Olaf Blanke and Oliver Kannape

Global Body Representations and Self-Consciousness

How does the cerebral cortex encode the body? How does the brain represent the surface, position, and movement of the body? Over the last 150 years and in parallel with advances in scientific and clinical methodology, many neuroscientists and neurologists have studied these questions. First important insights about the cerebral representation of movements were made by British neurologist Hughlings Jackson (1835–1911). Jackson was well-known for his clinical observations of behavior and his remarkable deductive grasp; simple partial (motor) seizures that affect specific parts of the motor cortex are still named after him ("Jacksonian seizures") and are excellent examples for how the brain represents bodily movement.

As described by Jackson in 1873, abnormal movements (i.e. cloni) during simple motor seizures may affect only certain body parts and follow a specific sequence: first affecting finger, then hand, then arm, and later the entire contralateral hemibody. Experimental data first in animals, later in humans have corroborated this evidence for localized bodily motor representation as well as bodily tactile representations.

Following observations by the Italian anatomist and physiologist Luigi Rolando (1773–1831), Gustav Theodor Fritsch (1838–1927) and Eduard Hitzig (1838–1907) heralded a new era in the concept of cortical localization that is still current today. Fritsch and Hitzig in particular carried out revolutionary experiments in dogs. Hitzig, born and educated in Berlin, upon graduation started to collaborate with Fritsch who also attended the medical school there. Working in a makeshift laboratory in Fritsch's home, they stimulated the exposed cerebral cortex of dogs with galvanic current revealing that the motor cortex and the non-motor cortex are located in two opposite places and that the stimulation of the motor cortex with electricity leads to muscular contractions of the body's other half. Fritsch and Hitzig also localized specific, strictly limited muscle groups using weaker currents and mapped crudely the motor representation of the cortex (Fig. 1).

These pioneering observations by Fritsch and Hitzig opposed the opinions of a majority of renowned contemporary physiologists, and it was not until British neurologist David Ferrier (1843–1928) repeated their experiments in primates that they gained widespread recognition. Ferrier's explicit purpose was to experimentally reproduce the effects due to the "discharging" and "destroying" lesions described by Jackson. Ferrier's seminal work thus provided, for the first

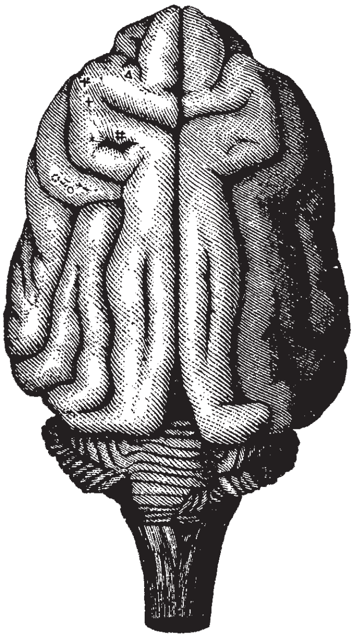

Fig. 1: Early mapping of a canine "motor cortex": Electrical stimulation caused movement only in the contralesional muscles. (ρ) Neck muscles. (+) (top) Foreleg extensors and adductors. (+) (below) Foreleg flexion and rotation. (#) Hind leg. Facial nerve (adapted from Fritsch and Hitzig, 1870, p. 313).

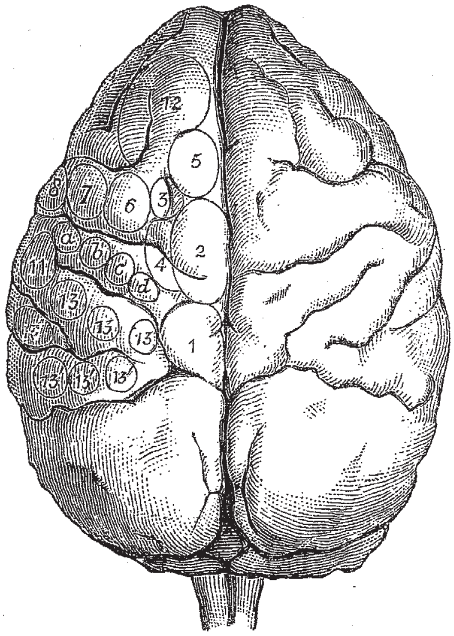

Fig. 2: Ferrier's projection of motor areas on the primate monkey brain. While these projections to the human cortex were inaccurate, they unveil the rudimentary idea of an "upside-down"'motor homunculus: Superior areas (1–4) are responsible for leg and foot movements, the middle area (6) for hand and arm movements, and inferior areas such as (7–10) for mouth, lips, and tongue movement as in articulation (Ferrier, 1876).

time, a solid experimental foundation for the more preliminary data of Jackson, Fritsch and Hitzig, namely the concept of localized motor or body representations.[1]

Ferrier also profited from an important methodological advance. Instead of using a galvanic electrical current, he employed faradic currents. This allowed him not only to reproduce the findings of Fritsch and Hitzig but to make comparable investigations in the monkey. The new technique further enabled Ferrier to achieve a more focal distinction of the primate's cerebral cortex delineating with precision the motor representation ("the motor-region"). Ferrier's work also separated motor from tactile body representations (Fig. 2).

Although David Ferrier had defined a localized cortical representation of body movements, it was still believed that somatosensory and motor cortex or these representations were intermingled in the same areas. The researchers who established that the pre-rolandic motor area on the precentral gyrus was separate from the sensory area (posterior to it) were Albert Sidney Frankau

1 Cf. Gustav Theodor Fritsch, Eduard Hitzig: Über die elektrische Erregbarkeit des Großhirns. In: Archiv der Anatomie, Physiologie und Wissenschaftlichen Medizin, 1870, pp. 300–332; David Ferrier, The function of the brain, London 1876.

