# Awareness of One's Own Body: An Attentional Theory of Its Nature, Development, and Brain Basis

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*I am body entirely and nothing beside.*

*Nietzsche,* Thus Spake Zarathustra

This discussion addresses a person's awareness of the disposition of his body parts and his belief that they are his own, and makes suggestions about their brain basis. In what way and under what circumstances are we normally aware of these facts about ourselves, and what can neuropsychological analysis contribute to our understanding of the mechanisms involved? Specifically, is there a localized neuronal representation dedicated to bringing the body into awareness, separate from the cerebral representation of somatosensory input in the sensory strip? Or does awareness of the body derive from selective attention to somatosensory input from the various body parts, without need for the ad hoc construct of a separate "body scheme"? If the latter is the case, how are shifts in attention to body parts organized? What reciprocal relationships might exist between attending to body parts and awareness of the self (self-consciousness)? How does awareness of the self develop?

## 1 Impairments of Bodily Awareness

Critchley (1950a) listed diverse organically determined anomalies in people's experience of their own bodies. Among these are neuropsychological impairments of bodily awareness labeled asomatognosias. These deficits comprise the inability to specify parts of one's own body by naming them or indicating them when named (autotopagnosia) (Pick 1908) and the unawareness that a body part is one's own (some cases of neglect) or that its function is impaired (anosognosia). Bonnier (1905) argued that what is lost in these disorders is the spatial representation of body parts whose sensation is preserved. Such a representation would be distinct from the mapping that constitutes the first cortical relay in the somatosensory cortex. There certainly are multiple somatosensory maps in the cortex (e.g., Mori et al. 1991) but they are not hierarchically organized. Also, critical findings in neuropsychology are not captured by this still prevalent concept of an egocentric body image represented as such in the brain (e.g., Vallar et al. 1993). I first discuss the disparity between the number and distribution of syndromes of partial asomatognosia that this formulation predicts, on the one hand, and the much smaller number documented, on the other. In this discussion I assume that only those syndromes that have been discovered to date exist. The future may falsify this assumption, but if it does, it will probably do so only to a minor extent, since the search for asomatognosias has been on for the best part of a century.

Among syndromes construed as partial impairments of the body image, a puzzling imbalance obtains. There is a prominent, even bizarre, but nonetheless well recognized syndrome of left neglect of the body that primarily implicates the left hand and arm. The patients ignore and often even disown these left body parts, and some deny any abnormality of their body. Have they suffered damage to the corresponding sections of their centrally represented body image? A far less striking but comparable deficit that involves the right side of the body also occurs. But reports of instances in which other parts of the presumed body image (face, neck, abdomen) are selectively ignored or disowned are conspicuously absent. If, as is generally supposed, the body image is specifically represented somewhere in the cerebrum and if left personal neglect is due to a lesion that inactivated the corresponding part of that representation, why are there no lesions that compromise other parts of the body image than those located at the extremes of the body's lateral axis? The cell assemblies that represent other parts of the body image could hardly be immune to naturally occurring damage. Why are there no other focal or partial asomatognosias? For that matter, why is anosognosia for dysfunction of a body part so disproportionately prominent for hemiplegia, and for left hemiplegia at that (Cutting 1978)? This disparity may imply that our neuropsychological theory of the body image is wrong. Specifically, there may not be any central representation dedicated to body image. I here revisit the concept of the body image and find reason to amend it so as to arrive at a different conceptual framework. To establish a foundation for this argument, I first discuss normal body awareness.

## 2 When Does One Attend to the Relative Disposition of One's Body Parts?

The locomotor system's specialization for movement and for posture (which is often preparation for movement) is primarily adapted toward exploring the environment and either acting upon a particular target or withdrawing from it. Toward these ends, detailed awareness of the position of the body is generally not needed and generally not available. Instead, unconscious machinery is invoked. This automatized system was called the body scheme by Head and Holmes (1911–1912). (For the distinction between body image and body scheme, see Gallagher 1986.) 'Schema' in this sense, rather than in the conscious sense as used by Bonnier (1905), is not implicated in asomatognosias, which are conceptualized as domain-specific disorders of bodily awareness.

