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The Head Bone's Connected to the Neck Bone: When Do Toddlers Represent Their Own Body Topography?

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Developments in very young children's topographic representations of their own bodies were examined. Sixty-one 20- and 30-month-old children were administered tasks that indexed the ability to locate specific body parts on oneself and knowledge of how one's body parts are spatially organized, as well as body-size knowledge and self-awareness. Age differences in performance emerged for every task. Body-part localization and body spatial configuration knowledge were associated; however, body topography knowledge was not associated with body-size knowledge. Both were related to traditional measures of self-awareness, mediated by their common associations with age. It is concluded that children possess an explicit, if rudimentary, topographic representation of their own body's shape, structure, and size by 30 months of age.

Children begin learning about their own bodies as newborns. Within a few hours of birth, neonates can tell if the hand caressing their cheek belongs to someone else or is their own (Rochat & Hespos, 1995). As infants use their bodies to engage the world—moving through space, watching their own hands and feet, playing with objects and people—they discover how their bodies move, what their bodies are capable of, and how their bodies and body parts relate to other things in the world (see Adolph & Berger, 2006, for a review). Thus, infants differentiate their bodies and actions from the physical and social world very early, developing a prereflective, ''tactile, auditory, and kinesthetic . . . bodily self'' (Butterworth, 1995, p. 93) over the course of the 1st year (Rochat, 1995).

This implicit, perceptually specified bodily self becomes explicit and available to conscious awareness beginning in the 2nd year of life as toddlers become able to take their own bodies and actions as objects of reflective thought (Bertenthal & Rose, 1995; Moore, 2007; Piaget, 1952; Rochat, 2001). Recent studies have shown that children become consciously aware of the size of their own bodies and of their bodies as potential obstacles or impediments late in the 2nd year of life, with development continuing into at least the 3rd year (Brownell, Zerwas, & Ramani, 2007; Moore, Mealiea, Garon, & Povinelli, 2007). The purpose of the current research was to build on and extend these findings to study very young children's explicit awareness of their body's shape and spatial configuration, sometimes termed *body topography* (e.g., Reed, 2002). To do so, we adapted tasks used to index such knowledge in adults and administered them to children between 20 and 30 months of age. This is the age when body self-awareness has been previously studied and when other aspects of objective self-awareness as traditionally measured are also developing, including mirror self-recognition, self-reference, and self-conscious emotions (e.g., Lewis & Ramsay, 2004).

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Dimensions of Body Representation

The conceptual framework underlying the current work rests on the proposal that children's earliest explicit representations of their own bodies are constructed along several distinct dimensions (Brownell et al., 2007). Two dimensions are the focus of the current study: (a) the body as a physical entity with objective attributes such as height and width (body-size awareness) and (b) the body as an organized collection of body parts with particular, stable spatial relations among them (body topography). This framework derives from empirical and theoretical work in cognitive neuroscience, adult neuropsychology, and developmental psychology.

Cognitive neuroscience researchers have confirmed that an abstract spatial representation of one's own body is associated with particular regions in the intact adult brain (Arzy, Thut, Mohr, Michele, & Blanke, 2006; Chaminade, Meltzoff, & Decety, 2005; Churchland, 2002; Devue et al., 2007; Ehrsson, Kito, Sadato, Passingham, & Naito, 2005; LeClec et al., 2000). Importantly, visual representations of the body in the brain are dissociable from movement-related representations of the body (e.g., Sugiura et al., 2006; Urgesi, Candidi, Ionta, & Aglioti, 2007) and also from the cortical network involved in the human mirror neuron system (see Peelen & Downing, 2007, for a review). Thus, the form of the human body is represented independently of the body's actions in the adult brain, raising the possibility that they are developmentally distinct as well.

Converging evidence from neuropsychological research with brain-injury patients has also shown that there are several distinct systems dedicated to the representation of one's own body (e.g., Schwoebel & Coslett, 2005; Sirigu, Grafman, Bressler, & Sunderland, 1991). For example, patients with damage to the left parietal area often cannot point to their own body parts (autotopagnosia) when an examiner names them (e.g., *elbow*, *chin*), even though they can locate body parts on animals, name human body parts after hearing them defined, and identify individual parts of inanimate objects such as bicycles (Guariglia, Piccardi, Puglisi, & Traballesi, 2002; Semenza, 1988). Such findings suggest a disruption in patients' topographic representation of their own body, which is dissociable from semantic representations of body parts. Other patients with left parietal damage find it especially difficult to imitate meaningless gestures (ideomotor apraxia) when the gesture is positioned at specific locations on the body. For example, a patient might watch an examiner model a gesture next to the ear only to imitate it next to the nose (Buxbaum & Coslett, 2001; Goldenberg, 1996). Because meaningless gestures directed to one's own body must be represented in terms of particular spatial configurations of the body and its parts, such errors suggest disrupted knowledge of the structure of the human body (Chaminade et al., 2005; Goldenberg, 1997; Goldenberg & Karnath, 2006). Notably, these sorts of impairments are not routinely associated with deficits in general motor function or the ability to perform everyday motor activities such as getting dressed or moving through space, again consistent with a distinction between visuospatial and movement-related representations of one's body. That these impairments occur in otherwise normally self-aware individuals further suggests that body self-awareness is a distinct aspect of objective self-awareness. However, research from adult neuroscience and neuropsychology cannot tell us how body self-awareness develops or how it might connect with other elements of the developing self.

Development of Body Self-Awareness

The world is represented from both first-person and third-person perspectives, and these two perspectives appear to become integrated relatively late in infancy, in the latter part of the 2nd year (Barresi & Moore, 1996; James, 1890; Kagan, 1981). This developmental achievement may be especially relevant for children's early body representations. To reflect consciously on one's own body shape and configuration requires integrating one's subjective, first-person experience of oneself with an objective, third-person perspective (e.g., Keysers & Gazzola, 2007; Moore, 2007; Povinelli & Cant, 1995).

Body topography. Slaughter and her colleagues (Heron & Slaughter, 2008; Slaughter & Heron, 2004) have systematically examined infants' developing third-person perspective on the human body as revealed in their knowledge about the body's canonical configuration. In a series of studies, they have established that 15- to 18-month-old infants can visually discriminate noncanonical body configurations (e.g., arms protruding from head instead of torso) from typical body shapes, but in a structured object-examination procedure infants do not reliably categorize typical versus scrambled bodies until 24 months. When an explicit categorization judgment was required, only 30-month-old girls were able to categorize typical versus scrambled bodies correctly; boys could categorize typical and scrambled cars by 24 months but could not categorize human body configurations at either 24 or 30 months (Heron & Slaughter, 2008). Thus, a detailed visuospatial representation of the human body becomes available in the 2nd year of life, when infants recognize the body as having a particular configuration, shape, and structure and are sensitive to the canonical spatial relations among body parts. During the 3rd year of life, knowledge of human body configuration becomes more explicit. However, there is no empirical work addressed to children's corresponding spatial representations of their *own* bodies; the primary aim of the current study was to fill this gap.