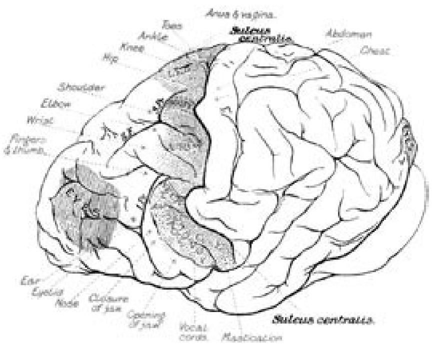

Fig. 3: Upside-down homunculus on the cortex of the primate apes. Adapted from Grünbaum and Sherrington (1902) who predicted a similar mapping for the human cortex.

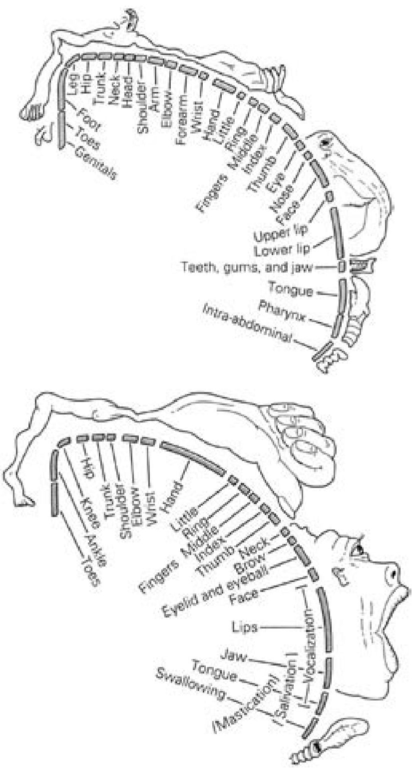

Fig. 4: Homunculi for the somatosensory and the motor cortex, demonstrating that the brain dissects the body's surface following a detailed topography (such as separate representations of single fingers, feet, face, or tongue) and with different sizes or magnifications for the different body parts (hand representation is larger than trunk representation). From Penfield and Rasmussen, 1950.

Grünbaum (1869–1915) and Charles Scott Sherrington (1857–1952). They worked with lightly anesthetized great apes and employed unipolar faradisation which allowed even finer localization than had previously been possible (Fig. 3).[2]

It was Wilder Penfield's exploration of body representations at the Montreal Neurological Institute that has received most attention and translated Sherrington's findings to humans.[3] In Penfield's now classical work, one such representation in humans encodes the body's surface in primary somatosensory cortex (see Fig. 4).[4] This representation dissects the body's surface following a detailed topography (such as separate representations of single fingers, feet, face, or tongue) and with different sizes or magnifications for the different body parts (i. e. hand representation is larger than trunk representation). This body map also follows a defined sequence when extending over the gyrus of the parietal cortex. Thus, the tongue and face are represented laterally, followed by hand and fingers, then trunk, legs, and feet.

2 Albert Sidney Frankau Grünbaum, Charles Scott Sherrington: Observations on the physiology of the cerebral cortex of some of the higher apes (Preliminary Communication). In: Proceedings of the Royal Society 69, 1902, pp. 206–209.

3 Wilder Penfield, Edwin Boldrey: Somatic motor and sensory representation in the cerebral cortex of man as studied by electrical stimulation. In: Brain 60, 1937, pp. 389–443; Wilder Penfield, Theodore B. Rasmussen: The cerebral cortex of man: A clinical study of localization of function, New York 1950; Wilder Penfield, Herbert H. Jasper: Epilepsy and the functional anatomy of the human brain, 2nd Edition, Boston, MA 1954.

4 Penfield, Jasper (as cited in footnote 3).

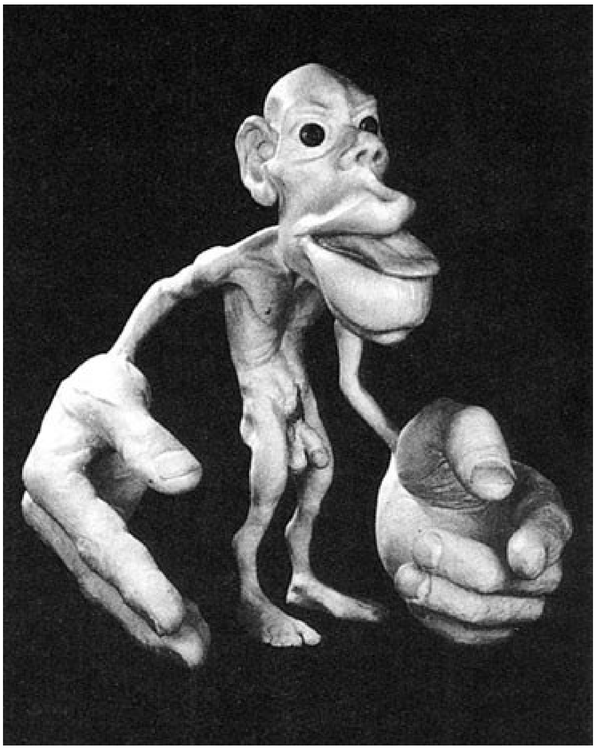

Fig. 5: Somatosensory homunculus. This "little man" reflects the amount of cortical area devoted to the somatosensation of a specific body part. Fine sensual skills require a larger cortical area, hence the disproportionately large hands. Natural History Museum, London.

