HUMAN BODY PERCEPTION FROM THE INSIDE OUT

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From Phantom Limb to Phantom Body

Varieties of Extracorporeal Awareness

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Corporeal awareness refers to the experience of having a body. While this may appear self-evident given our constant daily experience of embodiment, the neuronal processes mediating this experience are nonetheless highly manifold and complex. Corporeal awareness relies on perceptual functions (e.g., tactile, proprioceptive, gravitational, visual) and on motor programs for bodily action. Yet, it also comprises a sense of the self as the object of sensory stimulation and as the agent of motor intentions and executions. Moreover, identifying with a body implies knowledge of its borders. Thus, the study of corporeal awareness includes investigations of the many functionally organized spaces for each distinct sensory and motor representation that surrounds our body. In the past, various terms have been used to capture some of the heterogeneous functions that guarantee a continuous sense of embodiment. Some of the more frequently used terms are body schema, body image, body self, somesthesis, coaenesthesia, and somatognosia. Critchley (1955/1979) complained about the fact that these terms were employed more or less interchangeably despite the fact that they had originally been introduced to designate specific facets of bodily perception and representation. He therefore proposed the deliberately less definitive term *corporeal awareness* as an all-encompassing descriptor of the experience of having a body.

The present chapter provides a phenomenological account of those borderlands of corporeal awareness in which subjects experience a discrepancy between the spatial extents of their physical and phenomenal bodies. Such discrepancies may occur at the level of single limbs but also at the level of the entire body. This chapter begins with brief reviews of selected clinical and experimental findings pertaining to various manifestations of the phantom-limb phenomenon. This is followed by a discussion of what is referred to as the *hemiphantom* or *phantom half-body*, that is, the experience of a deafferented/deefferented half of one's body as an entity living a life on its own. Finally, an overview will be presented of a peculiar class of reduplicative disorders known as *autoscopic phenomena* in which one's entire body is experienced as a phantom.

While research on limb phantoms has enjoyed increasing popularity since the 1980s, investigations of whole-body phantoms are still largely a matter of clinical descriptions. However, experimental paradigms that have proven useful in elucidating the neuropsychological mechanisms underlying phantom-limb experiences can be adapted for the systematic study of phantom bodies. Also, the neuropsychology of spatial and conceptual perspective taking and of the experience of agency over one's actions should be considered for the interpretation of the psychological content of autoscopic experiences.

1. Phantom Body Parts

1.1. Amputation Phantoms

An *amputation phantom* is the persistent experience of the postural and motor aspects of a limb after its physical loss. The reluctance of the medical community to consider amputees' reports about such phantom limbs is reflected in the history of the subject. Riddoch (1941, p. 197) noted that the subjective survival of a limb "must be as old as survival from amputation." Early accounts of phantom limbs can be traced back at least to the 10th century. These accounts were intermingled with religiously motivated resurrection fantasies (Price & Twombly, 1978) to such a degree that it is difficult to separate keen introspective report from folk psychological interpretation. Later theories (see Finger & Hustwit, 2003; Halligan, 2002, for historical overviews) about the origins of phantom sensations can conveniently be dichotomized according to whether they focus more on peripheral or central processes. The essence of peripheral theories is pathetically captured in the words of Gallinek (1939, p. 420): "peripheral stimuli are the blood which the sensory ghost must drink in order to be awakened to its phantom existence." Such stimuli include random firings of axon terminals in the stump and irritations by scar tissue and neuromas (see, e.g., Katz, 1992). Later theories emphasized involvement of the central nervous system at the level of the spinal cord (Cronholm, 1951). A quarter of a century ago, peripheral and spinal factors were still considered by some authors as sufficient to explain the genesis of phantom sensations (see especially Carlen et al., 1978, who even ridiculed any postulate of a cortical involvement). However, subcortical and cortical reorganization had much earlier been described as essential concomitants of limb amputation. Specifically, it was argued that changes in the corporeal awareness of a lost hand in response to

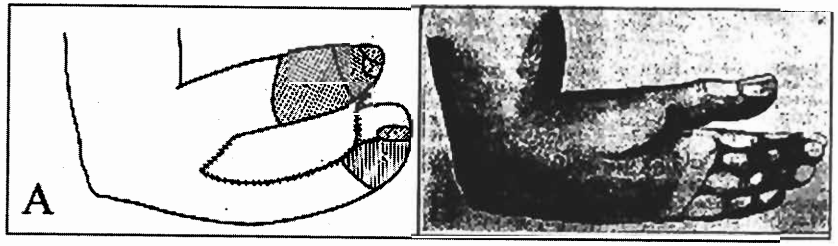


Figure 9.1. (A) Surgical reshaping of the forearm of a hand amputee into a tongue-like tool (Krukenberg hand). Shaded areas correspond to fields with systematic referral of touch to the phantom hand. (B) An artist's drawing of a patient's description of the reshaping of a phantom hand, previously felt in the space distal to the stump, within 12 to 24 hours after kineplastic surgery. The radial part of the arm was felt as a huge thumb opposing the four fingers felt within the ulnear part of the arm. This observation illustrates the tight interplay of peripheral and central factors in the genesis of phantom sensations. Adapted with permission from Brücke (1950, Figures 1 and 2).

reshaping of the forearm stump would constitute a "wholistic reaction of the sensory cortex and cortico-thalamic system" to the new functional properties of the arm (Brücke, 1950, p. 154; Figure 9.1; see Kallio, 1952, for an alternative, mostly peripheral interpretation of similar observations).

Since the 1980s, the literature on the cerebral correlates of amputation phantoms has grown exponentially. Along with prior animal research (Kaas et al., 1983; Pons et al., 1991), these studies helped to revise an axiom within the neurosciences, that is, the claim that the adult human brain is largely resistant to functional reorganization. A variety of behavioral and neuroimaging techniques have been used to monitor the cortical and subcortical reorganizational processes following limb amputation in humans (see Ramachandran & Hirstein, 1998, for review). Flor et al. (1995), using magnetic source imaging, described shifts in the cortical hand area (contralateral to amputation) in the magnitude of centimeters that correlated almost perfectly with a subject's rated severity of phantom limb pain.

However, referred-sensation studies have shown that nonpainful phantom sensations can serve as markers of plastic changes during deafferentation. *Referred sensations* are sensations localized to a phantom body part after stimulation (usually tactile) of a remote site on the subject's body known as the *trigger zone* (Aglioti et al., 1997). The most common trigger zone for upper-limb amputees is the subject's face (see also chapter 8). Clinically, these sensations have been extensively documented (e.g., Cronholm, 1951; Henderson & Smyth, 1948). Ramachandran et al. (1992) described representations of upper-limb phantoms, apparently somatotopically organized, on the face, chest, and axilla of several amputees. These and later authors interpreted the regular correspondence between the face as a trigger zone and the phantom hand as the site of referral as evidence for an "invasion" of the deafferented hand area into the neighboring postcentral area of face representation (see Clarke et al., 1996, for an inverse relationship between trigger and referral zones in a patient with intact hands but surgical deafferentation of the cheek). The exact neurophysiological mechanisms underlying these remapping phenomena are still unclear. The most commonly discussed mechanisms are axonal sprouting (intracortical and/or thalamocortical) and the unmasking of existing synaptic connections (see Kew et al., 1997, for discussion). However, the correspondence pattern between trigger zones and sites of referral does not appear to be stable over time and can change drastically within months (e.g., Halligan, Marshall, & Wade, 1994; Halligan, Marshall, Wade, et al., 1993). Thus, while there was great initial enthusiasm about and emphasis on the apparent somatotopy of referred sensations (Ramachandran et al., 1992), later investigations showed that trigger and reference zones could be located in body parts represented in clearly nonadjacent cortical areas (e.g., Grüsser et al., 2004; Knecht et al., 1996, 1998). Such findings suggest a possible subcortical mediation of sensory referral. For a crossmodal analogue of referred sensations, see Cacace et al. (1999).

Dynamic aspects of phantom limbs have been captured in many experiments. For example, the reality of virtual movements, or the voluntary movement with one's phantom limb, has been elegantly demonstrated in simple behavioral experiments (e.g., Franz & Ramachandran, 1998). Several neuroimaging studies have attempted to shed some light on the functional neuroanatomy of voluntary movements of amputation phantoms (e.g., Ersland et al., 1996; Lotze et al., 2001; Roux et al., 2003). These studies have shown that phantom movement sensations are associated with activations of primary and secondary sensorimotor cortical areas, even decades after the loss of a limb.

