

# Phantom Limb Syndrome: The Ghost of Your Missing Body

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A phantom limb is the sensation that an amputated or missing limb is still attached. Approximately 60 to 80% of individuals with an amputation experience phantom sensations in their amputated limb, and the majority of the sensations are painful. Phantom sensations may also occur after the removal of body parts other than the limbs, e.g. after amputation of the breast, extraction of a tooth (phantom tooth pain) or removal of an eye (phantom eye syndrome).

## Signs and symptoms

Although not all phantom limbs are painful, people will sometimes feel as if they are gesturing, feel itches, twitch, or even try to pick things up. The missing limb often feels shorter and may feel as if it is in a distorted and painful position. Occasionally, the pain can be made worse by stress, anxiety, and weather changes. Phantom limb pain is usually intermittent. The frequency and intensity of attacks usually declines with time.

Some people who have undergone gender reassignment surgery have reported the sensation of phantom genitals. The reports were less common among post-operative transgender women, but did occur in transgender men. Similarly, subjects who had undergone mastectomy reported experiencing phantom breasts; these reports were substantially less common among post-operative transgender men, but did occur in transgender women.

## Mechanism

Phantom limb pain (PLP) is a complex phenomenon that includes a wide variety of symptoms ranging from tingling and itching to burning and aching.

Until recently, the dominant hypothesis for the cause of phantom limbs was irritation in the severed nerve endings (called "neuromas"). When a limb is amputated, many severed nerve endings are terminated at the residual limb. These nerve endings can become inflamed, and were thought to send anomalous signals to the brain. These signals, being functionally nonsense, were thought to be interpreted by the brain as pain. Treatments based on this hypothesis were generally failures. In extreme cases, surgeons would perform a second amputation, shortening the stump, with the hope of removing the inflamed nerve endings and causing temporary relief from the phantom pain. But instead, the patients' phantom pains increased, and many were left with the sensation of both the original phantom limb, as well as a new phantom stump, with a pain all its own. In some cases, surgeons even cut the sensory nerves leading into the spinal cord or in extreme cases, even removed the part of the thalamus that receives sensory signals from the body.

By the late 1980s, Ronald Melzack had recognized that the peripheral neuroma account could not be correct. In his 1989 paper, "Phantom Limbs, The Self And The Brain" Melzack proposed the hypothesis of the "neuromatrix." According to Melzack the experience of the body is created by a

wide network of interconnecting neural structures. In 1991, Tim Pons and colleagues at the National Institutes of Health (NIH) showed that the primary somatosensory cortex in macaque monkeys undergoes substantial reorganization after the loss of sensory input. Hearing about these results, Vilayanur S. Ramachandran hypothesized that phantom limb sensations in humans could be due to reorganization in the somatosensory cortex, which is located in the postcentral gyrus, and which receives input from the limbs and body. Ramachandran and colleagues illustrated this hypothesis by showing that stroking different parts of the face led to perceptions of being touched on different parts of the missing limb.

Ramachandran argued that the perception of being touched in different parts of the phantom limb was the perceptual correlate of cortical reorganization in the brain. However, research published in 1995 by Flor et al. demonstrated that pain (rather than referred sensations) was the perceptual correlate of cortical reorganization. In 1996 Knecht et al. published an analysis of Ramachandran's hypothesis that concluded that there was no topographic relationship between referred sensations and cortical reorganization in the primary cortical areas. Recent research by Flor et al. suggests that non-painful referred sensations are correlated with a wide neural network outside the primary cortical areas.

Not all scientists support the hypothesis that phantom limb pain is the result of maladaptive changes in the cortex. Pain researchers such as Tamar Makin (Oxford) and Marshall Devor (Hebrew University, Jerusalem) argue that phantom limb pain is primarily the result of "junk" inputs from the peripheral nervous system.