Penfield described two similar homunculi, one for the motor cortex in the precentral gyrus, another for sensory cortex in the postcentral gyrus, reflecting detailed topography (separate representations of finger, feet, face, or tongue movements), different sizes for certain movements (i.e. hand motor representation is larger than foot motor representation), further translating Sherringtonian discoveries to humans. When plotted in 3D, these body representations later resulted in the probably most famous and most often reproduced picture in neurosciences: the "homunculus" (Figure 5 shows a model of the Sensory Homunculus).
Does the brain also contain more global body representations? In other words: are there representations encoding larger body regions (such as the upper body or the right or left hemibody) or the entire body at a single location as opposed to the tactile body representations in postcentral cortex that encodes small body parts at single locations? The answer is positive. Distinct brain regions have been described that still encode body-part specific representations, but are characterized by larger body parts, less spatial detail, and thus a more global body representation. This has been described in premotor cortex as well as the supplementary motor area and pre-supplementary motor area.[5] Hécaen and Ajuriaguerra (1952) also suggested – based on clinical observations including

5 Penfield, Jasper (as cited in footnote 3); this has recently also been suggested to be partly present in primary motor cortex on the precentral gyrus (Jerome N. Sanes et al.: Shared Neural Substrates Controlling Hand Movements in Human Motor Cortex. In: Science 268, 1995, pp. 1775–1777; Iole Indovina, Jerome N. Sanes: On Somatotopic Representation Centers for Finger Movements in Human Primary Motor Cortex and Supplementary Motor Area. In: NeuroImage 13, 2001, pp. 1027–1034.

illusory own body perceptions – that even larger body representations exist in the human brain and proposed that parietal cortex contains two distinct levels of body representation: one in superior parietal cortex for large body regions such as an entire arm or leg, whereas a site in inferior parietal cortex or temporo-parietal cortex contained a global body representation encompassing the entire body.[6] Such global body representations may also be illustrated by vestibular sensations or illusory sensations of bodily movement in the absence of any observable bodily movement.

Such sensations were described a long time ago in two patients who had the impression that their body was rolling off a table (without any observable movement).[7] Kahane et al. (2003) and Blanke et al. (2000) were able to make similar observations suggesting the presence of global body representations in inferior parietal cortex and the temporo-parietal cortex, probably related to interference with vestibular processing.[8] The patient reported by Blanke and his colleagues expressed during electrical stimulation in inferior parietal cortex that he felt that he was "sliding towards the lower end of the bed" and that "I'm rolling to the right and falling out of the bed". Collectively, these data strongly point to the existence of global body representations in posterior parietal and temporo-parietal cortex.

In the remainder of this article, several recent neurological, neuroimaging, and behavioural data on such global body representations from the authors' own studies will be reviewed. These global body representations are rather vestibu-

6 Henry Hécaen, Julian de Ajuriaguerra: L'héautoscopie. In: Méconnaissances et hallucinations corporelles, Paris 1952, pp. 310–343.

7 Otfrid Foerster: Handbuch der Neurologie, Berlin 1936.

8 Philippe Kahane, Philippe Ryvlin, Dominique Hoffmann, Lorella Minotti, Alim Louis Benabid: From hypothalamic hamartoma to cortex: What can be learnt from depth recordings and stimulation? In: Epileptic Disorders 5 (4), 2003, pp. 205–217; Olaf Blanke, Stephen H. Perrig, Gregor Thut, Theodor Landis, Margitta Seeck: Simple and complex vestibular responses induced by electrical cortical stimulation of the parietal cortex in humans. In: Journal of Neurology, Neurosurgery & Psychiatry 69, 2000, pp. 553–556.

9 For reviews see Olaf Blanke, Christine Mohr: Autoscopic phenomena of neurological origin. Implications for corporal awareness and self consciousness. In: Brain Research Reviews 50, 2005, pp. 184–199; Olaf Blanke, Shahar Arzy, Theodor Landis: Illusory perceptions of the human body and self. In: Handbook of Clinical Neurology 88 (Neuropsychology and behavioral neurology), 2008, pp. 429–458; Christophe Lopez, Pär Halje, Olaf Blanke: Body ownership and embodiment. Vestibular and multisensory mechanisms. In: Clinical Neurophysiology. Accepted, in press 2008.

lar or multisensory in nature than tactile or motor (as the post- and pre-central body representations) integrating information from vision, touch, balance, and the motor system.[9] The authors have argued before that these global body representations may turn out to be of crucial relevance for a neuroscientific approach to self-representations in the brain because key features of self-consciousness such as self-location (or embodiment) and mineness (or ownership)[10] are experienced as unitary, single, and coherent and not as multiple and fractured.[11] In consequence, the article will introduce empirical evidence from neurology, neuroimaging, and experimental psychology including virtual reality.

Abnormal global body representations: Neurology

Which neurological conditions have been described in the case of interference or damage with global body representations? The discussion will focus on one class of such neurological conditions, namely *autoscopic phenomena*. Autoscopic phenomena are illusory own body perceptions that affect the entire body and lead to striking abnormalities in bodily self-consciousness with respect to self-location and ownership (self-identification). Three types of autoscopic phenomena are described in the following: *autoscopic hallucination*, *heautoscopy*, and *out-of-body experience (OBE)*.

10 Olaf Blanke, Theodor Landis, Laurent Spinelli, Marianne Seeck: Out-of-body experience and autoscopy of neurological origin. In: Brain 127, 2004, pp. 243–258; Bigna Lenggenhager, Tej Tadi, Thomas Metzinger, Olaf Blanke: Video Ergo Sum: Manipulating Bodily Self-Consciousness. In: Science 317, 2007, pp. 1096–1099; Thomas Metzinger: Out-of-Body Experiences as the Origin of the Concept of a "Soul". In: Mind & Matter 3 (1), 2005, pp. 57–84; Idem: Empirical perspectives from the self-model theory of subjectivity: A brief summary with examples. In: Rahul Banerjee, Bikas K. Chakrabarti (eds.): Progress in Brain Research 168, 2008, pp. 215–246; Christophe Lopez, Olaf Blanke: Neuropsychology and neurophysiology of self consciousness: Multisensory and vestibular mechanisms. In: Adrian Holderegger, Beat Sitter-Liver, Christian W. Hess, Günter Rager (eds.): Hirnforschung und Menschenbild. Beiträge zur interdisziplinären Verständigung, Basel 2008 (in press).

