
NOTES ON SELF AWARENESS DEVELOPMENT IN EARLY INFANCY

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ABSTRACT

The current paper analyzes the development in early infancy of the bodily self as a component of self awareness. We specifically emphasize the conceptual distinction between the body schema and the body image as body representations, highlighting the empirical evidence that support their development early in the first year of life.

KEYWORDS: *body schema, body image, self development, infancy.*

Starting with the age of 18-months, when placed in front of a mirror after being surreptitiously marked on the forehead with a rouge spot, most of the infants investigate their own face in search of that mark (Amsterdam, 1972; Gallup, 1970). This has been interpreted as a sign that infants this age have some mental representations of their appearance (Wheeler, Stuss, & Tulving, 1997), a rapidly updatable expectation of what they look like from the outside (Nielsen, Suddendorf, & Slaughter, 2006). How do infants reach the point of holding such mental representations about the self is still a question in search of answers. What we do know today is the fact that long before the second year of life, infants do hold a sense of themselves as different from other entities in the environment (Rochat, 1998).

The *sense of self* refers to the ability to become consciously aware of one's own *bodily* and *mental states* (e.g., perceptions, attitudes, opinions, intentions for actions, emotions) as belonging to self. The basic components that allow the integration of mental and bodily states in order to generate a sense of self are represented by *first person perspective taking* (a phenomenological level referring

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to the attribution of the experiential multidimensional and multimodal space to one's own body) along with experiencing *the feeling of ownership*, experiencing *agency*, and the development of a coherent set of beliefs and attitudes embedded in *an autobiographic context* (Vogeley & Fink, 2003).

Several distinctions of the sense of self have been operated in both philosophical and psychological works. For example, Ulric Neisser (1988 cited in Gallagher, 2000) suggested important distinctions between *ecological*, *interpersonal*, *extended*, *private*, and *conceptual* aspects of self. The *ecological self* is the individual considered as an active agent in the immediate environment. This is characterized by a low level of self-awareness because it is based on a direct knowledge of oneself, and thus perceptual self-information. The *interpersonal self* emerges out of the interactions it engages in with other people in the environment, and the organism discovers more about itself and others by interacting with the social world. The *extended self* can reflect on itself over time, and it can generate thoughts about itself in the past and in the future. Then, the *private self* refers to how someone can process private self-information such as thoughts, feelings, and intentions. The *self-concept* is made up of abstract and symbolic representations of self. At this level of self, someone thinks about his/her roles, identity, traits, personal characteristics, and personal history (autobiography).

Although according to Vogeley and Fink's definition (2003) the final result is an explicit sense of self, throughout development the sense of self is most likely first experienced at implicit levels (Rochat & Striano, 2000), and these precede and coexists with later manifesting explicit forms of sense of self (Rochat, 2003; 2004). In other words, there is probably a transition from an ecological sense of self towards the development of a self-concept.

The bodily self

Holding a perceptual or an ecological sense of self requires the integration of afferent sensory information relating to the self in space (e.g., retinal, somaesthetic, proprioceptive, vestibular and auditory inputs) together with efferent information relating to motor output and the movement of the body in space, including the movement of the eyes, neck, trunk and limbs (Ventre-Dominay, Nighoghossian, & Denise, 2003). The integration of these multiple sources of sensorial information about the body relies on the integrity of several posterior parietal cortical regions (the superior parietal lobule, the parieto-insular region, and the temporoparietal junction – the submarginal gyrus, caudal parts of the superior temporal gyrus, and dorsal-rostral parts of the occipital gyri) (Giummara, Gibson, Georgiou-Karistianis, & Bradshaw, 2008). As a result of the activity of these integrative cortical areas, it is assumed that the space is coded with the reference to the individual (McGonigle, Hanninen, Salenius, Hari, Frackowiak, & Frith, 2002). Two types of sensorial information about the body seem to present higher relevance for the construction of a representation of one's body in space: the proprioception and the visual processing of the human body.

