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The Development of Body Structure Knowledge in Infancy

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Abstract

Although we know much about the development of face processing, we know considerably less about the development of body knowledge—despite bodies also being significant sources of social information. One set of studies indicated that body structure knowledge is poor during the 1st year of life and spawned a model that posits that, unlike the development of face knowledge, which benefits from innate propensities and dedicated learning mechanisms, the development of body knowledge relies on general learning mechanisms and develops slowly. In this article, we review studies on infants' knowledge about the structure of bodies and their processing of gender and emotion that paint a different picture. Although questions remain, a general social cognition system likely engenders similar trajectories of development of knowledge about faces and bodies, and may equip developing infants with the capacity to obtain socially critical information from many sources.

Keywords

development of body knowledge; body structure perception; social cognition; infant social development

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Like faces, bodies convey several kinds of socially significant information. In fact, bodies may be even more informative than faces in some cases (1). For example, adults detect *peak* emotions more accurately from bodies than from faces (2). Moreover, when facial information is not available (e.g., when a person is at a distance or turned away from the viewer), bodies may be the only visual source of social information.

Given the significance of information gleaned from the body, it is surprising that we know little about the development of body knowledge. The limited research findings have led to the proposition that visuospatial body representation is not well developed during the 1st year of life (3, 4). This contrasts with the general understanding that face representation in early infancy is fairly sophisticated, although not like that of adults (5). However, more recent studies suggest a range of conclusions about the extent of infants' body knowledge. In this article, we briefly review these studies and examine models of development of body knowledge in light of their findings. Our focus in the following sections is limited to the

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development of knowledge about the structure of human bodies. We describe initial findings that led to contradictory conclusions about infants' body representation and discuss newer evidence of early visuospatial body knowledge. Finally, we consider what these studies imply about the nature of developing body knowledge.

Research on body knowledge in adults has encompassed a variety of issues, including perception of the topology of bodies, the neural mechanisms that underlie body representation, action perception, agency and conscious awareness of self and others, and different levels of knowledge, such as sensorimotor versus lexical-semantic (Refs 1, 6–8). Although relatively sparse compared to research on face knowledge, the literature on the development of body knowledge has also addressed a wide range of topics, including self-knowledge (9), representation of body structure (4), perceptions of actions and intentions (10), perception of body motion (11), and the neural underpinnings of body perception (12). Here, we restrict our discussion to infants' representation of the shape and structure of human bodies, and their sensitivity to typical social characteristics (i.e., sex and emotion) derived from this kind of body information.

INITIAL FINDINGS

Many early studies used point-light displays (PLDs) to examine infants' knowledge of human bodies (11, 13). PLDs depict motion and structure by activating light points placed on actors' joints. In a review of these studies (14), Pinto argued that by 7 months, ".. . infants become sensitive to the global structure of the human body" (p. 315).

However, initial research by Slaughter and colleagues (15) produced a conflicting view. Twelve-, 15-, and 18-month-olds were shown pairs of normal pictures of static bodies versus scrambled pictures (e.g., legs attached to shoulders) as well as normal faces versus scrambled faces (e.g., eyes, nose, mouth displaced). Only 18-month-olds displayed a preference between normal versus scrambled bodies, whereas even the 12-month-olds discriminated between the normal and scrambled faces. Similar results were seen with habituation and serial touching procedures and with photograph and doll stimuli (3).

More recently, Heron and Slaughter (16) found that 9-month-olds discriminated intact bodies from scrambled bodies, provided they were tested on realistic 3D and life-sized stimuli. However, 6-month-olds failed to detect similar changes, and even 9-month-olds failed to detect changes in 2D photographs or small dolls (4). This suggested that infants have representations of the overall structure of human bodies by the end of the 1st year of life (around 9 months), but this knowledge is fragile, and robust body knowledge is available only during the 2nd year (4).

Based on infants' poor performance on body stimuli compared to face stimuli in their studies, Slaughter and colleagues (3, 4) concluded that the nature of development of body knowledge differs from that of face knowledge. Whereas face knowledge may be innate or use a genetically prepared face-specific learning system, body knowledge relies on general learning mechanisms rather than a dedicated system and develops slowly. However, in the next section, we describe recent research that argues against this latter proposition.

EVIDENCE OF EARLY VISUOSPATIAL BODY KNOWLEDGE

In this section, we describe studies that suggest that young infants are sensitive to body structure and shape, process bodies holistically, and derive information about sex and emotions from bodies. Collectively, these studies indicate that knowledge about body structure develops early.