In their mechanical detail, skilled movements are automatic and generally not under attentional scrutiny. Differences in the configuration and rate of displacement of body parts are experienced not as such but rather in terms of what is being explored or manipulated. These specifics of movement are used to infer properties about the environment—the size, shape, texture, and distance of a thing—and this is what is represented and available to awareness. A person only infrequently attends to the position of his body. As for the intention to move a body part, this is generally so quickly followed by the movement that the intention is not registered in awareness. The intention to move incorporates an image of the part to be moved as it reaches the target location. If the individual hesitates, then the lingering intention may convey the limb into awareness. When no objects are being acted upon or when the exploration of the environment goes awry, then attention may focus on the body parts themselves (as when any skilled-movement sequence fails, attention shifts to the level of individual moving parts). This type of bodily awareness is referred to the 'short-term body image' by O'Shaughnessy (this volume). Correspondingly, loss of bodily sensation primarily becomes apparent in terms of disordered movement and disordered posture, and we more frequently become aware of the body parts that customarily participate in action plans. Impaired awareness of body parts does not give rise to anything patients complain about. It usually only comes to notice on direct questioning.

Awareness of body parts during action can be likened to the marginal awareness of information in the peripheral visual field during focal attention. To contemplate the specific shape and disposition of one's body parts calls for focusing attention, which can be implemented only sequentially, one body part at a time. (The maximal extent of a body part that can simultaneously be the focus of attention remains to be determined.) Failing that, only some very general information is immediately available. But even in the absence of detailed information about body parts, one feels that one's body is complete. It appears that the body feels complete if no specific signals in awareness indicate that it is not, and such signals can only enter awareness if attention is focused on the representation of the body part in question. Hence the patient does not complain that body parts that are "neglected" are missing (see below). The body feels as it always felt. Correspondingly, since all movement is differential (i.e., selected from a set of alternative possible movements), it may be that when one moves, one has background awareness of alternative movement possibilities. But the exact nature of the set of alternatives is *not* in awareness, and if the set is depleted, this would not be experienced as a loss, and therefore would not be complained of.

## 3 How Does One Focus Attention on a Body Part?

The control of visual and bodily attention have in common that they are both subject to lateral bias when dysfunctional. Syndromes of unilateral neglect have been documented in both modalities, and with comparable left-sided preponderance. In experimental animals with appropriately placed unilateral brain resections, "circling" can be elicited by either visual or tactile ipsilesional stimulation. Attention is drawn ipsilaterally toward the lesion, and locomotion in that direction follows the anticipatory orientation (Kinsbourne 1974). If when the animal turns, the stimulus array still extends in the direction of turning, further turning, that is, circling, results.

Ample evidence indicates that visual orienting, at least along the lateral plane, is under the control of opponent processors and is directed along the vector resultant of their interaction (Kinsbourne 1974, 1994). I now suggest that somatosensory attention is also directed along the vector resultant of directionally organized opposing processors. An attentional shift to a unilateral body part requires an increase in the activation of the contralateral processor and reciprocally decreased activation of the ipsilateral processor. Attending to a unilateral body part might be a two-stage process: the segmental level of attending is established by an axial shift; then the lateral opposing interaction is calibrated so as to reach its target. If the processor on the right, which ordinarily directs attention leftward, is inactivated, this disinhibits the left processor so as to generate a rightward bias, attention being withdrawn from the left and overinvested in the right, as has so often been described in the visual-neglect syndrome (Kinsbourne 1994). A similar lesion on the left has the converse effect, though this is usually much less striking.

This proposed mechanism implies that the play of attention across body parts relies on some implicit knowledge of their structural articulation (perhaps hardwired into the somatosensory cortex). This I conclude from the fact that a neglect patient's ability to attend to a neglected body part does not appear to be modified by its location in egocentric space at that particular time. For instance, I have observed that if the patient's left forearm is placed across his chest, this does not result in lessened neglect of the hand and intensified neglect of the elbow, which is now the leftmost located body part. The implicit knowledge of the articulation of the body parts corresponds to the long-term body image, in the sense of O'Shaughnessy (this volume). In interesting contrast, within a body part, specifically the hand, there is a lateral gradient of response to double simultaneous touch, the direction of which depends on whether the hand is positioned palm up or palm down (Mattingley and Bradshaw 1994). The fact that both hands are so affected vividly demonstrates the somatosensory gradient of attention (Moscovitch and Behrmann 1994).