Corporeal awareness on the level of single limbs is shaped by interactions with the visual modality. For example, the phenomenon of *obstacle shunning* refers to the diminished awareness of a phantom limb during the observation of a physical object invading the space that the phantom appears to occupy (Jalavisto, 1950). Scattered observations and systematic explorations of shunning behavior (e.g., Abbatucci, 1894; Katz, 1920; Poeck, 1963; Riechert, 1934; Simmel, 1956) have revealed three major findings: (1) there are large interindividual differences in the degree of shunning as roughly 50% of amputees do not show any pronounced obstacle shunning; (2) among the physical objects used to test for shunning behavior, the human body appears to play a special role (with little data on the specificity of the amputee's own compared to other people's bodies); and (3) pronounced shunning tendencies may elicit unique phantom limb movements, that is, movements specific to the experimental situation (e.g., a wall-approaching test) and not usually experienced in

everyday life. One example is the "bending" of a phantom limb beyond regular joint constraints to avoid "contact" with solid matter (Poeck, 1963).

More recent experimentation on visual-somesthetic interactions has concentrated on the visual observation of one's own limb, specifically, the one contralateral to the amputated extremity. Critically, the spared extremity is observed in a mirror placed vertically in the parasagittal plane to thus match the purely somesthetic phantom percept with respect to handedness and perceived location in space (e.g., Ramachandran et al., 1995; Ramachandran & Rogers-Ramachandran, 1996). Under these conditions, observed touch applied to the real limb may also be felt in the phantom (but see Hunter et al., 2003). Observed movements of the existing limb may be felt as mirror movements in the phantom, a principle that has found therapeutic applications beyond the treatment of phantom-limb pain (Altschuler et al., 1999; Ramachandran et al., 1999).

In view of these empirical studies, it would appear that what was labeled a "sensory ghost" by Mitchell in 1866 (the term *phantom limb* was also coined in this work) has completely lost its ghostly character. It is important to note, however, that we still continue to be haunted by considerable misconceptions. First, the literature on phantom limbs is heavily biased toward the analysis of cases after amputation. Second, at least in the popular mind, "phantom sensation" is implicitly equated with "phantom pain." Figure 9.2 illustrates this point with data from 172 people who provided spontaneous associations to the

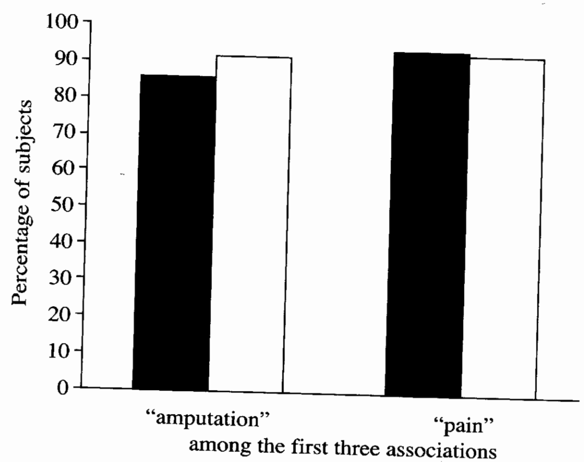


Figure 9.2. Stereotypes in spontaneous associations to the term *phantom* as used in medicine. Medically trained individuals (gray bars; $n = 84$) and laypeople alike (light bars; $n = 88$) show strong biases for association with the terms *amputation* and *pain*. These popular stereotypes are paralleled by an overrepresentation of reports on *painful* phantom sensations after amputation in the scientific literature.

term *phantom* as a medical term. Overall, these subjects wrote down an average of 5.8 associations to the term *phantom* in the allotted 60 seconds. Subjects were categorized as either "medically trained" or "laypersons." The medically trained subjects comprised general practitioners, neurology residents, and qualified nursing staff, as well as 48 fourth-year medical students. Laypersons had, for the most part, academic training in fields other than medicine and psychology. No differences were apparent between women's ($n = 87$) and men's ($n = 85$) associations. The population stereotypes somewhat anecdotally communicated in Figure 9.2 were similar for medically trained and untrained subjects. Clearly, amputation and pain are tightly associated with the medical term *phantom*.

Similar biases can be found in the medical literature. A search for the keyword "phantom sensations"[1] (December 2003) in the Web-of-Science for the publication years 1945 to 2003 produced 58 entries, more than 50% accompanied by the keyword "amputation" and more than 60% by "pain." The fact that amputation phantoms form just one of many different types of phantom-limb manifestations should become evident in this chapter. The overemphasis of pain among the many sensory qualities of phantom limbs (e.g., posture, temperature, weight, kinesthesis) can probably be explained by the fact that amputees usually complain about painful phantom sensations spontaneously, but mention painless phantom sensations only after specific inquiry (Egyd & Janke, 1967). Also, if present, phantom pain is a most distressing condition for which, judged by evidence-based medical criteria, no reliable therapeutic intervention can currently be offered (Stremmel et al., 2002). However, estimates of the prevalence of phantom-limb pain after amputation vary between around 80% (Houghton et al., 1994; Sherman et al., 1984) to less than 0.5% (Kolb, 1952, p. 586). In any case, both the tendencies to regard "phantom limb" as synonymous with "amputation phantom" and "phantom sensation" as synonymous with "phantom pain" hamper the recognition of a conceptual similarity between the phantom limb and phantom body.

1.2. Phantoms After Spinal-Cord Injury

Limb phantoms are also experienced after spinal-cord injury and may be defined as the phenomenal persistence of postural and, optionally, kinesthetic information about the deafferented and deefferented limbs. Lower limbs are thus affected in paraplegic patients (Conomy, 1973; Figure 9.3) while upper limbs are affected after brachial plexus lesions (Mayer-Gross, 1929), and both lower and upper limbs are affected in tetraplegia (Davis, 1975; Ohry et al., 1989). Important early contributions to general phenomenology and individual differences in corporeal awareness after spinal-cord injury can be found in Becker (1949), Bors (1951), Melzack and Loeser (1978), and Riddoch (1941).

Figure 9.3. Phantom legs in a patient with spastic paraplegia (sensorimotor impairment at the T-7 level) acquired in a motorcycle accident. Note that the phantom legs mimic the posture of the real legs shortly before injury. This patient failed to "get the legs back down to where they really were" (Conomy, 1973, p. 844). More typically, other patients with phantoms after spinal-cord injury can easily abolish the phantom-limb percept by looking at their real limbs. Reproduced from Conomy (1973, Figure 1) with the permission of Lippincott-Raven Publishers.

A recent population-based study found the prevalence of phantoms after spinal-cord injury comparable to that reported in amputees (Siddall & McClelland, 1999). Yet, "spinal phantoms" often escape the attention of the clinician because they are not specifically inquired about and are usually less vivid and not as persistent as amputation phantoms (Bors, 1951). Furthermore, spinal phantom sensations are often confounded with residual sensations, such as pain and paresthesias (Burke & Woodward, 1976). Finally, loss of consciousness during the trauma appears to decrease the chance that phantom limb experiences will be reported (Ettlin et al., 1980).

Most important with respect to the modification of corporeal awareness by crossmodal sensory integration is the observation that phantom leg sensations in paraplegia are frequently "suppressed" by visual feedback from looking at one's own paralyzed limbs (e.g., Conomy, 1973). Yet, occasionally, the view of one's existing limb does not suppress the compelling nature of somatic phantom sensations. In a case reported by Reichert and Sewekow (2002), a patient with a phantom arm after resection of an intraspinal tumor could feel his phantom in superposition with objects. This absence of obstacle shunning occurred despite the fact that the patient could clearly see both of his arms. It is possible that the spatial separation between the physical arm and the phantom arm may have prevented the suppression of phantom sensations by visual information.

Neuroimaging studies in paraplegic patients have documented large-scale reorganization of those cortical areas devoted to sensorimotor control. These changes are associated not only with the deafferented and deefferented lower limbs but also with the unaffected upper limbs (Bruehlmeier et al., 1998; Curt et al., 2002; Turner et al., 2001). Importantly, a recent fMRI study of paraplegic patients' motor imagery of the lower limbs showed high correlations between activations specifically in primary and secondary motor areas and the rated vividness of phantom foot movements (Alkadhi et al., 2005). Visual observation of simulated hand movements may enhance motor imagery–induced cortical activity in some patients with phantoms after brachial plexus avulsion and may lead to a reduction of phantom limb pain (Giraux & Sirigu, 2003).