To this end, we examined the development of 1- and 2-year-olds' topographic knowledge of their own bodies. Two components corresponding to those studied with adults were the focus: the locations of one's own body parts (body-part localization) and the spatial relation among one's own body parts (body configuration knowledge). Because own body topographic representations have not been studied previously in young children, it is also important to know whether these two putative components cohere, that is, whether children develop a higher order, more general topographic self-map that includes both the specific locations of their body parts and the spatial relations among them. It was therefore a further aim to determine whether body-part localization and body configuration knowledge are related.

Body size. Building on research showing that toddlers sometimes try to fit their bodies into miniature objects that are much too small for them (DeLoache, Uttal, & Rosengren, 2004) or try to fit through a much too narrow opening (Garon & Moore, 2002), we recently examined children's body-size errors between 17 and 30 months of age across multiple tasks (Brownell et al., 2007). Although most of the children made such errors, frequency of errors declined with age as children became more likely to take their own size into account when trying to fit into very small doll clothes, trying to squeeze through a small door to reach their mothers on the other side, or playing with doll-size toys or furniture. A third aim of the current research was to replicate those results, given the novelty of the tasks and the potential importance of the findings.

The fourth aim of the study was to evaluate the potential correspondence between body-size awareness and body topography knowledge. If explicit awareness of one's own body size, shape, and structure is, indeed, emerging in this period, it is important to determine whether and how these early developments are interrelated. Finally, given that scholars have suggested that reflective self-awareness may ground body self-awareness (e.g., Moore, 2007), or vice versa (Povinelli & Cant, 1995), the final aim of the study was to examine associations between dimensions of body self-awareness and more traditional measures of reflective self-awareness.

We expected to find age differences for each dimension of body self-awareness over the 2nd year of life, partly based on prior empirical findings, and partly because this is the period when reflective self-awareness first appears and undergoes significant developmental change (Lewis & Brooks-Gunn, 1979; Nielsen, Dissanayake, & Kashima, 2003). We further expected that measures of body-part localization and body configuration would cohere as components of the larger construct of body topography. However, we had no strongly grounded expectations for potential associations between body topography knowledge and body-size awareness. It is possible that these are somewhat distinct dimensions of developing body self-awareness as suggested by the fact that in adults, distortions in the body image that center on body size (e.g., some eating disorders, body dysmorphic disorder) do not covary with disruptions in spatial awareness of one's body (e.g., autotopagnosia, hemi-neglect). Finally, we expected that both body-size awareness and body topography knowledge would be associated with standard measures of reflective self-awareness insofar as body self-awareness would seem to be grounded in objectification of the self more generally.

Method

Participants

Participants were 61 children at two ages: 20 months (M = 20.4 months, SD = 0.99; 14 girls, 16 boys) and 30 months (M = 29.6 months, SD = 1.2; 13 girls, 18 boys). Families were recruited from a medium-sized urban area and nearby suburbs, and were predominantly middle class and Caucasian (86% Caucasian, 7% Asian, 5% African American, 2% Hispanic). All children were walking and were healthy and developing normally by parent report. Three additional children participated but their data could not be used because of motor delay, language delay, or probable autism spectrum disorder.

General Procedure

Procedures took place in two adjacent playrooms and were videotaped for later coding. Parents remained with their children at all times. A primary experimenter (E) administered all procedures with an assistant experimenter (AE) for some tasks. Children became comfortable with both experimenters during a warm-up free play period at the beginning of the session.

Five tasks were administered to assess body self-awareness. Two tasks evaluated children's knowledge of their own body topography, and three tasks evaluated children's understanding of their body size. Each task required 5–10 min to administer; all children received all tasks. The standard mirror self-recognition (rouge) task was also administered midway through the session, and parents completed questionnaires to assess children's self-understanding.

Body Topography Tasks

Two new tasks were developed to provide nonverbal assessments of young children's ability to represent the locations and spatial arrangement of their body parts. These were adapted from tasks used to study body representation deficits in adults with focal brain damage, as reviewed earlier. One task requires adults to point to their own body parts as the examiner names them. Another task requires adults to imitate meaningless gestures directed to particular locations on the body. Toddler versions of both tasks were created and extensively pilot-tested with 40 children between 18 and 32 months of age to provide the assessments used in the current study.

Sticker task: Body-part localization. This task assessed children's ability to locate particular body parts on themselves. Children were asked to place a sticker on an *unnamed* body location on themselves after watching E place a sticker at that location on AE. No body-part names or labels were used, to avoid confounds with developing lexical knowledge.

The child and both experimenters were seated on the floor, with AE directly across from the child, approximately 50 cm away. E drew the child's attention to AE and said, ''Watch, I'm going to put a sticker right there on [name],'' as she placed the sticker on AE. She then said again, ''See, I put a sticker right there,'' while she pointed to or touched the location on AE. She then handed a sticker to the child and said, ''Now you put your sticker on you right there, so it's just like [name]. You put your sticker right there on you.''

The first location was always the nose since previous research has shown that it is one of the first body parts learned: Eighty-five percent of 18-month-olds and 100% of 24-month-olds can point to their nose on request (Witt, Cermak, & Coster, 1990). Based on existing research on body-part naming (MacWhinney, Cermak, & Fisher, 1987; Witt et al., 1990) and parent report from pilot data, the six most often known body locations among 18- to 24-month-olds were determined (nose, hand, foot, head, back, and neck) as well as the six least known locations (forehead, wrist, elbow, calf, temple, and nape). We included both to guard against either floor or ceiling effects; we neither expected every child to know the most familiar, nor did we expect every child to fail the least familiar. These constituted the 12 standard locations presented to each child. Each location was demonstrated one at a time by E. The sticker remained fully visible on AE until the children placed their own sticker on themselves.

Children's sticker placements were scored from video records for accuracy (within 1 in. of location; adjacent location on same body part, different body part, nonbody location, refuse) by two trained coders. Because young children's motor limitations sometimes made it difficult for them to place the stickers with high precision and because it is unlikely that children of this age understand the notion of spot-on accuracy, accurate and adjacent locations were combined to yield the total number of ''correct'' sticker locations. Proportion correct was the measure used in analyses (number of correct sticker placements divided by 12). Interrater agreement was calculated for each coder with a master coder (one of the authors) on 31% of the sample (11% and 20% respectively; $\kappa s = 1.0$ and .96).