## 4 Why Are There No Local Autotopagnosias?

Somatosensory input from each side of the body is projected to the contralateral cortex. The cortical relay neurons are not the substrate of a body image in the sense of being essential to awareness of the existence of the body parts they represent. When a somatosensory map is lesioned, the individual feels a local numbness. He loses sensory acuity, but he remains aware of the existence of the body part itself. An extreme case is "conscious hemisomatognosia," in which the patient feels as though one side of his body has been amputated and that, unlike neglect, can equally involve either side of the body and is attributed to subcortical, not cortical, injury (Frederiks 1985). It has therefore been supposed that a representation (image) of the body is housed separately in the brain, distinct from the purely contralateral somatosensory maps. The findings of Semmes, Weinstein, Ghent, and Teuber (1963) implicate the left hemisphere as the site of such a map. Neuropsychologists believe that they are assessing the integrity of this map of the body when they ask patients to name body parts, indicate named body parts, or indicate body parts on a sketch of the body. Partial or complete destruction of this body image allegedly gives rise to partial or complete "autotopagnosia" (Nielsen 1938, Roth 1949, Critchley 1955).

As mentioned above, if a representation of the body image were hardwired into one hemisphere, or elsewhere in the brain for that matter, it would be expected to have suffered damage in its several parts in diverse patients, to the point that the anatomical correspondence between any body part and its representation in the body image should by now have been documented in cumulative case reports. But nothing of the kind has occurred. Local autotopagnosias have proven surprisingly hard to come by. Indeed, the literature presents local autotopagnosic syndromes only for left-sided body parts, in neglect of the person (see Critchley 1950b). The only bilateral partial autotopagnosias is finger agnosia. In this condition, which is due to left posterior parietal injury, the patient cannot name his finger or point to named fingers. But Gerstmann 1924 notwithstanding, finger agnosia is not a localized autotopagnosia. The difficulty that the finger agnosic experiences in naming her fingers or recognizing them when named is a consequence of a more general disability in discriminating on the basis of relative position, as are the other three elements of the Gerstmann syndrome (see Kinsbourne and Warrington 1962).

## 5 Is There a General Autotopagnosia?

Neither the inability to name body parts nor the inability to point to named body parts, Pick's operational criteria for autotopagnosia, are unequivocal evidence of a selective disorder of the body image. DeRenzi and Scotti observed that if disordered pointing to named body parts extends also to objects external to the body, this reflects a "general inability to analyze a whole into its component parts" (1970, 202). The patient may have a visuospatial agnosia. The visuospatial agnosic cannot use peripheral visual cues to help him direct his gaze. He is aware of only one object at a time, even if they overlap, and thus is lost in space. The patients described by Pick (e.g., 1922) mislocate body parts not only on their own body surfaces but elsewhere. Such a patient may reach across the table or under the chair for his eye or ear. He clearly suffers not from a static disruption or distortion of the body image but from an inability to shift attention flexibly among parts of the body. The fact that his search ranges beyond the confines of the body shows that the patient is unable to use somatosensory cues from body parts as targets toward which to orient, or at least as landmarks to constrain his search.

Some aphasics find it disproportionately difficult to name body parts (Goodglass et al. 1966, Assal and Buttet 1973, Dennis 1976, Semenza and Goodglass 1985, Goodglass and Budin 1988). This is to be construed as a semantic deficit, or "word category aphasia" (Yamadori and Albert 1973) rather than an autotopagnosia. That dementia also complicates the interpretation of apparent autotopagnosia was stressed by Poeck and Orgass (1971). However, Ogden (1985) reported a patient whose apparently selective difficulty in finding parts of the body was paralleled by an inability to describe their spatial relationships in words. Ogden believes that the patient is unable to form a mental image of his own body.

