second study, which was identical to the first except that both displays were presented with a right/left reversal, no significant preferences were found. This converges with Rochat's (Rochat & Morgan, 1995, this volume) findings and suggests the importance of spatial congruence in the directionality of motion for detection of temporal contingency. Also consistent with Rochat's findings, a third study demonstrated a significant preference for the noncontingent display when the views of both the live and prerecorded displays were novel for the infant (filmed underneath the palm), but right/left orientation was properly aligned. This suggests that as long as the right/left directionality of motion is preserved, spatial orientation per se is not critical for perceiving temporal contingency. Taken together, the results of these three sets of studies show a remarkably consistent pattern. By 5 months, infants are sensitive to proprioceptive information for the temporal contingency and directionality of movement of their bodies with respect to a visual display of that motion, and they show this sensitivity by selectively watching the more novel, noncontingent display.

This research raises a provocative question: Does the infant know that the legs/arms displayed by the live video image are their own? That is, does the contingency provided by this stimulation actually specify self to the infant, and if not, at what age does this understanding emerge? It is quite possible for infants to show discrimination of self from other on the basis of contingency or between one view of self and another, without attributing the contingent stimulation to the self. That is, the preferences could be based on familiarity with contingency rather than a full understanding of the meaning of the stimulation. This is an important question that cannot be addressed by the present data, but is the focus of current

research in our lab and is revisited below in the context of research on the visual self.

Investigations of "The Visual Self"

The visual self can be seen as having two overlapping components, the "visual-featural self" and the "visual-dynamic" self. The visual-featural self refers to what we typically think of as our visual appearance: "what I look like." It includes all of our permanent features and distinctive visual qualities, such as hair style, body type, facial configuration, etc. It is consistent with our commonly held definition of self-recognition. Mirror and video stimulation also provide information about dynamic visual qualities. The dynamic information for self consists of distinctive motion patterns, body postures, idiosyncratic gestures or facial expressions, and the relative movement of facial features that are typical of an individual. This information is also visually conveyed and may serve as a basis of self-recognition. Featural and dynamic information overlap in that motion provides excellent information for the visual appearance of an object (Gibson, 1969). For example, through motion, infants can abstract invariant relations that specify the shape of an object more easily than when the object is still (e.g., Owsley, 1983; Kellman & Spelke, 1983).

As a first step toward assessing the development of knowledge about the visual self, we conducted a study to determine whether and at what age infants could differentiate between a video film of their own face and that of an age-matched peer (Fadil, Moss, & Bahrick, 1993). Although prior research had documented excellent discrimination of both moving and still faces by infants and even neonates (e.g., Barrera & Mauer, 1981; Bushnell, 1982; Fagan, 1972, 1976), no researchers had yet assessed whether young infants could discriminate between the self and a peer solely on the basis of visual-featural information. Results of a study by Lewis and Brooks-Gunn (1979) suggested this ability did not emerge until the age of 15 months, when infants first distinguished between their own pretaped video image and that of another child.

Infants of 5 (N= 24) and 8 months (N = 32) were tested in a visual preference test under both a moving and a still condition. The infant's own face and upper body (wearing a yellow bib) was prerecorded while he/she watched an interesting toy presented in four different locations. This generated a film of the infant from the shoulders up, moving naturally while looking toward the left, right, center, and upward directions (or the reverse sequence), following the off-camera toy (see Figure 2). Thus, in the moving condition, consisting of four 30-second trials, the faces of both the self and peer were shown side by side, oriented in the same

general direction on each trial. In the still condition, consisting of four 15-second trials, still projections of the infants' faces were shown side by side, following the same pose sequence as before. This was accomplished by displaying a frozen image from the prerecorded film. A frame with a representative example of each face was selected, one from each orientation. A yoked-control design was used so that the face of each infant served as the face of the peer for the next infant of the same age. This controlled for any differences between faces (e.g., facial attractiveness, activity level, affect, etc.) with respect to the main variable in question (self vs. peer). The lateral positions of the two images were alternated across trials.