11 Of course this should not be misunderstood in the sense that only (one or) few global body representations exist(s) in the human brain and that this accounts for the unity and coherence of experience per se. Such global body representations integrate bodily signal processing, abstracting from body-part specific processing to higher levels of body representation. Similar hierarchies have also been described in the visual system (ranging from areas with small receptive fields encoding points of light to areas with large receptive fields coding for colour or faces). Global body representations are probably crucial building blocks for self representations, but there are several such self global representations in the brain and none of them should be considered as the self's internal homunculus or identity with the self.

They occur after damage to temporo-parietal, occipito-temporal, or parieto-occipital cortex[12] and are due to distinct patterns of multisensory disintegration of bodily sensory information. Interference with global body representations is characterized by the patient's impression of seeing a second own body and variable degrees of illusory self-identification and self-location with respect to that double or autoscopic body.[13]

Autoscopic Hallucination: Patients with autoscopic hallucinations suffer from a purely visual own body illusion. They experience seeing a double of themselves in extrapersonal space without sensations of disembodiment or abnormal self-location (Fig. 6, left). The patients do not self-attribute or self-identify with the illusory body (i.e. they do not misattribute this body as their own) and do not localize the self at the position of the illusory body (i.e. there is no abnormal embodiment), so that self-location is habitual and at the physical body position. Autoscopic hallucinations are often associated with visual sensations and visual deficits (such as visual field loss).

Heautoscopy: Contrasting with autoscopic hallucinations, patients with heautoscopy may experience the self to be localized at their habitual position or at the position of the illusory body (abnormal embodiment; Fig. 6, centre). They also have the experience of seeing a double in extrapersonal space. However, these patients always self-identify with the illusory body, at least partly and temporarily, creating a bistable situation in which the self seems either localized within the physical body or in the double. Hence, self-location and the visuo-spatial perspective are reported as if seeing the world from the physical body or from the position of the illusory body. Patients generally do not report disembodiment (even if localizing themselves at the position of the illusory body), but rather a sensation of duplication of the self or co-existence of two selves. In these cases one may also speak of an abnormality of the self-centered reference frame. Heautoscopy is often associated with somatosensory and vestibular sensations.

12 Blanke, Mohr (as cited in footnote 9); Olaf Blanke, Veronica Castillo: Clinical neuroimaging in epileptic patients with autoscopic hallucinations and out-of-body experiences. Case report and review of the literature. In: Epileptologie 24, 2007, pp. 90–96.

13 Erich Menninger-Lerchenthal: Das Truggebilde der eigenen Gestalt (Heautoskopie, Doppelgänger), Berlin 1935; cf. idem: Der eigene Doppelgänger, Bern 1946; Hécaen, Ajuriaguerra (as cited in footnote 6); Peter Brugger, Marianne Regard, Theodor Landis: Illusory reduplication of one's own body: phenomenology and classification of autoscopic phenomena. In: Cognitive Neuropsychiatry 2, 1997, pp. 19–38; Peter Brugger: Reflective mirrors: perspective taking in autoscopic phenomena. In: Cognitive Neuropsychiatry 7, 2002, pp. 179–194.

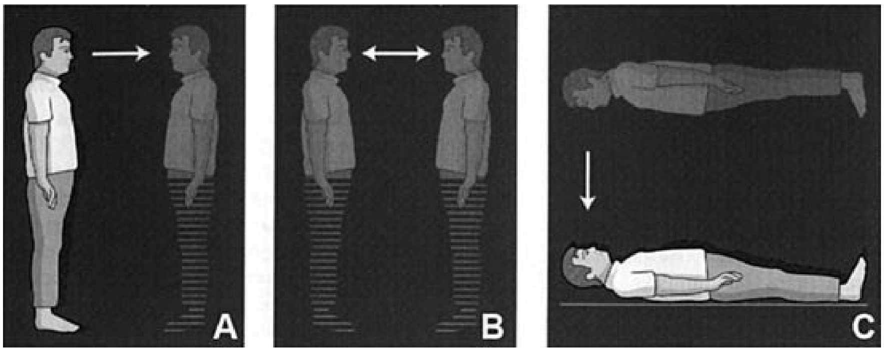

Fig. 6: Phenomenology of the three main autoscopic phenomena: Autoscopic Hallucination (A), Heautoscopy (B) and Out-of-Body Experience (C) with respect to visuo-spatial perspective (arrow), self-location and autoscopy. The position of the physical body of the subject is indicated as the non-transparent body. The transparent body represents the illusory body. Note that the self–body distinction is ambiguous for heautoscopy. The direction of the visuo-spatial perspective is indicated by the direction of the pointing arrow. In autoscopic hallucination the visuo-spatial perspective is body centred, in out-of-body experience it is from a disembodied position and in heautoscopy it is either simultaneous or alternating between physical and disembodied locations (Blanke, 2005).

Out-of-Body-Experience: Localization and identification of the self with an illusory body at an extracorporeal position is complete in *out-of-body experiences* (Fig.6, right).[14] In this third form of autoscopic phenomena patients always localize the self outside their physical body and experience to see their body from this disembodied location. Self-location is abnormal and the self is disembodied, not localized in one's body borders but at an elevated extracorporeal location. As in the case of heautoscopy, out-of-body experiences are associated with somatosensory and vestibular illusions such as "elevation, flying, lightness vertigo, sinking".