Meaningless gesture imitation: Body-part Configuration. This task assessed children's ability to represent the spatial relation among their own body parts. In adults, being able to maintain a meaningless hand gesture and to position it on the body requires explicit awareness and representation of one's individual body parts and the spatial relations among them (Goldenberg, 1996; Goldenberg & Karnath, 2006). Children were asked to imitate a meaningless gesture, a closed fist, positioned at particular body locations. Pilot testing had determined that children within this age range could imitate a closed fist without difficulty.

The child was seated at a child-sized table (65 cm × 45 cm × 40 cm). E sat diagonally to the child, approximately 40 cm to the child's right. She explained to the child that they would play a turn-taking game and then demonstrated one of nine different actions. Each action was demonstrated twice while the child watched. The child was encouraged to imitate after the second demonstration and was given approximately 30 s to do so. If the child did not imitate, the action was demonstrated once again with another opportunity to imitate. If the child failed to imitate again, the next action was demonstrated. For six of the actions, the experimenter demonstratively placed her closed fist on a specific body location (forearm, stomach, cheek, chin, forehead, or top of head). To control for individual differences in motor control, imitative ability, and/or motivation, the child was also asked to imitate three different actions with objects, all directed to the table top (slide a wooden block on the table, pat the table with a plastic dishwashing scrubby, and pound the table with a wooden cylinder). Each of these actions required the child to place the hand approximately in a fist shape to grasp the object, and all of the objects were nonspecific to the action demonstrated, thus all were novel action–object combinations.

Children's performance was scored from video records by two trained coders for the number of correct imitations. A response was considered correct if the child imitated the experimenter's action at the same location (within 1 in., and without penalty for confusions between left and right), using the same hand configuration (for gestures) and orientation (for gesture and objects) as the experimenter's. Interrater agreement for the number of correct trials was calculated on 21% of the sample ($\kappa = .91$).

Body-Size Tasks

Three tasks indexed children's ability to reason about their own body size relative to objects in the world. These were identical to those used in our prior study (Brownell et al., 2007) since one aim of the current study was to replicate those findings. Additional details about the tasks can be found in that publication.

Doll clothes. In this task, children were offered much too small doll clothes to wear. The child watched as the experimenter dressed a 30-cm doll in a doll-sized hat, jacket, and shoes. After placing each piece of clothing on the doll, the experimenter handed the child an identical piece of doll clothing and said simply, ''Here's your [hat, jacket, shoe].'' Attempts by children to put the doll clothes on themselves as if the clothing were full-sized were scored as errors (coding details given later).

Door choice. This task required the child to choose one of two doors to reach a parent on the other side of a 1 m × 2 m foamboard wall, only one of which the child could fit through (adapted from Garon & Moore, 2002). One door was a 30 cm × 30 cm hole in the wall, with a 10-cm square window above it through which the child could see the parent. Children could easily crawl through this door. The second door was tall and narrow (10 cm wide × 80 cm tall), and the child could also see the parent through this hole; however, it was much too narrow for the child's body. The child was placed equidistant between the doors, and the parent then called the child. Once the child had joined the parent on the other side, the experimenter called the child to return. Children's attempts to squeeze their bodies through the too small door were scored as errors.

Replica toys. In this task (adapted from DeLoache et al., 2004), children played with a standard set of child-sized toys (Little Tikes™ slide, toddler chair, cozy coupe car; Little Tikes Company, Hudson, OH) and then several minutes later played with a separate set of small, doll-sized replicas of the same toys; these were approximately 8–14 cm high, and one fifth to one sixth the height of the child-sized toys. Children were free to play with the replica toys however they wished for approximately 5 min. Attempts to use the replica toys as if they were full-sized, without considering that their bodies are too big for such small toys (e.g., trying to sit in the doll chair), were scored as errors.

Body-size awareness measures. Children's behavior was coded from the video records by two trained coders. An error was defined as a serious, nonpretend attempt, based on the child's action, facial expression, and effort. For example, a serious attempt to wear the doll jacket meant attempting with clear effort to put the hand and forearm fully into the sleeve; a serious attempt to sit in the doll-sized replica chair involved positioning the body appropriately and then sitting with one's full weight on the chair with a neutral facial expression (and perhaps surprise at the outcome). Each independent attempt was counted as an error. Interobserver reliability for the number of errors on each task was calculated on 21% of the sample; because the codes were not mutually exclusive and exhaustive, percent agreements rather than Kappas were calculated for the individual tasks, and ranged from 82% to 89%.

Reflective Self-Awareness

Three independent, age-appropriate measures of reflective self-awareness were obtained using established procedures: (a) mirror self-recognition, (b) parental report of the child's self-description and self-evaluation, and (c) parental report of the child's comprehension and production of personal pronouns. Mirror self-recognition was assessed using the standard, well-replicated ''rouge task'' (Amsterdam, 1972) in which the parent surreptitiously placed a dab of red lipstick on the child's nose during free play. A brief period of continuing play ascertained that the child neither noticed the lipstick nor tried to remove it spontaneously. The experimenter then held a 30 cm × 30 cm mirror in front of the child so that a full view of his or her own face was visible, drawing the child's attention to the mirror. If the child did not respond after approximately 10 s, the experimenter asked ''Who's there?'' while pointing to the mirror; if the child did not attend after an additional 10 s the experimenter asked ''What's on his or her nose?'' again pointing to the mirror.

Children's mirror-related behavior was independently coded from video records by two trained coders. Behaviors included touching or turning away from the mirror, saying own name, touching own nose, touching other parts of the face, attempting or requesting to remove the lipstick, and self-conscious behavior such as embarrassment. Children's performance was scored on a 3-point scale (after Asendorpf, Warkentin, & Baudonniere, 1996; Courage, Edison, & Howe, 2004; Rogdon & Kurdek, 1977): *pass* (2) if they said their own name, touched their own nose, or attempted or requested to remove the lipstick (48% of 20-month-olds, 81% of 30-month-olds); *ambiguous* (1) if they touched other parts of their face but not their nose, touched their nose upon hearing the word *nose* in the experimenter's attention-eliciting cue, or were self-conscious in front of the mirror (24% of 20-month-olds, 19% of 30-month-olds); *fail* (0) if they engaged in any other behavior, including saying ''baby,'' touching the mirror, ignoring it, or turning away from it without self-conscious behavior (28% of 20-month-olds, 0% of 30-month-olds). Interobserver reliability was calculated on 21% of the sample (κ = .88).