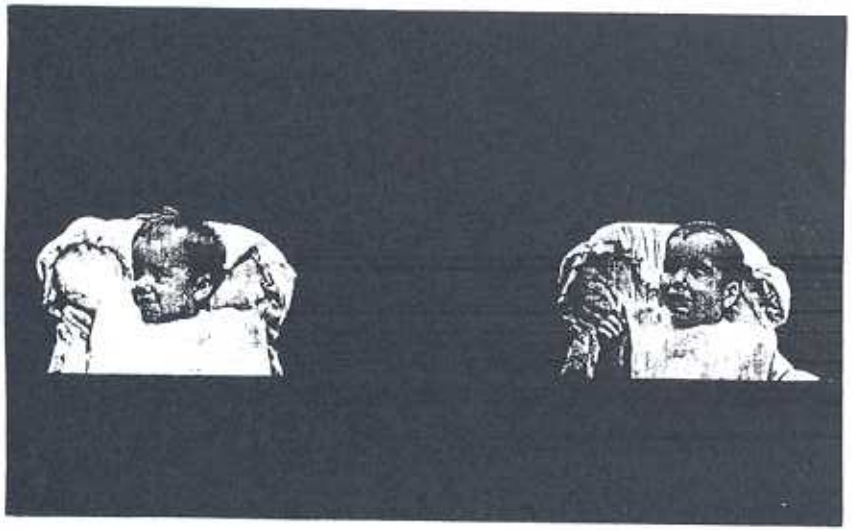

FIGURE 2. An example of the visual displays portraying an image of the self side-by-side with that of a peer. From Fadil, Moss, & Bahrick (1993).

Results indicated that both the 5- and 8-month-old infants spent a significant proportion of their total looking time (p <.01 and p<.05 for 5- and 8-month-olds, respectively) fixating the image of the peer (see Figure 3). Furthermore, when the results were broken down according to condition, both the 5- and 8-month-olds showed a significant looking preference for the peer when the faces were moving, but only the 8-month-olds significantly preferred the peer when the faces were still. Results of the 5-month-olds were in the expected direction, but attenuated. These findings provided clear evidence that both 5- and 8-month-old infants are able to discriminate the visual appearance and/or movements of their own face from that of an age-matched peer. Furthermore, consistent with the view that motion provides

an opportunity for abstracting properties of objects (e.g., Gibson, 1969; Owsley, 1983; Kellman & Spelke, 1985), it appears that making the distinction between self and other was somewhat easier when the faces were moving rather than still. The basis for this discrimination must have been visual-featural information at 8 months of age because infants in this group were just as good at discriminating the still as the dynamic displays. At 5 months, dynamic visual information may have played a more important role, or perhaps the moving displays provided better information about the visual features of the faces. In either case, discrimination of the visual-self appears to be present long before the age of 15 months observed by Lewis and Brooks-Gunn (1979).

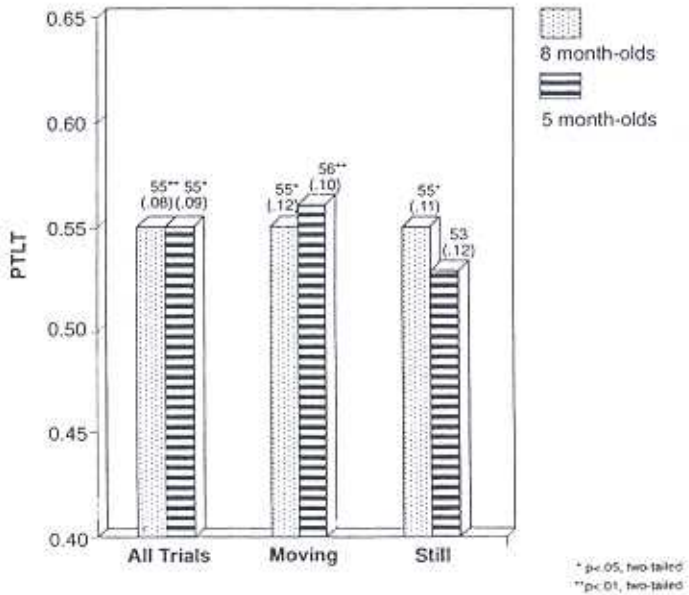

FIGURE 3. The proportions and standard deviations of total looking time (PTLT) spent fixating the display of the peer by 5- and 8-month-olds for all trials, and for the moving and still conditions separately. From Fadil, Moss, & Bahrick (1993).