## 6 Opposing-Processor Imbalance and Impaired Body Awareness

The static view of how the body is centrally represented, which leads one to expect that partial autotopagnosias should occur, is paralleled by the mistaken assumption that the parietal cortex represents "external space" in some static manner, for which reason some right-parietally lesioned patients cannot represent the left side of space. It is not so much that neglect patients cannot represent left-sided spatial extent per se as that they cannot use sensory or remembered information to represent the left sides of things, wherever the things might be located (evidence is reviewed in Kinsbourne 1987). An analogous situation obtains for body sensation. The brain activates a representation of whatever part of the body the individual orients to when and only when she orients to it. While she retains knowledge of the fact that there is a left side to her body, the patient with somatosensory neglect cannot use sensory information to represent the left extreme of the body.

If attending to body parts is under opponent processor control, as suggested above, a complete set of partial autotopagnosic syndromes would not be expected to occur. There can be no focal impairment in body awareness (just as there can be no "island of neglect" in a visual field). Impairments are most apparent at the extremes of the lateral axis. But which parts should be considered more lateral in the body? To judge from neuropsychological evidence, the hand and feet appear to be at the lateral extreme of the conceptual bodily field (or long-term body image). This is indicated by unilateral bodily neglect, which regularly implicates the hand most of all, the elbow (and foot) less, and more axial structures, like the left shoulder and left face, far less and only in the more severe cases (Bisiach 1991). It is as if the body were conceptualized in the "anatomical position": back straight, with arms outstretched to either side and legs straight and wide apart. That would make the hand and the foot the most lateral body parts. It is true that as the hand is most subject to neglect in the upper extremity, so the foot is most often neglected within the lower limbs. But why is neglect of the hand so much more striking than neglect of the foot?

Again I use as a model the visual control of lateral attention. It has become clear that the preponderance of neglect of the left is a consequence of a normally present bias of attention to the right (summarized by Kinsbourne 1987). The reason why the most severe neglect affects the left hand may be that the right hand is a particularly efficient attractor of attention. Whereas ownership of the left hand is denied in left personal neglect, ownership of the left foot is more typically conceded, though the fact that it is paralyzed is often denied (possibly a milder manifestation of the same malfunction). The representations of the two feet may not be in such pronounced potential imbalance as those of the hands in the neglect patient. The shoulders, sides of the back, and hips, which are bilaterally innervated, so often work in concert (rather than reciprocally) that there is little tendency even for a damaged unilateral processor to be overwhelmed by an intact one on the other side. It would follow that the paired body parts will prove to be subject to neglect in proportion to the extent to which the intact individual is normally selèctively aware of these body parts.

## 7 What Explains the Indifference and Denial Syndromes?

A patient may disregard a gross deficit such as hemiplegia on account of a general tendency to minimize problems, as occurs in some cases of frontal-lobe disease. But a selective denial of hemiplegia has to be otherwise explained. In such a case, ownership of the limb is acknowledged, and therefore the representation of the limb must be preserved. I suggest that what is lost in this case is the cerebral substrate of the intention to move the limb. If one cannot conceive of intending to move a limb, one cannot become aware that one would have difficulty in doing so. The sensory loss that so often coexists with denial of hemiplegia may render the intention more difficult to form, or it may exert some other effect.

When a limb is completely disowned, representing it kinesthetically and representing intentions for moving it have presumably been precluded by the cerebral damage. The limb, both in terms of experience and of agency, has lost its place in the patient's direct awareness. Visual information about the limb evidently does not suffice to generate the feeling of limb ownership. Therefore, its presence in plain sight and its visible attachment to the rest of the body poses a logical problem to the patient, though it by no means counteracts his proprioceptive nonexperience of the limb. The rationalizations with which patients disown the affected limb can be highly idiosyncratic (your hand, a nurse's, a monkey's, a snake) but usually exhibit negative valence: (cold, dead, alien). Conspicuously, the patients seem eager to evade any conversation that addresses the paradox that the limb they claim they have moved has not been seen to move, or that the limb they claim is not theirs is continuous with their body. The patients' ill-concealed aversion is to an analysis that could threaten their attempt at holding at bay a conflict between their knowledge and their experience, one that threatens an existential crisis.