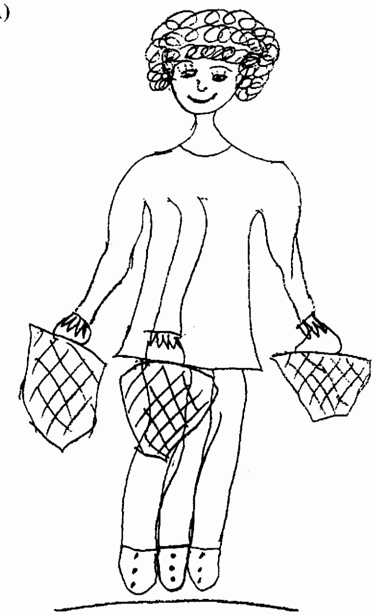
As in the literature on amputation phantoms, the issue of referred sensations has received special attention. While most reports found a referral of stimuli applied to normesthetic parts of the body to phantoms or deafferented body parts (e.g., Bors, 1979; Srinivasan et al., 1998), referral in an opposite direction does also occur (e.g., Nathan, 1956). An fMRI study of referred sensations after spinal-cord injury (Moore et al., 2000) provided clear evidence for a coactivation of regions widely separated from one another, both on the body surface and as representational loci within the postcentral gyrus.

1.3. Supernumerary Phantoms After Brain Damage

Given that the critical factor for the genesis of a phantom limb is a partial or full deafferentation and/or deefferentation of the corresponding real limb *at any level of sensorimotor integration*, phantoms are also experienced after damage to subcortical or cortical brain regions. The term *supernumerary phantom* thus refers to the awareness of having an "extra limb" in addition to the regular set of two arms and two legs.[2] In the medical literature of the early 20th century, such awareness was referred to as "pseudo(poly)melia" or a "reduplication of body parts" (see Weinstein et al., 1954, for a review of this early literature). Although the etiology of brain damage is commonly a vascular incident or a space-occupying lesion (Donnet et al., 1997; Halligan, Marshall, & Wade, 1993; Miyazawa et al., 2004; Sellal et al., 1996; Vuilleumier, Reverdin, et al., 1997), supernumerary phantoms have also been described after traumatic brain injury (Rogers & Franzen, 1992), during the course of a demyelating disease (Mayeux & Benson, 1979), or as an epileptic manifestation (Hécaen & de Ajuriaguerra, 1952; Riddoch, 1941). Typically, postural and movement qualities are reported whereas painful sensations are rather exceptional (e.g., Canavero et al., 1999). Movements of and tactile stimuli applied to a real limb can occasionally be transferred to the phantom (Hari et al., 1998; Figure 9.4A).

The key difference between supernumerary phantoms after brain damage and phantoms after the loss of a limb or its disconnection at the spinal level concerns the patient's insight into the reality of the phenomenon. As "real" as the latter may feel, they are always recognized as illusory percepts. In contrast,

(A)



(B)

Figure 9.4. (A) Experience of supernumerary "ghost limbs" in a patient with a bifrontal and anterior callosal lesion (drawing by the patient). While the *posture* of the phantom hand mimicked the one of the left hand with a time lag of up to one minute, its *movements* copied those of the right hand. Tactile stimuli to either left or right hand were transferred also to the other two hands, such as the patient would feel carrying three bags, or having three dogs on a lead, when in actuality only one object was present. Reproduced from Hari et al. (1998, Fig. 2), with permission from Elsevier. (B) The Australian artist Stelarc during a 1982 "Handwriting" performance. His project "Third Hand" involved the incorporation of an artificial supernumerary hand whose movements were controlled by abdominal and leg muscles. Avant-garde in the domain of art, Stelarc's experimentation could also contribute to the evolution of our scientific understanding of corporeal awareness. Photograph by K. Oki, with permission by Stelarc.

the experience of a supernumerary phantom is often commented on in delusional ways (Ehrenwald, 1930; Roth, 1944). As a rule, the more a patient's awareness of the physical limb contralateral to brain damage is compromised (up to the degree of complete "aschematia"; Bonnier, 1905), the more its phantom existence is experienced as the only reality that counts.

The designation of a supernumerary phantom limb as a "spare" limb (Grossi et al., 2002; Worthington & Beevers, 1996) or as "one I grew for protection" (Weinstein et al., 1954, p. 50) is indicative of some degree of anosognosia, that is, the denial of a sensorimotor hemisyndrome. Such an interpretation can be comforting to the patient. However, when in addition to the loss of pure motor control over the physical limb, one also loses one's sense of agency over the phantom, an individual's experience may be rather negative. Such emotionally distressing phantoms have much in common with an "alien" or "anarchic" limb (Marchetti & Della Salla, 1998) that may engage in self-destructive behavior, particularly after right-hemisphere damage (see Brugger, 2001, for further references). In these cases, the transition to somatoparaphrenic delusions (see below) becomes blurred.

Among the experimental studies conducted with patients experiencing supernumerary phantoms, the one by Hari et al. (1998; see Figure 9.4A) is significant. These authors reported a stroke patient who experienced a left "ghost arm" that vanished when the patient either looked at or moved the real left arm. An fMRI study showed that the phantom percept was accompanied by an activation of right-hemisphere motor areas, previously implicated in the preparation of motor actions in normal subjects (McGonigle et al., 2002). This patient did not provide a delusional interpretation of her supernumerary phantom; had she done so, the functional neuroanatomy of her ghostly limb would certainly have looked different. Specifically, the implication of cortical networks mediating motor intentions and the agency over bodily action would have been predicted (e.g., Blakemore et al., 2002; Spence et al., 1997). A unique approach to the phenomenology of supernumerary phantoms was offered by the Australian performance artist Stelarc (1995). In his project "The Third Hand," he extended his body with an additional hand, attached to his right arm and rendered functional by amplified EMG signals of his abdominal and leg muscles. This arrangement allowed him to write a word simultaneously with three hands (Figure 9.4B). Stelarc's introspective report of how he gained control over and agency of his artificial supernumerary limb is not only revealing for the interpretation of cases in which such functions are lost after brain damage, but is also relevant to research on the brain's assimilation of tools and prostheses (Iriki et al., 1996; Lotze et al., 1999; Maravita et al., 2001; Weiss et al., 1999). For a brief review of further experimental approaches to supernumerary phantom body parts, both limbs and nonlimb parts, see Brugger (2003a).

One more difference between phantoms after brain damage and "lower-level" phantoms concerns crossmodal aspects. While amputation phantoms

and phantoms after spinal-cord injury are almost never *seen* by mentally healthy amputees or paraplegics, some patients with supernumerary phantoms have reported both visual and postural-kinesthetic awareness of their "extra" limb (e.g., Critchley, 1953, pp. 244–245; Halligan & Marshall, 1995; Halligan, Marshall, & Wade, 1993; Todd & Dewhurst, 1955, p. 54). The patient of Miyazawa et al. (2004) who felt a supernumerary set of left upper and lower extremities (after left thalamic hemorrhage without anosognosia), could clearly see arms and legs but not hands and feet. This "spilling over" of corporeal awareness into the visual domain is unique to cases in which the deafferentation occurred on a highly integrated level. It should be noted, however, that visualization of amputation phantoms was reported in the early literature (e.g., Menninger-Lerchenthal, 1948; Price, 1976; Reny, 1899). These observations may be indicative of the powerful top-down effects of belief systems on lower-level sensory functions. Indeed, they give testimony to relatively neglected interactions between neuropsychological mechanisms and factors hitherto considered purely "social psychological" (see Brugger, 2001).