When might this ability have developed? We replicated the above study using younger infants aged 2 and 3 months. Results demonstrated no significant preferences for one image over the other at the age of 2 months. However, by 3 months of age there was an emerging preference for the image of the peer by the second block of trials (p <.05). These findings suggest that the ability to recognize one's face and distinguish it from that of another infant emerges between the ages of 2 and 3 months. Although it is unlikely, one cannot rule out the

possibility that this ability might emerge even earlier and might be expressed as a visual preference for the self, which would be consistent with our prior speculations about the detection of visual-proprioceptive contingency. Lacking definitive data with younger infants, however, we must conclude that infants' performance at 3 months is the best indicator of the emerging ability to differentiate between the faces of self and other. It is remarkable that infants as young as 3 or 5 months are familiar enough with their own visual appearances and/or motions to recognize their own faces as familiar and to discriminate them from those of other infants of the same age.

How might this ability have developed? Prior experience with their mirror image may be an important basis for this ability. Parents completed a questionnaire regarding the extent of their infant's exposure to their mirror image, video images, and photographs of self. Results indicated that all but 2 of our 104 infants had at least weekly experience with their mirror images, and most had daily exposure. At 8, 5, 3, and 2 months, the percentage of infants who had daily exposure to their image in the mirror was 88%, 87%, 83%, and 67%, respectively. However, all infants had negligible experience with photos or videos. Thus, exposure to the mirror may account for infants' familiarity with their visual images.

These findings again raise the question of whether the infants understood the meaning of the video stimulation they viewed. Infants could have shown discrimination and recognition of their image on the basis of familiarity, without an understanding that the image belongs to the "self." At what point might the infant come to understand that "this is me!"? Experience with mirror stimulation provides a perfect contingency between visual and proprioceptive stimulation that specifies self. Furthermore, infants have been exposed to this kind of perfect visual-proprioceptive contingency from birth onward in their intermodal explorations of their own bodies. We do not yet know when the ability to detect the relation between visual and proprioceptive stimulation emerges, although research reviewed earlier (e.g., Meltzoff & Moore, 1977; Nanez, 1988; Rochat, in press; Van der Meer, 1993) suggests it may be as early as the first month of life. However, it seems both reasonable and parsimonious to suppose that through mirror contingency, the appearance of the infant's face comes to signify the self. That is, once the perfect contingency between one's body motion and the visual stimulation from that motion specify self, then the face and its features observed in the mirror may also come to specify self because of the perfect visual contingency observed. In contrast, if no contingency were observed or the contingency did not specify self to the infant, the experience of seeing one's face in the mirror might at first be like that of seeing a familiar peer. In essence, without self-recognition, the mirror image of self would be similar to that of a familiar face to the infant. At

what point in development the familiar face seen in the mirror is perceived as belonging to the self is a provocative question for future research. It may occur as soon as the perfect contingency is detected, or it may develop over time and experience with the mirror.

One way to get closer to an answer to this question is by distorting the features of the infant's face in a video display and observing the infant's reaction. We can distort the features of the infant's face and the peer's face in the same manner, and assess whether infants respond differently from the way they respond under normal, "undistorted" conditions. Given that infants of 5 and 8 months previously showed a significant looking preference to the peer under a nondistorted condition, if they switched their preference to that of the self under a distorted condition, this would be evidence that their own face is perceived as special or different from that of a peer. This could be taken as preliminary evidence that the face seen in the video display is perceived as specifying the self. Put another way, if infants detect "something different about me," then one would expect that they would now look to the self rather than the peer, even though the peer face is also distorted in the same manner as the self. On the other hand, if infants do not yet attribute the image to the self, then their own image should be treated just like a familiar face. Because both the familiar and novel faces would posses the same distortions, infants ought to prefer the novel face as before because it would still be the more novel of the two faces.

