Bachelor Degree Project

UNDERSTANDING THE CONCEPTS PERIPERSONAL SPACE, BODY SCHEMA AND BODY IMAGE

Bachelor Degree Project in Cognitive Neuroscience

15 ECTS

Spring term 2012

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Understanding the Concepts Body Schema, Body Image and Peripersonal Space.

Submitted by Magnus Hübsch to the University of Skövde as a final year project towards the degree of B.Sc. in the School of Humanities and Informatics. The project has been supervised by Paavo Pylkkänen.

Date: 2012-05-20

I hereby certify that all material in this final year project which is not my own work has been identified and that no work is included for which a degree has already been conferred on me.

Signature: _____

Abstract

This study will look into to the concepts of Peripersonal Space, The Body Schema and The Body Image. It examines how the terms are typically used and describes the various views about the concepts found in the literature, as well as the contradictions between these views. In the section "The Difficulty to Differentiate the Concepts" the reader gets a deeper understanding of which criteria researchers use to differentiate the concepts from one another. The fact that there are changes in kineamethic model and sensation in humans when they are using a rake is proposed as support for the idea that also the body schema is involved in tool use. In differentiating the Body schema – Body Image from each other (and other types of body representation) we come to the conclusion that positive definitions about different representations is needed and that researchers should unite their views what the definitions should be. We also mention a problem based on the possibility on infinite body representations and a solution by a Bayesian model is proposed that looks at the input as well as the output in experiments.

Keywords: Body Schema, Body Image, Peripersonal Space, Body Concepts, Body Representations

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Introduction

Concepts are "constituents of thoughts… crucial to such psychological processes as categorization, inference, memory, learning, and decision-making". (Margolis and Laurence, 2011) In other words concepts help us to divide things into different categories so that we may better understand the universe. This study will focus three concepts that often is mentioned within the scientific literature; The Body Schema, Body Image and Peripersonal Space.

This study began with a question of how multisensory integration between different sensory modalities works. Going through the literature I found out that three main concepts were often used: The Peripersonal Space (PpS), The Body Schema (BS) and The Body Image (BI). It became clear that researchers often had problems to differentiate between the different concepts (Cardinali et al., 2009, Gallagher, 1986, de Vignemont 2010). After this realization the direction of the study changed.

At the core in each of these concepts there is some unique quality that defines them. At the core of the PpS we can find the immediate space surrounding each limb, especially the hands and head. This immediate space around us is better processed within our brain and enables us to better respond to objects close to us (Rizzolati et al., 1981; Brozzoli et al., 2011). At the core of the BS we find the non-conscious processes in the brain that enable us to know where body parts are in space that enables us to smoothly use our limbs without having to pay attention to them (Head and Holmes, 1911). Finally, the core of the BI is the way in which we consciously perceive our own and others' bodies (Schilder, 1935).

This is not the first study which has tried to achieve clarity about these concepts. Lucilla Cardinali and Claudio Brozzoli, for example, have in several articles mentioned the borderline between The BS and PpS. Shaun Gallagher, Jacques Paillard and Frederique de

Vignemont have tried to untangle The BS and BI from each other (Cardinali, 2009a) (Gallagher, 1986) (Paillard, 1999) (de Vignemot, 2010)

In what follows we will first introduce to the concepts. After that we will look at alternative explanations of and disagreements about the concepts.

The Concept Peripersonal Space

There is something called our body and there is something called the external world. Or is it so simple? The concept of PpS argues that we seem to have a space around our body that is much better processed than the space outside of our reaching distance. The concept is based on research with bimodal neurons, reacting on visual, auditory or tactile sensory stimulation (Rizzolatti, 1981). A bimodal neuron may, for example, react both on visual stimuli near our right hand as well as touch to the same hand. If an object moves close to the hand the neuron will react so as to inform us of the approaching object. Because the PpS is represented in a higher degree than the external space, it also helps us to better interact with the environment close to us (Brozzoli et al., 2011). This may either help us in a conscious decision, as in grasping an object, or in a non-conscious behavioral response (Cardinali et al., 2009a).

History

The idea of a personal space is quite old and originates with Hediger who while studying zoo animals found that a certain proximity to the animal would result in a flight response of the animal. This study will focus on the neurological research of Giacomo Rizzolati et al. and their followers called peripersonal space.

Rizzolati et al. (1981) studied single cell recordings in the periarcuate area of macaque monkeys. With the recordings they discovered bimodal neurons reacting both to pure somatosensory experiences (touch) and/or joint movement as well as visual stimuli close to the body. During the study the researcher sat in front of the animal and moved various objects from different angles and different speed towards the animal. When a certain object came close to the animal the neuron would respond in the same way as it responds to a pure tactile stimulus. The procedure was repeated several times until the borders of the visual responding region could be assessed (~1m). The neurons found reacting this way were labeled as peripersonal neurons. A large amount, 25 of 48 penetrations contained this kind of neurons. Some of these bimodal neurons only reacted on visual and tactile stimuli less than 10 centimeters to the body and these were labeled as pericutaneous neurons. Together they "create" a Peripersonal space. It was found that mostly the hand and facial areas that were covered by this type of multisensory experience. This came to question if not humans do have the same type of multisensory interface?