1.4. Phantoms of Congenitally Absent Limbs

Another type of phantom is known as *congenital phantom limb* or *aplasic phantom limb*. These terms refer to the corporeal awareness of a limb that has been missing since birth, that is, in congenital limb aplasia. While the number of case reports of congenital phantoms is impressively large, there remains a relative paucity of experimental investigations. This underrepresentation of empirical research within the huge literature on phantom limbs may explain the absence of a generally accepted theory of congenital phantoms. In fact, the genuineness of congenital phantoms is not unequivocally appreciated. Some authors are still inclined to dismiss the possibility of phantom awareness of a limb that has never physically developed (e.g., Flor et al., 1998; Montoya et al., 1998; Skoyles, 1990). In this context, reference to Pick (1915) is usually provided. This author authoritatively stated that congenital phantoms could not exist because the respective limb "had never been part of the body scheme" (p. 260). Among the speculations offered to account for congenital phantom limbs are the following:

Speculation 1: Stump Characteristics

In many persons reporting congenital phantoms, absence of proximal limb structures is accompanied by at least some rudimentary preservation of distal body parts ("intercalary aplasia"; O'Rahilly, 1951). Based on an analysis of such cases, it was suggested that phantom sensations comprised kinesthetic illusions resulting from an abnormally enhanced motility of these distal body parts (Simmel, 1961). This idea may make sense in the context of a very particular subset of limb dysplasia. Obviously, however, it cannot explain the occurrence of phantoms for limbs missing in their entirety nor the highly specific features of distal phantom parts, such as entire sets of properly arranged fingers. Furthermore, phantom temperature sensations in a limb absent since birth (Lacroix et al., 1992) can hardly be encompassed by abnormally represented movement information for residual body parts.

Speculation 2: Spared Representation of the Contralateral, Intact Limb

Early case reports of congenital phantoms frequently involved persons missing only one limb (see Scatena, 1990; Vetter & Weinstein, 1967, for comprehensive reviews). Accordingly, the phantom sensations of these individuals were interpreted as transpositions of sensorimotor maps from the intact limb of one hemisphere to the other (e.g., Burchard, 1965; Grouios, 1996). The core idea here was most clearly summarized by Grouios (1996) in his introduction of the case of a 12-year-old boy born without his right forearm (5 cm above the elbow). The child experienced phantom fingers of his missing hand. Grouios (1996) concluded:

> It seems that the upper and lower limbs in people with congenital limb deficiency are linked in the brain as a result of frequent co-activation. Hence, sensory input of the left upper limb, for example, projects not only to the somatosensory cortex of the right cerebral hemisphere but—by identified or unidentified commissural pathways—to mirror-symmetrical points in the left cerebral hemisphere. It thus contributes to a weak formation of the cortical representation of the right upper limb. (pp. 503–504)

It is most evident that, as convincing as such a theory may appear for cases of *unilateral* limb absence, it fails to account for the situation where *both* upper and/or *both* lower limbs are missing. Such cases are not unique (e.g., Brugger et al., 2000; Poeck, 1964; Saadah & Melzack, 1994; Weinstein & Sersen, 1961), and their theoretical importance was recognized early on (Valentin, 1836, p. 643). Importantly, the phantom sensations reported by persons with bilateral limb aplasia are not qualitatively different from those described after unilateral defect.[3]

Speculation 3: Hand-Mouth Coordination

Behavioral and ultrasonic data on the thumb-sucking behavior of human fetuses have demonstrated a functional link between hand movements and anticipatory mouth opening. Based on these data, Gallagher et al. (1998) proposed that an innate motor schema of hand-mouth coordination may be responsible for phantoms of congenitally absent limbs. In the absence of a hand, the cortical area involved in face representation may invade the cortical areas involved in hand representation. "Activation of the expanded face-representing neural map may also reactivate the indigenous limb-representing neurons and thus cause the phantom experience" (Gallagher et al., 1998, p. 59). As thoughtful as these reflections are in the struggle to explain the genesis of upper-limb congenital phantoms, they obviously cannot be used to explain the formation of phantoms of feet and legs that have never physically developed. Indeed, as if anticipating such a critique, Gallagher and colleagues (1998) included only cases of upper-limb phantoms in their tabular overview of previously published cases of congenital phantoms.

To test the various predictions outlined above, we recently presented the case of A. Z., a 44-year-old woman born without forearms and legs (Brugger et al., 2000; Figure 9.5A). For as long as A. Z. can remember, she has experienced phantom forearms including hands and fingers. The symmetric bilateral absence of her upper extremities ruled out the possibility that representations of an intact limb were responsible for the genesis of her phantom hands. Since her conically shaped upper stumps were free of any appendages (i.e., rudimentary fingers), we could also reject Simmel's (1961) proposal that congenital phantom limbs reflect the increased mobility of distal appendages. Finally, the fact that A. Z. reported a distinct awareness of phantom legs and feet, including first and fifth toes (Figure 9.5A), cannot be explained by referring to an innate schema for hand-mouth motor interactions (Gallagher et al., 1998). In contrast, behavioral data indicated an intact postural representation of hands. Specifically, A. Z.'s performance in hand/foot laterality tasks (which require a speeded motor decision as to whether pictures of a hand or foot display a left or a right limb) showed a reaction time pattern that replicated the pattern produced by subjects born with intact bodies (e.g., Parsons, 1987). Most convincing was a regular "medial-lateral gradient" for palm views of left and right hands (Funk, 2001; Figure 9.5B). The significant reaction time advantage for medially over laterally oriented hands indicated that A. Z.'s visual recognition of hands was constrained by biomechanical joint constraints in the same way as that of normal subjects (Parsons, 1994) and that of persons born with only one upper extremity but no phantom sensations of the missing limb (Funk & Brugger, 2002). When A. Z. performed self-paced movements with her phantom fingers while lying in an MR scanner, phantom finger movements consistently activated cortical areas similar to those described in comparable studies with amputees (e.g., Ersland et al., 1996), without however involving the primary sensorimotor cortex (Figure 9.5C). Finally, transcranial magnetic stimulation (TMS) over the sensorimotor cortex, but also at premotor and parietal stimulation sites, elicited specific phantom hand and finger sensations (Brugger et al., 2000).

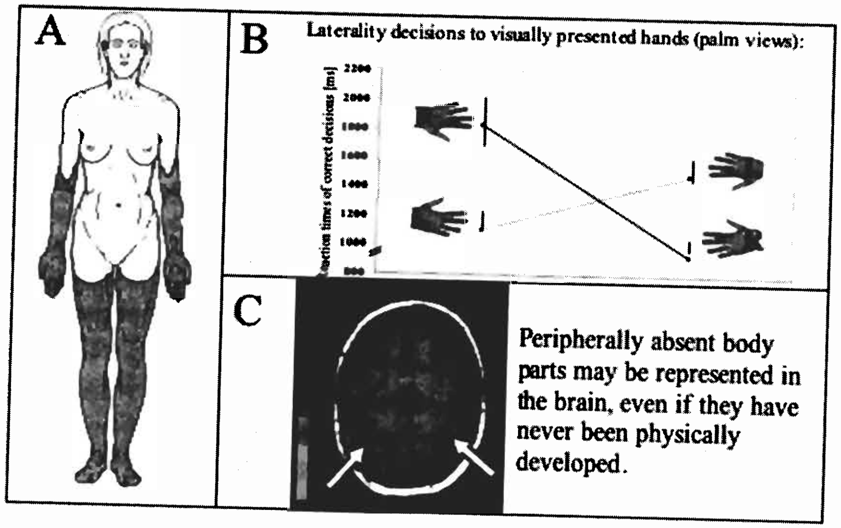


Figure 9.5. (A) A. Z., a 44-year-old woman born without forearms and legs but with vivid phantoms (shaded areas) of most missing body parts. Drawing by Peter Roth, Zürich. (B) A. Z.'s reaction-time pattern to visually presented hands ("a left or a right hand?") was constrained by the awkwardness of displayed postures, despite the fact that her brain has never received any information about hand posture. Data reproduced from Funk (2001) with the permission of the author. (C) Rhythmic movements of the right phantom fingers activated the premotor and parietal cortex bilaterally but not the primary sensorimotor areas for hand representation (arrows). Modified from Figure 3 in Brugger et al. (2000). *See color insert.*

On first consideration, the results obtained with A. Z. appear to constitute unequivocal evidence for an innate representation of the human body or at least its extremities. Melzack (1990; Melzack et al., 1997) proposed the concept of a *neuromatrix*, or a neural network integrating different components of corporeal awareness across modalities and extending throughout selective areas of the whole brain while mainly comprising the posterior parietal lobes and thalamocortical and limbic loops. According to his view, the rough spatial distribution of the neuromatrix is genetically prewired while the specific synaptic connections are later modulated by sensory experience (see Abramson & Feibel, 1981; Mikorey 1952; Poeck, 1964, 1969; and Weinstein & Sersen, 1961, for earlier related proposals). We have noted, however (Brugger et al., 2000, 2001) that there still remains the theoretical possibility that a somatic (postural and kinesthetic) limb representation could have been built up by the regular visual observation of other people moving their limbs. We are currently exploring the functionality of A. Z.'s "mirror system" (Buccino et al., 2001; Rizzolatti et al., 2001) and wish to compare it with that of people born with a similarly incomplete body, but with an "amelic corporeal

awareness," that is, no history of phantom sensations (see Funk et al., in press, for preliminary findings).

