Topic Page: Phantom Limb

Definition: **phantom limb** from *Collins English Dictionary*

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1 the illusion that a limb still exists following its amputation, sometimes with pain (**phantom limb pain**)

Summary Article: **Phantom Limb**
From *Encyclopedia of Perception*

Healthy, wide awake, and sober, we rarely ever see things, hear voices, or smell odors without a corresponding stimulus. Quite different is the situation after the loss of a limb. Amputees almost invariably continue to feel their lost body parts, sometimes with compelling vividness, in some cases paired with the sensation of mild to excruciating pain. The sensation of a limb that is not physically present is referred to as *phantom limb.* Phantom limbs can teach us very basic lessons about the projective nature of perception. They illustrate the fact that the perception of our own body differs in important ways from the perception of any other object in the outside world. Current research interests in postamputation phantom limbs focus on the functional and structural reorganization of the central nervous system after sudden changes in its communication with the periphery. Phantom limbs after amputation have thus radically changed scientists' views about the adult brain's plasticity: The observation of fast and significant adaptations of cortical areas in response to the loss of a limb has disproved the longstanding notion that maturation would necessarily imply a growing degree of hard wiring of neuronal connections.

Yet, perhaps the most fundamental challenges to theories of body perception come from phantom limbs experienced out of the context of amputation. Phantom sensations of limbs that never physically developed stimulate discussions about innate components of bodily experience. Conversely, patients with lesions to the spinal cord or brain may develop phantom limbs without a physical loss of the corresponding limb, and which are felt spatially separated from their flesh-and-blood counterparts.

Finally, phantom limbs have always inspired philosophical thoughts about the nature of the self and its relation to the body. What happens if we amputate, in a thought experiment, first a finger, then a hand, an arm, and gradually remove even more of the periphery? This question leads us to the concept of a “phantom body” and to currently unresolved issues of how the brain generates, not only out-of-limb sensations, but full-blown out-of-body experiences. This entry discusses postamputation phantom limb phenomena, painful phantom limb experiences and cortical reorganization, and other areas beyond amputation and phantom limbs.

Postamputation Phantom Limbs

Reports about phantom limbs predate the times when successful surgical techniques of amputation were available. Since at least the 10th century, soldiers have described that they would still feel the leg they had lost in combat. Such accounts were taken as evidence for a divine resurrection of the limb, in analogy to the purported resurrection of the entire body after death. In the medical literature, the first detailed description of the phantom limb phenomenon appeared in the 16th century. It is accredited to Ambroise Paré (1510-1590), a French barber, whose skills in using knives advanced him to the country's leading military surgeon, not only admired for the success of his amputations, but also for the development of artificial limbs. As Paré's reports remained largely descriptive, they did not stimulate much dispute among professionals, and the topic vanished from the medical literature for more than three centuries. It resurfaced in the late 19th century in the work of the American neurologist Silas Weir Mitchell (1829-1914). Mitchell, also a prolific novelist, was confronted with the phenomenal persistence of lost limbs in the course of the American Civil War. It is to him that we owe the term *phantom limb.*

During Mitchell's lifetime and the first half of the 20th century, one prominent theoretical question was whether the origin of phantom limb sensations, especially those experienced as painful, had to be sought in the amputation stump (“peripheral theories”) or rather at the level of spinal cord and/ or brain (“central theories”). Propagators of peripheral theories pointed out that manipulations of the stump (e.g., massage, thermal and electrical stimulation, local anesthesia) would sometimes lead to a reduction of phantom limb pain. In fact, when a limb is severed, radical changes occur at the amputation site. These comprise sprouting of axons and the formation of nodules (neuromas) by the cut nerve fibers. Abnormal firing patterns are a consequence, and these were considered as causative factors in the generation of phantom limb pain. However, distorted impulses from the stump will naturally also pass into the spinal column before ascending through higher-order relay stations, such as the brain stem and thalamus, to ultimately reach the somatosensory cortex. That is why, from today's perspective, the question of an exclusively peripheral or central determination of the phantom limb percept is moot. Center and periphery are interconnected, that is, any changes at the level of the stump will necessarily be accompanied by changes in the brain. The focus of current research on phantom limb phenomena is almost entirely directed to the cerebral cortex—arguably as a consequence of the powerful technologies available to directly monitor the brain's reaction to gross changes in the periphery of our body.

Painful Phantom Limbs and Cortical Reorganization

Whereas probably every amputee is familiar with nonpainful phantom limb sensations, estimates of the incidence of specifically *painful* postamputation phantom limbs vary considerably. Although more that 50% of all amputees have experienced a painful phantom limb at some time after the loss of a limb, severe and chronic phantom limb pain is relatively rare. As a rule, phantom limb pain is more prominent in amputees with preamputation pain (related to disease or injury) and with painful sensations in the amputation stump. More than 50 different treatment methods have been described in the literature, ranging from stump manipulations to a broad range of pharmacological interventions and finally to invasive techniques involving thalamic stimulation or surgical removal of cortical tissue. Not one single method has proven effective for all amputees, but almost every method has brought relief in single cases.