Contemporary Research on the Peripersonal Space

Since single cell recording would be unethical in humans more clever methods were needed to give support for this idea. This could be assessed by help of patients with neurological damage which had caused the patients to experience extinction. In patients with extinction the presentation of a stimulus to the ipsi-lesional side of the body may go unperceived if a stimulus is presented simultaneously on the opposite, contra-lesional, side of the body. If only one stimulus is presented patients with extinction will have little trouble recognizing it regardless of which side of the body it is presented on. Di Pellegrino et al. (1997) were interested in what happened if a purely visual stimulus were presented near the hand of the ipsi-lesional side of the body. What they found was that the same extinction

pattern was shown as if the stimulus would have been a tactile one. A visual stimulus to one side of the body could in other words eliminate the ability to feel a tactical stimulus to the opposite side. This gave neuropsychological support for a PpS in humans integrated by a visuo-tactile system.

One of the biggest findings after Rizzolati's discovery was the observation of what happens when monkeys learn to use a tool instead of their hand when reaching for an object. In a single cell recording study by Iriki et al. (1996) monkeys learned to use a rake to reach distant objects. Bimodal neurons in the post-central gyrus now began to display new visual responses. Instead of just reacting on visual stimuli closing into the hand, the neurons also reacted on stimuli closing into the rake. The study also found a certain set of neurons in the shoulder and chest area. These neurons reacted on visual stimuli within reaching distance of the arm of the monkey. Interestingly, during tool use the shoulder / chest neurons began to react to visual stimuli within the reaching distance of the rake. The visual receptive field in other words incorporated the reaching distance of the tool. This only seems to happen when the tool is used actively by the animal and not when the animal holds the tool passively in its hand (Holmes and Spence, 2004).

Another important finding was that the neurons are body part centered. Graziano et al. (1994) studied the bimodal neurons in the premotor cortex in macaque monkeys. The neurons responded to visual stimuli close to the hand and the arm. It was discovered that "they are in arm-centered, not retinotopic coordinates" (Graziano et al. 1994, p. 1054). In other words they provide a representation of near space for specific body parts.

It is believed that PpS enables us to better interact with objects (Brozzoli et al., 2011). For example, removal of the postarcuate regions within the pre-motor cortex where neurological representation of the mouth is found will cause a severe impairment for monkeys

to grasp with their mouth (Brozzoli et al. 2011). It has also been speculated that the PpS may help to activate early flight response (Cardinali et al, 2009a)

Summary

The Peripersonal space is the space immediately around our body which extends 5-50cm out from our limbs and is mostly found in hand and facial areas (Rizzolati et al. 1981). This area is better processed than the space outside our reaching distance. The foundation for this is bimodal neurons reacting to two different stimuli, usually tactile and visual (visou-tactile neuron). If a bimodal neuron becomes activated by tactile stimulation, for example to our right hand, the same bimodal neuron may also become activated if only a visual stimulus is presented near the same hand. The visual receptive field is body part centered. If the hand is moved the same neuron will become activated when visual stimuli closes into the hand (Graziano et al. 1994, 2000). The PpS also has plastic properties. If a monkeys learns to use a tool to grab objects outside of reaching distance the neuron that reacts to visual stimuli close to our hand will be extended so it instead react to visual stimuli closing into the tool (Iriki et al., 1996). The PpS may be conscious or non-conscious and seems to have several evolutionary advantages (Cardinali, 2009a). It may anticipate activation, enable early fight or flight tendencies and it may also help us to interact with objects in a skillful manner (Maravita et al. 2003; Brozzoli et al. 2011). The PpS is also multisensory by definition (Cardinali, 2009a). The bimodal neurons may be found in several areas in a monkeys, including premotor area 6, parietal areas (Broadmann's area 7b and the ventral intraparietal area, VIP), and the putamen (Brozzoli et al. 2011).

The study of PpS by Iriki et al. (1996) have also been described to produce changes to the body schema, so in the next section we will have a look at what the BS is.

The Concept Body Schema

Even without our focused attention our body seems to be able to make use of itself quite well. It knows where our limbs are situated, it knows how to avoid an obstacle and it knows where on the body we are being touched.

The BS contains information about how kinesthetic, proprioceptive, tactile and visual information is combined so that we constantly have an updated model of our body. The term body schema is also used across several disciplines such as neurology, philosophy and psychology (Kammers et al., 2009). For example, it is used for different kinematic models in robots (J. Strum, 2012).

History

The word body schema was introduced by Head and Holmes in their article Sensory Disturbances from Cerebral Lesions (1911). Head was a British neurologist interested in how lesions to different parts of the nervous system created psychological and behavioral disturbances in patients. In the article they conducted discrimination tests on neurologically damaged patients to determine which abilities have been diminished in comparison to the undamaged contra-lesion part of their brain. For example the subjects were asked to localize their arm in certain positions or determine the weight of an object in their hand. Head and Holmes concluded that primary sensations of touch, pain, heat and cold are highly complex and undergo much regrouping before they arrive at the final sensory centers. "Afferent Impulses on their way from the periphery to the cortex pay toll first of all to the unconscious coordinating mechanisms of the spinal cord and cerebellum" (Head, 1911, p182).

Head and Holmes also comment on connections within the cortex. "Evidently, one of the faculties which we owe to cortical activity is the power to relate one sensation to

another… Recognition of weight, size, shape, form and texture depends entirely on this faculty." (Head, 1911, p185) This is an important feature of the body schema. Our body schema integrates many different sensory systems so we can use our body without even thinking about it. In order to do so the brain needs to have a non-conscious understanding of how our limbs are constructed and how much they weigh etc.

Head and Holmes argue that we can become aware of our body parts, but the recognition of posture is not something that constantly is within the central field of attention. When we give it attention, it is measured against the non-conscious mechanism. This they argue is in contrast with the writings of Herman Munk. Munk argued that all postures are based on mental images of postures. Head and Holmes figured that even if their patients could not recognize their posture the mental image of the posture was preserved. It can therefore not be the standard to which we refer alterations in posture.

