The bodily self and its disorders: neurological, psychological and social aspects

Brugger, P; Lenggenhager, Bigna

Abstract: PURPOSE OF REVIEW The experience of ourselves as an embodied agent with a first-person perspective is referred to as 'bodily self'. We present a selective overview of relevant clinical and experimental studies. RECENT FINDINGS Sharing multisensory body space with others can be observed in patients with structurally altered bodies (amputations, congenital absence of limbs), with altered functionality after hemiplegia, such as denial of limb ownership (somatoparaphrenia) and with alterations in bodily self-consciousness on the level of the entire body (e.g. in autoscopic phenomena). In healthy participants, the mechanisms underpinning body ownership and observer perspective are empirically investigated by multisensory stimulation paradigms to alter the bodily self. The resulting illusions have promoted the understanding of complex disturbances of the bodily self, such as out-of-body experiences. We discuss the role of interoception in differentiating between self and others and review current advances in the study of body integrity identity disorder, a condition shaped as much by neurological as by social-psychological factors. SUMMARY We advocate a social neuroscience approach to the bodily self that takes into account the interactions between body, mind and society and might help close the divide between neurology and psychiatry.

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The bodily self and its disorders: neurological, psychological and social aspects

Peter Brugger\textsuperscript{a,b} and Bigna Lenggenhager\textsuperscript{a,b}

Purpose of review
The experience of ourselves as an embodied agent with a first-person perspective is referred to as ‘bodily self’. We present a selective overview of relevant clinical and experimental studies.

Recent findings
Sharing multisensory body space with others can be observed in patients with structurally altered bodies (amputations, congenital absence of limbs), with altered functionality after hemiplegia, such as denial of limb ownership (somatoparaphrenia) and with alterations in bodily self-consciousness on the level of the entire body (e.g., in autoscopic phenomena). In healthy participants, the mechanisms underpinning body ownership and observer perspective are empirically investigated by multisensory stimulation paradigms to alter the bodily self. The resulting illusions have promoted the understanding of complex disturbances of the bodily self, such as out-of-body experiences. We discuss the role of interoception in differentiating between self and others and review current advances in the study of body integrity identity disorder, a condition shaped as much by neurological as by social-psychological factors.

Summary
We advocate a social neuroscience approach to the bodily self that takes into account the interactions between body, mind and society and might help close the divide between neurology and psychiatry.

Keywords
body integrity identity disorder, illusion paradigms, interoception, social neuroscience

INTRODUCTION

Human beings are self-conscious individuals whose thinking and behaviour is grounded in basic bodily processes. These processes transcend the sole domains of somatosensation and motor action; our body can be seen, its parts can be localized in space in pitch darkness, we know where we are heading to, and can follow our heart. Body space is a multisensory space, continuously made up by exteroceptive, proprioceptive and interoceptive impressions. The bodily self is made up of the multiple interactions between these impressions. Accordingly, the range of disorders affecting a person’s bodily self is considerable; the body can be experienced as lost, not belonging, not under control, empty, ugly, detached or duplicated.

Human beings represent a social species. However private and intimate a person’s body may appear, bodily selves leap out to embrace the space they share with others, ‘body image is a social phenomenon’ ([1], p. 217). Social neuroscience strives at understanding the interplay between neural, psychological, social and cultural processes. Although the brain–computer metaphor may serve to illustrate those disorders of the ‘body-in-the-brain’ [2] that have classically been treated in neurological textbooks, a social neuroscience of corporeal awareness needs to adapt its metaphors to the ‘body-in-the-brain-in-society’. Brains thus rather resemble cell phones [3], whose broadband connectivity enables a person to swiftly navigate social space and to get in touch with conspecifics’ embodied selves.

