Limb loss and the brain

Functional imaging studies are suggesting that much of what we think happens to the brain after amputation may be wrong.

...loss of a limb can be devastating. Many everyday tasks, from getting dressed to preparing food, are infinitely harder for those with one hand. In addition, most amputees continue to experience sensations, usually painful, that seem to originate from their lost limb – phantom pain. Influential theories have been developed to explain the origins of phantom pain – but, says Tamar Makin in Oxford, they are probably wrong.

I feel like I’m tearing out a few leaves from the textbook,” she says. “Almost everything that has been established by previous work, I find opposite evidence for.”

Phantom pain is part of a wider range of research interests. “My primary interest is in brain plasticity,” this notion that a brain area could be retrained to carry a new functional role later in life, says Dr Makin. “I call it plasticity, but it’s actually more like reorganisation, an extreme form of plasticity.” As well as shifting right on fundamental aspects of brain function, she hopes that a better understanding of such reorganisation could ultimately help those whose brains are affected by injury, ageing, neurodegeneration or disease.

Her studies focus primarily on amputation which, she suggests, has two important consequences for the brain. Firstly, it provides a natural trigger for reorganisation, as brain areas are deprived of inputs they previously received from a hand. But although deprivation has dominated research, loss of an arm causes people to change their behaviour markedly: “There are a million little things in your routine that are disrupted and you have to figure out how to solve. So there’s very strong behavioural pressure to learn to use your body in a different way, to adapt to your disability.”

These behavioural adaptations could potentially also be major drivers of changes in the brain.

Remapping the brain

Much of what is known about the brain’s response to amputation has come from studies in monkeys. Deprived of inputs from the missing limb, the area of somatosensory cortex previously devoted to the hand is ‘taken over’ by neighbouring regions of cortex. According to the ‘maladaptive plasticity’ theory, the mismatch between the existing neural architecture and these new inputs creates the experience of phantom pain. “It’s a hugely influential theory,” says Dr Makin.

Oddly, though, the hand area is typically taken over by the lower part of the face and lips. “This is a bit curious, because the lower part of the face is not a cortical neighbour of the hand. The representation has to jump over the upper part of the face.”

An alternative explanation is that the lips take over hand territory because the animals start using them to compensate for the loss of a limb. Although difficult to test directly in monkeys, Dr Makin realised this idea could be addressed in amputees.

Having lost a limb, amputees are forced to make multiple adaptations in everyday life. “They come up with unique strategies to solve simple problems like how to open a bottle of water with one hand,” says Dr Makin. However, amputees vary significantly in the extent to which they use their residual arm. In particular, individuals who are born without a limb due to a congenital abnormality typically make extensive use of their residual limb.

To gain an objective measure of laterality, or asymmetry in limb usage, Dr Makin fitted accelerometers to participants’ upper arms. “We just asked them to go back home and go through their regular routines for the next few days,” participants also completed surveys on their use of the residual arm in bimanual tasks.

“We immediately saw a very clear dissociation between the acquired amputees and the congenitals [people born with a missing hand],” recalls Dr Makin. The latter were much better at using their residual arm on daily tasks, while the ‘acquired’ tended to rely heavily on their remaining ‘good’ arm.

These differences were associated with major differences in brain activity. When amputees wiggled the fingers of their good hand or...