Parents completed the UCLA Self-Understanding Questionnaire developed for this age group (Stipek, Gralinski, & Kopp, 1990), with 17 items rated on a 3-point scale (0 = *definitely not*, 1 = *sometimes/just starting to*, 2 = *definitely*). Items tap self-recognition, self-description, and self-evaluation (e.g., recognizes self in photos; uses own name; says ''me,'' ''mine''; uses terms like *good* or *bad* about self); Cronbach's alpha = .91. Parents also completed the toddler form of the MacArthur Communicative Development Inventory (MCDI; Fenson et al., 1994). Because we were interested in words referring to self and other, and because use of personal pronouns has previously been shown to relate to mirror self-recognition in this age group (Lewis & Ramsay, 2004), we used the *Pronouns* subscale of the MCDI for which the parent indicates whether the child understands (a) or understands and says (b) eight personal pronouns (e.g., *her*, *you*, *me*); Cronbach's alpha = .93. The three measures of reflective self-awareness were significantly intercorrelated (rs = .35–.59, ps = .001–.005), so were standardized and summed to produce a single, global measure of reflective self-awareness (Cronbach's alpha = .77).

Results

Preliminary analyses indicated that there were no sex differences on any measure; thus, analyses were collapsed over sex. Table 1 shows mean values and standard errors for all variables. Substantive analyses were conducted to address several questions. The first set of analyses examined age differences for each aspect of body knowledge (body-part localization, body configuration, body size) and for reflective self-awareness. The second set tested associations between body-part localization and body configuration to determine whether there was evidence for a general topographic representation of one's own body in children of this age. The third set examined associations between body-size awareness and body topographic knowledge to determine whether they are part of a more general body-awareness construct or whether they are distinct. The final set of analyses examined associations between elements of body knowledge and reflective self-awareness. Not all children completed all tasks; thus, ns vary slightly across analyses.

Age Differences

Univariate or multivariate analyses of variance (ANOVAs) with two levels of age (20 and

Table 1
Mean Values and Standard Errors for Body Knowledge and Self-Awareness Measures With Significance Test Results for Age Differences (ANOVA)

	All children (n = 61)	20-month-olds (n = 30)	30-month-olds (n = 31)	F	p value
Body-size tasks (no. of errors)					
Doll clothes	2.12 (0.31)	2.93 (0.36)	1.37 (0.22)	6.58	.013
Door choice	1.63 (0.23)	2.32 (0.26)	0.93 (0.15)	10.05	.003
Replica toys	2.88 (0.42)	4.11 (0.46)	1.73 (0.33)	8.49	.005
Body-part localization (proportion correct)					
Sticker task	0.27 (0.28)	0.19 (0.20)	0.35 (0.33)	4.87	.031
Body-part configuration (proportion correct)					
Imitation: Gestures to self	0.17 (0.05)	0.08 (0.04)	0.26 (0.04)	10.03	.003
Imitation: Object actions to table	0.77 (0.03)	0.76 (0.07)	0.78 (0.07)	0.004	*ns*
Reflective self-awareness (z score)[a]	−0.04 (0.32)	−1.83 (0.22)	1.69 (0.23)	60.89	.001

[a]MSR + UCLA self-understanding + CDI personal pronouns.

30 months) were conducted as appropriate on the measures of each dimension of body representation and on the composite measure of reflective self-awareness. As expected, we found systematic age differences for each measure.

Body-part localization. Children were asked to place stickers on 12 different body locations on themselves after watching a sticker placed at each location on another person. A univariate ANOVA with proportion of correct sticker placements as the dependent variable yielded a significant age effect, $F(1, 59) = 4.87$, $p = .031$, $\eta^2 = .08$. Older children placed nearly twice as many stickers on or adjacent to the correct body part as did younger children (see Table 1), although it should also be noted that even older children were still far from perfect. Some children frequently placed stickers on surrounding objects instead of on themselves or refused to place several stickers anywhere (n = 15). When these children were removed from the analysis, average performance rose (20 months, M = 0.23; 30 months, M = 0.47), and the significant age effect remained, $F(1, 44) = 9.57$, $p = .003$, $\eta^2 = .18$.

Body configuration. Children were asked to imitate a meaningless gesture directed to their own bodies at six different locations; in the comparison condition they were asked to imitate three different actions with an object directed to a table top. A repeated measures ANOVA with location (self, table) as the within-subjects factor and age as the between-subjects factor was conducted on the proportion of correct imitations (see Table 1). A significant effect for location emerged, $F(1, 55) = 17.20$, $p < .001$, $\eta^2 = .76$, as well as a marginally significant interaction between age and location, $F(1, 55) = 3.69$, $p = .06$, $\eta^2 = .06$. As evident in Table 1, younger children performed as well as older children when imitating actions directed toward the table but performed less accurately than older children when they had to imitate a gesture directed to their own body.

Body size. The number of times children attempted to fit themselves into small doll clothes, through small openings, or onto or into miniature toys that were much too small was recorded. A multivariate ANOVA with the three measures of body-size awareness (doll clothes errors, door choice errors, and replica toys errors) as dependent variables yielded a significant age effect, multivariate $F(3, 52) = 6.48$, $p = .001$, $\eta^2 = .27$. The follow-up univariate tests for age differences on each dependent variable were also significant (see Table 1, for Fs and p values). Thus, on all three measures, 30-month-olds produced significantly fewer errors than did 20-month-olds, replicating the findings of Brownell et al. (2007). Also as in Brownell et al., children's performance in the current study was correlated across the three tasks (rs = .22–.35, ps = .10–.006).

Reflective self-awareness. A composite measure of reflective self-awareness was created from mirror self-recognition scores, children's self-description and self-evaluation, and their personal pronoun comprehension and use. The ANOVA yielded a significant age effect, $F(1, 59) = 60.89$, $p < .001$, $\eta^2 = .51$, as expected (see Table 1).

Evidence for a Topographic Body Representation

To determine whether children's body-part localization and body configuration knowledge

Table 2
Intercorrelations Among Body Knowledge and Self-Awareness Measures

	Personal pronouns	UCLA self-understanding	Mirror self-recognition	Reflective self-awareness[a]	Sticker task[b]	Imitation: Gestures to self[b]	Imitation: Object actions to table[b]
UCLA self-understanding	.81***						
Mirror self-recognition	.35**	.42***					
Reflective self-awareness[a]	.80***	.82***	.41**				
Sticker task[b]	.29*	.30*	.21†	.33**			
Imitation: Gestures to self[b]	.28*	.40**	.26*	.36**	.53***		
Imitation: Object actions to table[b]	.03	.14	.31*	.21†	.35**	.38**	
Body-size tasks (sum of errors)	−.21†	−.37**	−.28*	−.33*	−.13	−.13	−.08

Note. df = 57 to 61, depending on the number of children completing a given task.
[a]Summary score. [b]Proportion correct.
†$p < .10$. *$p < .05$. **$p < .01$. ***$p < .001$.

constituted related components of a higher order topographic representation of their own bodies, Pearson correlations were calculated between children's performance on the sticker task and their performance on the imitation task (see Table 2 for correlation coefficients). The significant association suggests that young children do possess a general topographic representation of their own bodies.