In conclusion, these three distinct illusory own body perceptions are abnormal global body representations that are characterized by abnormal self-identification and self-location and range from absent (autoscopic hallucination) to partial (heautoscopy) and to fully abnormal (out-of-body-experience) self-identification and self-location with respect to another body in another location in the extrapersonal space.

Further analysis by Olaf Blanke and his colleagues in 2004 and by Blanke and Mohr in 2005 suggested that autoscopic phenomena result from a failure to integrate multisensory bodily information.[15] This consisted of disintegration in bodily space (due to conflicting somatosensory and visual information) and a second disintegration between corporal and extracorporeal space (due to con-

14 Also cf. Orrin Devinsky, Edward Feldmann, Kelly Burrowes, Edward Bromfield: Autoscopic phenomena with seizures. In: Archives of Neurology 46, 1989, pp. 1080–1088; Brugger et al. (as cited in footnote 13); Olaf Blanke, Stephanie Ortigue, Theodor Landis, Marianne Seeck: Stimulating illusory own-body perceptions. In: Nature 419, 2002, pp. 269 – 270.

15 Blanke et al. (as cited in footnote 10); Blanke, Mohr (as cited in footnote 9).

flicting vestibular and visual information). While bodily space is disturbed in all three forms of autoscopic phenomena, differences are mainly due to differences in strength and type of the vestibular dysfunction and the resulting disturbance of the gravity-centered reference frames and its integration with bodily space (or the body-centered reference frame). Out-of-body experiences are associated with a strong vestibular disturbance, probably of otolithic origin,[16] leading to abnormal gravity-centered coding and disintegration between body-centered and object-centered reference frames. Heautoscopy is associated with a moderate and more variable vestibular disturbance, presumably originating from the semicircular canals, leading to abnormal body-centered coding but relatively normal gravity-centered coding.

The strong disturbance of body-centered processing in heautoscopy is assumed to lead to alternating or simultaneous self-location at the physical and/or illusory body. Finally, autoscopic hallucinations are not associated with abnormal gravity-centered coding and minimally abnormal body-centered coding. The high frequency of visual hallucinations and hemianopia in patients with autoscopic hallucinations suggest that deficient visual processing of bodily information is the main causing factor for abnormal body-centered coding in autoscopic hallucinations. The different types of autoscopic phenomena have been linked to distinct brain regions. Thus, it was shown that out-of-body experiences and heautoscopy are primarily associated with damage or electrical stimulation at the temporo-parietal junction, whereas autoscopic hallucinations are associated with damage in temporo-occipital cortex (Fig. 7).

Hallucinated self-portraits and painted self-portraits

With respect to images or *Bildwelten* in the neurosciences, the authors have proposed to consider these three distinct types of hallucinated own body images as hallucinated "self-portraits" generated by interference with cortical global body representations; moreover, the author proposed that some of the phenomenological and neurocognitive characteristics of autoscopic phenomena can also be found in the pictorial phenomenology of self-portraits.[17] Correspondingly, it was suggested by art historians to describe self-portraits also as reduplicative

16 Blanke et al. (as cited in footnote 10).

17 Olaf Blanke: Visuo Spatial Neglect in Lovis Corinth's Self- Portraits. In: International Review of Neurobiology 74 C, 2006, pp. 193 – 214; Idem: I and me. Self-portraits in brain damage. In: Frontiers of Neurology and Neuroscience 22, 2007, pp. 14 – 29.

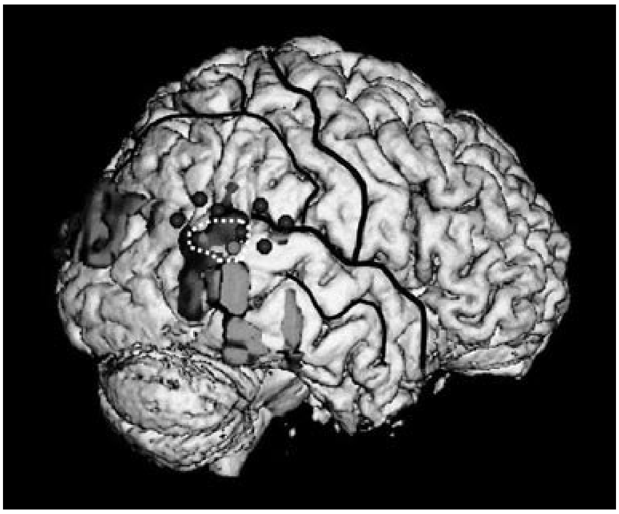

Fig. 7: Lesion locations in five patients with autoscopic phenomena associated with disembodiment. A distinct colour is used for every patient. The results of the individual lesion analyses of the patients overlap centred on the temporo-parietal junction (area indicated by dashed white line). Thick black lines indicate sylvian fissure and central sulcus; thin lines indicate superior temporal sulcus, postcentral sulcus and intraparietal sulcus (Blanke, 2004).

phenomena since self-portraits contain the painter twice: as the painting painter and the painted painter.[18] This comparative analysis revealed that some of the neurocognitive mechanisms of autoscopic phenomena might also be employed by artists of self-portraits and beholders of such paintings. Based on this analysis a preliminary division of the genre of self-portraiture in three major types of self-portraits was proposed that reflects the characteristics of autoscopic hallucination (visual self-portraits), out-of-body experience (disembodied self-portraits), and heautoscopy (corporeal self-portraits).