Proprioception refers to the sense of the position of the parts of the body relative to the other neighboring parts of the body, or the body as a whole. Proprioceptive information is primarily signaled by receptors in the muscles, tendons, joints and skin, information that is processed by the multimodal neurons in the posterior parietal cortex (Kammers, van der Ham, & Dijkerman, 2006). The high relevance of the proprioception for the generation of the bodily sense of self is given by the fact that it combines efferent information (effort, force and balance) about body's own actions with afferent information from somatosensory receptors in the skin, viscera, muscles spindles, tendon organs and joints (Feldman & Latash, 1982; Tsakiris et al., 2005), providing this way feedback on the body's own actions. The information that specifies the position of each body part is not equally processed in the human brain, rather the sources of sensory input that have the greatest spatial acuity are favored. For example, this is the case of the visual input that is favored over the proprioceptive one during phenomena like visual capture of limb position, when the felt position of a limb is perceived to occupy an illusory seen position (Giummarra et al., 2008). For the specific case of visual processing of human body parts, like judging the laterality of the presented body parts or processing allocentric versus egocentric perspectives of the body-like stimuli, the extrastriate body area, a region in the occipitotemporal cortex, seems to be specifically involved (Urgesi, Berlucchi, & Aglioti, 2004).

This sensorial and perceptual information specifies the representations of one's own body. Highly relevant for the early development of the perceptual sense of self, *the body schema* is a plastic and dynamic representation of the spatial and biomechanical properties of the body, formed based on multiple sensorial inputs (e.g., proprioceptive information from the muscles, joints and skin) that interact with the motor systems. It is considered that the body schema is not just a global model of the existing parts of the body, but rather is an active system of motor capacities of the body that function without the necessity of effortful perceptual monitoring and without conscious awareness. This representation consists of both sensorial information about the body and of other significant objects in the environment that become associated with the body (e.g., the prosthesis for the amputees) (Gallagher, Butterworth, Lew, & Cole, 1998).

Another body representation is *the body image*. Body image has been defined as a representation of conscious perceptions and beliefs related to one's body, that is owned, but abstract and disintegrated (Gallagher, 2005). We talk about someone's body image when we refer to his/her perceptual experience of his/her own body, including being aware of the position, movement and posture of the limbs; also when we refer to his/her conceptual understanding of the body in general, and to his/her emotional attitude toward the body (Gallagher & Cole, 1995).

Both body schema and body image are assumed to be involved in the generation of complex processes related to the bodily self. Embodiment is such a complex process that refers to the perception that one's sense of self is localized within one's bodily borders. Failure to integrate complex somatosensory,

proprioceptive, visual and vestibular information leads to atypical manifestations of self-embodiment, like the out-of-body experiences when a person experiences vestibular illusions of detachment, the impression of seeing the world from a distant or elevated visuo-spatial perspective, and the autoscopic impression of seeing one's own body (Blanke & Arzy, 2005).

The extrastriate body area (EBA) in lateral occipitotemporal cortex seems to be specifically relevant for the generation of the complex processes of embodiment. In a study with adults, subjects were confronted with two mental imagery tasks: an *own-body transformation task* and a *mirror task* (Arzy, Overney, Landis, & Blanke, 2006). In *the own-body transformation task*, subjects were presented with a schematic drawing of a human body, and either the right or left hand of the figure was marked. The subjects were asked to imagine themselves in the position and orientation of the schematic human figure, as shown on the computer screen, and to indicate which hand was marked. In *the mirror task*, the same schematic human figure was shown, but subjects were instructed to imagine that the schematic figure, as shown on the computer screen, was the mirror reflection, as seen from their habitual point of view. During task performance, event related potentials were acquired based on electroencephalographic recordings. Mental own-body imagery activates EBA and TPJ (temporo-parietal junction), but location and timing of this activations depend on whether mental own-body imagery is performed with mentally embodied (mirror task) or disembodied (own-body transformation task) self location. First activity was recorded at ~318 ms in the left EBA, which coded for embodied self location; and after that, at ~367 ms the right TPJ (and probably continuously the left EBA) got activated, coding for disembodied self location. Therefore, more than likely, both integrity in the temporoparietal junction functioning, as well as integrity of its connections with other relevant areas plays a significant role in the generation of a sense of self as distinct from other entities in the environment.