Following this logic, 5- to 8-month-old infants (N = 14) were tested in a procedure similar to before, but under only the moving condition because it provided the most robust results. They were all marked with two rouge spots, one on each cheek. The rouge was unobtrusively applied by the parent in the waiting room, prior to filming for the study. The infants' faces were then prerecorded as before, but to shorten the filming procedure, only two orientations were used: the right and left 3/4 views. Then the forced-choice preference test was administered. It was identical to the moving condition of the prior study, except infants viewed trials of their own and another infant's face side by side, both displaying bright rouge dots on each cheek. Results were strikingly different from before. This time infants showed a marginally significant visual preference for the image of self, consistent with our predictions of self-recognition (t (13) = 2.04, p = .06). Further, when compared with the prior results of the 5- and 8-month-olds, infants showed a significant shift in the direction of attention ($t(68)$ = 3.67, p = .0005). That is, previously, when no rouge spots were visible, infants showed a preference for the novel face. However, when rouge spots were visible, they shifted their attention to the familiar face; the self. Given that both the peer and self had the same novel features, it is unlikely that this shift in the direction of the visual preference was due to novelty. Rather, it is more likely that by the age of 5

months, infants recognized the image of their face as specifying the self or as somehow different and more special than that of a peer.

These findings of an attentional shift from the undistorted to the distorted conditions are only preliminary and require replication. Thus, the conclusions are tentative. However, along with our prior findings of discrimination between video displays of the self and peer by 3-, 5-, and 8-month-olds, the implications stand in sharp contrast to some prevailing views and to the interpretation of data from the self-recognition studies with toddlers. Specifically, our research calls into question two conclusions drawn from the prior body of research: First, that infants do not discriminate their own face from that of another infant until the age of 15 months; and second, that it is not until 15–18 months that the image in the mirror is attributed to self (e.g., Amsterdam, 1972; Butterworth, 1992; Damon & Hart, 1988; Lewis & Brooks-Gunn, 1979). In contrast, the results of our research show that by 3 months of age, discrimination of self from other on the basis of visual information provided by the face is possible. Furthermore, our attentional shift data suggest that some understanding of the meaning of this stimulation occurs well before toddlerhood and possibly by 5 months of age. This is, however, not to suggest that such young infants have a well-developed concept of self. There is a great deal of learning and developmental change that must occur in the months and years ahead (see Damon & Hart, 1988, for a review). The data do suggest that 5- to 8-month-old infants may perceive the stimulation generated by the self as different from that generated by others in important ways. Future research will explore the nature of this difference.

Concluding Remarks

This chapter summarized research exploring the development of infants' sensitivity to two types of information for self: intermodal proprioceptive-visual contingency and visual-featural information. Several findings and conclusions emerged from these studies:

1. Detection of visual-proprioceptive contingency for temporal relations is present by 5 months of age and perhaps earlier (Bahrick & Watson, 1985; Schmuckler, 1994). Sensitivity to visual-proprioceptive contingency for spatial relations is also present at 5 months (Rochat & Morgan, 1995; Schmuckler, 1994) and emerges by 3 1/2 months (Rochat, 1995). Thus, the potential for perceiving self and differentiating self from other on the basis of temporal contingency and spatial congruence between visual and proprioceptive information is present early in infancy.

2. Even by the age of 2 months, infants are frequently exposed to mirrors. Most infants in our samples at each age (2, 3, 5, and 8 months) were exposed to their own mirror images at least daily. This may serve as a basis for familiarity with their own visual appearance.

3. By 3 months of age, infants are able to discriminate between a prerecorded videotape of their own face and that of another infant (Fadil, Moss, & Bahrick, 1993). They show a preference for the face of another baby over their own, demonstrating familiarity with their own visual appearance. This finding stands in contrast to prior conclusions that featural discrimination of one's own face from that of a peer does not emerge until 15 months of age (Lewis & Brooks-Gunn, 1979).