Against this background, our opinion review is presented in three parts. We first discuss recent advances on some classic disorders of the bodily self, emphasizing empirical studies that help...
KEY POINTS

- Disorders of the bodily self span all levels of body representation, from single limbs to the entire body in a social context.
- Integration of exteroceptive and interoceptive information underpins the bodily self and self-other distinction.
- Many disorders of the bodily self are shaped by both neurological and social factors; we discuss body integrity identity disorder (BIID) as a paradigmatic case.
- A social neuroscience approach is needed to fully understand the bodily self and its disturbances.

transcend the view of the bodily self as an exclusively private issue. We will then comment on what we think is probably the most significant trend in the research literature, that is the increasing attention given to interoceptive awareness. It may read paradoxical, but the sense of the interior condition of our body may open up a window to the understanding of others. Finally, we consider one unusual condition, body integrity identity disorder (BIID), which seems to ideally exemplify how neurological factors and higher-level social norms can both significantly contribute to the experience of body and self as a unity.

NEUROLOGY OF THE BODILY SELF: FROM SINGLE LIMBS TO WHOLE BODIES

Phantom phenomena illustrate that the bodily self does not necessarily match the physical body. They are observed after the loss of limbs, but also in hemiplegia, that is after deafferentation of a hemi-body or, in autoscopic reduplication, of one’s entire body [4,5].

The phantom limb

Phantom limb phenomena have always fascinated neurologists, philosophers and layman alike. Invisible, yet frequently pictured [6*], they nicely illustrate that the borders of the bodily self do not need to correspond to the borders set by bone and flesh. Research on phantom sensations has focused on phantom pain ([7] for a review), whose underlying mechanisms are currently controversially discussed; the classical view of painful phantom sensations as the consequence of maladaptive reorganization [8] was challenged by data suggesting that pain is rather associated with preserved function and structure in the deprived cortical area, but reduced functional connectivity in primary somatosensory cortex [9*]. Nonpainful phantom sensations do not seem to be related to the same reorganizational processes and appear to rely more on posterior parietal areas. A transcranial direct current stimulation study showed alleviation of painful phantom sensations after stimulation over sensorimotor areas and suppression of nonpainful phantom sensations with posterior parietal stimulation [10]. Although these observations are important, they do not address the merging of the bodily self with others, a process presumably mediated by the mirror system [11*]. Extensive experimentation with a person born without arms (but no phantom sensations) revealed that the visual identification of manipulable artefacts allows action comprehension in the absence of motor representations [12,13*]. Such observations are important because they constrain theories of phantom sensations in limb aplasia [14]. Not commenting on presence or absence of phantom sensations is therefore inexcusable in any report on persons with congenitally absent limbs, as elucidating the employed paradigms may be [15,16]. Complementary to the above findings, normally limbed individuals can ‘merge’ with the body representation of a visually observed armless person, and they do so as a function of their cognitive-emotional empathy [17*]. Also after traumatic amputation, empathy seems to facilitate the referral of touch observed on others’ bodies onto the phantom limb [18]. Finally, work in healthy participants documented the influence of empathy as well as social perception on the bodily self and shared body representations ([19–21] for reviews).

Somatoparaphrenia

Patients with anosognosia for their hemiplegia sometimes deny ownership of the paralyzed part of their body, claiming that it belongs to somebody else, often a close relative or a person of the care team. Once poignantly labelled ‘personification anosognosia’ [22], somatoparaphrenia represents the ‘filling in’ of a deafferented body part by the phantom presence of somebody else.

Recent work in the field has shown that anosognosia and somatoparaphrenia are dissociable [23], and the loss of ownership, but not the loss of insight into paralysis, is accompanied by a reduced autonomous response to incoming threat [24]. Having patients with somatoparaphrenia adopt a third-person perspective can drastically change bodily self-consciousness. For instance, viewing one’s own hand in a mirror (as if one observed it from the perspective of another person) abolished somatoparaphrenia in one patient [25], while intermanual
depression is a widespread condition, often associated with psychological distress and social isolation. The impact of depression can be profound, affecting not only the individual but also their relationships and overall quality of life. Therefore, it is crucial to identify and address the underlying causes of depression, which may include biological, psychological, and environmental factors. Early intervention and support can significantly improve outcomes for patients with depression.
There is an increasing attention to the interoceptive sense in the current literature. We think this is more than a transient fad, but a trend that will significantly contribute to our understanding of the nature of the self, especially in its interactions with the social environment. Interoception means more than the continuous monitoring of one's physiological condition. It is at the heart of a person's emotional life and her hedonic capacities. Influential theories of emotion have relied on the interoceptive sense, but the recent upsurge is more broadly motivated. It embraces neurological, psychological and social aspects of the bodily self. On the level of functional neuroanatomy, many contributions elucidate the role of the insula for the integration of interoception, exteroception and emotion processing [72], specifically with respect to the binding of body and self [73]. Psychologically, interoceptive awareness, that is the sensitivity to consciously monitor internal body signals, is now recognized as an important personality trait, though with acknowledged cultural variations [74].

