BBC.CO.UK

The volume of sensory information which the brain receives is enormous: it comes from the muscles, the joints, the tendons, and touch. To avoid overloading, the brain copes with all this hierarchically. It has learnt to ignore the signals it has come to expect, such as the stretching of our skin when we walk, or the sensation of the soles of our feet on the ground. These signals are dealt with in the unconscious parts of our brain, 'lower down' in the system. Information only reaches the 'higher' parts of the system - the conscious parts - when the experience is new or unexpected. Every movement we make starts in our brain. Once we've decided to make a movement, the motor cortex in the brain sends out a command to the appropriate muscles to make them move. But it doesn't stop there. Within 60 milliseconds, a message is sent back from the body's sensors to report back on how the movement went. Was it right? Did it succeed? Based on this information, the brain responds by sending an updated command to improve the movement which generates yet more feedback. In small children and in people learning a new movement skill, you can actually see the results of this, as their ankles wobble and their balance sways. This 'loop' system - message out, message in and so on - is how we control movement, make it more accurate, more precise, smoother and more elegant

Proprioception is tested by police officers using the field sobriety test where the subject is required to touch his nose with his eyes closed. People with normal proprioception may make an error of no more than 2 cm. People with severely impaired proprioception may have no clue as to where their hands (or noses) are without looking. Proprioception is what allows someone to learn to walk in complete darkness without bumping into the furniture. Without the appropriate integration of proprioceptive input, an artist would not be able to brush paint onto a canvas without looking at the hand as it moved the brush over the canvas; it would be impossible to drive an automobile because a motorist would not be able to steer or use the foot pedals while looking at the road ahead; we could not touch type or perform ballet; and one would not even be able to walk without literally "watching where you put your feet".

Oliver Sacks once reported the case of a young woman who lost her proprioception due to a viral infection of her spinal cord. At first she was not able to move properly at all. Later she relearned by using her sight (watching her feet) and vestibulum (or inner ear) only. She eventually acquired a stiff and slow movement, which is believed to be the best possible in the absence of this sense.

Apparently, temporary loss or impairment of proprioception may happen periodically during growth, mostly during adolescence. Possible experiences include: suddenly feeling that feet or legs are missing from your mental self-image; the need to look down at arms, hands, legs, etc. to convince yourself that they are still there; falling down while walking, especially when attention is focused upon something other than the act of walking (e.g., looking at a person who started talking or reading a billboard). The proprioceptive sense can become confused because humans will adapt to a continuously-present stimulus; this is called habituation or desensitization. The effect is that it seems as though proprioceptive sensory impressions disappear, just as a scent seems to disappear when a person smells it for a prolonged period of time. People who have a limb amputated may still have a sense of that limb; this is termed a phantom limb. This phenomenon is not limited to one sensation, however. Phantom sensations that are perceived as movement, pressure, pain, itching, or hot/cold as well can occur. (Note: The work of V. S. Ramachandran indicates that despite popular belief, the phantom limb phenomenon is actually the result of neural signal bleed through the brain's sensory maps, rather than from stimulation of nerves.)

Phantom limb pain – pain appearing to come from where an amputated limb used to be – is often excruciating and almost impossible to treat. New approaches, based on a better understanding of the brain's role in pain, may be opening the way to new treatments. After amputation of a limb, an amputee continues to have an awareness of it and to experience sensations from it. These phantom limb sensations are also present in children born without a limb, suggesting that perception of our limbs is 'hard-wired' into our brain and that sensations from the limbs become mapped onto these brain networks as we develop. If phantom limb sensations are normal then so too, alas, is phantom limb pain. This occurs in a majority of those who lose their limbs. In fact, limbs do not need to be lost; it also occurs in conditions in which the brain is disconnected from the body, such as peripheral nerve injuries and after spinal cord injury, when an area becomes insentient (and usually paralysed). The pain is described in various ways: burning, aching, 'as if the hand is being crushed in a vice,' etc. Such words, however, cannot fully encompass the experience of living with such a pain.

In those with chronic pain after spinal cord injury it is frequently the pain rather than the paralysis that interferes with work and social life. One woman has said that paralysis does not stop life, but pain may.

There may be many mechanisms underlying phantom limb pain. Damage to nerve endings is often important: subsequent erroneous regrowth can lead to abnormal and painful discharge of neurons in the stump, and may change the way that nerves from the amputated limb connect to neurons within the spinal cord. There is also evidence for altered nervous activity within the brain as a result of the loss of sensory input from the amputated limb. Unfortunately, phantom limb pain is generable intractable and chronic; once it develops it persists and is rarely improved by present medical treatments. Destructive surgical procedures are also of limited use. They can be effective for a few months, but pain always returns, frequently worse, and so surgery is only performed in patients with terminal illness.

In his last book Patrick Wall suggested that pain might be considered a 'need state', like thirst, rather than simply a sensation. If so then the 'need' might involve movement to avoid or reduce pain. Evidence that stimulation of the motor cortex (the area that controls movement) can reduce phantom limb pain has been around for some time. Perhaps more surprising was a trial by Ramachandran and Rogers-Ramachandran in 1996. They asked people with amputations of the arm and phantom limb pain to place their arms inside a mirror box so that they saw their remaining arm mirror-reversed to look like their amputated one. When they moved their remaining arm in the box they were 'fooled' into thinking they were moving their amputated one, and their pain was reduced. Although this has proved less effective in some subsequent trials, it did suggest that phantom limb pain might reflect a loss of motor control to the limb, as well as loss of sensory input from it. More recently the mirror box has been used with some success in pain that is not due to sensory loss. In fact, a box may not be required. In phantom limb pain due to a peripheral nerve injury (brachial plexopathy), Giraux and Sirigu have shown that merely training patients to imagine their paralysed arms moving in relation to a moving arm on a screen in front of them can relieve phantom limb pain. They suggest that these attempts to link the visual and motor systems might be helping patients recreate a coherent body image, and so reduce pain as a result of reduced and disordered input. If this approach is successful, it may be that relatively simple treatments, such as patients imagining that they are swinging a golf club with their amputated limb, could have significant pain-relieving benefits.

Finally, in experiments still being developed, we are constructing an arm in virtual reality which subjects with phantom limb pain will move themselves using motion capture techniques. Movement of their stump will be captured by a movement-tracking device, and used to project the movement of the reconstituted limb in virtual reality. We anticipate that this will lead to a sense of re-embodiment in the virtual arm and hence to a reduction of the pain. These new approaches are all based on a shift in emphasis in phantom limb pain away from the site of damage – the stump – to the centre of pain processing: the brain. It appears that disordered inputs from the limb's sensory systems, combined with disrupted motor signal back to the limb, generate a mismatch between the brain's built-in map of the physical body and what is actually perceived. For some reason, this mismatch results in pain.

Whichever of these new techniques proves effective – and simple enough to be used – the prospects for relief from pain are probably brighter than at any time since Weir Mitchell first coined the term phantom limb pain in 1872.