Electrical Neuroimaging (EEG) and Mental Imagery

Autoscopic phenomena allow investigating global body representations based on phenomenological and neuropsychological findings in neurological patients.[19] Studies by the authors with healthy subjects not affected by the described phenomena support the idea that temporo-parietal cortex (that is lesioned in neurological patients with autoscopic phenomena) is activated when they imagined themselves being in the position and visual perspective that is generally reported by people experiencing spontaneous out-of-body experiences.[20] This suggests that mental imagery for one's own body relies on brain mechanisms encoding multisensory global body representations in temporo-parietal cortex.

18 Cf. exhibition catalogue "Moi je, par soi-même. L'autoportait au XXe siècle", Musée du Luxembourg, 31.3.–25.7. 2004 a.o., edited by Pascal Bonafoux. Paris 2004; also Otto Pächt: Rembrandt, Munich 1991.

19 Brugger (as cited in footnote 13); Blanke et al. (as cited in footnote 14); Dirk de Ridder, Koen Van Laere, Patrick Dupont, Thomas Menovsky, Paul van de Heyning: Visualizing out-of-body experience in the brain: In: New England Journal of Medicine 1, 2007, 357 (18), pp. 1829–1833.

20 Olaf Blanke, Christine Mohr, Christoph M. Michel, Alvaro Pascual-Leone, Peter Brugger, Marianne Seeck, Theodor Landis, Gregor Thut: Linking OBEs and self processing to mental own body imagery at the temporo-parietal junction. In: Journal of Neuroscience 25, 2005, pp. 550–557.

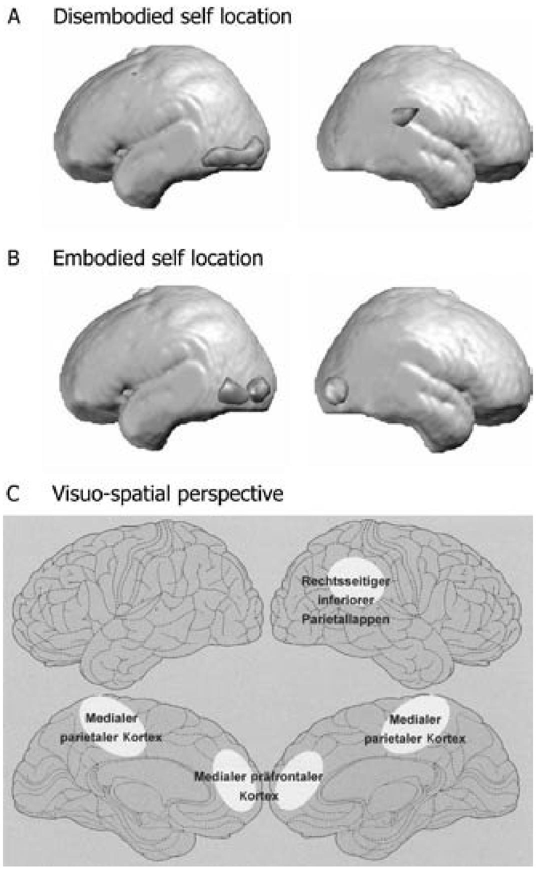

Fig. 8: Disembodied and embodied self-location was shown to activate differently the temporo-parietal junction and extrastriate body area (A, B), Arzy et al. (2004). Changes in visuo-spatial perspective rely on a similar network but also include the medial parietal and medial prefrontal cortex (C), Vogeley and Fink (2003), David (2006).

This was further indicated by data showing that temporo-parietal activation during global body imagery correlates with behavioural measures (such as speed of responses and accuracy) and the frequency of illusory own body perceptions. Thus, Christine Mohr and colleagues found that the number of illusory own body perceptions (as measured by the perceptual aberration scale)[21] predicts the speed and accuracy with which subjects perform mental imagery tasks relying on global body representations.[22] Interestingly, the frequency of such illusory own body perceptions predicts not just behavior,[23] but also temporo-parietal activation in global own body imagery (Fig 8).[24]
In a related study in 2006, Shahar Arzy and colleagues extended these findings and manipulated imagined self-location.[25] Brain activation during mental own body imagery with disembodied self-location (as in OBEs) was compared with brain activity during mental own body imagery with embodied self-location (as in autoscopic hallucinations). Arzy and his colleagues described distinct brain activation patterns when employing disembodied and embodied

21 Lauren J. Chapman, Jean P. Chapman und Michael L. Raulin: Body-image aberration in schizophrenia. In: Journal of Abnormal Psychology 87, 1978, pp. 399 – 407.
22 Christine Mohr, Olaf Blanke, Peter Brugger: Perceptual aberrations impair mental own body transformations. In: Behavioural Neuroscience 120, 2006, pp. 528 – 534.
23 Mohr et al. (as cited in footnote 22).
24 Shahar Arzy, Christine Mohr, Christoph M. Michel, Olaf Blanke: Duration and not strength in temporoparietal cortex positively correlates with schizotypy. In: NeuroImage 35, 2007, pp. 326 – 333.
25 Shahar Arzy, Gregor Thut, Christine Mohr, Christoph M. Michel, Olaf Blanke: Neural Basis of Embodiment: In: Journal of Neuroscience 26 (31), 2006, pp. 8074 – 8081.

self-location, compatible with clinical lesion data. This suggests that imagined self-location and imagined visuo-spatial perspective can be employed in order to investigate the central mechanisms of global body representations and seem to rely on at least partly shared brain systems.