In certain congenital and infantile hemiplegias the affected limb is not explicitly denied but is disused out of proportion to the severity of the motor deficit, except in bimanual activities. It would be of interest to find out whether vestibular stimulation is effective in temporarily shifting attention to such a limb, as it is in neglect (Bisiach, Rusconi, and Vallar 1991; Rode et al. 1991). If the central cell assemblies that react to signals from the limb are weakened, vestibular stimulation could activate them and return such a limb to full awareness. If they are so completely eliminated that neither deliberate nor automatic use of the limb is possible, vestibular stimulation may or may not be effective. (Both types of outcome have been documented in neglect.)

## 8 To What Does One Attend When One Attends to the Body?

It is not clear that attending to a body part brings proprioceptive sensations into consciousness. Subjectively, the experience when attending is more akin to a local touch, perhaps self-generated by means of a slight muscular contraction (see Humphrey 1992 for discussion of the relationship between body sensations and movements).

Whether, in order to attend to a body part, one has to be aware of its actual position (as derived from the short-term body image) is unclear. The perceived position of the body is the result of interacting information of kinesthetic, tactile, and visual origin. Schilder (1935) points out that the awareness of body position is synesthetic. It requires an act of deliberate analysis to identify the modality through which information about the position of the body is being acquired at any moment. Because visual and tactile representations can become conscious in their own right, attention can be selectively focused upon their individual contributions to the awareness of body parts. In contrast, kinesthetic contributions are unconscious and cannot be deliberately deconfounded. In the absence of the other indicators of bodily position, touch can serve. In the weightless condition (zero gravity) a touch to the flat of the heels gives the feeling of being upright; a touch to the top of the head, of being inverted (Lackner and DeZio 1984).

As already discussed, in the extreme pathological case in which a body part is disavowed, there is a clear conflict between vision, which continues to register the continuity between the implicated part and the rest of the body, and proprioception, which no longer represents the part in awareness. In cases of phantom limbs there is a similar conflict, but in the reverse direction. 'Phantom limb' refers to an experience not infrequently reported by amputees. The patient with a phantom continues to experience the limb, and even to incorporate it into the movements of his body (Straus 1970). For instance, when a man with an amputated leg stumbled, he felt himself extend his missing phantom leg, as it were, to save him from falling. The state of preparedness to move will normally not persist long enough to be included in awareness (in order to join the dominant focus of awareness, a representation has to endure for longer than a minimal period of time, as discussed by Kinsbourne, in press), because the movement itself rapidly supervenes and supplants the intention. When the limb has been amputated or did not develop, it cannot move, and the persisting intention unmatched by the expected movement feedback, conveys the limb into awareness (indeed, into excessive, unwanted awareness: the phantom limb is continually in consciousness, whereas normal limbs fade into the background). But that this cannot be the only explanation of the continual obtrusiveness of a phantom is demonstrated by the existence of a phantom breast, a situation in which movement is not an issue.

Kinesthetic dominance in the perception of a body part is illustrated in normal people who experience an illusory stretching of particular muscle groups when vibration is applied to the overlying skin under isometric conditions. The examples that follow derive from Lackner's systematic application of a method that induces in the subject the illusion that his limb has moved (e.g., Lackner and DeZio 1984). If a limb muscle is vibrated so as to stimulate the muscle spindle receptors, there follows a reflex muscle contraction, known as the "tonic vibration reflex" (Eklund and Hagbarth 1966). If the vibrated limb is precluded from moving, then the subject experiences a movement in the same direction as would result were the vibrated muscle stretched (Goodwin, McCloskey, and Matthews 1972). It follows that commands to the musculature are monitored, and their expected consequences are compared with the actually resulting patterns of proprioceptive activity and body motion. This effect is most pronounced in darkness, but though attenuated, it still occurs in the presence of disconfirming visual feedback.