2. The Phantom Half-Body: Personification in Somatoparaphrenia

Among the agnosias, anosognosia undoubtedly provides the most challenging puzzle to behavioral neurologists. Patients with this disorder fail to recognize those symptoms of an illness that are most obvious to any third person. In the narrow sense, anosognosia refers to the nonrecognition, or even active denial, of hemiplegia, that is, the paralysis of one half of the body (Babinski, 1914). Almost always associated with a neglect of the contralesional side of space, anosognosia is a typical parietal lobe disorder (Ramachandran, 1995), more frequently observed after right-sided than left-sided lesions. Several hypotheses have been proposed to account for anosognosia for sensorimotor hemisyndromes (for an overview, see Vuilleumier, 2004), but none can fully explain the diversity of symptoms displayed by different patients.

One condition frequently associated with anosognosia is *somatoparaphrenia* (Gerstmann, 1942), that is, the delusional rejection of the ownership of the disabled side of the individual's own body (commonly, the left side). Somatoparaphrenia involves a productive elaboration that reflects a breakdown in the distinction between oneself and others (Boisson & Luauté, 2004; Paulig et al., 2000). It is this awareness, distorted as it may be, of one side of one's body that we here conceptualize as a *phantom half-body*. Patients may conceive of their paralyzed limbs as belonging to the examiner, a family member, or some unknown human being. Some reports describe a restriction of the disownership to a single limb, mostly the hand, but it is unclear how far this "restriction" actually results from the structure of the interview itself.

In any case, somatoparaphrenia has also been labeled a *personification anosognosia* (Juba, 1949), and this label points out a key link among supernumerary phantom limbs, phantom half-bodies, and the reduplications of one's entire body. Specifically, each of the above conditions can be described as a gradually increasing personification of one's own body parts. Indeed, the split-off, paralyzed half-body is sometimes designated as a "hemiplegic twin"; yet, hemiplegia is not a necessary condition for the experience of one's hemibody as a phantom. Benedek and von Angyal (1939) described a patient with only a mild hypoesthesia, that is, an impaired tactile sense, of the left side of his body. Nevertheless, this patient denied ownership of his left side. He referred to it as "his brother" for whom he felt pity because he appeared to be paralyzed. This tendency to attribute one's own deficits to other people, whether real or imaginary, was termed *transitivism* by Wernicke (1900). Transitivistic reactions demonstrate that a deficit in one's own corporeal awareness may be well recognized at an implicit level, without evoking, however, an overt emotional concern about one's own state of health. In the place of pity for "the other," anger may be expressed if, for instance, patients complain about having to eat and breathe for themselves as well as for the one lying beneath (Ley & Stauder, 1950; von Stockert, 1944). Such "residual identification" with the part of the body that is claimed to be someone else is also evident in the patients' frequent emphases that the illusory person looks similar to themselves, is a family member, carries a similar name, or has the same occupation.

Published attempts to experimentally manipulate a patient's experience of somatoparaphrenia are relatively rare. It is known that the delusional interpretation, along with anosognosia proper, may temporarily be abolished by caloric vestibular stimulation (Ramachandran, 1995; Rode et al., 1992). This procedure activates the vestibular cortex contralateral to the stimulated ear and arguably restores sensory and attentional functions (Bottini et al., 1994), especially those of the right hemisphere (Dieterich et al., 2003). On the other hand, somatoparaphrenic delusions about left-sided limbs can be extended to involve also the right side of the body when that right side is experimentally rendered "paralyzed" by transient immobilization (Guthrie & Grossman, 1952). The influence of visual self-observation on claims about limb disownership was investigated by Verret and Lapresle (1978). These authors introduced the case of a woman with anosognosia who claimed that her medical doctor was continuously lying along her left side, and she was concerned about his frequent touching her body with his hand. When this doctor showed her his two hands, she was prepared to believe that he had three hands rather than acknowledge that something was wrong with her own left hand. These authors showed that their patient's delusion was dependent on visual perception of her own body. When this was prevented, she immediately recognized her left side as belonging to herself. Interestingly, visual observation of herself in a mirror (while direct view of her own body was still shielded) also restored self-recognition, ruling out the possibility that the personification of her left side could have been conceived of as a "filling-in" process in the course of a severe left-sided neglect. In another patient with somatoparaphrenia and neglect, Daprati et al. (2000) found no influence of visual observation of one's own moving hand on ownership judgments.

An important contribution to the mechanism of "incorporation" of non-body parts into corporeal awareness was provided by Aglioti et al. (1996). In a patient with somatoparaphrenia, claims about disownership of the left hand spread to several rings she still wore on that hand. Temporarily moved over to her right hand, the same rings were immediately recognized. Other objects, never previously associated with the left hand, were normally commented on when placed on the left hand. In a review of this work (Berlucchi & Aglioti, 1997, p. 561; italics added) the authors concluded that "somatoparaphrenia suppresses both the *me* and the *mine* experiences of the disowned body part and related paraphernalia." They further emphasized the importance of their case for the understanding of an "extended corporeal awareness," that is, one that includes inanimate objects such as tools, vehicles, prostheses, and so on.[4]

It is also worth noting that one clinical feature sometimes associated with somatoparaphrenia, exosomesthesia (Roth, 1944; Shapiro et al., 1952), provides another, more vague example of extended body boundaries. Exosomesthesia refers to the feeling of touch localized in objects in peripersonal space and is possibly related to the phenomenon of "extracorporeal phantom tics" as reported in a different context (Karp & Hallett, 1996).[5] An intriguing dissociation between tactile sensitivity and ownership of a body part was described by Bottini et al. (2002). The authors applied tactile stimulation to the hands of a blindfolded stroke patient with anosognosia whose somatoparaphrenic delusion involved the personification of her left side as her niece. Each touch stimulus was announced as being applied to (1) the patient's right hand, (2) the patient's left hand, or (3) the niece's hand. Right-hand stimuli were recognized 100% correctly, left-hand stimuli with 0% accuracy *as long as attention was directed to the paralyzed hand*, but left-hand stimuli were recognized 80% correctly after directing the patient's attention to a delusion-compatible representation of the same body part. This finding shows that top-down expectations may temporarily boost tactile sensitivity in a hypoesthesic region of the body. At the same time, it elegantly proves that spared tactile sensitivity in a body part does not necessarily lead to a sense of ownership for this particular part.

More systematic experimental studies comparing patients' interpretations of supernumerary phantoms with somatoparaphrenic delusions are needed to justify the conceptualization of somatoparaphrenia as the experience of a "phantom hemibody." As yet, such a notion rests primarily on clinical grounds. Especially in the German and French neurological literature of the first half of the 20th century, the phantom half-body was placed somewhere halfway between the supernumerary phantom limb and the various phantoms of the entire body, to which we now proceed.

3. Whole-Body Phantoms: Autoscopic Phenomena

Autoscopic phenomena involve the visualization of one's entire body in extracorporeal space or the feeling that "another body" (by inference, one's own) is lying, standing, or walking close by. This class of phenomena can thus be conceived of as a duplicative experience of one's own body. The duplication may be restricted to the visual modality, in which case an image of one's own body is seen as if one watched oneself in a mirror (autoscopic hallucination). Phenomenologically more similar to the experience of phantom body parts is the "feeling of a presence," a mere somesthetic illusion that lacks visual features and must be viewed as an extension of corporeal awareness into extracorporeal space. Visual and somesthetic senses merge in what is usually referred to as a *doppelgänger experience*, or heautoscopy. *Heautoscopy* is defined as an experience in which one sees another person who is clearly identified as one's own self and whose body is also felt to be a duplication of one's own (see section 3.3 and Figure 9.6B). A similar merging of visual and bodily duplication occurs in an out-of-body experience (OBE). The difference between heautoscopy and an OBE is the following: in heautoscopy, the person reports an encounter with another embodied self, while in OBE one experiences a shift in spatial perspective, that is, a detachment from one's own body, which is then viewed as if from a location in extracorporeal space. This shift in spatial perspective may be accompanied by a shift in psychological perspective, that is, a shift in the experienced relationship between the two selves. With the study of doppelgängers and OBEs (for variants of autoscopic phenomena not considered in the present chapter, see Brugger et al., 1997), we enter a subfield of neuropsychology that pushes the use of the prefix "neuro" to its limits. Historically, these experiences belonged to the domain of parapsychology, a field that has provided valuable phenomenological accounts but whose theoretical models assumed a physical separation of body and mind in a literal sense and has thus remained out of the main body of scientific inquiry (Brugger, 2003b).