Developmental aspects of the bodily self

Research concerning the early development of the bodily self has not all the time followed the conceptual distinction between different representations of the body, like the body schema or the body image that we have just mentioned (but see Rochat, 1998). Several studies, though, do provide an important source of information about the specificity of this development in infancy. The current scientific efforts to validate different concepts related to the bodily self by specifying their distinct neurobiological underpinnings (see Giummara et al., 2008; Gallagher et al., 1998; Arzy et al., 2006), motivate promoting them in the developmental area as well. The current paper aims exercising this conceptual distinction from a developmental perspective, without being exhaustive.

The development of the body schema relies both on innate components and on the continuous experience of the moving body in the environment. That some aspects of the body schema are innate is supported by several sources of

evidence. On one hand, it has been shown that people suffering from congenital limb absence manifest phantom limb sensations (Melzack, Isreal, Lacroix, & Schultz, 1997). Phantom limbs is a common phenomenon encountered in patients which for one reason or another have suffered limb amputation, deafferentation or spinal cord injury, and consist of continued perception of the missing limb. The phantom limbs are generally perceived to occupy a certain body space, as having a particular size, shape, and posture (Giummara, Gibson, Georgiou, & Bradshaw, 2007), and to be the source of certain sensations, like pain (Kooijiman, Dijkstra, Geertzen, Elzinga, & van der Schans, 2000). The fact that people who have never received sensorial information from a limb manifest the experience of having it, suggests that the neural structures of the somatosensory cortex that are normally associated with it, still generate a neural representation of the limb, just as a result of its genetic pre-specification (Gallagher et al., 1998).

Another source of evidence comes from hand-mouth coordination studies in newborns and intrauterine developing fetuses. For example, using 4-dimensional ultrasonography, Myowa-Yamakoshi and Takeshita (2006), have shown that at the age of 19 to 35 weeks of gestation, half of fetuses' arm movements resulted in the hand touching the mouth either directly or indirectly. Moreover, the fetuses opened their mouths before their hands came in contact with their mouths. As well, the analysis of arm movements in infants between feeding times has shown that approximately one-third of all arm movements resulting in contact with any part of the head lead to contact with the mouth, either directly (14%) or following contact with other parts of the face (18%) (Lew & Butterworth, 1995). A significant percentage of the arm movements that result in contact with the mouth are associated with an open or opening mouth posture, compared with those landing on other parts of the face. It has been suggested that this hand-mouth coordination in the fetus and the neonate may be an early form of orally targeted reaching linked to the appetitive system. For example, Rochat and his colleagues (1988) have found that sucrose solution placed on the neonates' tongue generates suckling like postures with hand sucking. At the neurobiological level, results from primate studies offer support for the speculation that there is a network in the prefrontal cortex dedicated to the feeding behavior that might be responsible for the observed hand-mouth coordination. It seems that there are specific interconnections between regions in the orbital and medial prefrontal cortex which receive gustatory inputs from cortical and subcortical areas and from regions of the somatosensory cortex that represent the hand, arm, and face. More precisely, in the orbital and medial prefrontal cortex, neural projections from somatosensory areas responsible for representation of hand, arm, face, mouth, and tongue meet projections from premotor areas. In area 13l, projections from somatosensory representations of mouth and tongue converge with inputs from premotor areas (which contain a representation of the mouth and hand and are connected with the perioral regions of the motor cortex), the gustatory cortex, and related subcortical structures (Carmichael & Price, 1995). It is, therefore, possible, that some aspects of the body schema are pre-specified, like the motor affordances and location of the hand. In

cases where that specific part of the body does not develop, as it happens with the patients suffering from congenital limb absence, stimulation of other components of the network might generate the illusion of the existence of the absent limb. Most likely, these pre-specified components of the body schema do develop as a result of the subject's experience with motricity and the characteristics of the environment that constrains it, reason for which, for example, the phantom limb sensations in people with congenital limb absence are not as "rich" as those experienced by the amputees (Melzack, 1990; Gallagher et al., 1998).