### Table 1. Prominent experimental paradigms to investigate the bodily self

<table>
<thead>
<tr>
<th>Paradigm</th>
<th>Description</th>
<th>Variations of the illusion:</th>
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</thead>
<tbody>
<tr>
<td>Rubber hand illusion (RHI)</td>
<td>Synchronous stroking of the invisible real hand and a seen fake hand induces illusory ownership for the latter [33]</td>
<td>Illusion based on visuo-cardiac synchrony [34]</td>
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<td>Illusion based on the mere expectation of touch RHI [35]</td>
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<td>Illusion induced by self-stroking [36] (modified after [37,38])</td>
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<td>Illusion based on auditory-tactile synchrony (‘Marble Hand illusion’ [39])</td>
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<td></td>
<td>RHI in a special group of participants:</td>
<td>RHI can restore tactile awareness after spinal cord injury [40]</td>
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<td></td>
<td></td>
<td>RHI is enhanced for patients with somatoparaphrenia [25,41]</td>
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<td></td>
<td></td>
<td>RHI correlates positively with body dissatisfaction in body dysmorphic disorder [42]</td>
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<td>RHI in monkeys alters properties of neurons in S1 and M1 [43]</td>
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<td></td>
<td>Illusory body perception and higher cognition:</td>
<td>RHI with an outgroup hand can change implicit biases towards this group [45]</td>
</tr>
<tr>
<td>Full body illusion (FBI)</td>
<td>Synchronous stroking of either the back [46] or the front body [47,48] and the corresponding point of a virtual avatar leads to illusory ownership for the latter</td>
<td>Illusion based on visuo-cardiac synchrony [49]</td>
</tr>
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<td></td>
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<td>Illusion induced by self-stroking (in MRI environment [50])</td>
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<tr>
<td></td>
<td>Illusory body perception and higher cognition:</td>
<td>Illusory identification with a smaller/taller body changes object size perception [51,52], with a child body also implicit trait associations [52]</td>
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<td>Illusory disembodied perspective alters the formation of episodic memory (and associated physiological activity) in the left hippocampus [53]</td>
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<tr>
<td>Enfacement effect</td>
<td>Synchronous stroking of the own face and the face of a person sitting in front of you leads to illusory self-identification with the latter (measured by increased self-attribute of morphed images) [54,55]</td>
<td>A related illusion not involving stroking is the ‘strange-face-illusion’ in which prolonged inter-subjective gazing induces the perception of strange faces [56]</td>
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<td></td>
<td>RHI in a special group of participants:</td>
<td>RHI in a special group of participants:</td>
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<tr>
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<td></td>
<td>Enfacement illusion demonstrated in newborns (looking preference paradigm) [57]</td>
</tr>
<tr>
<td></td>
<td>Illusory body perception and higher cognition:</td>
<td>Illusory body perception and higher cognition:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Strength of illusion depends on sympathy (defined by previous interactions) [20]</td>
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<td></td>
<td></td>
<td>Enfacement illusion facilitates emotion recognition [58]</td>
</tr>
<tr>
<td>Mapping self-aspects on body templates</td>
<td>Elaborating on [59], participants have to map certain aspects of the self (e.g. the self [60], certain body landmarks [61] or emotions [62])</td>
<td>The self is not localized at one, but rather at two places: one centred on the upper torso and one on the upper head [62]</td>
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<td>Even in healthy participants, the subjective body metric does not correspond to the metric of the physical body [63]</td>
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<td></td>
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<td>Basic and complex emotions are systematically mapped onto specific body locations in a cross-culturally stable way [51]</td>
</tr>
</tbody>
</table>