"For this combined standard, which all subsequent changes of posture are measured before they enter consciousness, we propose the word ´schema`" (Head, 1911, p187). This schema is a postural model that constantly changes. "Every new posture or movement is recorded on this plastic schema, and the activity of the cortex brings fresh groups of sensations evoked by altered posture into relation with it" (Head, 1911, p187). Head and Holmes also proposed the possibility for several different schemata's; the recognition of for instance a certain touch requires reference to another schema. This they call a superficial schema, which is "a central mapping of somatotopic information derived from the tactile information" (Head and Holmes, 1911, p.187) Some patients are able to discriminate that they are being touched, but not in what position their limb lies at. Head and Holmes therefore believe that the body schemas are temporal and non-conscious processes that relate posture, movement and sensations before they become available for a conscious report.

Even though the concept BS was introduced over a hundred years ago we do not know much about it (Graziano, 2000).

Contemporary Research on the Body Schema

Cases of Autotopagnosia are often seen as a deficit to the BS (Haggard and Wolpert, 2005). In autotopagnosia people may become unable to localize and orient different parts of their body. In a case by Schwoebel et al. (2001) they examined a woman (J.D) who had been diagnosed with autotopagnosia "due to a car crash". J.D was unable to tell if the position of body parts was left or right relative to each other and she also failed to update the position of body parts after passive movements. A test showed that J.D seemed to update her body position regarding objects in the environment (extrinsic egocentric coding) instead of how they were relatively to each other (intrinsic egocentric spatial coding) (Schwoebel et al., 2001).

In cases of deafferention people may lose the sense of touch to parts of their body. In a case by Gallagher and Cole (1995) they examine IW who became deafferented from a viral illness. IW lost the ability to feel touch and proprioception from the neck down and it took him many months just to learn to walk and how to control his movement. Over time he became able to have control over his body, but this relied heavily on visual feedback. Normal people seldom have problems in performing motor acts while we concentrate on other things, but for IW this was almost impossible. In order to know where his body parts were in space and how to move them he was dependent on vision. This is in contrast with blind people, who can move their body without this constraint. This shows the dependency on proprioception within the BS for it to automatically update (Gallagher and Cole, 1995; Haggard and Wolpert, 2005).

One disorder that is often described as an deficit to the BS is Ideomotor apraxia (de Vignemont, 2010) In cases of ideomotor apraxia, patients have difficulties timing, sequencing and spatialy organize gestural movements (Petreska et al., 2007). For example, if a patient with ideomotor apraxia is asked to comb their hair, they may do so but moves the hairbrush in an awkward fashion around their head with never touching their hair.

Summary

The concept of body schema was first introduced by Head and Holmes (1911). The BS serves as a constantly updated coherent model of our body. The BS is spatially coded, modular, updated with movement, adaptable, supramodal, coherent and interpersonal (Wolpert and Haggard, 2005). It is also dependent on several sensory systems such as proprioception, kinesthetic and the ability to feel touch. If one of these systems fails us our body schema is also compromised. Several areas are involved in monitoring the posture and movement of the body. Both superior parietal lobe, Area 5 as well as other cortical areas seems to play an important role for the body schema (Graziano, 2000; di Russo et al, 2006)

The concept of body schema is often interchangeably used with that of the body image (Gallagher, 1995). But what is the classical conception of the BI? This is what we will look into in the next section.

The Concept Body Image

How do we perceive our own body and how do we relate our own body to the bodies of other people? This is what the concept of Body Image tries to explain. The term BI follows roughly the common use of the term (Gallagher, 1986). The BI is the (mostly) conscious image we have of our own body and the body of others. The BI is tightly linked to

the concept of body schema. As an example let us consider a dancer. A dancer needs to learn new postures and be in perfect control over his / her body and to do this he will have a great insight to his BI. Over time the dancer evolves in his moves so that certain moves will be executed outside of the field of attention. These will instead be handled by a higher order body schema (Gallagher, 1986).

History

The term body image was introduced by Paul Schilder in his book "The Image and appearance of the human body" (1935). The BI was a reaction to how psychology had a diminished role in the concept of BS. Schilder explains that "The body image of the human means the picture of our own body which we form in our mind, that is to say the way in which the body appears to us" (Schilder,1935, p. 7). Schilder chose the term Image since it emphasizes that we are not talking about a mere sensation or imagination, "there is a self-appearance of the body" (Schilder,1935, p. 7).

Schilder also infers that our own postural model (Schilder uses the word postural model as equivalent to body image) has connections to how we perceive others. This, he says, is shown by the fact that when a person loses the ability to discriminate between left vs. right on himself, he also loses the ability to determine left or right on others. The body image is inseparable from emotions and actions; it is in this way that we are inseparable from the body image of others. If we want a deeper insight into social psychology we should also study it from the level of our body image (Schilder, 1935)

When talking about disorders to the body image he says that there is no psychic nature without any brain mechanism involved. The psychic life, he says, is built up in different layers which are connected with different plans of organization within the brain. A tendency to neglect a damaged part of one's body can be due to brain damage, but it can also

be a form of repression. Many of his conclusions may be questioned. Still he emphasizes the importance of the psychic life, alongside the physical brain. This also helps us to see the difference between the subjective reports of one own body compared to objective measures of the body.

Now days the term Body Image is found in several different disciplines. The common use of the term often relates to how one perceives one's body, just as Schilder proposed.

