Developing a sense of bodily self

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Abstract

Without any internal representation of the body, we would be unable to perform the most basic actions, such as reaching for a pen or holding a book. Humans and animals are able to acquire their body representation in their development, but for robots this is a very hard task.

Up to date, no general methodology exists about how a robot could learn its body representation. We propose a developmental approach to build the bodily self from the robot own multimodal sensorimotor experiences of self-observation and active interaction with the environment.

Background

Developing bodily self, insights from developmental psychology:

- infants are capable of demonstrating a sense of their own body as a differentiated entity (self-world differentiation) [1, 2]
- self-perception primarily occurs as result of the infant's intermodal experience with visual-proprioceptive, proprioceptive-auditory, and tactile (“double touch”) information [1]
- sensori-motor and visuo-spatial body representational systems probably develop initially distinctly, and get together later in development [3]

Monitoring of action and bodily self, insights from neuroscience:

- the brain contains a sophisticated model of the body that is continually updated on the basis of the multimodal input including vision, somesthesis, and motor feedback [4, 5]
- the problem of embodiment and body ownership is related to the methods of encoding spatial informations by humans; of particular importance are body-centered and gravity-centered reference frames (out-of-body experiences, heautoscopy) [6]
- the sense of ownership is based on multimodal sensory integration; visual and somatosensory cues (rubber hand illusion) [7]

Approach

- **initial phylogenetic configuration include**: grasping reflex, equilibrium reactions, righting reactions, distinction between self- and non-self touch, distinction between stimulation originating from either the own body or an external source
- **the system develops** in two steps, which are discussed below

Step 1. Piaget's primary circular reactions (¨construction process¨)

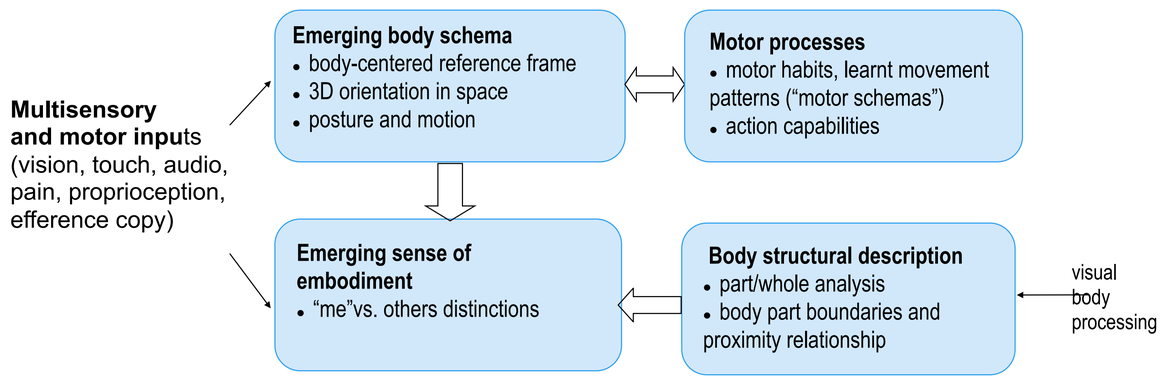
① simple, repetitive acts involving the robots own body are performed

② movements are being monitored proprioceptively and vestibulary, and a basic body schema that includes kinematics (length of body segments and their relative position) and dynamics (moments of inertia, weight) is constructed

③ different kinds of bodily senses originating from self-observation experiences are combined and cross-referenced

④ during self-produced movement the correlation between motor commands and motion in the visual field is used to outline the body silhouette