Unexpectedly, however, children's ability to locate stickers on their own body was also associated with their imitation of object actions directed to the table (see Table 2), suggesting that some factor related to general imitative skill or motivation might also be at work and could explain the above association. To control for this possibility, we recalculated the correlation between children's score for imitating gestures to their own bodies and their score for placing stickers on particular body parts, partialing out their ability to imitate actions with objects; the correlation remained significant, partial $r(57) = .43$, $p = .001$. Finally, we further partialed age; children's ability to imitate meaningless gestures to their own body remained significantly associated with their ability to locate particular body parts on themselves above and beyond both general imitative ability and age, partial $r(56) = .32$, $p = .014$.

Associations Between Topographic Body Representations and Body-Size Awareness

To determine to what extent topographic body knowledge and body-size awareness are distinct or related, Pearson correlations were calculated between a composite measure of body-size awareness (the total number of body-size errors across all tasks; Cronbach's alpha = .61) and the measures of each of the other two components of body awareness, that is, body-part localization and body configuration. Neither of these correlations was significant (see Table 2 for correlation coefficients), including when age was partialed from the calculations. A composite score for body topography knowledge was also created as the sum of z scores for the sticker and gestural imitation tasks, and was likewise unrelated to the number of body-size errors. It thus appears that there are two distinct aspects of early body self-awareness, one related to children's knowledge of their own body size and one related to the topographic representation of their body and its parts.

Associations Between Body Representation and Reflective Self-Awareness

Finally, to determine whether the different aspects of body self-awareness indexed in the current study were associated with reflective self-awareness as traditionally assessed, Pearson correlations were calculated between the composite self-awareness measure and the composite measures for body-size awareness (number of errors), $r(59) = −.33$, $p = .01$, and body topography knowledge (number correct), $r(64) = .38$, $p = .002$. The same results were obtained when the self-awareness composite was correlated with the separate measures for body-part localization and body configuration knowledge individually (see Table 2), as well as when the composite measure of reflective self-awareness was decomposed into its individual constituents. When age was partialled, associations became nonsignificant (rs < .20). Thus, as expected, reflective self-awareness was associated with each dimension of body self-awareness studied here;

however, these relations were carried by their common association with age.

Discussion

Early developments in children's explicit, conscious representations of their own body's objective physical characteristics such as shape, size, and configuration were explored in the current study. Development of body self-awareness is relatively uncharted despite continuing interest in the growth of self- and other-understanding (Brownell & Kopp, 2007), and the potential for identifying the roots of childhood body image in infancy (Smolak, 2004). We report evidence that children's topographic representation of their own bodies emerges between 20 and 30 months of age.

We further found that this aspect of early body knowledge appears to be constituted of two related dimensions. One dimension reflects knowledge about where specific body parts are located on one's own body even when these are not named or previously known. The second reflects knowledge about how one's body is spatially configured, that is, how one's body parts are arranged or spatially organized in relation to one another. Both appear to be still relatively immature at 2½ years of age, pointing to continuing development over the preschool years. We also found that children become aware of their own body size during the 2nd year of life, replicating previous findings (Brownell et al., 2007). Interestingly, children's awareness of their body's topographic characteristics was unrelated to their body-size awareness. Both were related, however, to a multifaceted measure of self-recognition and self-awareness, albeit mediated by their common associations with age.

Together with other recent research (e.g., Brownell et al., 2007; Moore et al., 2007; Nielsen, Suddendorf, & Slaughter, 2006), the findings from the current study confirm that body self-awareness is a unique aspect of the development of an objective, conscious self. The results further suggest that the child's developing body image, even in its initial and relatively primitive form, is constituted of multiple, distinct dimensions. In particular, previous research showed that body self-awareness emerges in the 2nd year as explicit awareness of one's physical characteristics like size, mass, or solidity, and of being able to enter into object–object relations with other physical objects by serving as an obstacle, tool, encumbrance, or container (Brownell et al., 2007; Moore et al., 2007). The current results suggest that it is somewhat later, in the 3rd year of life, that awareness of the topographic or spatial organization of one's body also appears. By age 2½, then, children have a beginning knowledge of their own body's size, shape, and structure.

Of course, toddlers' conscious awareness of their own body size and configuration does not arise de novo, but emerges out of and builds on an extensive implicit and perceptually based bodily self established over infancy. This includes sensitivity to body dimension parameters (e.g., Adolph & Avolio, 2000) and to one's own body parts such as hands (McCarty, Clifton, & Collard, 1999). For example, before 12 months of age infants can scale motor actions like reaching or throwing to take account of object size, position, orientation, speed, or function in motor planning tasks (e.g., Claxton, Keen, & McCarty, 2003; Lockman, Ashmead, & Bushnell, 1984; von Hofsten, Vishton, Spelke, Feng, & Rosander, 1998; Witherington, 2005). With the advent of reflective self-awareness in the latter half of the 2nd year, this implicit, sensorimotor knowledge of one's body becomes available to conscious awareness. As Moore (2007) has argued, it is during this period that infants' developing first-person knowledge of their own bodies becomes integrated with their developing third-person knowledge of others' bodies. This, in turn, permits conscious reflection on body characteristics of both self and others, thereby also grounding the subsequent development of the body image.

Own Body Topography

To study toddlers' own body representations, we created age-appropriate modifications of tasks used by investigators of adults' representations of their own body configuration (e.g., Goldenberg & Karnath, 2006; Guariglia et al., 2002; Schwoebel, Buxbaum, & Coslett, 2004). In one task, children were asked to locate body parts by placing a sticker on a particular location on their own body after watching an adult place a sticker at that location on an assistant's body without naming the location or body part. On average, 20-month-old children were able to locate only two or three common body parts (e.g., nose, hand, foot), whereas 30-month-olds were able to locate four or five (e.g., nose, hand, foot, head, neck). These findings indicate that children's knowledge of the specific locations of their own body parts is quite primitive at 20 months of age, but is well in evidence by 30 months, even though still immature.

A similar procedure was used by DeLoache and Marzolf (1995) to study preschoolers' ability to use a doll to represent their own body. In that study, when an experimenter placed stickers on four specific places on the child's body (forearm, knee, foot, and neck) and then asked the child to place stickers in the same places on the doll, 32-month-old children placed only 1.6 stickers correctly out of the 4 possible. Moreover, children found it equally difficult to perform the procedure from doll to self. This suggests that for 2-year-olds, mapping between one's own body and a doll's body may be even more difficult than mapping between one's own body and an adult's body, possibly because of additional cognitive demands in forming a representational relation between self and a pretend object. More relevant for the current study, these findings confirm that during the 3rd year of life children's spatial knowledge of their own bodies undergoes substantial progress.