Contemporary Research on the Body Image

In line with the common use of the term, McCabe and Ricciardelli (2001) investigated weight gain, weight loss and increased muscle strategies at 1266 adolescents. They "discovered" that females tended to be less satisfied with their body and more often engaged in methods for weight loss than men did. The men on the other hand more often engaged in methods to increase weight and muscle tone. Adolescents with high BMI (Body Mass Index) tried to lose weight more often. In comparison there was no correlation between BMI and a tendency to gain weight or increase the muscle tone. The social influences were also found to be an important factor. Females experienced more feedback from their parents and media regarding their weight than men did (McCabe and Ricciardelli, 2001).

We may also look at the BI from a neuropsychological level. Ramachandran proposes that if we study neurological syndromes such as phantom limb we might understand the neural mechanism underlying our BI and emotional responses. Ramachandran uses the term BI to describe how we view our self as a physical body over time. Phantom limb is a ghostly sensation that one's limb is still present even if it has been severed from the body. Ramachandran examined 18 patients with this type of disorder and found that applying stimulus to the face, such as cold, hot or rubbing, evoked the sensation at precisely localized

points on the phantom limb as well. The sensation of the phantom limb can in other words exist outside its original position. In Ramachandrans case the patients perceived that the hand was attached to the face. According to Ramachandran this is due to the organization and reorganization within the somatosensory cortex and these findings provide strong support for a remapping hypothesis within the somatosensory cortex (Ramachandran, 2000). In a secondary study he observed patients with a nagging pain or involuntary movements at their phantom. This, he figured, was possibly a result of the lack of visual and proprioceptive feedback. Ramachandran used this knowledge to create a mirror in which the patient could watch their healthy hand from the perspective of their phantom. In six out of ten cases patients were able to feel their phantom and in some cases it even helped to relieve the pain from their ghostly limb (Ramachandran, 2000).

We can also examine our BI with the help of bodily Illusions. In the classic experiment of rubberhand illusion, people may perceive a sensation in their real arm when a stimulus is delivered to a fake arm. During the experiments the subject's real arm is hidden from their view and a rubber arm is instead presented in a realistic body position. If the patient's real hand and rubber hand are touched simultaneously for a period of time, the subject will after some time perceive a tactile stimulation delivered exclusively to the rubber hand (Botvinick and Cohen, 1998). Later in this study we will take a closer look on this illusion.

Summary

The concept of Body Image, coined by Paul Schilder, follows roughly the everyday use of the term, which is the way we look at our own and people's bodies. Schilder was influenced by Freud and other psychologists view on the conscious and unconscious. Some of his thoughts are therefore severely outdated. However, some other thoughts, such as

the importance of how the appearances of others help to form our own body image, can be found within contemporary research (McCabe and Ricciardelli, 2001) The term is today used in several fields such as neuropsychology, neuroanatomy and experimental psychology. In neuropsychology researchers such as Ramachandran (2000), Botvinick and Cohen (1998) make use experimental data to show how the BI is formed and how we may distort it.

The Difficulty to Differentiate the Concepts

It is when we try to differentiate between the concepts that things become difficult. The above-mentioned research and statements have hopefully helped the reader to get a conception of the concepts; the problem is that not everybody would agree what has been said about the concepts. For example, Haggard and Wolpert (2005) argue that autopagnosia often is mentioned as a deficit to the BS. If we compare this with Schwoebel et al. (2001) they say that this is a deficit to the body's structural description, which is a somatic map of the body. To understand the problems we will have to go in detail into some of the research. We will also examine possible solutions to the problems.

The difference between the body schema and peripersonal space

When the concept PpS was introduced it was a mere neurological finding that showed that visual and tactile sensory stimulation was integrated. Around each limb we have responding visual-tactile neurons that fire when objects come close to the limb. Earlier, in the Pps section of this study, we ascribed Irikis (1996) and Graziano (1994) research as properties of the PpS. This is not something very obvious since in the original article by Iriki et al. they describe the extension of the visual receptive field (vRF) as a change to the BS, not the PpS.

If we look at Graziano et al. (1994) they studied the vRF on body parts and discovered that the vRF of bimodal neurons could be body part centered. In most other regions of the brain the vRF is retinocentric, that is, when the eyes move the visual receptive field moves with them. In the study they used single cell recording to examine visual responses of primary bimodal cells within the ventral premotor cortex. As with Rizzolati et al. (1981), the study by Graziano et al. used macaque monkeys. They kept one monkey awake during the experiments whilst another monkey was kept anesthetized. The monkeys visual- and somatosensory RF was plotted by stroking the skin and manipulating the joints, as well as presenting visual objects presented on a wand. They studied 141 (anesthetized monkey) and 211 (awake monkey) neurons in which 27% respectively 31% where bimodal. In the anesthetized animal the head was fixed into position so that the limitations of its gaze could easily be identified. When the arm was dragged over to the ipsilateral side the vRF followed with it although the eyes remained fixed suggesting that the vRF is arm-centered, not retinocentric. In the animal that was awake they also studied the effect of changing the gaze relatively to the arms position. The team used a small white ball approaching the animal from four different trajectories. This was done from three possible eye positions, yielding twelve different positions in total. The effect on arm position and spatial location of the visual response showed to be significant, whilst the effect of the eye postition was not. This gave further support that the vRF of the neurons was arm-centered, not retinocentric.