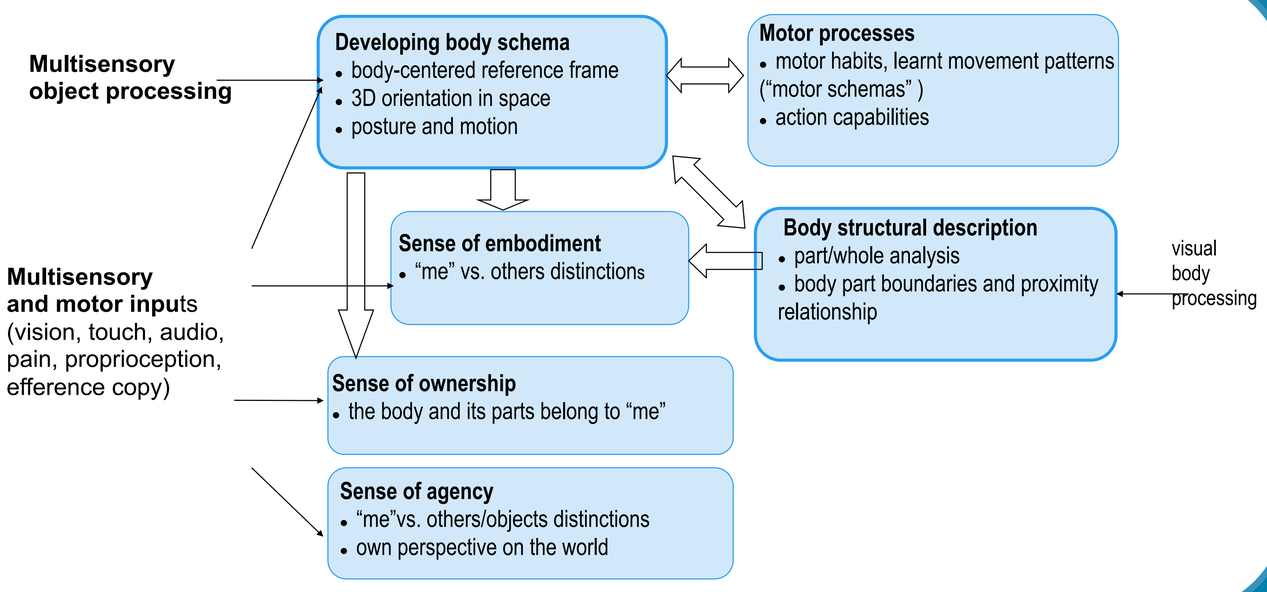
⑤ combined “double touch” and multimodal correlation allow the robot to learn that its body is a distinct entity in the environment



Step 2. Piaget's secondary circular reactions (¨making interesting sights lasts¨)

① simple, repetitive actions performed with objects, such as looking at the objects, pointing, touching, moving the fingers over a surface, manipulation etc.

② exploratory actions performed on objects provide a lot of experience for further development of the body representation and perception



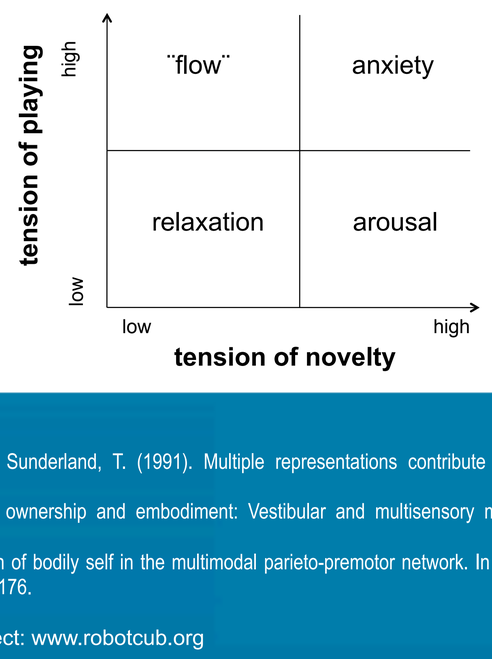
- **motivational system based on machine psychodynamic theory**

→ the key concepts are**: tensions** and **defence mechanisms**; the raising of these tensions is felt as unpleasure and their lowering as pleasure; defence mechanisms are used when a given tension cannot be reduced using the available repertoire of behaviors

→ two main tensions: **tension of playing** and **tension of novelty**

Tension of playing accumulates due to the lack of motor activity, and discharges while the robot performs an action.
Tension of novelty accumulates in response to constant (or similar) motor activity and discharges when some changes to movement patterns are introduced.

The interplay between these two tensions leads to exploration of a wide variety of actions and the selection of the optimal pattern to make the interesting events lasts.



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* robot images from the RobotCub Project: www.robotcub.org