Sensitivity to the Organization of Body Parts

Like faces, bodies are defined by the presence of certain parts arranged in a typical manner (e.g., arms and legs attached to torsos at particular locations). Thus, a basic aspect of body knowledge is sensitivity to the organization of body parts. In one study (17), 3-month-olds responded similarly to scrambled versus intact bodies as they did to scrambled versus intact faces, suggesting that young infants are sensitive to the overall organization of body parts. In another study (18), 3½-month-olds were tested for preference between an intact body and one with parts reorganized in a side-by-side comparison (Figure 1). Infants preferred the reorganized bodies when the stimuli were upright but not when they were inverted, suggesting early sensitivity to the organization of body parts. This inversion effort indicates that preference in the upright condition was not based on low-level image features. The results of this study suggest that infants are sensitive to the typical arrangement of body parts by as early as 3½ months.

Holistic Processing of Bodies

Adults perceive faces as holistic gestalts rather than as a collection of disparate individual features. That is, they process information about parts of faces (such as eyes) in a manner that depends on other parts. In a study that used a part-whole procedure to demonstrate holistic face processing in adults (19), participants were tested for discrimination between features (e.g., Tom's nose vs. Harry's nose) in isolation or in the context of the whole face. Performance was superior in the whole-face condition, indicating that adults process faces holistically (20). Moreover, adults tend to process faces more holistically than they do other objects, leading some researchers to argue that faces are a special category of stimuli (21). Some studies suggest that infants as young as 3 months process faces holistically (22; but see 23), indicating early development of specialized face processing.

Bodies are also processed as holistic entities by adults (24) and children (25). We used the Tanaka and Farah (19) approach to examine holistic body processing in infancy (26). We tested 5- and 9-month-olds' discrimination between body postures that differed in the orientation of an arm and a leg (Figure 2). Infants were tested in three conditions: features in the context of intact bodies, features in isolation, and features in the context of scrambled bodies. Both 5- and 9-month-olds detected posture changes in whole body images but did not detect the same changes in the other two conditions, suggesting that by 5 months, infants process bodies holistically.

Sensitivity to the Relative Size of Body Parts and Body Shape

Knowledge of body structure also includes representation of the relative size of body parts and the shape of bodies. Even young infants are sensitive to these characteristics of bodies.

In one study (18), we familiarized 3½-month-olds to proportionally distorted bodies (e.g., long torso, short legs) and tested them for a preference between these bodies versus their corresponding normally proportioned bodies. Separate groups of infants were tested with upright and inverted bodies. Infants in the upright condition preferred the normal bodies, while those in the inverted condition did not. This inversion effect suggests that performance in the upright condition reflects body representation. The results of this study demonstrate infants' sensitivity to body-part proportions early in life (27). Infants' processing of the relative size of body parts also suggests sensitivity to body shape because changes in the relative size of parts alter the overall shape of bodies.

In a test of infants' sensitivity to body shape (28), 9-month-olds preferred unattractively shaped male bodies to attractive ones. In contrast, 3½- and 6-month-olds did not. Thus, while infants exhibited knowledge about male body shapes, this preference was not evident until about 9 months. However, even younger infants may be sensitive to shape differences in female bodies because prior research suggests that infants have greater knowledge about females than males (29). To examine this issue, we tested 3½-month-olds' and newborns' preferences between images depicting different waist-to-hip ratios (WHRs; see Figure 3; 30). The older infants preferred a 0.7 WHR (typically associated with females; see 31) to a 0.9 WHR (typically associated with males), but newborns did not prefer one WHR to the other. These results indicate that sensitivity to body cues signaling sex categories develops early in life.

The set of studies described so far indicates that infants process body shape, structure, and posture, in some cases even by 3 months (also see 32). To adults, body shape and posture provide information about socially useful characteristics of people, such as sex and emotion. Next, we review studies examining infants' sensitivity to these types of social information in bodies.

Sensitivity to Sex Cues in Bodies

Adults identify readily the sex of a person, even in highly impoverished stimuli (e.g., PLDs; 31). While the research described earlier on infants' sensitivity to waist-to-hip ratios suggests that even 3½-month-olds are sensitive to the shape cues that signal a person's sex, it is unclear whether this sensitivity translates into knowledge about sex from body information. We addressed this issue by examining whether infants respond to mismatches of sex information from bodies and faces (33). Five- and three-and-a-half-month-olds were shown images of males and females paired with mismatched images containing a male head matched to a female body or the opposite configuration (Figure 4). Only the 5-month-olds discriminated (preferring the sex-incongruent stimuli), suggesting that infants are sensitive to sex information in bodies by 5 months and match sex category information across faces and bodies.