3.1. Phantom Bodies: The Feeling of a Presence

The *feeling of a presence* is the vivid experience that some invisible being occupies a precisely "felt" location in near extrapersonal space. The phenomenon is also known as *Anwesenheit* (Thompson, 1982), *concrete awareness* (*leibhafte Bewusstheit*; Jaspers, 1913), and *false proximate awareness* (Koehler & Sauer, 1984). An elderly patient of Critchley's (1953, p. 242) with bilateral cortical atrophy reported that she "would wake in the night with the very intense feeling that somebody was in the room—a person she knew; indeed, with whom she was very familiar. Sometimes, she was at a loss to decide who this could be, but on many occasions, it would dawn on her that this person was none other than herself."

Another of Critchley's patients experienced the purely somesthetic bodily reduplication as an aura of a migraine attack (Critchley, 1986, p. 203; see Lippman, 1953; and Podoll & Robinson, 2001, for similar cases): "They are both 'me' and 'I.' They are about a foot apart, the 'new' body being always on the right side. Yet I've never seen him with my eyes, though I feel his presence very intensely."

Although identification with one's own body or self is rarely reported as explicitly as in Critchley's cases, several phenomenological features justify the conceptualization of the felt presence as an extension of one's own corporeal awareness into extracorporeal space: (1) as in phantom limbs, the spatial localization of the felt being is commonly precise, despite the lack of confirmation of any presence by the visual modality; (2) there is a synchrony of movements such that the invisible being walks along with the patient and often imitates arm and leg movements, either simultaneously or with a time lag (as in Hari et al.'s 1998 case of a supernumerary phantom arm); (3) in cases of focal brain lesions, the parietal lobes are most frequently affected while visual areas are usually spared; (4) after unilateral parietal lobe lesions, the phantom presence is confined to the contralesional space. If strictly lateralized presences are reported after *bilateral* lesions, the right side of space is more often mentioned (Brugger et al., 1996); and (5) as in cases of a personification of one's phantom half-body (see above), a transitivistic function of "alien" felt presences is sometimes obvious (Bychowski, 1943). Thus, exhausted mountaineers frequently overcome hopeless situations by caring for "the other," who climbs with them and whose presence is felt compellingly enough to be offered food (e.g., Smythe, 1934).

Together, these observations suggest that the feeling of a presence rests on postural and kinesthetic representations of one's own body that are falsely localized in extrapersonal space. Ownership over these nonvisual components of corporeal awareness does not need to be acknowledged, not even by those persons who explicitly note distinct changes in bodily awareness during the experience (such as sensorimotor weaknesses or feelings of depersonalization; Brugger et al., 1999). The illusion must thus be considered an invisible, purely "somesthetic *doppelgänger*" (Grüsser & Landis, 1991). For auditory variants of the illusion in the presence of temporal lobe dysfunction, see Gloning, Gloning, and Hoff (1957, case 2) and Blanke et al. (2003).

3.2. Visual Doppelgänger (Autoscopy)

In contrast to the feeling of a presence, autoscopic hallucinations lack any somesthetic component. Originally labeled "mirror hallucinations" (*hallucinations spéculaires*; Féré, 1891; Nouet, 1923), they involve the seeing of one's own body or only one's face as if reflected in a mirror (Zamboni et al., 2005). Unfortunately, most modern reviews of autoscopic phenomena (e.g., Dening & Berrios, 1994; Devinsky et al., 1989; Leischner, 1961) intermingle autoscopic hallucinations and multimodal doppelgänger experiences. Yet, in the French neurologic literature of the turn of the 19th century, the unimodal visual character of autoscopic hallucinations was clearly recognized (Sollier, 1903). This visual variant of autoscopic phenomena is the only one that occurs exclusively after overt brain damage. Occipital areas are primarily involved as the visual symptoms that often accompany autoscopic hallucinations (e.g., light flashes, colored photisms) are typically of elementary nature and thus indicative of low-level visual processing deficiencies. Correspondingly, autoscopic

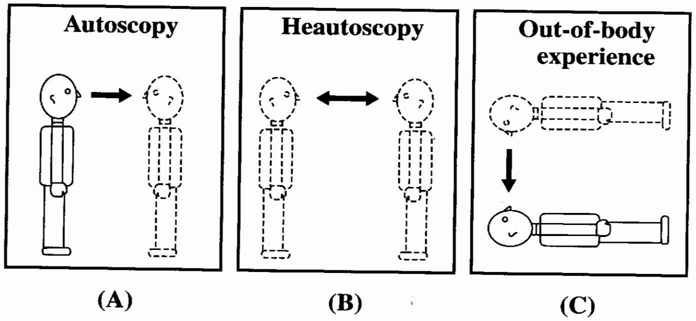


Figure 9.6. Three types of autoscopic phenomena. (A) In an autoscopic hallucination, the patient (*left*) sees himself as reflected in a mirror. Corporeal awareness is not transferred to the hallucinated image, and the perspective is clearly body-centered. (B) Heautoscopy, or "seeing one's self," implies the existence of two selves. Corporeal awareness spreads to the doppelgänger, and the perspective may shift between egocentric and alter-ego-centered. (C) In an out-of-body experience, the observing self appears to perceive the body from a location in extracorporeal space (often, but not necessarily, from a vantage point). Modified from Figure 5 of Blanke et al. (2004).

hallucinations, such as the appearance of one's face or body against a background, are most frequently seen after visual cortex damage with occasional simultaneous impairment of the temporal lobes (Maximov, 1973). Involvement of the "extrastriate body area" (Downing et al., 2001) in the lateral occipitotemporal cortex seems likely. If the image of oneself is lateralized, it is usually to the left visual field (Brugger et al., 1997), reflecting, perhaps, the dominance of the right hemisphere in the recognition of one's own face (e.g., Kircher et al., 2001; see Keenan et al., 1999, for review). Consistent with the absence of aspects of corporeal awareness, other than visual representation, in an autoscopic hallucination, is the point in phenomenal space on which the observer's perspective rests. This perspective is always body-centered, that is, the patient describes the hallucination as observed from a regular within-body perspective (Figure 9.6A).

3.3. *From Seeing to Being One's Own Doppelgänger: Heautoscopy and Out-of-Body Experiences*

Heautoscopy means "seeing one's self" and thus implies the existence of *two* selves, one who observes and one who is observed. Unlike in autoscopic hallucinations, visual aspects of bodily reduplication do not predominate. On the contrary, one's doppelgänger is typically described as a pale, foggy, ghostlike, and transparent figure. More important are feelings of psychological affinity toward one's double. As in the feeling of a presence, the doppelgänger is experienced as a space-occupying entity, which is, however, always recognized

as "another me," even if the visual features do not match one's own ("dissimilar heautoscopy": Grotstein, 1983; Sollier, 1903; "heterosexual heautoscopy": Carp, 1952; Letailleur et al., 1958). Increasing ownership over the one encountered in extrapersonal space, that is, the doppelgänger, is paralleled by increasing feelings of depersonalization and a sense of "hollowness" of or detachment from one's real body. In many instances, patients are at a loss to decide where in space to localize the "real me," within the boundaries of the physical body or beyond (Figure 9.6B).

As is evident from this unstable perspective, the transition between heautoscopy (*seeing* a doppelgänger) and an OBE (*being* the doppelgänger) is necessarily blurred. The defining feature of an OBE is the illusory perception of one's own body *from outside* (Figure 9.6C). The term *doppelgänger* is never used in a person's description of an OBE. A proposed mechanism common to both types of autoscopic reduplication is the deficient integration (1) of proprioceptive, tactile, and visual aspects of corporeal awareness, and (2) of information pertaining to personal and extrapersonal space (Blanke et al., 2002, 2004). Implication of the temporoparietal junction, reportedly mediating these integrative functions (e.g., Làdavas, 2002), is in fact suggested in a majority of clinical case reports on autoscopic phenomena (Blanke et al., 2004; Menninger-Lerchenthal, 1946).