Graziano et al (1994) argues bimodal cells this arm-centered coordination system would be useful for hand and eye coordination, such as guiding the arm toward or away from visual targets. This may also be true for other parts of the body such as the head. Such a body part centered system would certainly be useful when grasping with the mouth. The view of multiple spatial structures and coordination system is in contrast with the original view that all visual space is encoded by one master coordination system.

Even if Graziano et al.(1994) never mention PpS it is clearly it is within of the field Rizzolatis original study. In several article this is described as a change to the PpS (Cardinali, 2009a).

In Iriki et al. (1996) research they use single cell recording of the bimodal neurons at the intraparietal cortex in macaque monkeys. If we simply compare these facts with Rizzolatis (1981) original study we may see that they use the same technique as Rizzolati but that they study the intraparietal cortex instead of the periarcuate cortex. One could argue that this would be enough to differentiate the two, since PpS is simply ascribed to as the space found immediate around the animal depending on PpS neurons found in the periarcuate cortex. This classification though would only be to ignore the problem since the neurons share the same properties regardless in which part of the brain they are found. Visou-tactical neurons have since Iriki et al´s study been found in several part of the brain, including premotor area 6, parietal areas (Broadmann's area 7b and the ventral intraparietal area, VIP), and the putamen (Brozzoli et al. 2011). If we continue our search we will find that methods are similar between the two studies with the researcher moving objects (mostly food) towards the animals hand to assess the border in which the neuron becomes activated. Iriki et al. (1996) analyzed 59 bimodal neurons reacting on both somatosensory and visual stimuli. When the vRF had been assed they began letting the monkey retrieve small pellets of food with the tip of a rake instead of their hand. After using the rake for five minutes the vRF was once again assed. They found that in the densest areas, 29% of the neurons vRF were expanded, elongated along the axis of the tool. For these types of neurons Iriki et al. use term distal type. After 3min of rest the vRF contracted to its original size and this even happened if the monkey held the tool passively in their hand. Another kind of neurons (25%) was labeled proximal types of neurons. These kinds of neurons had a somatosensory RF on the skin over the shoulder, neck and breast. What was remarkable was that these cells was activated when

the experimenters hand was moved towards the shoulder and entered the space accessible to the hand. After use of the rake this area was expanded, responsive to region which was accessible to the handheld rake. As with the distal type of neurons, the vRF contracted if the monkey just held the rake passively in their hand for a few minutes. The vRF expansion is with other words associated with the animal's intention to use the tool and is not merely a result of physical configuration of the body. The result was also shown to be in line with Grazanio et al (1994) discovery. The recordings where independent to the where the animal had their gaze. The vRF was thus not retinotopic.

In the discussion Iriki et al. questions what kind of information that is coded by bimodal neurons.

> "bimodal neurons where postulated to code the Peripersonal space in body-centered coordinates… In the present study, however, the visual RF was altered when the monkey used the rake as an extension of its hand. Based on the previous interpretations, this phenomenon implies that the structure of the peripersonal space is modified. Alternatively, the body-centered coordinates system itself may be altered. In other words, the visual image of the body in space (or body schemata) is coded in these bimodal neurons and, by using a tool as an extension of the hand, the image of the hand was expanded to include the tip of the tool, resulting in extension of the visual RF… We propose that the extended visual RF of bimodal neurons shown here represent the neural correlate of the schema of the hand in which the tool was incorporated" (Iriki et al., 1996, p.2328 - 2329)

What Iriki et al (1996) thus proposes is that the change of vRF is a change to the BS of the hand. This is in line with Head and Holmes original proposal that "It is to the

existence of these “schemata” that we owe the power of projecting our recognition of posture, movement and locality beyond the limits of our own bodies to the end of some instrument held in the hand” (Head and holmes, 1911, p.188). Head and Holmes believe that anything that participates in the conscious movement of our body will be added this model of ourselves and becomes part of these schemata. “A woman´s power of localization may extend to the feather in her hat” Head and holmes, 1911, p.188).

Much of the debate regarding PpS and BS has since been about tool use. According to Cardinali et al, (2009a) and Holmes and Spence (2004) the BS ad PpS are tightly connected in a unique composition. For example, both seem to rely on action. We saw this in the case when the monkey held the rake passively in their hand the vRF shrank to its original state. Studies has since then confirmed that the space around human individuals can be “remapped” following tool use. An example is Patient P.P who suffered a right hemispehere stroke which caused him to have a near space neglect. When P.P then was asked to use a stick, extending outside the bisection of his the neglect, it caused P.Ps neglect to extend as well. An alternative explanation to this could be that tool use causes the BS to be altered, and because of this change, the PpS is altered with it (Berti and Frassinetti, 2000).

But is the BS really changed when we use tools? Cardinali et al. (2009 a,b) committed a study to show if this is possible. The BS they say, is needed to control bodily movements and it relies on somatosensory representations. They agree on that tools may be incorporated into the BS but it has never been shown. In an experiment (Cardinali et al., 2009b) they used a mechanical grabber to physically extend the arm. After the use of the grabber the kinematics of subsequent free-hand grasping movements was altered. These after effects can be generalized to pointing movements regardless which kind of tool that was used. Furthermore it effected the perception of the length of the arm. After tool-use subjects

experienced that touch to their elbow and middle fingertip felt like it was farther apart. According to Cardinali et al., (2009b, p. 478) this indicated that "tool-use alters the body schema and also show that what is modified is the somatosensory representation of instrinct properties of the body morphology" With other words, this shows at that the BS can be altered following tool-use.