**BODY PERCEPTION FROM THE INSIDE OUT**

There is an increasing attention to the interoceptive sense in the current literature. We think this is more than a transient fad, but a trend that will significantly contribute to our understanding of the nature of the self, especially in its interactions with the social environment. Interoception means more than the continuous monitoring of one's physiological condition. It is at the heart of a person's emotional life and her hedonic capacities. Influential theories of emotion have relied on the interoceptive sense, but the recent upsurge is more broadly motivated. It embraces neurological, psychological and social aspects of the bodily self. On the level of functional neuroanatomy, many contributions elucidate the role of the insula for the integration of interoception, exteroception and emotion processing [72], specifically with respect to the binding of body and self [73]. Psychologically, interoceptive awareness, that is the sensitivity to consciously monitor internal body signals, is now recognized as an important personality trait, though with acknowledged cultural variations [74]. It predicts,
for instance, the urge to imitate observed body movements [75] susceptibility to the loss of self-other boundaries [76] and the size of individuals’ autonomic response to caress-like hand movements in peripersonal space [77]. These latter studies document the relevance of interoception for social neuroscience. Paradoxically, the very sense devoted to the control of an individual’s inner milieu may turn out to be a window to other selves; a possible mediator are empathic, ‘shared’ emotions, arguably an ontogenetically very early form of social awareness [78]. What remains to be established are the links between interoception and the frontoparietal system of multisensory peripersonal space [79] on the one hand and the right parietal lobe representation of social distance [80] on the other hand. A further line of research to be developed is an integrative approach that unifies interoceptive and other ‘private’ senses such as proprioception and the vestibular sense. Anatomically, convergence zones of interoceptive and vestibular signals have been described at the brainstem level, but to our knowledge, there is no behavioural exploration yet of the interactions between interoceptive and vestibular processing. Despite the early recognition that the sense of space and balance is barely separable from the sense of having a body [81], the importance of the vestibular system for the bodily self has only recently been rediscovered (reviews in [82–84]). The vestibular system plays a key role in coding egocentric reference frames, modulating perspective taking [85] and promoting self-other distinction [82]. These characteristics make the vestibular system contribute in important ways to higher social cognition both in health and disease ([84,86,87] for reviews).

**THE BODILY SELF IN SOCIAL INTERACTIONS**

The clinical pictures of many neuropsychiatric disorders, though painted on a neurological canvas, are coloured with a paintbrush constrained by social norms. People suffering from anorexia may show reduced connectivity in extrastriate cortex [88] and, on the behavioural level, may erroneously conceive themselves too big to pass a regular doorway [89]. But individual manifestations of their eating disorder strongly depend on normative standards regarding the appearance of a healthy body and on the severity of individual dysfunctions in the processing of social stimuli [90]. Likewise, persons with body dysmorphic disorder may show abnormal neural network organization [91], but their suffering emerges, by definition, from a comparison of their own bodily appearance with that of conspecifics. A recent review of several phenomenologically distinct, biopsychosocially grounded disturbances of the bodily self proposed that one common denominator could be a vulnerability of right prefrontal cortex [92]. Depending on environmental and social factors, this vulnerability would lead to a preoccupation with one particular aspect pertaining to body and self. Although hard to be tested empirically, such a view avoids the pitfalls of missing the big picture by unilaterally concentrating on either brain or society. We have recently delineated the foundations of a social neuroscience of one particular disorder of the bodily self that tries to unify brain, mind and society [93]. A description of the condition is provided in the following section.

**Body integrity identity disorder**

BIID was defined as ‘an unusual dysfunction in the development of one’s fundamental sense of anatomical (body) identity’ ([94], p. 919). Affected people typically report a feeling of ‘overcompleteness’ and desire amputation of one or more limbs. Evidence is accumulating that this desire is accompanied by structural and functional alterations in areas of the cortex known as core to the binding of body and self. Table 2 summarizes all empirical studies we are aware of published during the review period [95,96,97–99].