Vibration was applied by a hand-held electromagnetic physiotherapy vibrator, 120 pulses per second, for three minutes per trial, to the skin overlying selected muscles of blindfolded subjects. Three postures were studied:

- The subject touches his nose with his index finger. The biceps muscle is vibrated. The arm appears to extend, and the finger and nose also feel longer. The triceps muscle is vibrated. The body parts seem to shorten. Individuals vary. For some, the nose is pushed back into the head. For some, the index finger passes through the nose. For some, the head is extends backward.
- The subject touches the top of his head with his palm or finger tip. With biceps vibration, the head seems to extend upward to a point. With triceps vibration, the finger feels as though it has penetrated the skull, or as if the head is pushed into the trunk.
- The subject stands with arms akimbo, hands pressed to the waist. With biceps vibration, his waist seems to balloon. With triceps vibration, there is the feeling of a narrowed (wasp) waist.

Even positions that violate the laws of physics, in that two body parts occupy the same location, are reported. The experienced position of a phantom limb may also coincide with another body part. One learns that the sense of joint position counts for little. The changes in the apparent lengths of muscles are not effectively counteracted by signals from the joints to the effect that the implied joint displacement has not occurred. If a veridical representation (image) of the body exists in the brain, this evidently does not preclude people from readily experiencing their bodies in physically improbable or even impossible ways. This type of observation is more readily accommodated by the view that the representations of separate body parts are separately referred to their spatial locations and then related to each other than that an articulated image of the body is adjusted on an ongoing basis to reflect changing sensory input.

Static (as distinct from moving) visual stimuli have little effect on body sensation. When people see themselves in distorting mirrors, the visual alteration does not induce a corresponding change in felt body shape or position. But can a change in how a body part feels change how it looks? Apparently so, as evidenced by numerous accounts of neglect patients perceiving their left upper limb as swollen or otherwise distorted (Schilder 1935, Critchley 1950b, Weinstein and Kahn 1955). If there is no visually stable framework, vision follows kinesthesis in normal subjects. If vibration is applied to a limb in the dark, a source of light attached to the pointed index finger appears to move according to the felt movement of the limb (Lackner and DeZio 1984).

The dominance of proprioception in the control of normal perception of bodily shape and position sets personal neglect apart from largely visually based extrapersonal neglect, and these two types of neglect are indeed often dissociated (Bisiach et al. 1986). Opposing processors that control lateral visual and somatosensory attending are presumably separately localized in the brain.

## 9 A Body Scheme Acquisition Device?

Like the syntactic competencies of the "language-acquisition device," the computations that enable fluent postural change become increasingly available as the nervous system matures, and this is largely how motor milestones are attained. In a classic experiment, Held and Hein (1963) reared kittens in darkness, except for three hours each day, during which they were yoked together in such a manner that one ("active") kitten could move, whereas the other ("passive") one are was pulled along with it but could not independently initiate locomotion. In this way, both animals obtained the same visual experience, but only one could practice visually guided behavior. When the passive kitten, up to that point deprived of visuomotor experience, was unyoked from its actively moving partner, it staggered and lacked age-appropriate motility. Less stressed but actually more telling was the corollary finding that although kittens were maintained in this yoked arrangement for up to six weeks, the resulting gap in visually guided behavior was found to be completely closed at a 48-hour retest. This shows that the emergence of locomotion depends rather little on practice and very much on neural maturation. Within at most two days, kittens caught up on six weeks of deprived experience. Rather than learn movements one at a time, we seem to calibrate our motor-control systems to prevailing circumstances, including terrestrial gravity. This computation is quickly done (and quickly adjusted in other than the usual one-gravity circumstances). The long time that it takes for motor development to be completed is due not to the need for protracted practice but to the slow emergence of ever more differentiated neural motor-control mechanisms.

Activities of the types described above suggest preprogrammed responding to situations involving a body scheme, and this could be dramatized by saying that there is a device for acquiring a body scheme. The body image may also emerge at an early stage.