In contrast to the findings from these two studies, lexical acquisition studies indicate that 12-month-olds can identify two body parts on average when asked to point to them by name (Witt et al., 1990) and that by 18–24 months of age children can name and point to several specific body parts on themselves (Bretherton, McNew, & Beeghly-Smith, 1981; Kopp, 1994). However, learning to point to specific body parts on command may be a result of highly practiced routines and thus need not depend on or reflect a more general representation of the spatial configuration of the body, including where various unrehearsed body parts are located and how body parts are arranged and organized in relation to one another. This is why, in the current study, we included body parts for which children did not yet have names (e.g., elbow) and refrained from naming those body parts for which they were likely to possess a label (e.g., nose, foot). We are confident, therefore, that children's performance in the current study was not a result of stereotyped routines for pointing to specific, well-rehearsed body locations on request. Instead, we conclude that children's explicit self-representations undergo significant developmental change at the end of the 2nd year of life and into the 3rd year.

In the second task used to index their body topography knowledge, children were asked to imitate a meaningless gesture (closed fist) placed at different locations on the body (e.g., top of head, stomach). This requires consideration of multiple relation among specific body parts, both those involved in making and maintaining the gesture itself, and the location on the body at which the gesture is placed (Goldenberg, 1996). We found that 30-month-old children were able to position their fists accurately on their own bodies more than 3 times as often as were younger children. Importantly, younger and older children were equivalent in their ability to imitate object-related actions directed to a table top. Thus, it was not general imitative ability that limited the younger children's performance, but the specific ability to imitate a gesture directed to locations on their own bodies. Like the results for children's knowledge of where their body parts are specifically located, these findings indicate that knowledge of how their own body is spatially organized is also quite rudimentary in 1-year-olds, becoming evident in young 2-year-olds, though clearly still primitive even then.

These data are consistent with previous findings that imitation of unfamiliar and/or nonvisible bodily movements and gestures is more difficult than imitation of familiar movements or imitation with objects, both in normal children under 24 months and in children with autism (Abravanel, Levan-Goldschmidt, & Stevenson, 1976; Brownell, 1988; Jones, 2007; Masur, 1993; Masur & Ritz, 1984; Rogdon & Kurdek, 1977; Rogers, Hepburn, Stackhouse, & Wehner, 2003; Stone, Ousley, & Littleford, 1997). They are also consistent with several recent anecdotal reports of children's inaccurate matching responses when they imitate behavior with or on specific body parts. For example, when 14- or 18-month-old infants watched an adult illuminate a light by using her forehead or elbow to touch the light, they imitated body-part-specific actions only approximately; that is, they used their mouth, chin, cheek, or even ear to touch the light, rather than the forehead as modeled (Herold & Akhtar, 2008; Southgate, Gergely, & Csibra, 2009), or they used the back of the hand instead of the elbow as modeled (Herold & Akhtar, 2008). In a different study, when 12- and 18-month-old infants were asked to imitate actions with objects on their own body after watching an experimenter model the behavior on herself (e.g., roll a car on an arm, tap a plastic ring against the cheek), children often failed to use the correct body part when they imitated; for example, they would tap the ring on their chin instead of their cheek (Carpenter, Tomasello, & Striano, 2005). Together, these data converge on the conclusion that the ability to represent explicitly the spatial relation among one's own body parts begins to take form late in the 2nd year of life, between 20 and 30 months of age.

Despite the rather pronounced demand differences in the sticker (body-part localization) and imitation (body configuration) tasks, children who performed better on one task also performed better on the other, even with both age and general imitative ability controlled. Performance on body-part localization and meaningless gesture imitation tasks is also strongly associated in adults with brain damage (r = .78; Schwoebel et al., 2004), and seems to call on similar regions of the brain (Goldenberg & Karnath, 2006). Our data thus suggest that by 30 months of age young children, like adults, begin to access consciously a general representation of their own bodies' spatial organization. Even these 2-year-olds, however, were far from ceiling on either task, which indicates that development of this complex aspect of body self-awareness must be ongoing well past the toddler years.

Own Body-Size Awareness

The current study provided an independent replication of our previous work in which we found developmental changes over the 2nd year in children's knowledge of their body size (Brownell et al., 2007). Interestingly, a recent study has shown that young children between 16 and 60 months of age are poor at scaling their reaching actions to the size of their own hands; 1- and 2-year-olds, in particular, tried repeatedly to fit their hands through impossibly small openings to reach something on the other side, even after their hands became stuck (Ishak & Adolph, 2008). Thus, the ability to imagine and attend to one's own body size begins to emerge in the 2nd year of life and appears to continue developing over the preschool years.

The fact that body-size awareness and body topography knowledge were not associated with each other suggests that these body representations are somewhat distinct and may develop partly independently of one another. Christie and Slaughter (2009) similarly found no associations between infants' sensorimotor body representations and their visuospatial body representations, prompting those authors to suggest that different body representation systems may initially be differentiated, then become integrated over the course of infancy and early childhood. Another possibility is that there are additional task demands, or perhaps affordances, unique to some of the body-size awareness tasks used here and by Brownell et al. (2007). If fitting through doorway openings, for example, relies on children's affordance detection rather than (or in addition to) explicit knowledge of their own body size, then failure may reflect other performance factors such as immature impulse control, or other demand factors such as low cost for failure. Teasing apart potential contributions to failure on such tasks holds promise for better understanding the mechanisms that contribute to eventual success, and the circumstances in which explicit body knowledge can or must be invoked.

Reflective Self-Awareness and Body Self-Awareness

Body-size awareness and body topography knowledge were associated with traditional measures of reflective self-awareness, including mirror self-recognition, self-description and self-evaluation, and language about self and other. However, this association was carried by the strong common associations with children's age. These findings contrast with those of Moore et al. (2007) who found that toddlers' ability to move themselves off a rug attached to the rear of a shopping cart before pushing it was related to mirror self-recognition, even with age controlled. However, the association with self-recognition was modest in that study, leading the authors to propose that body self-awareness and mirror self-recognition tap different, but related, aspects of developing self-awareness. We draw the same conclusion from the findings of the current study, noting further that mirror self-recognition is mastered by most children by 24–30 months of age, whereas children's body self-awareness remains rather rudimentary at 30 months of age, with development extending into early childhood. Reflective self-awareness may thus be a necessary foundation, but not sufficient to account specifically for growth and change in body-size awareness or topographic body knowledge.

This proposal is consistent with recent arguments for a somewhat extended developmental course for other complex aspects of self-recognition (Suddendorf, Simcock, & Nielsen, 2007). For example, there is a developmental lag of about 1 year between children's mirror self-recognition and their ability to recognize themselves in real-time video, even after controlling for differences in the perceptual features of the two types of display. Suddendorf et al. (2007) speculate that this developmental asynchrony is explained by an immature mental self-image among younger children, which is lacking in the abstraction necessary to support a general, intermodal representation of their own appearance. It would be interesting in future research to determine whether the child's primitive body image, as reflected in the kinds of tasks used in the current study, consolidates during the same period in development as video and shadow self-recognition, which are presumably also based on an objective, integrated, spatially configured own body representation. Such a general representation of one's appearance may serve as a developmental link between the perceptually specified bodily self of infancy and the later emergence of the body image in early childhood.