Although their results are compatible with the idea that BIID is primarily a disease of the brain [100], alternative approaches deserve more attention than they currently receive among neurologists and in the neuroscience community. An essay drawing on the concept of Merleau-Ponty’s ‘sexual schema’ complains that most neurologically oriented empirical studies on BIID neglect the fact that for the vast majority of affected persons, the concept of amputation has a strong erotic connotation [101], thus presumably evocating shared body representations. In fact, the oversimplification of the rich symptom complex that BIID entails may help publishing a focal research finding, but represents a disservice to medical decision making and ultimately to the suffering of the persons concerned. Neurologists’ fear that, as soon as symptoms of paraphilia or obsession are in the foreground, psychiatrists should rather be in charge, is unfounded. Apotemnophilia, the precursor label for BIID, is a paraphiliadesignating sexual arousal by amputations. The spatial adjacency of insula and SII for leg representation could account for the higher frequency (at least four-fold) of legs than arms as amputation target in BIID [96*]. As ‘the insula supports an integration of body and mind’ ([102], p. 616), such observations could support an integration of neurologically and psychiatrically motivated approaches.
<table>
<thead>
<tr>
<th>Study (alphabetical order) and method</th>
<th>Studied population(s)</th>
<th>Major findings</th>
<th>Strengths and weaknesses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bottini et al. [95], Facial emotion recognition and disgust ratings for pictures and verbally described disgusting situations</td>
<td>5 men with AD for one leg, 1 man with AD for both legs, 1 woman with AD for one arm. Control participants matched for sex, age, and education</td>
<td>All BIID participants show normal emotional facial recognition and disgust ratings of verbally described scenes. Five men with unilateral AD showed lowered disgust ratings for images specifically depicting violations of the body envelope (i.e. amputations)</td>
<td>Strength: Multiple case study design (no mixing of different clinical manifestation of BIID)</td>
</tr>
<tr>
<td>Hilti et al. [96*], Structural MRI and surface-based morphometry. Questionnaire on amputation desire, erotic connotation, pretending behavior. Psychiatric, neurological and comprehensive neuropsychological examination</td>
<td>13 men with BIID; 8 with AD for left leg, 2 with AD for right leg, 3 with AD for both legs. Control participants matched for sex, age, handedness, footedness and education</td>
<td>No neurological or neuropsychological dysfunctions, minor psychiatric distinctive features disappear after removal of scale items reflecting body dissatisfaction. Right hemisphere cortical thickness and or surface area reduced in superior and inferior parietal lobule, SI, SII, anterior insula; increased left hemisphere cortical surface area in inferior parietal lobule and SII. Individual surface area of inferior parietal lobule correlates negatively with strength of amputation desire</td>
<td>Strengths: Relatively large sample size; comprehensive clinical testing, first study of structural brain correlates of BIID</td>
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<tr>
<td>Lenggenhager et al. [97], Assessments of feeling of estrangement for all four limbs before and after caloric vestibular stimulation</td>
<td>As in ref. [2], above</td>
<td>No changes in estrangement ratings nor in skin temperature after stimulation in either ear</td>
<td>Strength: Speculations about efficacy of caloric vestibular stimulation have been put to the test</td>
</tr>
<tr>
<td>Oddo et al. [98], Psychometric assessment of psychopathological and personality characteristics and of coping strategies</td>
<td>15 men with BIID; 12 with AD for one leg, 2 for both legs (1 not specified)</td>
<td>BIID participants show slightly elevated depressiveness and anxiety compared with population norms. Personality characteristics comprise high agreeableness and autonomy. Coping strategies are characterized by self-control and self-affirmation</td>
<td>Strength: Largest sample of persons with BIID in which personality features and coping strategies were assessed</td>
</tr>
<tr>
<td>van Dijk et al. [99]</td>
<td>5 men with BIID (2 with AD for left leg, 3 with AD for right leg) and 10 matched controls</td>
<td>Selectively for the affected limb BIID participants show reduced activity in left ventral premotor cortex to tactile stimulation and, irrespectively of the leg, a generally heightened activity to touch in a large somatosensory network</td>
<td>Strength: First functional MRI study in BIID, tested cortical response to both motor execution and tactile stimulation</td>
</tr>
</tbody>
</table>