If we look closer into their conclusion however we may run into a problem. There is no doubts that something else than the PpS has been changed. The only one problem is that their conclusion may run into to a rhetorical fallacy; to begs the question. Cardinali et als. say that the BS is somatosensory experience and then they give support to their own conception. What BS really is can be debated. This is something we will see in the next section.

The difference between the body schema and the body image

Ever since Schilder introduced the concept Body Image debates and confusion have existed in how the concepts BS and BI should be used (Gallagher, 1984). In the beginning this confusion came from the way Schilder (1935) used the term body schema interchangeably with body image (Gallagher, 1984). According to Head and Holmes (1911) BS is constituted by non-conscious brain processes. To some degree Schilder agrees with this, but he also wants to ascribe problems within the consciousness to many of the disorders Head and Holmes speak about. Gallagher (1986) argues therefore that the main disagreement about the concepts is whether it is possible to ascribe consciousness to one concept but not the other (consciuos vs non-consious). Paillard (1999) agrees with Gallagher that there is division between the BS and BI, but Paillard base his division between the taxonomies on a functional criterion (action versus perception). Shortly we will look deeper into his taxonomy. This type

of division between two concepts is called a dyadic taxonomy (Vignemont, 2007). Another type of taxonomy, a triadic taxonomy, has also gained support in recent time. Instead of just make a difference between the BS and BI, the taxonomy introduces a third body representation, the body structural description (BSD), which splits BI into two concepts instead of one (Schwoebel and Coslett, 2005; de Vignemont, 2010). The BS is used in a similar fashion in both Paillards dyadic taxonomy and the Schoebwels triadic taxonomy (de Vignemont, 2010). The BS is a dynamically updated representation of the body. It used to code the position and relationship of body parts when we use them for action. This comes from multiple sensory and motor inputs and for example proprioceptive, tactile and visual inputs (Schwoebel and Coslett, 2001, 2005). Within the triadic taxonomy the BI (or body semantics), is a lexical-semantic representation. This is the conceptual knowledge of body. It is used to know the name of body parts as well as its function and relationship to objects. The new contribution BSD is topological map of the body. It is a representation of the shape and location of the body parts on one self and others and comes mainly from visual input (Schwoebel and Coslett, 2001, 2005).

> "The triadic taxonomy is grounded in the dissociation between apraxia (disruption of the body schema), autotopagnosia (disruption of the body structural description), and body-specific aphasia (disruption of the body semantics)" (de Vignemont, 2010, p.3).

In the next section we will take a closer look at these taxonomies and what they really represent.

A Dyadic and Triadic Taxonomy

So now we can argument whether the taxonomy should be divided into two or three bodily representations. What kind of support exists for respective classification? To

understand on which criteria the classifications is being made we need to take a closer look at the research by Paillard (1999) who supports a dyadic taxonomy and Schwoebel and Coslett (2005) who proposes the triadic taxonomy.

Paillard dissociates the BI and BS by two clinical cases. The first case, R.S, is a stroke patient who experienced “blind sight” in a tactile sense. The second patient, G.L, suffers from extensive neuropathy and is unable to point to stimulated area on her body on without the aid of vision.

In the first case, patient R.S suffered from artery malformation in her occipital lobe. Because of complication during the operation of the malformation it resulted to an obstruction to her left posterior parietal artery. After the stroke R.S suffered from, among other things, the inability to feel stimulation to the distal part of her left arm. Joint position sense, thermal and pain sensations where all absent. Since tactile stimulation went undetected R.S was unable to perceive and tell if she felt a stimulus delivered to her lower right arm. Regardless of the deficits there was very little motor deficit under visual guidance. She had no problem to point with her deafferented arm to a stimulus delivered to her intact arm. More interesting was in the reverse condition. When she was asked to a point at a stimulus delivered to her deafferented arm she did so automatically in the first few trials. When she discovered what she was able to do she became very surprised and expressed; "But, I don’t understand that. You put something there; I do not feel anything and yet I got there with my finger. How does that happen?" (Paillard, 1999, p. 200) This case shows localization ability without a sense of detection which also has been found in two more cases after Paillards first discovery. R.S is thus believed to have an intact BS because she is able to point at a stimulated body area even if she is unaware of the stimulus. The BI is however compromised since she cannot tell that she perceived the stimulus.

In the second case, G.L, suffered from Guillain–Barré syndrome and a second episode of polyneuropathy. She was deafferented from the below the nose, feeling a loss of touch, vibration, pressure and kinesthetic senses. Pain and temperature sensations were still present and her motor system was still intact. Because of the damage to the peripheral nerves and the loss of kinesthetic information G.L was dependent on vision to localize the position of her body parts in space.

> "When prevented for looking at her right arm for instance and asking her to match the position of both arms while looking at her left arm, she can do it only if the right arm remains in the last position that she has been able to see. If, however, the unseen arm is passively displaced by the experimenter she becomes completely lost and disoriented." (Paillard, 1999, p. 202).

Because that thermal and pain sensation was present, G.L could sometimes use these senses localize her body parts. For example she was able to know if her arm was pressed against her chest or if it was on the table. She could do this by comparing the temperatures of the surfaces. Experiments showed that G.L had no problem to verbalize where a cold or pricking stimulus had been applied. With visual guidance she could point to her own body or to a body sketch to show where she had been stimulated. However, if the visual guidance was absent she had great difficulties to point to an applied stimulus with only crude orientation ability remaining. Furthermore, if the arm was moved under blindfolded conditions and a stimulus was applied, she would still believe her arm was in its original position. The experiment suggest that she could use a visual driven exocentric system to coordinate her moves but that her egocentric system for updating her body position was damaged. Thus Paillard conclude; G.L is "unable to update proprioceptive her postural schema and cannot calibrate the location of tactile stimulus in her body schema" (Paillard, 1999, p. 206) Instead she has to resort on

memory of her last body position and visual representation of her body. The tactile stimulus can thereafter be located within a memorized "body image" which can be verbally expressed. However, how the BI is able to direct certain target-goal directed moves remains an open question (Paillard, 1999).

