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Phantoms in The Brain: The Deception of Our Senses

Long Ly

Phantoms in The Brain

The Deception of Our Senses

Written by Long Ly
Illustrated by Mattie Decardy Torris

French military surgeon Ambroise Paré (1510-1590) was operating on wounded soldiers when he noticed a strange recurrence — patients complaining of sensation or pain in their amputated limb(s). What was abnormal, however, was that these soldiers did not feel pain or other sensations at the stump but rather in the missing region formerly the limb. Following the first account of this strange phenomenon, many other prominent physicians and biologists, such as German physician Aaron Lemos, Scottish anatomist Sir Charles Bell, and American physician Silas Weir Mitchell, reported the same sensations. The absurdity of this account kept it from being adequately investigated until Weir Mitchell.

Sir Silas Weir Mitchell served as a physician during and following the Civil War, frequently treating wounded soldiers. During the pre-antibiotic times, gangrene commonly followed the injury, necessitating soldiers' limbs to be sawed off by surgeons. Mitchell saw amputees frequently complaining about phantom sensations in their missing limbs. He found the phenomenon intriguing and wrote an article about the phenomenon in a popular magazine called Lippincott's Journal under a pseudonym. The sensation was supposedly so strange that he did not publish it in a medical journal due to the lack of scientific grounds and the risk of ridicule from his colleagues. Mitchell aptly coined the phenomenon "phantom limb" in the article.

Since Weir Mitchell's article, there have been several proposed theories on the cause of phantom limb pain (PLP) after the condition was acknowledged as real and advanced neuroscientific knowledge. A paper in The Canadian Journal of Psychiatry, published in the late 1970s, stated that the phantom limb was merely due to wishful thinking. The authors thought that patients with this sensation desperately need the arm back, therefore experiencing the phantom. They hypothesized that this phenomenon behaved similarly to how people can imagine the ghost of a close one or have recurring dreams. Another more grounded, explanation was that the feeling was due to irritation of the frayed and curled-up nerve endings at the stump delivering

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information to higher brain centers,which was processed as somatosensory information in the missing limb rather than the stump. However, cortical reorganization is the most recent, well-supported, and realistic theory. This still does fully explain what causes PLP. To understand this, we need to know more about how we feel.

Imagine you stepped on a thumbtack. You experience a sharp, painful sensation, followed by your quickly retreating your foot from it. How do we 'sense' the pain? Why do we sense pain? How do we move away from the thumbtack instinctively? As simple and intuitive as our reactions and movements seem, the sensation is profoundly intriguing and physiologically complex. The thumbtack activates the sensory neurons it reaches, which send a signal from the place of contact along the spinal cord to the somatosensory cortex encoded as an electrical signal, known as an action potential. The somatosensory cortex is a specific region of the central nervous system that specializes in receiving and interpreting incoming sensory information, then sending this information to other parts of the brain, thereby inducing a response – i.e., you pulling away from the thumbtack. And thus, while unintuitive, we do not 'feel' with our hands. Nor with our legs, mouth, or nose. We feel with our brain, our central nervous system. Even if we have all our limbs intact along with the nerves, none of that matters if we cannot send that signal to the brain, which is why spinal cord trauma often leaves people paralyzed and unable to feel or move.

Knowing our sensory perception, what is the phantom limb phenomenon, and how does it work? The brain is an incredible organ, capable of processing vast amounts of information, but beyond that, it can also reorganize itself. The somatosensory cortex is subdivided into many regions responsible for processing different body parts — the digits of the hand, the face, the legs, and more. This map is can change itself, giving more cortical volume to certain body parts than others.

As an example, imagine the first time you tried playing the piano. You fumble around with the keys, play all the wrong notes, slam the keys too hard, feel like a mess, and cannot seem to get it right. However, you notice that with time, you continuously get better. You play more fluidly, your performances sound like performances, and your fingers move more proficiently. Although much of this has to do with auditory training, muscle memory, and coordination, a small part of it is also because you feel more with your digits and can move them better.

A study comparing the cortical activity of professional musicians and amateurs showed that when the musicians' digits are touched or moved, a much higher level of cortical activation was recorded through functional MRI, indicating that the remapping of the somatosensory cortex is possible. So, what if your arm was amputated, and there is no longer information reaching the part of the somatosensory cortex that receives that arm's sensory information? Researchers have found that adjacent areas of the somatosensory cortex responsible for other body parts take over the unused cortical area. A study on amputees showed that even when a limb is amputated, the brain area corresponding to the former limb can be stimulated if you stroke certain regions of the face — amputees feel a tingling sensation not only in the face but also at the former limb. Thus, it is hypothesized that cortical reorganization and subsequent activation of brain regions responsible for receiving information from the former limb are primarily responsible for phantom limb sensations and phantom limb pain. However, PLP is likely a cause of several contributing factors.

For example, severed nerves that are used to receive information from the amputated limb may form neuromas, inflamed ends of axons, in which phantom pain may occur. Moreover, following nerve injury due to amputation, there is evidence that neurons in the posterior horn of the spinal cord become oversensitized. The process is characterized by long-term potentiation — the strengthening of synapses that lead to increased long-term synaptic transmission. All such observations are correlational, and there has unfortunately been no definitive pathophysiology of PLP.

Although researchers have yet to find a definitive cause of PLP, there is a simple yet intriguing treatment for PLP called mirror therapy, developed by doctor Vilayanur Subramanian

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Ramachandran. Dr. Ramachandram is a prominent Indian-American scientist who pioneered our understanding of the brain's sensation and perception, particularly concerning PLP — its potential causes, implications, and treatments. Dr. Ramachandran observed that PLP patients commonly described their pain as being due to the missing limb 'clenching its own first' without the patient being able to release the phantom fist, which is called learned paralysis.

Ramachandran hypothesized that when the brain sends a signal to attempt to move the amputated limb, the visual system gives feedback that there is, for obvious reasons, no movement. This process is repeated many times until the brain learns that the amputated limb will not move. Ramachandran thought that if the patient could 'learn' paralysis, it may be possible to 'unlearn' it. He initially thought about virtual reality — having the patient see a virtual arm moving, which can create a visual illusion where the arm was restored. However, as virtual reality was costly, Dr. Ramachandran thought of a much less expensive way to create the same illusion — a mirror. The procedure starts with the patient placing a mirror opposite to the existing limb, then making the intact limb move. If the patient looks at the mirror, it can give the illusion of movement even in the missing limb. This process sendsvisual feedback to the patient that they do have control of the missing limb.

One hypothesized explanation for this phenomenon is the work of the mirror neuron system. Mirror neurons are a type of brain cell that respond equally when we perform an action and witness someone else perform the same action. Mirror neurons fire the same way when patients used to have their amputated limb versus when the patient is observing the mirror limb moving. When using the mirror box, these mirror neurons are activated, which helps in the recovery of affected parts. Although there have been studies supporting the effectiveness of mirror therapy, there is currently little long-term research on the effects of mirror therapy for PLP and. Thus, much work needs to be done on PLP and its potential treatments.

Sensory perception is a crucial puzzle of the brain that remains to be solved, both to advance our understanding of the brain and to treat its conditions. Phenomena like PLP prove to be a valuable tool for us to study how the brain 'senses' and processes that information.