AD, amputation desire; BIID, body integrity identity disorder.
More explicitly addressing social aspects, a recent essay [103] is based on the analysis of blogs posted during a period of more than 15 years on an Internet interaction forum for people with BIID. It reports findings that are important beyond sociological and should inform any neuropsychiatric approach to BIID. In a nutshell, the author’s analysis (see also [104]) shows that, first, BIID is not confined to an ‘overcompleteness’ in body structure, but includes the desire to become paralyzed, blind or deaf. Such longing for a functional impairment has been described earlier [105] and is covered by the labels ‘transableism’ or ‘transability’ [103]. Second, over the years, an individual’s constellation of symptoms is strongly shaped by the symptom constellation of others posting their blogs on the site and by the currently dominating view of BIID as expressed in social media. This reflects the famous ‘looping effect’ [106] that describes an interaction between the ways of classifying illnesses and the symptoms serving classification. Third, as reflected by inconsistencies in terminology [107], BIID is thus a condition ‘under construction’, that is it moves along a moving trajectory between human diversity (inclusion in Diagnostic and Statistical Manual of Mental Disorders (DSM-5) was debated, but rejected [108]) and mental illness, much like it happened for gender identity disorder (GID) some decades ago [109]. Neurological studies should attempt to meet these sociological concerns to fully accommodate the complexity of BIID, appreciating old wisdom about the bodily self as a social rather than an exclusively private phenomenon [1]. It is our hope that a social neuroscience view of bodily self-consciousness will not only assist in bridging the gaps between brain, mind and society but also diminish the divide between neurology and psychiatry [110].

CONCLUSION
The mutual interplay between clinical observation and experimental findings (derived, for instance, from illusion paradigms) has elucidated the multisensory nature of the bodily self. New developments in the field comprise the growing attention given to the interoceptive and vestibular senses in connection with the process of self-other distinction and the bodily self in a social context. This context plays a prominent role in certain neuropsychiatric disorders (e.g. BIID) and makes a social neuroscience view of the bodily self indispensable.

Acknowledgements
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Conflicts of interest
There are no conflicts of interest.

REFERENCES AND RECOMMENDED READING
Papers of particular interest, published within the annual period of review, have been highlighted as:
- of special interest
- of outstanding interest


This article highlights the contribution of illustrating the experience of phantom limbs to the clinical and theoretical understanding of painful and painless phantom phenomena. It emphasizes that most revealing are those sketches provided by patients themselves or drawn by an artist according to their guidance.

9. This article challenges the proposed link between cortical reorganization and phantom pain. In an fMRI study, phantom pain was associated with maintained representation of the missing (‘phantom’) hand, as well as with preserved structure. Moreover, relationships between phantom pain and functional isolation of the deprived hand area from its counterpart (intact hand) suggest that the maintained representation is dysfunctional.

12. This study reviews empirical work on the human mirror mechanism and motor cognition more broadly and delineates the way from bodily self to intersubjectivity. It argues that sensorimotor systems for interactions with the world around us are decoupled from the final motor pathway and, by exaptation, are now reused for apparently abstract cognitive functions including social communication.


The authors tested the prediction, inherent to motor theories of action comprehension, that observed hand actions, compared with actions executed with other body parts, would be more difficult to grasp for a participant born without arms. As long as action stimuli were photographs or videos, the participant performed equally well as normally limbed observers. However, he showed a selective deficit for manual actions when these were shown in a degraded way (point-light displays). The experiment shows that the mere visual analysis of body form and motion is sufficient for action understanding and thus improves motor theories of action comprehension.