Sensitivity to Emotions Expressed by Bodies

Bodies are significant sources of emotional information for adults (1, 2). We examined infants' sensitivity to emotional signals from bodies by testing whether 3½-month-olds and 6½-month-olds match emotional body movements and static postures to emotional vocalizations (34, 35). Infants were shown videos or still images of actors depicting happiness or sadness. The actor's face was covered so that the only visual cues to emotion came from the actor's body. An actor depicting happiness and another depicting anger were presented side-by-side on a computer monitor, and a happy or angry vocalization (e.g., laughing or grunting) was presented simultaneously. Separate groups of infants were tested with images presented upright and inverted. At 6½ months, infants who saw actors in the upright position matched body emotions to vocalizations, that is, they looked longer at the happy actor when a happy sound was played, but longer at the angry actor when an angry sound was played. Infants of the same age who saw actors in the inverted position did not have a preference, indicating that the matching in the upright condition was not driven by low-level stimulus properties. In contrast, 3½-month-olds failed to match body emotions to vocalizations whether tested with static bodies or with videos of body movements. Thus, infants' sensitivity to emotions portrayed in body posture and actions develops between 3½ and 6½ months. In a separate study using different measures (36), researchers saw a similar developmental change from 4 to 8 months in sensitivity to body emotions.

THE NATURE OF THE DEVELOPMENT OF BODY KNOWLEDGE IN INFANCY

What does the evidence just described indicate about the nature of the development of body representations and the mechanisms that drive development? First, these studies suggest that knowledge about the structure of bodies develops more rapidly than proposed by the Slaughter and Heron (3, 4) model. Infants are sensitive to the organization of body parts and overall body shape by as early as 3½ months. Second, 5-month-olds process body information holistically and derive sex information from bodies, while 6½-month-olds process emotions from body posture. These results suggest that infants not only are sensitive to body shape and structure early in life, but also derive socially relevant information from these aspects of body images. Moreover, the gap between the development of face knowledge and body knowledge may not be as large as Slaughter and colleagues (3, 4) suggested. Overall, the results suggest that face and body processing develop similarly. Although the timing of some key developmental milestones may not be identical, both are likely driven by a general social cognition system that encompasses many social stimuli, including faces, bodies, and voices (37, 38).

A variety of factors, including test stimuli and procedures, might account for the outcomes in recent studies that differ from the Slaughter studies. Many of the original Slaughter and Heron studies tested infants using images of male bodies, whereas the newer studies examined infants' performance using images of female bodies, with which infants are likely to be more familiar. Moreover, the Slaughter studies typically involved successive discrimination procedures in which test stimuli were presented one at a time, whereas many of the newer studies used the more sensitive paired-comparisons procedures in which stimuli were contrasted side by side (39). Whatever the reasons for the different outcomes, researchers should examine the conditions under which infants exhibit sensitivity to body information to understand the limits of early knowledge about the body.

Mechanisms of the Development of Body Knowledge

Many models assume that the origins of face processing are based on innate mechanisms that focus infants' attention on faces. For instance, Morton and Johnson (40) explicitly assumed the presence of an innate face processor, while Pascalis and Kelley (41) posited an evolutionarily based system dedicated for face processing at birth. Similarly, Simion et al. (42) argued for a system at birth that responds to certain features of visual stimuli that evoke faces, although these features may not necessarily be specific to faces. Most models also assume that postnatal experience builds on this starting point and helps guide the development of a face-processing system during infancy that allows effective functioning in the social world.

We suggest that the development of body representation similarly benefits from an early system that is sensitive to bodies. Rudimentary aspects of body representation—at least to the extent of viewing one's body as different from other things in the environment—are evident early in life (for a review, see 9). Based on these findings, Rochat concluded that ".. . rather than confused and disorganized, we are born with an implicit sense of the body as an entity that is differentiated, organized, and situated in the environment" (9, p. 738). Moreover, Longhi and colleagues (43) found that newborns responded to the possibility/impossibility of hand movements. These findings are consistent with the notion that, as is true for faces and voices, an innate system prepares the neonate to attend and respond to body information soon after birth. At the same time, the findings reviewed earlier suggest many aspects of body information processing follow similar developmental trajectories as face processing.

The initial start provided by an innate system that facilitates attention to both faces and bodies is likely bolstered by the large amount of exposure infants subsequently have to these stimuli. Proprioceptive knowledge of one's own bodily experiences may also contribute to the development of knowledge about bodies in general (9, 44). Therefore, our view is that body knowledge, like face knowledge, likely benefits from experience with one's own body as well as from the pervasive social environment of the typically developing infant.