Paillard believes that the difference between the BS and BI is regarding to its function. He makes this claim by looking on the where and what pathways of the brain. The where pathway should be extended to include “how to get there” and be ascribed to the BS. The “what” pathway should on the other hand include “how to use it”, which would be a part of the BI.

If we look at the triadic view, Schwoebel and Coslett (2005) add the body structural description (BSD) beside the already existing representations BS and BI. The representation of BSD could very well be an unnecessary; therefore Schwoebel and Coslett had to show that one of the representations could be compromised even if the other ones remained intact. In order to do so seventy single-hemisphere stroke patients and 18 control subjects were assessed under different conditions. Let us have a closer look into which tests that was used to differentiate the three.

To test the BS of the patients and control subjects a “hand imagery/action” task and a “hand laterality” tasks was performed. The “hand imagery/action” test includes imagining and executing a set of finger movements. Because there is a very close correlation in the time it takes to execute the two it is believed that BS is involved in both simulating and executing actions. In the “hand laterality task” the subjects are shown a picture of a hand in different positions whereupon the subjects have to indicate if it is a left or right hand. The hand laterality task has been used extensively to investigate the BS in both normal subjects and patients with brain lesions. To tests BSD the tasks involved “localization of isolated body

parts”,” localization of tactile input” and “matching body parts by location”. Just to get a conception, the “localization of isolated body part” test included pictures of 24 individual body parts. The subjects were then asked to point at the same part on of their own body. The tests assessing the BI involved “matching body parts by function” and “matching of body part to clothing and objects”. In the matching body parts by function test the subjects were shown a picture body part. The subjects were then asked to point to 1 of 3 pictures indicating which body part is closest to the function of the first body part. The function is "what they can do" with that body part. An elbow is for example similar to a knee in function. In “matching body parts to clothing and objects” test the subjects were asked to match a piece of clothing or accessory with the related body part.

The experiment showed that patients could have a deficit to only one of the representation and have the other ones intact. Seven subjects showed impairments on the “hand imagery/action” task but performed normally on all of the other body representation measures. Six subjects showed exclusively defects on the hand laterality test. Two subjects showed deficits only on the BSD measures and three subjects were impaired only on the BI taks. By these results, and by cross referencing the impairments between the subjects, Schwoebel and Coslett (2005) could therefore conclude that there was a difference between BS, BI and BSD.

How many representations do we need?

Which of the dyadic and triadic view of the representation is then the right one? It should also be mentioned that there are several dyadic views. While Paillard supports a functional distinction, saying BS is used for action and the BI for recognition, Merleau-Ponty distinguished between a short time and long time representation of the body (Gallagher, 1986). The short-term on-line representation update the current state body, it is a

representation of the actual body. The long-term off-line representation represent properties represent bodily properties such as the size of body parts and its spatial organization. This is a representation of the more stable habitual body (de Vignemont, 2010). Gallagher (1995) support a division between the BS and BI but based on its availability to consciousness.

According to de Vignemont (2007) the number of bodily representations could be almost infinite, it is just a matter of which factors involved in each tests. The subject may for example be able to point at body parts on her own body but not the body of others. Should we then have to divide the body representation for the knowledge of our own body and another for the body of others?

This does not make the representations unnecessary according to de Vignemont (2007), but we need to be clear of a few things. First of all, there must be a unity within each kind of body representation. For the moment the BS or BI can be based on several criteria, such as conscious/non- conscious or functionality, as mentioned before. Second, representations must have positive definitions ascribed to them. Without knowing what the concepts are it would be impossible to test them. Third, we must be aware of the risk of infinite multiplication. Most of the research is based on neuropsychological data. The tests can be formed in several different ways and the data can be interpreted in just as many ways (de Vignemont, 2007, 2010). To establish a good taxonomy of body representations it is not enough to describe the specific functions of a body representation. To establish a good taxonomy one have to take the input, content, dynamics and spatial frame reference into account.

Kammer et al. (2009) also argues that the list of body representations could be infinite but base his claim in how tasks are performed in illusionary tasks in normal subjects. The rubber hand illusion can for example be performed in several different forms and the

sensation the subject experience may depend on how it is performed. For example, the stimulus applied during the “transformation" period can either be done synchronous or asynchronous to the both hands and *only* if the stimulus is applied synchronous to the index fingers of the both hands will the subjects feel a proprioceptive drift. The proprioceptive drift is a feeling that the real arm is closer to the rubber arm then it in fact is. The tendency to feel a relocation of their real arm will then depend on how the task is performed. What is really interesting is that a kinaesthetic investigation shows that it does not make any difference if the participant feels a proprioceptive drift; their ability to locate their arm is equally good as before. This may show dissociation between the robustness of the BS against illusions and to the illusion sensitivity of the BI. With other words we would have dissociation between an action oriented BS and a perception based BI.

However, the robustness of the motor response seems to depend on the exact type of motor task and how the induction method of the illusion is performed. If both the thumb and index finger was induced, the kinaesthetic investigation showed that the ability to grasp with their hand changed. So in one configuration we had a robustness of the BS and in another we did not.