The impetus to investigate changes in the cortical representation of the body after amputation came from observations in animals. During the last quarter of the 20th century, evidence was accumulating that monkeys who had lost a finger showed a reorganization of the area of the cortex previously responsible for the processing of tactile input from that finger. Specifically, this area would now process tactile information from the adjacent fingers, a phenomenon called *cortical remapping.* After deafferentation of a whole arm (i.e., interruption of afferent signals from arm to brain), the area of the cortex that would normally respond to stimulation of the hand was found to be responsive to sensory input from the face. Comparably massive reorganization in the somatosensory cortical map could soon be demonstrated in the adult human brain. Noninvasive techniques, such as magnetic source imaging and functional magnetic resonance tomography, allow the monitoring of activity in areas of the cortex known to process sensory information from circumscribed parts of the periphery. Thus, in arm amputees, the areas coding for inputs from the hand and face (adjacent to one another on the brain's surface) were found to have merged, the former area of hand representation having shifted toward that responsive for facial touch. The more severe amputees' rating of phantom hand pain, the greater these functional cortical shifts were in centimeters. This finding indicated that any factor preventing the cortex from remapping would probably also prevent the occurrence of pain. One of these factors is the use of a functional prosthesis. Contrary to solely cosmetic prostheses, functional models allow the amputee to move parts of the artificial hand, either mechanically or by myoelectric impulses, that is, by electrical signals that make a muscle contract upon the willed intention to move. Thus, the functional properties of the lost hand (grasping, picking, pinching) are not entirely lost, and the hand motor cortex is not completely deprived of its ancestral tasks. In fact, it was repeatedly demonstrated that the more frequently a prosthesis is used, the smaller the representational shifts in the primary motor cortex and the less phantom limb pain was felt.

Another way to fool the brain in “believing” that a lost hand is resurrected is achieved with the aid of a mirror, which is placed vertically between the phantom hand and the remaining hand. Movements of the hand are observed in the mirror and perceived as the apparent “resurrection” of the other, lost hand (note that the mirror image of a left hand is a right hand and vice versa). This mirror therapy can alleviate cramping pain in a phantom hand, whose fingers appear to be clenched against the palm in a frozen position. If the amputee mimics this posture with the fingers of the existing hand, which is steadily observed in the mirror as it is slowly opened, the merging of seen and felt images of the absent hand may restore motility in the phantom fingers and thus abolish the painful sensations. Although repeated exercises with a mirror box can reduce an individual's phantom limb pain, the major impact of mirror therapy consists in the rather transient relief it provides during acute bursts of cramping pain.

Beyond Amputation and Beyond Phantom Limbs

What about people born without an arm or a leg— would they experience phantom sensations of their missing body part? Not according to theories of phantom limb as a process of remembering, that is, based on the brain's memory of previous tactile and motor impressions about a limb. However, cases of differentiated and vivid phantom limbs in people with congenital absence of a limb have repeatedly been described since the 19th century. Currently, it is debatable whether these observations are evidence for innate components of body schema or whether the brain's “mirror system” may induce feeling a limb by the habitual visual observation of others, who move their corresponding body part. The human mirror system integrates action observation, motor imagery, and motor execution and is presumably important for imitation learning and empathic responding.

The previous presence of a limb is not essential for the occurrence of a phantom limb, and the physical absence of body parts is also not a necessary precondition. For example, people who have experienced a complete severance of the spinal cord have lost any sensory awareness of their body below the injury and are also unable to move their legs (paraplegia). These people may experience phantom legs that are often frozen in a position the legs had taken during injury and typically vanish during visual contemplation of the paralyzed limbs. Vision also interferes with experimentally induced phantom limbs in healthy volunteers; here, illusions of a dissociation between physical and felt (phantom) limb positions can be elicited by anesthesia, tendon vibration, or other manipulations. As soon as the subject watches the real limb, the phantom limb illusion breaks down.

Whereas insight into the illusory nature of a phantom limb percept is always preserved in healthy subjects, amputees, and paraplegics, reality monitoring may be hampered in patients with phantom limbs after brain lesions. Such *supernumerary phantom limbs* are felt in addition to a physically present arm or leg, although, as a rule, the latter is compromised to a variable extent by sensory and/or motor impairment. Specifically after damage involving the parietal cortex, delusional elaborations of a paralysis on one side of the body (hemiplegia) are relatively common. Patients would insist, for instance, that their paralyzed arm belonged to somebody else. In some cases, a personification of the entire hemiplegic side is observed, and a dispute develops between the patient and what British neurologist MacDonald Critchley (1900-1997) labeled the “hemiplegic twin.” It seems only a small step from phantom hemibody to full-blown reduplications of one's entire body, such as in *doppelgänger* and out-of-body experiences. The study of these neuropsychiat-ric aspects of corporeal awareness and their possible evolution from the relatively simple case of the phantom limb may in the future lead to fundamental insights into how the brain mediates our experience of an embodied self.

See also

Body Perception, Body Perception: Disorders, Cortical Reorganization Following Damage, Experience-Dependent Plasticity, Out-of-Body Experience, Pain: Neuromatrix Theory, Proprioception

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