It must be noted, however, that heautoscopy and in particular OBEs are also reported by apparently healthy persons. Repeated occurrence of OBEs may be interpreted by the subject as a "paranormal" ability. Nevertheless, a subsequent diagnosis of a neurological disease such as temporal lobe epilepsy (Vuilleumier, Despland, et al., 1997) or multiple sclerosis (Zurfluh, 1983) suggests that these experiences may have to be interpreted as the first manifestations of the disorder. Often, heautoscopy and OBEs occur in the same person, and frequent alternation between the two variants is reported within a single episode of bodily reduplication, especially in the course of a seizure disorder (Kamiya & Okamoto, 1982; Lunn, 1970). We have documented a dramatic case of repeated rapid perspective changes (heautoscopy versus OBE) in a patient with complex-partial seizures (Brugger et al., 1994):

> This 21 year old man had been suffering from seizures since age 15. They originated in the left mesio-basal region that contained a tumor. After having stopped anticonvulsive medication against the advice of his doctors, he woke up one morning and, to his amazement, saw himself still lying in bed. As he was anxious to get to work, he tried to wake up the body in the bed first verbally, then by aggressive attempts to shake the body and even jumping on it. The localization of the observing self switched repeatedly from the one being upright to the one passively lying in bed. While being the supine one, he felt completely awake, though paralyzed and increasingly scared by the attacks of "the other me." In

> order to stop the "intolerable feeling of being divided in two" he finally jumped out of a window of his third floor appartment [*sic*]. A large bush saved his life.

The issue of perspective taking may provide a springboard for the fusion of physiological and psychological theories of autoscopic phenomena. The physiology of the maintenance of and shifts in first-person perspective is no longer beyond our grasp (see Vogeley & Fink, 2003, for review). Indeed, there is reason to believe that the ability to shift one's spatial perspective may be a prerequisite for higher-order transformations in perspective related to imitation and empathy (Gallese, 2001; Hatfield et al., 1994; Ruby & Decety, 2003).

In autoscopic phenomena, the shifts in spatial perspective illustrated in Figure 9.6 are systematically related to changes in the subject's psychological perspective toward the phantom double. During autoscopic hallucinations, maintenance of a body-centered perspective is unshakable. The visual doppelgänger is observed with amazement but never elicits confusion about "being in two places at once." In contrast, the unstable spatial perspective experienced during heautoscopy is frequently perceived as threatening and may be accompanied by self-destructive behaviors (Carp, 1952; Maack & Mullen, 1983; Wigan, 1884). Finally, the subjectively unequivocal spatial detachment from one's own body in an OBE is almost always paralleled by an emotionally detached attitude toward a serious illness or a life-threatening danger. The role of denial in OBEs has been repeatedly emphasized (Ehrenwald, 1974; Menz, 1984), and transitivistic reactions are the rule. Subjects during an OBE in the course of a near-death experience (Greyson, 2000) are subjectively convinced that it is their *bodies* that face danger, not their selves. The description of an OBE during a near-drowning, taken from the belletristic literature, may illustrate this point:

> In his mind, Findlayson had already escaped from the boat, and was circling high in the air to find a rest for the sole of his foot. His body—he was really sorry for its gross helplessness—lay in the stern, the water rushing about its knees. "How very ridiculous!" he said to himself..., "The poor beast is going to be drowned.... I am on shore already. Why doesn't it come along?" (Kipling, 1893/2003, "The Bridge Builders," p. 19)

One phenomenological detail common to both heautoscopy and OBEs concerns the illusory perception of nonbody parts during bodily reduplication. While this issue has received some attention in the older literature, its treatment is underrepresented in more recent work. Gurewitsch (1933) mocked Menninger-Lerchenthal's (1932) analysis of Goethe's heautoscopic experience, in which he saw himself sitting on a horse. Gurewitsch argued that, according to Menninger-Lerchenthal's view of the doppelgänger as an externalized body schema, Goethe would have reduplicated not only his own body schema, but also that of the horse. Menninger-Lerchenthal (1935, pp. 164–166) rejected the validity of this critique, pointing out that, for a person on horseback, the horse transiently becomes a part of his own body schema. In fact, the reduplication of body-related paraphernalia such as clothes, tools, or vehicles is the rule both in heautoscopy and OBEs and is reminiscent of the incorporation of hand-related paraphernalia in amputation phantoms and their reduplication in cases of supernumerary phantom arms (Hari et al., 1998; see Figure 9.4A). The view, from an apparent out-of-body location, of environmental objects beyond grasping space poses a different problem. There are many indications, especially from scattered observations in the parapsychological literature, that vision in an OBE involves the synesthetic integration of auditory environmental cues, much like the phenomenal visual experience of patients who deny their cortical blindness (Goldenberg et al., 1995). For the role of the vestibular system in shaping complex visual phenomenology, see Skworzoff (1931) and Blanke et al. (2004).

4. Research Perspectives

Encounters with a phantom of one's own body and self or experiences of oneself as a phantom are incomparably more complex than are sensations of a single phantom limb. To equate a (supernumerary) phantom arm with "an autoscopic double of the real arm" (Todd & Dewhurst, 1955, p. 54) or the heautoscopic doppelgänger with a "phantom of the entire body" (Mikorey, 1952) and an OBE with a "generalized version of the phantom limb experience" (Metzinger, 2003, p. 488) may be considered oversimplifications, if not mere metaphors. After all, whole-body amputations do not occur, nor are patients reporting autoscopic reduplications in a state of complete bilateral deafferentation/deefferentation (but see Bilikiewicz, 1969; and Wisdom, 1953, for thought-provoking speculations). Yet, from a phenomenological perspective, subjects' descriptions of the perceived lawfulness of out-of-body states are highly reminiscent of those of subjects describing out-of-limb experiences.

One example concerns the phenomenon of obstacle shunning, repeatedly mentioned above in connection with phantom limbs. If, during an OBE, subjects walk around in a virtual environment, their reactions to contact with solid matter vary greatly. Some report being unable to "penetrate" (imagined) obstacles; others easily pass through furniture and walls (Figure 9.7A); while still others do so only with considerable reluctance (e.g., Bruce, 1999; Leaning, 1928; Monroe, 1971).[6] It would be unwise to disregard such meticulous descriptions just because most of them originate from the parapsychological literature. Taking phenomenology seriously does not imply accepting paranormal interpretations. It rather opens up the possibility of investigating phenomena that have retained a "ghostly" character solely because they have not yet been subject to experimental scrutiny.

The case of obstacle shunning is a neat illustration of the modifications of corporeal awareness by "intuitive physics," that is, top-down influences by knowledge about the behavior of physical objects. Paradigms to quantify the strength of such interactions between perception and knowledge exist. Most elegant is a method introduced by Shiffrar and Freyd (1990), who showed that visual apparent motion of body parts is influenced by the depiction of a solid object along with two rapidly alternating pictures of a limb at slightly different locations (Figure 9.7B). As long as the temporal interval between the two pictures is brief (typically <300 ms), the apparent motion trajectories of the body part pass right through the solid object. However, with longer inter-stimulus intervals, obstacle shunning manifests itself as an adjustment of these trajectories such that the path of apparent motion becomes curved and thus avoids the location of the solid object. This methodology should be applied to

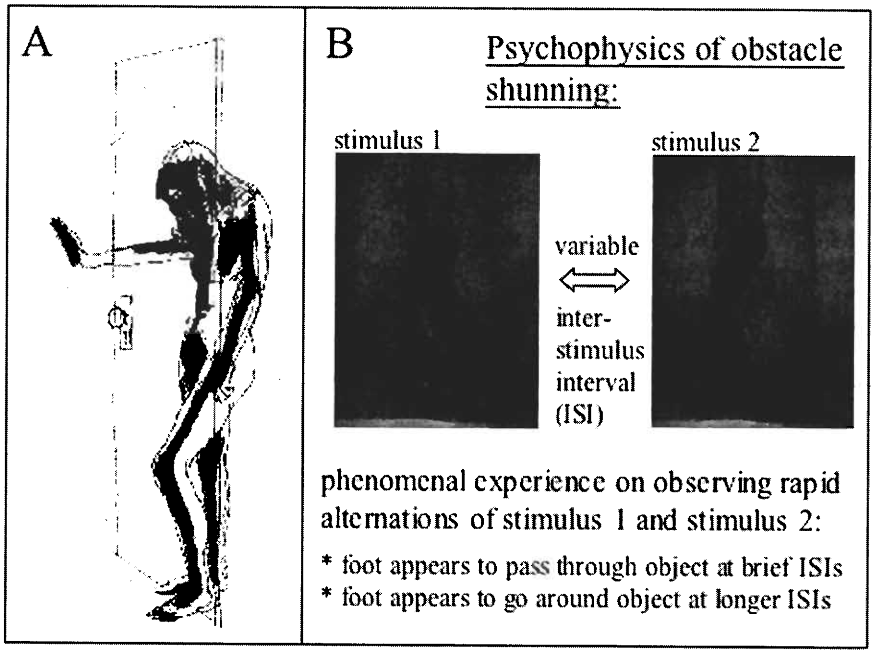


Figure 9.7. (A) During an out-of-body experience, some individuals report an ability, others an inability, to "penetrate" solid matter. The decreased ability to maintain corporeal awareness at a position in space seen or imagined to be occupied by a solid object is reminiscent of obstacle shunning in amputees (see section 1.1). (B) Solidity constraints in the perception of apparent motion of the human body (Shiffrar & Freyd, 1990). Individual differences in obstacle shunning may reflect individual differences in the susceptibility to visual-somesthetic interactions. Reproduced from Vieira (1986, Figure 262), with the permission of the author.