Body knowledge in infancy may also be an offshoot of faceprocessing mechanisms. Because of the yoked nature of experiences with faces and bodies, any specialized face mechanism operating soon after birth might also incorporate body characteristics into the knowledge base. For instance, an infant who acquires information about female faces might also acquire knowledge about the female bodies correlated with such faces. Thus, the development of body knowledge might benefit from bootstrapping from face knowledge.

Current accounts of the development of body knowledge are largely speculative because of the general paucity of research on body representation in infancy. In particular, the dearth of studies on newborns' representation of bodies makes it difficult to make strong statements about the early origins of body knowledge. Although empirical evidence argues against significant qualitative differences in the nature of development of knowledge about the body versus the face, it may be premature to conclude that the two types of knowledge have identical developmental trajectories and inducing mechanisms.

Also, most studies reviewed here have used looking-time procedures to document preferences related to perceptual differences in images. These perceptual sensitivities may not reflect the kind of abstract and explicit conceptual knowledge of bodies possessed by adults. Thus, ongoing research should seek to understand how such basic perceptual representations in infancy translate into richer conceptual knowledge in adulthood.

Finally, even in studies of adults, research on body knowledge has traditionally been a "poor relation" to research on face processing (45). Similarly, too little attention has been paid to the early development of body knowledge. Given the significance of body information to social functioning, this situation needs to be corrected if we are to achieve a comprehensive understanding of the development of social cognition.

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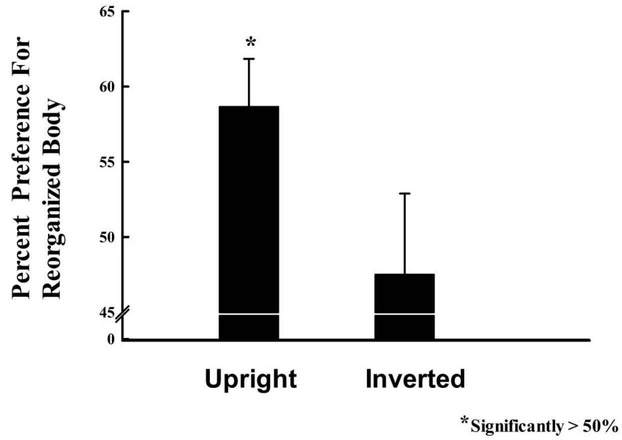

Figure 1.

Examples of intact and part reorganized stimuli (top part). Preference was tested by presenting a stimulus of each kind side-by-side. Separate groups of infants were tested with upright and inverted stimuli. Three-and-a-half-month-olds preferred the reorganized images in the upright condition but not in the inverted condition (bottom part).

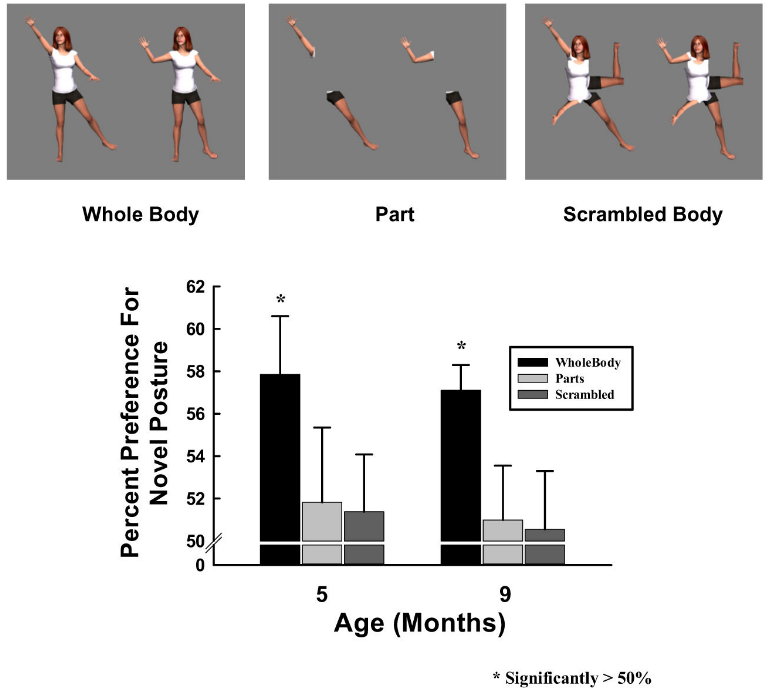

Figure 2.