References

Abravanel, E., Levan-Goldschmidt, E., & Stevenson, M. B. (1976). Action imitation: The early phase of infancy. *Child Development*, *47*, 1032–1044.

Adolph, K., & Avolio, A. (2000). Walking infants adapt locomotion to changing body dimensions. *Journal of Experimental Psychology: Human Perception & Performance*, *26*, 1148–1166.

Adolph, K., & Berger, S. (2006). Motor development. In W. Damon & R. Lerner (Series Eds.) & D. Kuhn & R. S. Siegler (Vol. Eds.), *Handbook of child psychology: Vol. 2. Cognition, perception, and language* (6th ed., pp. 161–213). New York: Wiley.

Amsterdam, B. (1972). Mirror self-image reactions before age two. *Developmental Psychobiology*, *5*, 297–305.

Arzy, S., Thut, G., Mohr, C., Michele, C., & Blanke, O. (2006). Neural basis of embodiment: Distinct contributions of temporoparietal junction and extrastriate body area. *Journal of Neuroscience*, *26*, 8074–8081.

Asendorpf, J. B., Warkentin, V., & Baudonniere, P. M. (1996). Self-awareness and other-awareness. II: Mirror self-recognition, social contingency awareness, and synchronic imitation. *Developmental Psychology*, *32*, 313–321.

Barresi, J., & Moore, C. (1996). Intentional relations and social understanding. *Behavioral & Brain Sciences*, *19*, 107–122.

Bertenthal, B., & Rose, J. (1995). Two modes of perceiving the self. In P. Rochat (Ed.), *The self in infancy: Theory and research* (pp. 303–324). Amsterdam: Elsevier.

Bretherton, I., McNew, S., & Beeghly-Smith, M. (1981). Early person knowledge as expressed in gestural and verbal communication. In M. Lamb & L. Sherrod (Eds.), *Infant social cognition: Empirical and theoretical considerations* (pp. 333–353). Hillsdale, NJ: Erlbaum.

Brownell, C. (1988). Combinatorial skills: Converging developments over the second year. *Child Development*, *59*, 675–685.

Brownell, C., & Kopp, C. (2007). Transitions in toddler socioemotional development: Behavior, understanding, relationships. In C. Brownell & C. Kopp (Eds.), *Socioemotional development in the toddler years: Transitions and transformations* (pp. 1–42). New York: Guilford.

Brownell, C., Zerwas, S., & Ramani, G. (2007). ''So big'': The development of body self-awareness in toddlers. *Child Development*, *78*, 1426–1440.

Butterworth, G. (1995). An ecological perspective on the origins of self. In J. L. Bermudez, A. J. Marcel, & N. Eilan (Eds.), *The body and the self* (pp. 87–106). Cambridge, MA: MIT Press.

Buxbaum, L. J., & Coslett, H. (2001). Specialized structural descriptions for human body parts: Evidence from autotopagnosia. *Cognitive Neuropsychology*, *18*, 289–306.

Carpenter, M., Tomasello, M., & Striano, T. (2005). Role reversal imitation and language in typically-developing infants and children with autism. *Infancy*, *8*, 253–278.

Chaminade, T., Meltzoff, A., & Decety, J. (2005). An fMRI study of imitation: Action representation and body schema. *Neuropsychologia*, *43*, 115–127.

Christie, T., & Slaughter, V. (2009). Exploring links between sensori-motor and visuo-spatial body representations in infancy. *Developmental Neuropsychology*, *34*, 448–460.

Churchland, P. (2002). Self-representation in nervous systems. *Science*, *296*, 308–310.

Claxton, L., Keen, R., & McCarty, M. (2003). Evidence of motor planning in infant reaching behavior. *Psychological Science*, *14*, 354–356.

Courage, M. L., Edison, S. C., & Howe, M. L. (2004). Variability in the early development of visual self-recognition. *Infant Behavior and Development*, *27*, 509–532.

DeLoache, J., & Marzolf, D. (1995). The use of dolls to interview young children: Issues of symbolic representation. *Journal of Experimental Child Psychology*, *60*, 155–173.

DeLoache, J., Uttal, D., & Rosengren, K. (2004). Scale errors offer evidence for a perception-action dissociation early in life. *Science*, *304*, 1027–1029.

Devue, C., Collette, F., Balteau, E., Degueldre, C., Luxen, A., Maquet, P., et al. (2007). Here I am: Cortical correlates of visual self-recognition. *Brain Research*, *1143*, 169–182.

Ehrsson, J., Kito, T., Sadato, N., Passingham, R., & Naito, E. (2005). Neural substrate of body size: Illusory feeling of shrinking of the waist. *PloS Biology*, *3*(12), e439.

Fenson, L., Dale, P. S., Reznick, J. S., Bates, E., Thal, D., Pethick, S. J., et al. (1994). Variability in early communicative development. *Monographs of the Society for Research in Child Development*, *59*(5, Serial No. 242).

Garon, S., & Moore, C. (2002, April). *Development of the objective self*. Paper presented at the International Conference on Infant Studies, Toronto, ON.

Goldenberg, G. (1996). Defective imitation of gestures in patients with damage in the left or right hemispheres. *Journal of Neurology, Neurosurgery, and Psychiatry*, *61*, 176–180.

Goldenberg, G. (1997). Disorders of body perception. In T. Feinberg & M. Farah (Eds.), *Behavioral neurology and neuropsychology* (pp. 289–296). New York: McGraw-Hill.

Goldenberg, G., & Karnath, H. (2006). The neural basis of imitation is body part specific. *Journal of Neuroscience*, *26*, 6282–6287.

Guariglia, C., Piccardi, M., Puglisi, A., & Traballesi, M. (2002). Is autotopoagnosia real? EC says yes. A case study. *Neuropsychologia*, *40*, 1744–1749.

Herold, K., & Akhtar, N. (2008). Learning from a third-party interaction: Relations with self-recognition and perspective taking. *Journal of Experimental Child Psychology*, *101*, 114–123.

Heron, M., & Slaughter, V. (2008). Toddlers' categorization of typical and scrambled dolls and cars. *Infant Behavior & Development*, *31*, 374–395.

Ishak, S., & Adolph, K. E. (2008). *Fitting through openings: Body scaling in infants, children, and adults*. Manuscript in preparation.

James, W. (1890). *Principles of psychology*. New York: Holt.

Jones, S. (2007). Imitation in infancy: Development of mimicry. *Psychological Science*, *18*, 593–598.