Kammers et al. (2009) argues:

“The dual and the triadic model are mainly interested in the final output of bodily information processing, and this is where they disagree. This focus on body representations per se is at the expense of the investigation of the building up of those body representations.” (Kammers et al., p. 336)

The Bayesian approach

Instead of introducing yet another body representation based on the former experiment one should look at what the problems are when ascribing a body representation to healthy individuals in body illusions. First of all there is disproportionate focus on the output. One should not only to look at the output, but also the input and interplay between the two. With other words it equally important to look at how the task is performed, not only what comes out of the experiment. Second, there is still is no consensus in the debate about what the representations should contain. Therefore it is crucial to identify different models before conducting an experiment. Last but not least one also needs to objectively test the models against each other to know which model that best explains a phenomena. One way to do this would be with the Bayesian selection method.

The Bayes factor is a statistical measure which can be used to calculate the posterior model probability of a model. The quantity reflects the probability that the model is correct given the data. In this case the Bayesian factor would allow to directly comparing several model to each other without the loss of data. It also has a naturally incorporated Occam´s razor. This means that if two models explain the data equally well the Bayes factor prefers the simpler model.

In a simplified explanation you may have a semantic task, a ballistic motor task and a purely perceptual localization task. The data can thereafter be collected and tested in one single experiment. This can evaluate which of the models best explain the data. Potentially this solution could lead to more consensuses within the field.

The Bayesian model put a high constraint on prior knowledge (de Vignemont, 2010). If we were to make a good definition / conception of the different representation, then it would be at least possible to test how well they work.

Discussion

This study does not compare BS and PpS, neither is there any literature comparing the both concepts. Regarding to what have been said it would very well not contribute to the field to doing so. In comparison to BS and BI, the PpS has a neurological basis that is well explored. There is also less disagreements (if any) of what the PpS really is. The disagreements between the PpS and BS are instead based on if the certain experiments imply a change of the BS. But as we saw, it is not easy to say what the BS or BI are since there is no consensus within the field. Rizzolati et al. (1998) believes there is no such thing as a Body schema. He base this on that we have gained a larger understating in how the motor areas are constructed. The conception that there are only two motor areas is wrong. They interact with other cortical and subcortical areas in a way we could not even imagine. The body schema then is only a misconception of the interaction between these subcortical and cortical centers. Each center processes multisensory information in a reference frame to the body part in which it receives information from the selected body part and enables a response (Holmes and Spence, 2004).

If we once again look at the debate between the PpS and BS we may perceive it to be pseudo problem. But as former said, one first needs to give the representations good definitions before one can test them. Cardinali et al. (2009a) may be doing so by suggesting the BS may be involving proprioception, kinesthesis and touch. The PpS on the other hand is involving vision, auditory signals and touch. The PpS is therefore useful for defensive movements and voluntary actions and it has its basis in the parietal-frontal bimodal neurons. The BS is useful for our bodily knowledge for actions and is believed to be constructed by the pre-frontal and parietal cortex. Haggard & Wolpert (2005) on the other hand seem to ascribe

some role for how vision enable us to use our body schema, "For example, the visual and proprioceptive representations of hand position each have characteristic biases and variability, yet we perceive our hand in a single location because the brain optimally combines these sources of information" (Haggard and Wolpert, 2005, p. 2). This is then in contrast with Cardinalli et al, 2009 who want to remove the visual properties from body schema and give the attribute to PpS. It seems though that Haggard & Wolpert (2005) want to admit PpS role for how we interact with the environment, but in the end it is properties of the body schemas.

> "The updating process may underlie the finding that the visual receptive fields of many parietal neurons follow the hand when the hand moves (Graziano & Gross, 1993). This mechanism would allow the body scheme to modulate perceptual processing of objects according to their position in peripersonal space. This would be essential for control of grasping or avoidance movement." (Haggard and Wolpert, 2005 p. 262)

The two concepts have many similarities; in some regards it seems that they sometimes are one and the same. It may be so that the BS is a part of the skeleton of PpS (especially when it comes to tool use) (Cardinali et al. 2009a).

The representations (as well as we know them) are also intertwined. In order to point to a certain body part both your body schema and body image must be intact. The best way to argue for a certain body representation would therefore be by double dissociation experiments. But as we saw earlier, it is not as easy as it seems.

Conclusion

This study has looked at the concept body schema, body image and peripersonal space. The debate between PpS and BS is based on if tool-use induce a change to the BS and

not only the PpS. A solution to see if the BS was changed during tool was brought forward by Cardinali et al. (2009b). It showed that the tool use induced new types of sensations and kinaesthetic movements after the use of tools. This may be interpreted as a change of the body schema. The debate about the body schema and body image has several aspects to it. First of all, several researchers have their own definition about the concepts. Second, the tasks involved in separating the two (or three) concepts will create the possibility of an "indefinite" number of body representations. A possible solution to the problem of indefinite number of body representations is the Bayesian model. With this we can compare the a priori knowledge of the representation with the data in order to work out to which category it belongs. There are also other views on the concepts; Rizzolati for example wants to remove the conception of BS based on our larger understanding of the motor cortex.

At last I want to mention Maravita et al. (2004). Also they recognize the ambiguously use of the term body schema. According to him and his team the BS should not be used as an explanatory concept, instead it should be viewed as problems still require explanation. According to this study this would not be such a bad idea.

If the reader wants a deeper insight to the problems brought up in this study, "Body schema and body image—Pros and cons" by Frederique de Vignemont (2010) as well as "Peripersonal space and the body schema: two labels for the same concept?" by Cardinali et al. (2009a) is recommended.

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