Examples of whole body, part, and scrambled test stimuli (top part). In each condition, infants were initially familiarized to an image containing two identical body postures and then tested with the familiarization posture and a novel body posture. The novel posture was created by changing the position of one arm and one leg from the familiarization body posture. Both 5- and 9-month-olds discriminated posture changes in the whole condition but not in the part or scrambled conditions (bottom part).

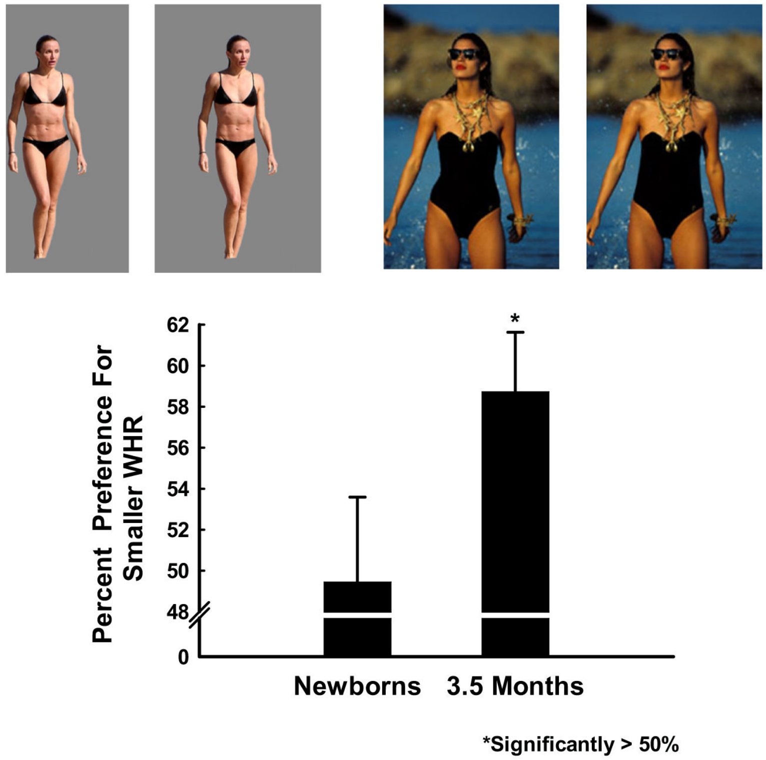

Figure 3.

Examples of images with 0.7 and 0.9 waist-to-hip ratios (WHRs; top part). The left image in each pair depicts the 0.7 WHR whereas the right image depicts the 0.9 WHR. Preference was tested by presenting a stimulus of each kind side-by-side. Three-and-a-half-month-olds preferred the images with the smaller waist-to-hip ratios but newborns showed no preference (bottom part).

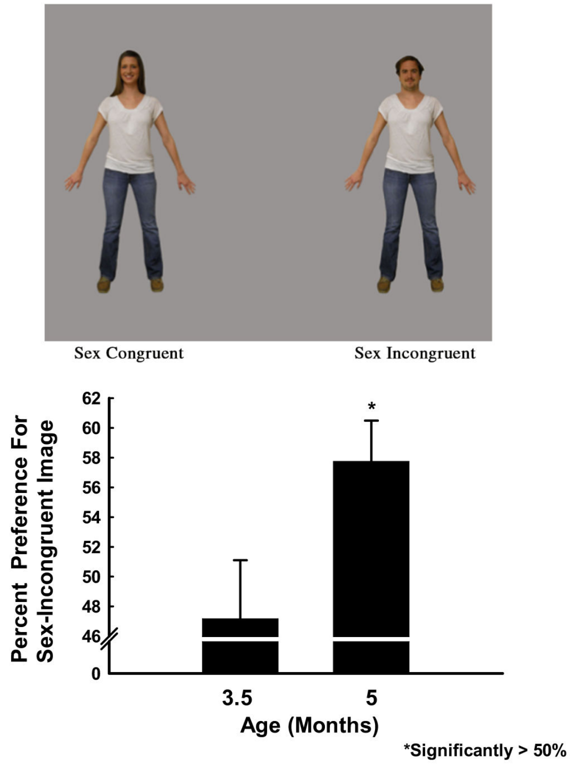

Figure 4.

Examples of sex-congruent and sex-incongruent images (top part). Preference was tested by presenting a stimulus of each kind side-byside. Five-month-olds preferred the incongruent images but 3.5-month-olds showed no preference (bottom part).