4. Preliminary results suggest an attentional shift when features of the infant's face as well as that of a peer are marked with a rouge spot. Infants aged between 5 and 8 months no longer prefer to watch the face of a peer. Rather, they tend to watch their own face more. This suggests that there is something different or special about stimulation from the self.

Thus, evidence of self-knowledge is apparent in two domains in early infancy. Contingency and visual-featural information are different sources of information for self, and thus their development may proceed according to different timetables. However, they also form part of a coordinated system of knowledge about the self. Development in one domain influences development in the other. The perfect contingency generated by visual stimulation from one's body motions is excellent information for self and for differentiating between what is self versus not-self. It may serve as a primary source of information about the self. Through experience with mirror stimulation, sensitivity to this perfect contingency may subsequently facilitate the understanding that one's visual features specify the self. Future research in our lab will unravel the interdependence between development in these two domains by conducting training studies with infants who do not yet show evidence of discriminating the self from another infant in video presentations.

As discussed earlier, Gibson's (1979) theory posits that our perceptual systems provide information about the self and about the environment at once. This view provides a point of departure for the developmental process and suggests that infants perceive a differentiated self from the beginning. Although the findings of infant and newborn capabilities outlined in the beginning of this chapter and the data presented here are consistent with this view, the conclusions are still inferential. There is no direct test of whether a preverbal infant knows that the self is a separate object among other objects in the environment, or recognizes that "this is me!" in the mirror. Ascribing meaning to the infant's actions or ability to discriminate between two displays is a difficult task, and conclusions should be

viewed with caution. At a minimum, converging evidence from varied approaches is required. This problem is especially apparent if our criteria for self-recognition include conscious awareness of the self as separate (e.g., Bertenthal, 1992). Along similar lines, most recent discussions of the development of self suggest that the infant's understanding of self is at first "preconceptual" or perceptual (e.g., Butterworth, 1990; Meltzoff, 1990; Neisser, 1993; Rochat, in press), and later, knowledge of self becomes "conceptual." We eventually attain a self-concept that is available to conscious awareness. I would agree that self-knowledge progresses from perceptual to conceptual; however, the dichotomy seems arbitrary. At what point does the transition from preconceptual to conceptual knowledge occur and how does this occur? At present, there is no single or best answer to this question. The view elaborated here is that through development, there is a growing awareness of the self as separate. Perceiving and conceiving fall along a continuum and differ in degree, not kind. Knowledge about the self becomes progressively more elaborated, explicit, and available to consciousness in a number of different domains. This development may occur at different rates for information in different domains, and development in one domain may influence development in another. Thus, knowledge in some areas may become more explicitly conceptual prior to knowledge in other areas. This process may even continue into adulthood, as self-understanding evolves and implicit knowledge becomes more explicit. Thus, there is no single point where the system of knowledge about the self shifts from perceptual to conceptual, nor is there a point where knowledge in a single domain shifts from perceptual to conceptual. It is a dynamic, gradual, and ongoing process over the lifespan.

In the context of these words of caution, the research reported here challenges the prevailing view that the child's conceptual understanding of the significance of his or her mirror image and other stimulation from the self does not emerge until well into the second year. The attentional shift observed in infants when features of their own faces are distorted suggests that there is already a growing awareness of something special about the visual stimulation from oneself that sets it apart from that generated by others. Before revising our view of infants' understanding of the meaning of their images in the mirror, however, it is important to replicate these findings and to provide converging evidence from other domains and with different procedures. Research is currently in progress in our lab to address these issues. Furthermore, when taken together with the ongoing discovery of new capabilities in infancy for detecting and responding to stimulation arising from the self (see other chapters in this volume), it is clear that our concept of the emergence of self-knowledge requires updating. Because this topic stands at the interface between perception, cognition, and social and personality development, new discoveries

about the infant's emerging sense of self promise to have a far-reaching impact on theories in developmental psychology.

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