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Author
Raffi, Liza

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IT'S ALL JUST SMOKE & MIRRORS

Liza Raffi

Ever since the invention of the mirror, man has used his reflection as a tool for composing and constructing body image. Research into potential therapies for a novel pain syndrome has taken this age-old practice a step further by exploring whether a mirror's virtual image can trick the brain into integrating into that body image a limb that no longer exists, allowing one to control and exercise it. Phantom limb pain, which affects over 85% of upper and lower extremity amputees, is at once clinically well documented and etiologically confounding. Written off in the past as a psychological maladjustment to the emotional and practical upheaval resulting from losing a limb, phantom limb pain has been increasingly examined in the last two decades from a neuroscience perspective geared toward understanding its potential physiological underpinnings. Mirror Visual Feedback (MVF) therapy, developed by Dr. Vilayanur Ramachandran, has made preliminary strides both as a therapeutic option for treating phantom limb pain and as a research tool for teasing apart the various causal mechanisms that could be at play. In this article we will take a look at the methods and merits of MVF, as well as interesting insights into the plasticity of adult neural networks that have been uncovered by Ramachandran and others' work.

While the sensations experienced as pain in a phantom limb vary and may depend on numerous factors – the limb removed, the length of time spent with injury before its removal, use of a prosthesis – sensations of cramping, stretching, paralysis, and intermittent sharp pain are among those most frequently described. Medications, such as narcotics and antidepressants, have had some success in slowing or preventing the uncontrolled pain signals but come with a wide array of side effects, including risks of addiction and dependence. Nerve blocks, slightly more invasive, use the injection of a local anaesthetic or corticosteroid between

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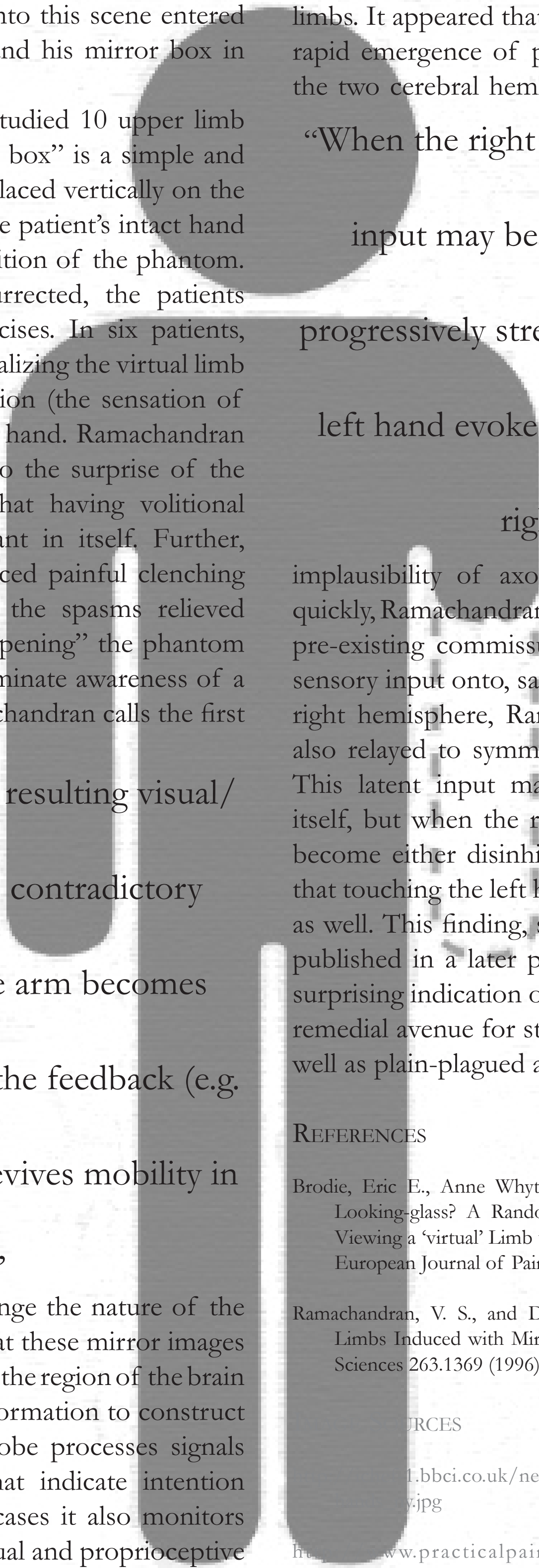
the spine and the amputation site to sever the pathway of the pain signal. If the phantom pain is debilitatingly severe one may even opt for surgical revision of the stump site. Unfortunately, effectiveness of any of these methods is largely unproven, with response rates rarely exceeding that of placebo treatments (Brodie et al). Into this scene entered neurologist Vilayanur Ramachandran and his mirror box in 1996, the beginning of MVF therapy.

Ramachandran and his team studied 10 upper limb amputees. The so-called "virtual reality box" is a simple and inexpensive construction. A mirror is placed vertically on the table so that the mirror reflection of the patient's intact hand is 'superimposed' on the perceived position of the phantom. With the phantom arm visually resurrected, the patients are then guided through various exercises. In six patients, movement of the intact hand while visualizing the virtual limb resulted in the same kinesthetic sensation (the sensation of one's body movement) in the phantom hand. Ramachandran notes that this occurrence was often to the surprise of the patients, several of whom attested that having volitional control over the phantom was pleasant in itself. Further, of the five patients who had experienced painful clenching spasms prior to the study, four had the spasms relieved when the mirror was used to aid in "opening" the phantom hand. One patient was even able to eliminate awareness of a phantom limb altogether -- what Ramachandran calls the first amputation of a phantom limb!



> "If motor commands and the resulting visual/proprioceptive feedback are contradictory (as they are in amputees) the arm becomes immobile; however, restoring the feedback (e.g. using the virtual reality box) revives mobility in the phantom."

What could be aligning to change the nature of the phantom? Ramachandran postulates that these mirror images provide key feedback to the parietal lobe, the region of the brain which integrates various streams of information to construct a dynamic body image. The parietal lobe processes signals from the motor/pre-motor cortex that indicate intention to move a body part, and in normal cases it also monitors performance of those actions using visual and proprioceptive feedback. Proprioception is one's sense of where their limbs are in space based on a network of receptors in the skin, and is a component of the kinesthetic sense described above. If motor commands and the resulting visual/proprioceptive feedback are contradictory (as they are in amputees) the arm becomes immobile; however, restoring the feedback (e.g. using the virtual reality box) revives mobility in the phantom. More than anything, Ramachandran was amazed by what appeared to be the systematic and topographical referral of sensation from patients' normal limbs to their phantom limbs. It appeared that within three weeks, there had been the rapid emergence of precise and organized pathways linking the two cerebral hemispheres in the adult brain. Due to the implausibility of axonal growth across those distances so quickly, Ramachandran hypothesizes that the exercises enhance pre-existing commissural connections. While we know that sensory input onto, say, one's left thumb is projected onto the right hemisphere, Ramachandran further suggests that it is also relayed to symmetric locations on the left hemisphere. This latent input may ordinarily be too weak to express itself, but when the right hand is amputated this input may become either disinhibited or progressively strengthened so that touching the left hand evokes sensations in the right hand as well. This finding, strengthened by fMRI and PET images published in a later paper published by Ramachandran, is a surprising indication of neural plasticity in adults and possible remedial avenue for stroke victims suffering from paralysis as well as plain-plagued amputees.

> "When the right hand is amputated [ipsilateral] input may become either disinhibited or progressively strengthened so that touching the left hand evokes sensations in the [phantom] right hand as well."

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