Despite a great deal of research on the underlying neural mechanisms of phantom limb pain there is still no clear consensus as to its cause. Peripheral mechanisms (areas of the nervous system outside the brain) and central neural mechanisms (inside the cortex) are among the hypotheses that have gained the most support over recent years. However, none of these theoretical constructs appears to be able to explain the phenomenon of phantom limb pain independently and many experts believe that multiple mechanisms are likely responsible.

## **Treatment**

Most approaches to treatment over the past two decades have not shown consistent symptom improvement. Treatment approaches have included medication such as antidepressants, spinal cord stimulation, vibration therapy, acupuncture, hypnosis, and biofeedback. Reliable evidence is lacking on whether any treatment is more effective than the others.

Most treatments are not very effective. Ketamine or morphine may be useful around the time of surgery. Morphine may be helpful for longer periods of time. Evidence for gabapentin is mixed. Perineural catheters that provide local anesthetic agents have poor evidence when placed after

surgery in an effort to prevent phantom limb pain.

### **Mirror box**

One approach that has received public interest is the use of a mirror box. The mirror box provides a reflection of the intact hand or limb that allows the patient to "move" the phantom limb, and to unclench it from potentially painful positions.

As of 2011, however, the quality of evidence is low. There is a wide range in the effectiveness of this approach. The potential for a person to benefit from mirror therapy is not predictable and appears to be related to the subjective ability of the patient to internalize the reflection of a complete limb as their own limb. About 40% of people do not benefit from mirror therapy.

### **Recent research**

In 2009 Lorimer Moseley and Peter Brugger carried out an experiment in which they encouraged seven arm amputees to use visual imagery to contort their phantom limbs into impossible configurations. Four of the seven subjects succeeded in performing impossible movements of the phantom limb. This experiment suggests that the subjects had modified the neural representation of their phantom limbs and generated the motor commands needed to execute impossible movements in the absence of feedback from the body. The authors stated that: "In fact, this finding extends our understanding of the brain's plasticity because it is evidence that profound changes in the mental representation of the body can be induced purely by internal brain mechanisms-the brain truly does change itself."

In 2012 V.S. Ramachandran and Paul McGeoch reported the case of a 57-year-old woman (known as R.N.) who was born with a deformed right hand consisting of only three fingers and a rudimentary thumb. After a car crash at the age of 18, the woman's deformed hand was amputated, which gave rise to feelings of a phantom hand. The phantom hand was experienced, however, as having all five fingers (although some of the digits were foreshortened). 35 years after her accident, the woman was referred for treatment after her phantom hand had become unbearably painful. McGeoch and Ramachandran trained R.N. using mirror box visual feedback, for 30 minutes a day, in which the reflection of her healthy left-hand was seen as superimposed onto where she felt her phantom right hand to be. After two weeks she was able to move her phantom fingers and was relieved of pain. Crucially, she also experienced that all five of her phantom fingers were now normal length. Ramachandran and McGeoch stated that this case provides evidence that the brain has an innate (hard-wired) template of a fully formed hand.

In 2012 an experiment was conducted in which it was demonstrated that the movement of phantom limbs are "real" movements that involve the execution of a motor command. Amputees

can also carry out imaginary movements of their phantom limbs; however, these movements do not lead to a feeling that the phantom limb has changed position. This research indicates that clinicians using motor training for pain relief need to distinguish between imagined movements and real movements of phantom limbs.

In 2013, experiments involving eight subjects were reported by Nadia Bolognini (University of Milano-Bicocca) in which transcranial direct current stimulation (tDCS) was used to temporarily reduce phantom limb pain. The researchers found that this type of stimulation could produce short-term (under 90 minutes) reduction of pain without affecting other amputation-related phenomena.

In 2013 research conducted by Tamar Makin (Oxford University) indicated that after amputation the area of the cortex that received information from an amputated hand may be taken over by the remaining hand. Her research suggests that the extent of this transition is determined by the extent to which the person uses the remaining hand to perform the functions of the missing hand.

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