Infants do seem to perceive their body as a result of the integration of diverse sensorial information. As early as the age of 24 hours, newborns show signs that they integrate proprioceptive and tactile information about their own body. The rooting response appears consistently in all healthy infants and is represented by head turn with mouth opening as a result of tactile stimulation at the infant's corner of the mouth. It has been found that newborns manifest significantly more rooting responses when they are touched on the cheek/corner of the mouth by the experimenter than when they touch themselves (Rochat & Hespos, 1997). This implies that the newborn specifies their own body based on the proprioceptive information associated with the hand movement and/or the tactile sensation from the hand touching the face with the tactile sensation from the cheek/face being touched by the hand.

As well, there is evidence that supports the idea that early in the first year of life infants do form a representation of their own body that specifies its spatial properties. In this respect, several studies have been done that employ preferential looking experimental paradigms. These are based on the principle that infants tend to preferentially attend visually towards stimuli that are novel for them (Fantz et al., 1962). In this respect, if an infant is presented either simultaneously or successively with two stimuli, from which one was previously encountered, while the other was not, it is expected that the infant will look longer towards that stimulus that is new to him/her. In terms of body schema, it was hypothesized that if infants hold information about the spatial position of their limbs based on the integration of proprioceptive and visual information, they will prefer to look at images of their limbs (e.g., legs) that do not respect these specifications, being, therefore, new compared to what they have been previously seen (Morgan & Rochat, 1997; Rochat, 1998; Rochat & Morgan, 1995). In these studies, infants are presented simultaneously with an image of their own legs as they would be specified via direct visual-proprioceptive feedback and with an on-line distorted image of their legs (e.g., up-side down from their normal view, as someone else would see them, or right/left reversed). At the age of 3-months infants look longer to the images of their legs that violate the normal spatial position, suggesting that they have already some sort of integration of visual and proprioceptive sensorial information into their own body schema.

But most of the time, infants are not dealing with a static body, rather they are perceiving it in motion, and from this perspective they have to acquire and integrate the related sensorial information into their body schema, and also to use it

in order to calibrate their ongoing or future actions. It seems that early in the first year of life, more detailed and precise information is needed in order to build an accurate body schema, and as this information gets integrated, infants become better able to discriminate their body from other similar entities in the environment, even in those situations where they are provided with just partial details about its physical properties. Several studies provide evidence that support this assumption. Using the same aforementioned preferential looking paradigm approach, infant subjects have been presented either simultaneously or alternatively with either realistic video images of their own and of another infant moving legs (Bahrick & Watson, 1985; Geangu, 2007; Morgan & Rochat, 1997) or with schematic point-light displays of their own and of another infant moving legs (Schmuckler, 1996; Schmuckler & Fairhall, 2001). The realistic image and/or the schematic image of the legs were presented across two conditions: with detailed visual specification of the joints or masking it (i.e., by the use of baggy trousers - Morgan & Rochat, 1997 or by placing the point lights off-joint - Schmuckler & Fairhall, 2001). In conditions in which one's own legs and the legs of another person have approximately the same spatial and physical appearance and differ visually just in the pattern of motion, the area of the joints seems to be highly salient. Younger infants (3-, 5-, and 6-month-olds) are not able to discriminate, as indicated by preferential looking, between their own moving legs and the moving legs of another infant in those conditions where they do not have access to the visual information about the joints (Geangu, 2007; Morgan & Rochat, 1997; Schmuckler & Fairhall, 2001). It seems that only later on, by the time they reach the age of 7- and 9-months, they successfully discriminate between the two in the situations when they are provided only with partial information (Geangu, 2007; Schmuckler & Fairhall, 2001).