Kagan, J. (1981). *The second year: Emergence of self-awareness*. Cambridge, MA: Harvard University Press.

Keysers, C., & Gazzola, V. (2007). Integrating simulation and theory of mind: From self to social-cognition. *Trends in Cognitive Science*, *11*, 194–196.

Kopp, C. (1994). *Baby steps: Your child's behavior in the first two years*. New York: Freeman.

LeClec, G., Dehaene, S., Cohen, L., Mehler, J., Dupoux, E., Poline, J., et al. (2000). Distinct cortical areas for names of numbers and body parts independent of language and input modality. *NeuroImage*, *12*, 381–391.

Lewis, M., & Brooks-Gunn, J. (1979). *Social cognition and the acquisition of self*. New York: Plenum.

Lewis, M., & Ramsay, D. (2004). Development of self-recognition, personal pronoun use, and pretend play during the second year. *Child Development*, *75*, 1821–1831.

Lockman, J., Ashmead, D., & Bushnell, E. (1984). The development of anticipatory hand orientation during infancy. *Journal of Experimental Child Psychology*, *37*, 176–186.

MacWhinney, K., Cermak, S., & Fisher, A. (1987). Body part identification in 1- to 4-year-old children. *American Journal of Occupational Therapy*, *41*, 454–459.

Masur, E. F. (1993). Transitions in representational ability: Infants' verbal, vocal, and action imitation during the second year. *Merrill-Palmer Quarterly*, *39*, 437–456.

Masur, E., & Ritz, E. (1984). Patterns of gestural, vocal and verbal imitation in infancy. *Merrill-Palmer Quarterly*, *30*, 369–392.

McCarty, M., Clifton, R., & Collard, R. (1999). Problem solving in infancy: Emergence of an action plan. *Developmental Psychology*, *35*, 1091–1101.

Moore, C. (2007). Understanding self and others in the second year. In C. Brownell & C. Kopp (Eds.), *Transitions in early socioemotional development: The toddler years* (pp. 43–65). New York: Guilford.

Moore, C., Mealiea, J., Garon, N., & Povinelli, D. (2007). The development of body self-awareness. *Infancy*, *11*, 157–174.

Nielsen, M., Dissanayake, C., & Kashima, Y. (2003). A longitudinal investigation of self-other discrimination and the emergence of mirror self-recognition. *Infant Behavior & Development*, *26*, 213–226.

Nielsen, M., Suddendorf, T., & Slaughter, V. (2006). Mirror self-recognition beyond the face. *Child Development*, *77*, 176–185.

Peelen, M., & Downing, P. (2007). The neural basis of visual body perception. *Nature Reviews: Neuroscience*, *8*, 636–648.

Piaget, J. (1952). *The origins of intelligence in children*. New York: International Universities Press.

Povinelli, D., & Cant, J. (1995). Arboreal clambering and the evolution of self-conception. *Quarterly Review of Biology*, *70*, 393–421.

Reed, C. (2002). What is the body schema? In A. Meltzoff & W. Prinz (Eds.), *The imitative mind: Development, evolution, and brain bases* (pp. 233–245). Cambridge, UK: Cambridge University Press.

Rochat, P. (Ed.). (1995). Early objectification of the self. In *The self in infancy: Theory and research* (pp. 53–71). Amsterdam: Elsevier.

Rochat, P. (2001). Origins of self-concept. In G. Bremner & A. Fogel (Eds.), *Blackwell handbook of infant development* (pp. 191–212). Malden, MA: Blackwell.

Rochat, P., & Hespos, S. (1995). Differential rooting response by neonates: Evidence for an early sense of self. *Early Development and Parenting*, *6*, 150–158.

Rogdon, M., & Kurdek, L. (1977). Vocal and gestural imitation in 8- 14- and 20-month-old children. *Journal of Genetic Psychology*, *131*, 115–123.

Rogers, S. J., Hepburn, S. L., Stackhouse, T., & Wehner, E. (2003). Imitation performance in toddlers with autism and those with other developmental disorders. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, *44*, 763–781.

Schwoebel, J., Buxbaum, L., & Coslett, H. (2004). Representations of the human body in the production and imitation of complex movements. *Cognitive Neuropsychology*, *21*, 285–298.

Schwoebel, J., & Coslett, H. (2005). Evidence for multiple, distinct representations of the human body. *Journal of Cognitive Neurosicience*, *17*, 543–553.

Semenza, C. (1988). Impairment in localization of body parts following brain damage. *Cortex*, *24*, 443–449.

Sirigu, A., Grafman, J., Bressler, K., & Sunderland, T. (1991). Multiple representations contribute to body knowledge processing. *Brain*, *114*, 629–642.

Slaughter, V., & Heron, M. (2004). Origins and early development of human body knowledge. *Monographs of the Society for Research in Child Development*, *69*(2, Serial No. 276).

Smolak, L. (2004). Body image in children and adolescents: Where do we go from here? *Body Image*, *1*, 15–28.

Southgate, V., Gergely, G., & Csibra, G. (2009). Does the mirror neuron system and its impairment explain human imitation and autism? In J. Pineda (Ed.), *Mirror neuron systems: The role of mirroring processes in social cognition* (pp. 331–354). New York: Humana Press.

Stipek, D. J., Gralinski, J. H., & Kopp, C. B. (1990). Self-concept development in the toddler years. *Developmental Psychology*, *26*, 972–977.

Stone, W. L., Ousley, O. Y., & Littleford, C. D. (1997). Motor imitation in young children with autism: What's the object? *Journal of Abnormal Child Psychology*, *25*, 475–485.

Suddendorf, T., Simcock, G., & Nielsen, T. (2007). Visual self-recognition in mirrors & live videos: Evidence for a developmental asynchrony. *Cognitive Development*, *22*, 185–196.

Sugiura, M., Sassa, Y., Jeong, H., Miura, N., Akitsuki, Y., Horie, K., et al. (2006). Multiple brain networks for visual self-recognition with different sensitivity for motion and body part. *NeuroImage*, *32*, 1905–1917.

Urgesi, C., Candidi, M., Ionta, S., & Aglioti, S. (2007). Representation of body identity and body actions in extrastriate body area and ventral premotor cortex. *Nature Neuroscience*, *10*, 30–31.

von Hofsten, C., Vishton, P., Spelke, E., Feng, Q., & Rosander, K. (1998). Predictive action in infancy: Tracking and reaching for moving objects. *Cognition*, *67*, 255–285.

Witherington, D. (2005). The development of prospective grasping control between 5 and 7 months. *Infancy*, *7*, 143–161.

Witt, A., Cermak, S., & Coster, W. (1990). Body part identification in 1- to 2-year old children. *American Journal of Occupational Therapy*, *44*, 147–153.