## 10 A Body-Image-Acquisition Device

Applied to the classical question of the ontogeny of awareness of one's own body and its noncontinuity with external objects, the attentional approach suggests a new formulation. The developing child may first acquire a sense of self when it becomes able selectively to attend, in however ill differentiated a fashion, to its individual body parts in the somatosensory modality. It would then become acquainted with the internal causal consistency of their positions and displacements relative to its own volitions. The assumption that the visual channel soon reveals to the infant which body parts are its own (Neisser 1978) may be mistaken. Logically, the visual channel should soon betray which (body) parts are always present and one's own and which (external) objects are present only sometimes (Neisser 1978). But the mechanisms for accomplishing this during development (Gibson 1969, Bower 1974) may follow rather than precede somatosensory attending. Poeck and Orgass (1964a, 1964b) found that blind children developed knowledge of their body at about the same age as sighted children.

The top-down nature of an infant's earliest knowledge of its body is indicated by the observation that children with amelia, where the limbs never begin to develop, sometimes report phantom limbs (Weinstein and Sersen 1961, Poeck 1964). If these claims can be sustained, there must be a cerebral representation of topographically differentiated proprioceptive input that develops regardless of whether any input from the part in question ever reaches the brain. It may be relevant that phantoms, which involve exaggerated rather than reduced attention to a body part, are, in contrast to neglected limbs, more common on the right side of the body (Shukla, Saku, Tripathi, and Gupta 1982). Whether such a purely centrally established representation is stable in the absence of sensory input is a separate question. Poeck's data show that phantoms are less frequent and more often transitory in the very young. Such findings are quite consistent with other "disuse effects" that have been documented in the developing nervous system, for instance in amblyopia. But if an amelic infant really can have a phantom limb, that indicates that cerebral somatosensory representations can become established independently of feedback from the periphery.

It is possibly relevant that amelia is usually bilateral. This means that there is no rivalry for attention by the representation of an intact contralateral limb, and this favors the genesis of a phantom, according to the attentional model.

## 11 The Self as Emerging from Background Body Sensation

The amelia findings teach us that simply attending to the representation of a body part (without any possibility of seeing it or feeling it touched or knowing where it is) suffices to identify a body part as existing and being (conceptually) one's own. The ability to attend to (i.e., activate) one's own representations of the parts of one's body may be an essential precursor of the acquisition of the concept of the self ("self-consciousness"). Also, if one can attend to a body part via bodily sensation, one will not make the mistake of misidentifying it as another's (Evans 1982), a mistake that could occur if one were to use the visual modality only.

The focus of attention, the figure, is experienced as arising in or emerging from a ground. In the case of the body, the ground is the familiar feeling that one's body exists as a backdrop to whatever one is thinking, experiencing, or doing, though its various parts are not being monitored. This ever present background may be the basis for constructing the continuity of the experiencing self.

The background "buzz" of somatosensory input may indicate his body to the child. It would be in line with principles of cognitive development (Vigotsky 1962, Gibson 1969) if a decontextualized construct of a self as "mental" and distinct from the body were a later emerging abstraction. (Analogous would be the relationship between purposive movement, which is present early on, and internalized thought, feasible only later when the child has acquired the inhibitory capacity that enables him to dissociate central activity from its realization in differential movements.) Underlying the person's feeling of ownership of the body would be the ownership of the rest of the body by each body part, specifically, whichever body part happens to be the focus of attention at the time. The body part at the focus of attention "owns" its background of body sensation. The construct of the self is abstracted from this origin in sensation. Thus the self has no specific location but rather is coextensive with the field of bodily sensations. It must have called for a very refined sensibility on the part of Zarathustra to have been able to see through the abstraction of a self having a body to the self's origin in being a body, and to realize that, stripped of elaborations, "I am body entirely and nothing beside."

I liken an attended body part to an attended object in the visual field, and its background (the somatosensory field) to the background visual field. The somatosensory field does not present the rest of the body in detail as an articulated object. The undifferentiated nature of the background to focused somatosensory attention might explain why the patient who neglects a limb nonetheless does not feel incomplete (in his body or himself). The background sensation is not experienced as different from before the injury. The neglect patient's inability to attend to the implicated limb means that he cannot conceive of attending to it. So there is no way in which any abnormality with respect to the neglected limb can come to the patient's attention by the somatosensory route.