Other important lines of research on global body representations have focussed on changes in visuo-spatial perspective (or first-person perspective) as opposed to self-location. As indicated above, both phenomena have been proposed to be important for models of the global self as self-consciousness is characterized by being centered (an aspect that is probably related to self-location) and perspectival directedness (an aspect that is probably related to the first-person perspective).[26] Also note that both phenomena are disturbed in OBEs . Several recent studies have investigated global body representations as manipulated through changes in or first-person perspective and interestingly also highlighted the importance of the right temporo-parietal cortex among other brain regions.[27]

Illusory global body representations: Virtual Reality

Although one's first-person perspective and self location are tightly associated under normal conditions and in autoscopic hallucinations and most OBEs, this may not be the case in all instances. For example, some patients with heautoscopy[28] and experiences that are closely related to OBEs[29] may report dissociations between their visuo-spatial perspective and self-location (Fig.9). This suggests that the neural mechanisms of both phenomena – that are crucial aspects of global body representations – rely, at least partly, on distinct brain mechanisms. The final section is thus to describe the experimental induction of

26 Metzinger: Empirical perspective (as cited in footnote 10).

27 Perrine Ruby, Jean Decety: Effect of subjective perspective taking during simulation of action: A PET investigation of agency. In: Nature Neuroscience 4, 2001, pp. 546–550; Kay Vogeley, Gereon R. Fink: Neural correlates of the first-person-perspective. In: Trends in Cognitive Science 7, 2003, pp. 38–42; Kay Vogeley, Mark May, Afra Ritzl, Peter Falkai, Karl Zilles, Gereon R. Fink: Neural correlates of first-person perspective as one constituent of human self-consciousness. In: Journal of Cognitive Neuroscience 16, 2004, pp. 817–827; Nicole David, Bettina H. Bewernick, Michael X. Cohen, Albert Newen, Silke Lux, Gereon R. Fink, N. Jon Shah, Kay Vogeley: Neural representations of self versus other: visual-spatial perspective taking and agency in a virtual ball-tossing game. In: Journal of Cognitive Neuroscience 18, 2006, pp. 898–910.

28 Blanke et al. (as cited in footnote 10); Blanke, Mohr (as cited in footnote 9).

29 De Ridder et al. (as cited in footnote 19).

an illusion in healthy participants that manipulates global body representations by multisensory bodily conflict.[30] During this illusion participants experience a virtual body as if it was their own body (self-attribution) and localize their self at a different position in space (self-location) using virtual reality. This reveals that an experience – that shares characteristics with heautoscopy (illusory self-attribution; embodied visuo-spatial perspective) and OBEs (abnormal self-location) – can be induced in healthy subjects. Moreover the illusion reveals that self-location and visuospatial perspective are dissociable in healthy subjects. The experimental procedure was based on the so-called *rubber-hand illusion* (RHI).
During the RHI participants misattribute a fake rubber hand to their own body, while the participants' real hand is out of view. This is achieved by synchronously stroking the seen fake hand and the subject's actual (unseen) hand in the same fashion.[31] The RHI results from a multisensory conflict between vision, proprioception, and touch, which is dominated or "captured" by vision, probably leading to the misattribution.
Furthermore, several studies have demonstrated that the RHI is also associated with a mislocalization of one's hand toward the fake hand or illusory body-part location.[32] Yet, the RHI does not allow investigating global body representations as defined here as this does require the investigation of global body representations (i.e. self-identification, self-location, visuo-spatial perspective). Studies on the RHI only investigate body-part ownership or the attribution and localization of a body part with respect to the global bodily self, i.e. a part-to-whole relationship.
How can self-identification, self-location and visuo-spatial perspective be modified experimentally? For this Lenggenhager et al. (2007) employed visual capture (as in the RHI) and applied multisensory conflict to the entire body. Through a head-mounted display (HMD) participants (see the person in fig. 9 wearing dark blue trousers) saw their own body (with light blue trousers; virtual body) in 3D as if standing two metres in front of them. They also saw

30 Lenggenhager et al. (as cited in footnote 10).

31 Matthew Botvinick, Jonathan Cohen: Rubber hands 'feel' touch that eyes see. In: Nature 391 (6669), 1998, p. 756; K. Carrie Armel, Vilayanur S. Ramachandran: Projecting sensations to external objects: Evidence from skin conductance response. In: The Royal Society, Proceedings: Biological Sciences 270 (1523), 2003, pp. 1499–1506; Manos Tsakiris, Patrick Haggard: The rubber hand illusion revisited: Visuotactile integration and self-attribution. In: Journal of Experimental Psychology: Human Perception and Performance 31 (1), 2005, pp. 80–91.