subjects with phantom limbs or phantom bodies who vary in their shunning behavior. We would predict stronger solidity constraints in those subjects who report shunning behavior in their spontaneous phantom experiences as compared to subjects who do not. Such a finding would provide a plausible basis to a phenomenon as yet considered too bizarre to be investigated.

Unjustified neglect of phenomenological detail is not restricted to reports from parapsychological sources. The neurological literature on hemiphantoms and phantoms of the entire body is replete with clinical observations whose meaningfulness for a neuropsychological understanding of corporeal awareness could only be appreciated after further experimentation. Among the relatively low-level somesthetic aspects of such phantoms, we mention a consistent bias, not present for amputation phantoms, for a more salient representation of the upper parts of the body. In fact, meaningful interactions with one's hemiphantom in somatoparaphrenia are more often reported for the "action dominant" upper limbs. Consistent with this, in autoscopic phenomena, visualization is sometimes restricted to head, arms, and chest (Blanke et al., 2004; Conrad, 1953; Genner, 1947; but see Blanke et al., 2002).

Interestingly, work with healthy subjects has produced evidence for a similar relative overrepresentation of the upper extremities. Reed and Farah (1995) explored the perception of changes in another person's limb positions as influenced by simultaneous movements of the observer's own limbs. Changes in arm positions were easier to detect than those in leg positions. The pattern of results further suggested that information about one's own body is used in a mandatory way when judging another person's visually perceived body posture (for additional discussion, see chapters 7 and 11). Reed and Farah's work is thus an early contribution to a growing body of literature on the intimate relationships of action observation and action execution (see Gallese & Goldman, 1998; Rizzolatti et al., 2001, for overviews). The system matching these two processes should be one central focus of future research concerning the variability of individual phantom experiences. Potential contributions of this system to the genesis of phantoms could be of particular theoretical importance in the discussion of innate components of corporeal awareness, both for body parts (see above) and for entire bodies (e.g., Ring & Cooper, 1999).

Among the "higher-order" phenomena of phantom experiences are those pertaining to the distinction between self and nonself. While phantoms after peripheral or spinal deafferentation are always considered an integral part of one's own body and self (except in cases of psychotic elaboration; Gallinek, 1939; Stip & Perreault, 1993), this distinction may get blurred in the face of hemi- or whole-body phantoms. Maintenance of a body-centered perspective appears to prevent one's reduplicated body from taking an autonomous role and thus becoming out of control of one's own intentions (Brugger, 2002). This clinical observation is consistent with a view of a continuum from motor to conceptual cognition (Amorim, 2003; Ruby & Decety, 2003). The psychological content of autoscopic reduplications may thus be shaped by a patient's awareness, more or less compromised, of the true source of own action plans. On the one hand, currently popular experimental designs to investigate agency attributions in normal subjects or selected patient groups (e.g., Farrer & Frith, 2002; Knoblich, 2003; see Blakemore & Decety, 2001; and Wegner, 2002, for overviews) should be applied also to patients with autoscopic phenomena. On the other hand, once-popular but apparently forgotten clinical concepts, such as that of transitivism should be revived. Intriguingly simple experiments have shown that the projection of one's own disturbances of corporeal awareness onto other people depends on the alignment of one's own body axis with that of others (Gloning, Hift, et al., 1957), an observation highly relevant to transitivistic own-body projections onto merely hallucinated bodies (Schilder, 1919).

Certainly, in addition to promoting studies with special populations, more efforts should be undertaken to refine the methods to evoke phantom sensations in healthy subjects. These comprise the provocation of a transient limb deafferentation, for example, by intravenous regional or by pressure-cuff-induced anesthesia (e.g., Brasil-Neto et al., 1992; Gross & Melzack, 1978; Melzack & Bromage, 1973) and the application of vibratory stimulation (Craske, 1977; Jones, 1988; see also chapter 8 for discussion). The latter technique allows the transient dissociation of objectively realized and subjectively felt positions of one's limbs by tendon vibration. Clever elaborations of this basic technique have been introduced to elicit the experience of various nonlimb phantoms. Most famous is the "Pinocchio illusion," i.e., the experience of a phantom nose (Lackner, 1988; for the use of tendon vibration to produce a phantom of one's entire body, see Lackner, 1992).

Both phantoms of paraplegic patients and vibration-induced phantoms in healthy subjects typically disappear upon looking at the real limb. Little is known about the precise nature of this visual-somesthetic interaction. It is known, however, that vision and somatosensation are highly cooperative senses (e.g., Newport et al., 2001; see also chapters 3, 4, and 5). Although under certain conditions, vision will "capture" proprioception, under other conditions the brain is more inclined to believe proprioceptive information rather than vision (e.g., Mon-Williams et al., 1997; Wann & Ibrahim, 1992). Understanding the processes that regulate these shifts in visual-proprioceptive dominance is especially important for a better understanding of transitions from seeing to being one's own doppelgänger. As *feeling* a phantom hand can be induced by watching the mirror image of one's existing hand (Ramachandran et al., 1995), continuous observation of an online image of one's entire body can produce an effect of whole-body visual capture (Stratton, 1899), just as the person immersed in a virtual-reality environment actually *feels* herself to be at the place where her own body is seen (Rheingold, 1991, p. 264).

Notes

1. The keyword *phantom* alone would have included also articles using the term in a completely different meaning. These include the definition of a dummy used for demonstrations during medical training or for simulation purposes. In our 1-minute experiment, subjects who produced associations to this type of phantom (medical students, exclusively) were not considered for the analyses.
2. According to this definition, phantom limbs after spinal-cord injury would also appear to belong to the category of "supernumerary phantoms." Traditionally, however, the term is reserved for the awareness of extra limbs after brain lesions (Brugger, 2003a).
3. In direct opposition to this "bilateral representation" hypothesis (Grouios, 1996), Kinsbourne (1995) proposed an attentional model of congenital phantoms that views intact representations of one spared limb as *inhibitory* to the genesis of phantom sensations. This made him overestimate the actual incidence of bilateral (as opposed to unilateral) limb aplasia (p. 217).
4. It should be noted here that individual patients' reactions to the sight of paraphernalia vary greatly. One patient of Sandifer (1946) accused his doctor of wearing his (the patient's) ring when urged to look at his left hand, which he claimed to be the doctor's. Confabulative "incorporation" of a nurse's arm, including her wristwatch, was reported by Critchley (1953, p. 239). On the other hand, mere visual observation of a scar on the left, subjectively disowned arm could restore ownership for a patient discussed by Juba (1949, case 2).
5. An equivalent of exosomesthesia can be produced in normal subjects who watch an examiner touch a rubber hand aligned with their own hand, which is similarly touched but remains concealed from vision (Botvinick & Cohen, 1998; Pavani et al., 2000; chapter 8). The taps thus delivered are felt "out there" in an apparent out-of-body location. This rubber-hand effect has generated significant secondary research, in particular in connection with clinical disorders involving unilateral somatosensory deficits (Farnè et al., 2000; Rorden et al., 1999).
6. This latter author reports the absence of shunning behavior during an OBE. Trajectories of phantom body motion were nevertheless constrained by higher-order conceptual knowledge about physical objects: "I went out into the corridor, and I just went through the door (force of habit I suppose, for my exit might just as well have been through the wall, because I did not open the door at all but just went through)" (Leaning, 1928, p. 27).

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