## 12 Body Sensation, Episodic Memory, and the Self

Any act of episodic (autobiographical) remembering must include a representation of the self in the context of the remembered event (Kihlstrom 1993). If the individual is engrossed in what is happening, there will be no spare attention available to represent the self as part of the scene. But the background of body sensation may nonetheless anchor the event to the individual's autobiography. Background awareness of one's body (its feeling, its potential for action) puts the stamp of personal experience on the scene. Conversely, one may imagine a scene and know that it has not been previously experienced because the background of bodily sensation is missing from the image. In infancy, this awareness of the body, as a salient source of immediately available sensation, may be more obtrusive than in the adult, as currently (concretely) experienced percepts are thought generally to capture the infant's attention (e.g., Gibson 1969, Kinsbourne 1993). If so, recollection of an early event might depend on a regression to this early concrete stage in body awareness. This might explain infantile amnesia.

## 13 How Are Body Parts Represented?

How is the predetermined representation of body parts structured? Perhaps a body part's relative prominence is determined by the extent to which one would normally use it in action under focused attention. As we have seen, phantoms exhibit distortion in favor of an emphasis on moving parts, such as the hand and wrist experienced as direction attached to shoulder and missing forearm and upper arm. An interesting parallel is to be found in the apparent systematic distortions in the body image of congenitally blind children. Kinsbourne and Lempert (1980) observed how such children represented the body in plasticine; moving parts (arms and neck) as well as the ears, were exaggerated in size relative to the trunk. Moving parts are also prominent in phantoms, which leads to distortion in the virtual anatomy of the phantom limb in favor of its most motorically differentiated components.

Roughly speaking, the representation of body parts is carved at the body's joints. Joints permit differential movement of the articulated parts. Multiply jointed body parts (fingers, hands, forearms) appear to be more discretely represented than larger but unjointed parts (abdomen, back, buttocks), and this is consistent with the view that body representation is primarily referenced to action. So, attending to a body part might have little to do with its moment-to-moment egocentric position.

The representations of discretely moving parts appear to depend least on sensory input, since they can be enhanced by selective attention alone. When a pathological bias in the control of attention leaves them unrepresented, however, the patient is most apt to deny ownership of these moving parts, regardless of sensory input and however plausible ownership might seem on other grounds. Indeed, sensory stimulation, if experienced, is referred to the other side of the body (allesthesia). Yet while the attentional imbalance is temporarily corrected by use of vestibular stimulation, even a severely neglected limb is experienced in the normal manner (Bisiach, Rusconi, and Vallar 1991). Manipulating unilateral central activation corrects what appeals to reason and to manifest visual reality cannot.

## 14 Conclusions

The attentional shifts that focus awareness on individual body parts are organized along axial and lateral (and perhaps saggital) coordinates as they play across the sensorimotor cortex. Disordered bodily perception results either from spatial disorganization of attentional shifts or from their extreme lateral bias. The mental operations that result in the conscious awareness of the body are guided by a person's knowledge about the relationships between his body parts, not by a separate fixed egocentric representation of the body. As with any familiar articulated dynamic structure, specifics of articulation between body parts can on occasion be brought into awareness by activating the corresponding areas of the sensorimotor cortex. The sensation of the body derives from a virtual rather than a hardwired set of representations.

If one cannot activate a representation by selective attending, it will not contribute its content to focal awareness. If the representation is in a weakened state, it will not participate in the control of automatic activities either. As long as one can focus somatosensory attention on a body part (even if it be an invisible and intangible phantom body part or it is completely numb), one feels that it is one's own. If one cannot focus somatosensory attention on it, one may even disown it (as in neglect) even though it is visibly, palpably, and logically part of one's body. As soon as the infant becomes able to focus attention on its body parts and their internally causally coherent behavior, it is equipped to develop a sense of self. This it will acquire not by bringing into play a homuncular representation of its body but as an expression of the coordination of information about its several body parts that is represented primarily in the somatosensory modalities.

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