This article studied normally limbed participants’ neural response to the observation of hand movements and body actions, both reflecting the participants’ physical ability, that is while watching residual limb movements executed by a woman born without arms. Extra-activations in parietal cortex during visual observation of impossible compared with habitual movements were interpreted as reflecting the human tendency to attend different reference in one’s vs. others’ bodily self by visual experience. More empathic participants activated the posterior part of the action observation network more strongly.
31. A compelling example of this viewpoint comes from the study by personality deficits in the course of dissociative psychiatric disorders. See also Ref. [1].
40. This study shows that healthy participants self-identify with an avatar once its silhouette is illustrated in synchrony with the avatar’s individual heart beat as an inter-ceptively available stimulus. See also Ref. [34].
44. This study investigated the cortical maps of the rubber hand illusion in two monkeys, who touched observers of a virtual arm while depth electrodes recorded activity from primary sensorimotor cortex. Responses to virtual touch were delayed compared with real touch due to involvement of polysynaptic pathways between visual cortex and M1/S1. This is important for neurorehabilitation programs after stroke. These require proficiency in prostheses that can profit from ownership transferred to the prosthesis.
50. This method was put to the test and found to reliably induce a full-body illusion. Applications of the stimulation paradigm will facilitate the study of agency in extending bodily self-consciousness to an observed human body.
51. This study introduces the method of ‘topographical self-report’ of emotions. This article studies the encoding of verbal information gathered in a dyadic social interaction as a function of the participant’s observer perspective: in-body vs. out-of-body induced full-body illusion paradigms. The latter leads to worse episodic recollection 1 week later, accompanied by deficient hippocampal activation. The work highlights the interactions between bodily self and cognitive functioning and has important implications for the understanding of memory deficits in the course of dissociative psychiatric disorders. See also Ref. [1].
54. This study shows that healthy participants attribute ownership over an artificial hand once it is stroked in synchrony to the individual heart beat as an inter-ceptively available stimulus. See also Ref. [49].
61. This study introduces the method of ‘topographical self-report’ of emotions. This requires individuals to indicate, on provided body maps, where a specified target emotion would induce activations or deactivations. Five experiments are reported that show a consistent and culturally universal attribution of specific basic and complex emotions to distinguish body regions. The method opens up new ways to objectively characterize the emotional bodily self and has the potential to provide a biomarker for emotional disorders.
64. Patrizi ML. Le point de mire de I’attention autoscopique et la localisation de son expression motrice [The focus of autoscopic attention and the localisation of its motor expression]. Arch Ital Biol 1912; 57:205–212.

The bodily self and its disorders Brugger and Lenggenhager
Degenerative and cognitive diseases


This study describes that healthy participants’ tendency to recall autobiographical memories from an embodied, first-person perspective is associated with greater volumes of the right precuneus. The work contributes significantly to the role of the precuneus beyond spatial functions and bodily representation. See also Ref. (85).


The concept of ‘interoceptive predictive coding’ offers a groundbreaking extension of theories of agency previously formulated for the motor system. The process compares actual interoceptive signals with signals predicted on the basis of generative models informed by motor and autonomic efference copies. The author outlines how interoceptive inference may lead to the experience of body ownership and argues that it is mediated by the anterior insular cortex.


This experiment established interoceptive awareness (sensitivity to one’s own heartbeat) as a predictor of healthy participants’ automatic response specifically in a social setting. Moreover, the study reports a modulation of the interactions between interoception and social disposition by the distance between one’s own body and an actor’s caresses-hand movements. In brief, the experiment illustrates that the body self draws on a common metrics of physical, emotional and social space.


86. Derooalle D, Lopez C. Toward a vestibular contribution to social cognition. Front Integr Neurosci 2014; 8:16.


An investigation of the neuropsychatology of paresial and insular cortex in 13 persons with the desire for leg amputation, who did not differ from a matched healthy control group in thorough psychiatric, neurological and neuropsychological examinations. Structural changes in right hemisphere cortex were not only found in superior and inferior paretal lobe but also in S2 and S1 and in the anterior insula. Strength of amputation desire was negatively correlated with the surface area in right inferior paretal cortex. Speculations about the high frequency of leg (compared to arm) amputation as related to erotic connotations of BID are offered.