Also related with the development of a body schema, we do have evidence that infants process information related to the biomechanical properties of their body. At the age of 2 months, beyond mere response-stimulus association, they integrate auditory sensorial information and proprioceptive information about oral sucking activity in order to modify their pattern of oral activity to obtain a desired melodic sound (Rochat & Striano, 1999). A dummy pacifier connected to an air pressure transducer that recorded the oral action has been placed in the infant's mouth. Each time the infants applied a pressure on the pacifier above a predetermined threshold they could hear either: nothing, a sound that had the pitch variation proportionate with the oral pressure, or a sound with random pitch variation. 2-month-old infants, but not newborns, showed signs of modulation of their oral activity, with significant more frequent pressures on the pacifier just at the threshold, significantly reduced average pressure amplitude, a tendency toward less frequent high pressure amplitude on the pacifier, and a tendency toward lesser variability of pressure amplitude. Since infants were reinforced with temporally contingent auditory feedback during both contingent and non-contingent conditions, it has been inferred that their oral response modulation is an index of

integrating auditory and oro-haptic sensorial information (Rochat & Striano, 1999) about their body mechanical activity.

Given the fact that the *body image* refers to someone's perceptual experience of his/her own body, including being aware of the position, movement and posture of the limbs; his/her conceptual understanding of the body in general, and his/her emotional attitude toward the body (Gallagher & Cole, 1995), probably one of the most important hallmarks in its early development is represented by passing the facial mirror recognition test (Lewis & Brooks-Gunn, 1979; Lewis, 1991).

This performance is proposed to be based on the existence of a mental representation of infant's own appearance (Wheeler, Stuss, & Tulving, 1997), and it is consistently manifested after the age of 18-months (Lewis & Brooks-Gunn, 1979; Lewis, 1991). More specifically, the task consists of serendipitously marking the infants with a red spot or a sticker on their forehead or on another part of the body, like the legs (Nielsen, Suddendorf, & Slaughter, 2006). After the spot is placed, the infants are presented with a mirror. If they show signs of noticing the spot/sticker and make attempts to touch it, it can be inferred that they notice a change in their own image, based on the representation that they have of themselves. Since the same pattern of response is recorded for both the modification of the face appearance and for the modification of the legs appearance, it has been inferred that it's not specific to the representation of the face, but of the body in general (Nielsen, Suddendorf, & Slaughter, 2006). At first, these abilities seem to be fluctuating, as children this age can recognize themselves in an on-line video presentation, but not when this is delayed by 3 minutes (Povinelli, 2001). It seems that only after the age of 3 or 4 years, children have a temporally stable own body image.

Bodily self development is dependent on the characteristics of the interactions presented by the social environment they are living in. Indirect evidence for this claim has been provided particularly for the development of the body image.

Cross-cultural studies have shown that the parental style is significantly associated with the age at which children manifest indices of holding a body image as assessed by mirror self-recognition test. One hypothesized aspect of the parental style that influences the development of this representation of the body consists of differentiated guidance in the interaction with the physical world. For example, infants of the Nso tribes in Cameroon, that benefit from a proximal parental style, that reduces their interaction with the external world (e.g., the infants are carried closely tied to their mothers' body without being encouraged to engage in face-to-face interactions or to explore objects around them) manifest delayed emergence of the ability to recognize themselves in the mirror. This is in contrast with infants raised in a distal parental style (e.g., urban families in Greece), characterized by face-to-face interaction, stimulation of object exploration, that manifest mirror self recognition during the typical age interval from 18- to 24-months (Keller, Yovsi, Borke, Kärtner et al., 2004).

In this paper we have presented recent research findings related to the neuropsychological mechanisms that underlie the ability to experience our bodies as a distinct entity in the environment. Distributed neural networks that have distinct patterns of connectivity seem to be associated with different aspects of the bodily self, which favors the theoretical trend of conceptually differentiating between them. More importantly, developmental studies of bodily self-awareness also present evidence that seems to favor such a conceptual distinction. Less is known, though, about the neurobiological correlates of the development of the body schema or of the body image, despite the existent brain imaging techniques (i.e., electroencephalography/event related potentials) that proved efficient for the study of brain activity even in very young infants. Further investigation is required in order to unravel to what extent the proposed conceptual differentiation of the bodily self is valid for early development, and what are the characteristics of the brain activity associated with it.

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