32 Botvinick, Cohen (as cited in footnote 31).

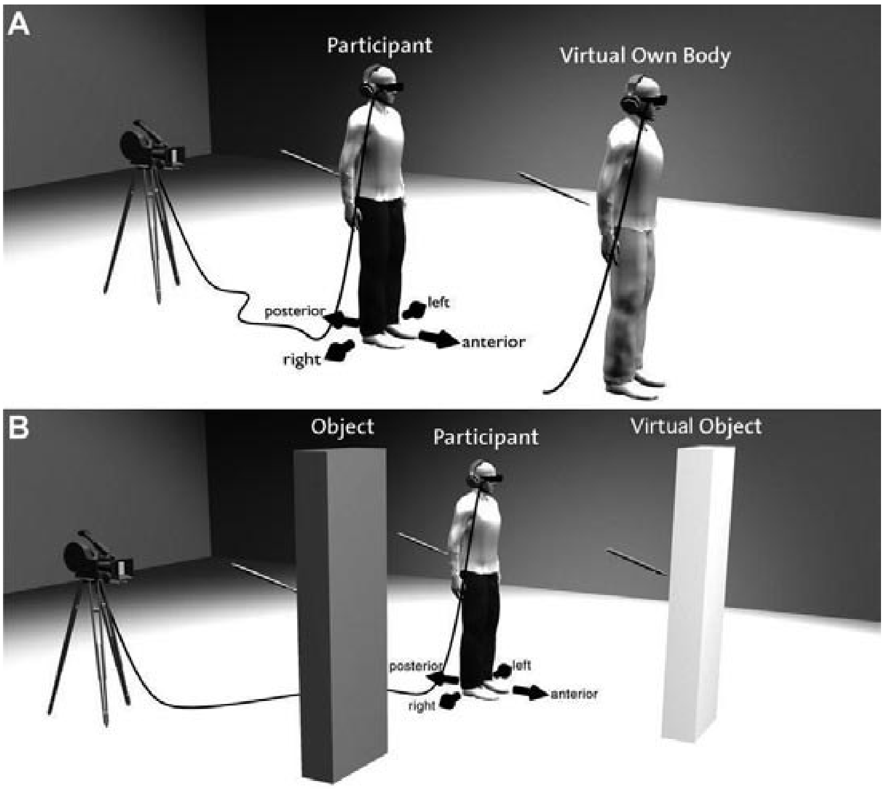

Fig. 9: Video Ergo Sum Setup: (A) The participant (dark trousers) sees through a head-mounted display his own virtual body (light trousers) in 3D, standing 2 m in front of him and being stroked synchronously or asynchronously at the participant's back. (B) In another condition the participant sees a virtual noncorporeal object (light gray) being stroked synchronously or asynchronously at the back. Dark colours indicate the actual location of the physical body or object, whereas light colours represent the virtual body or object seen on the display (Lenggenhager et al., 2007; Illustration by M. Boyer).

their virtual body being stroked synchronously or asynchronously with respect to their back.

As predicted and corresponding to the RHI, participants showed a drift toward the virtual body in the synchronous condition but not or less so in the asynchronous condition (illusory self-location). Although, none of the subjects reported disembodiment (as is classically observed in OBEs), these data suggest that participants localized their bodily self *outside* their actual bodily borders. This was corroborated by participants' self-identification with the virtual body and self-attribution of the visual stimuli applied to the "skin" of the virtual body. In a control condition, the participant saw either a virtual non-corporeal object (light gray) being stroked synchronously or asynchronously at the back revealing no illusory touch, self-identification, and self-location.

This study revealed that global body representations are likely to be as manipulable as body part representations. Moreover this suggested that one's self-location can be dissociated from the location of one's visuo-spatial perspective confirming clinical observations. This was extended by a study of Henrik Ehrsson employing a similar, but distinct, experimental virtual reality technique allowing modifying also one's visuo-spatial perspective.[33] In conclusion, the authors believe that such experimental paradigms combining multisensory bodily stimuli with virtual reality might turn out to be an important tool for studying global body representations and their role in self-representations in the brain.

The thinking body: Philosophical contexts and practical conclusions

David Hume famously claimed that when he introspected he was unable to catch his self without a perception and was unable to observe "anything but the perception" itself. He concluded that the self (or the observing introspective subject) is nothing but a bundle or collection of different perceptions; this struggle of Western philosophy with the body and self was also exemplified in René Descartes' effort to separate mind and body.

Today there is a renewal of scientific interest in how bodies think, how conscious thought and subject is embodied and likely to be related to partial as well as global body representations. In this context, recent discussions of embodiment and body-representation draw largely on Maurice Merleau-Ponty's work that was fascinated by humans' "being-in-the-world" and the way human consciousness is incarnated in the world. For Merleau-Ponty and later psychologists William Gibson (1952) and Ulrich Neisser (1988) cognition is embodied and functions as part of a relationship between subjects with a body and external objects. Recent years have seen increasing research in philosophy and cognitive science on body representations and how the conscious self might be fundamentally linked to neural own body representations.

33 In this study subjects reported a modification in the location of their visuo-spatial perspective towards the camera location that was filming the subject's body during the stroking. It is not known whether this illusion was associated with changes in self-location (H. Henrik Ehrsson: The Experimental Induction of Out-of-Body Experiences. In: Science 317, 2007, p. 1048).

The present article summarized recent empirical data from neurology, neuroimaging, and experimental psychology suggesting that especially the brain's global multisensory body representations[34] might turn out to provide insights on critical aspects of the conscious self including such key aspects as "my self-location", "my first person perspective" and "my identification with my body". The experimental induction of illusions of the global multisensory self opens a new avenue for the investigation of the neurobiological, functional, and representational aspects of self-consciousness and should include the entire spectrum of autoscopic phenomena (ranging from autoscopic hallucinations and heautoscopy to full-blown disembodied states such as out-of-body experiences) as well as other illusory own body perceptions affecting the entire body.
In consequence, it is predicted here that the merging of virtual-reality based technology with state-of-the-art neuroimaging will be crucial to describe the neurobiological mechanisms of bodily self-consciousness. Such a joint approach might eventually allow describing brain processes while humans catch their selves in virtual reality settings.

34 Sensorimotor or motor global body representations are likewise to be important building blocks of the conscious self, but have so far not received much scientific attention (Elena Daprati, Nicolas Franck, Nicolas Georgieff, Joëlle Proust, Elisabeth Pacherie, Jean Dalery, Marc Jeannerod: Looking for the agent: an investigation into consciousness of action and self-consciousness in schizophrenic patients. In: Cognition 65, 1997, pp. 71–86; Marc Jeannerod: From my self to other selves. A revised framework for the self/other differentiation. In: Patrick Haggard, Yves Rossetti, Mitsuo Kawato (eds.): Sensorimotor foundations of higher cognition. Attention and Performance XXII, Oxford 2007, pp. 233–248.; Oliver Kannape et al.: Motor control and motor awareness in a full body agency task using virtual reality. In: FENS Meeting 2008, Abstract P11849.