Contemporary Hypnosis (2002)
Vol. 19, No. 2, 2002, pp. 75–84

HYPNOTIC MIRRORS AND PHANTOM PAIN: A SINGLE CASE STUDY

David A. Oakley[1] and Peter W. Halligan[2]

[1]Department of Psychology, University College London, UK, [2]School of Psychology, University of Cardiff, UK

Abstract

Using hypnosis, two main approaches to modifying phantom limb pain experience can be identified: ipsative imagery, which makes use of the patient's own imaginative interpretation of how the pain is generated, and a simulated movement approach. The latter approach shares many similarities with the 'mirror' technique recently advocated and used by Ramachandran (in non-hypnotic settings) to create the experience of movement and in some (but not all cases) relief from pain in patients with a phantom limb. In this case study, we report the use of a hypnotically induced 'virtual' mirror experience that modified long standing intractable phantom limb pain despite generating a qualitatively inferior experience of movement in the phantom limb compared to that produced with an actual mirror. These preliminary findings suggest that the use of hypnotic movement imagery for the management of phantom limb pain is worth further investigation both in terms of its comparative ease of use and because of its potential for informing discussion as to the possible neurocognitive mechanisms involved.

Key words hypnosis, mental representation, movement imagery, phantom limb pain, suggestion, treatment

Introduction

Phantom limbs — the experience of persisting sensory perceptions after limb amputation — remain one of the best-known but puzzling phenomena within medical science (Ramachandran and Hirstein, 1998). Recent estimates suggest that the incidence of phantom experiences lies between 70 and 100%. In a significant proportion of these individuals (between 50 and 85% according to Jensen, Krebs, Nielsen and Rasmussen, 1983) the phantom limb experience is accompanied by pain (phantom limb pain). Different accounts have been put forward to explain phantom limb pain (see Grouios, 1999). One view is that phantom limb pain represents a continuation, or 'memory', of normally transduced pain present before or as a result of the incident that gave rise to the amputation (Melzack, 1973). However, this cannot be the complete story since many patients have no conscious experience of any pre-amputation pain in the limb in question. Other accounts include the release of spinal cord neurons from inhibition following loss of afferent impulses (Carlen, Wall, Nadvorna and Steinback, 1978), and more recently, the consequences of brain reorganization in adjacent cortical areas after limb amputation (Flor, Elbert, Knecht, Weinbruck, Pantev, Birbaumer, Larbig and Taub, 1995; Ramachandran and Hirstein, 1998).

Current attempts to explain phantom limb pain in terms of post-amputation brain reorganization follow the landmark studies by Merzenich, Nelson, Stryker, Cynader, Schoppmann and Zook (1984), and Pons, Garraghty and Mishkin (1988) that showed that after deafferentation (severing of sensory nerves) in primates large areas of the brain representing the deafferented body part underwent large-scale sensory and motor reorganization. Much of the human (and primate) body is represented by distinct brain areas located in the somatosensory and motor cortex on either side of the central sulcus. Consequently, even after limb removal (or its functional equivalent where the nerve supply is interrupted as in cases of brachial plexus avulsion) the brain areas representing those parts remain structurally and functionally intact. It has been argued that the activation of these bodily disconnected brain areas by adjacent brain areas (representing other intact body parts) may be a partial neurophysiological explanation for the production and maintenance of the continuous perceptual experience that is the 'phantom limb'. This functional remapping results in some cases in the referral of selective sensory information from an intact body area (such as the face or shoulder) to the phantom limb (Halligan, Zeman and Benger, 1999). The remapping hypothesis is supported by functional imaging (Kew, Halligan, Marshall, Passingham, Rothwell, Ridding, Marsden and Brooks, 1997) and behavioural studies (Ramachandran, Stewart and Rogers-Ramachandran, 1992; Halligan, Marshall, Wade, Davies and Morrison, 1993). Given the magnitude and speed of onset of the reorganization (within 24 hours of amputation) it is unlikely to be a product of neural sprouting but rather the unmasking of existing but previously inhibited neural pathways (Ramachandran and Blakeslee, 1998). In addition, these abnormal plastic changes in the central nervous system associated with the phantom experience have been used to explain the consistently high incidence of pain attributed to a limb that no longer exists (Ramachandran and Blakeslee, 1998).

Previous attempts to control phantom limb pain using hypnosis

Hypnotic procedures using suggestion and imagery have a long and established history of treating a range of painful conditions (Chaves, 1989; Montgomery, DuHamel and Redd, 2000). However, relatively little research appears to have been carried out to evaluate the effectiveness of hypnotic suggestion with phantom limb pain. One study by Cedercreutz and Uusitalo (1967) reported the use of hypnosis in a study of 37 amputees with phantom limb pain. In 20 subjects the pain disappeared completely and in 10 there was a significant improvement. At follow-up (1–8 years) eight subjects remained symptom-free and 10 could still be classed as significantly improved. Unfortunately, no details of the hypnotic interventions used with these 37 cases were provided. There are a small number of case reports that do give an account of the hypnosis procedures used for phantom limb pain control. In a recent review of 12 cases Oakley, Gracey Whitman and Halligan (2002) identified two main treatment approaches from the literature:

- *Ipsative imagery*: in this approach the individual's own pain-related imagery is used and is manipulated in hypnosis to transform the pain experience. For example, Chaves (1993) reported a female patient with phantom limb pain who described her pains as 'like biting ants climbing up' around her ankle and 'like thousands of tight rubber bands' around her knee and thigh. These pains were successfully alleviated with hypnotic imagery, which involved decapitating the ants, which fell to the floor, and cutting the rubber bands with scissors and watching the severed bands fly across the room.

- *Simulated movement*: in this approach, suggestions in hypnosis are used to help generate experiences of normal posture and movements in the phantom limb, which in turn, can have the effect of alleviating the phantom limb pain. This approach is particularly appropriate in cases where the phantom limb is reported to be in an uncomfortable or painful position (Oakley et al., 2002).

It is this second approach that is considered here. The approach is based in part on the assumption that mental activities, such as imaging and executing a movement, share very similar or common neural processes. Hence, mental practice of various tasks, such as rehearsing a movement in imagery, can lead to a significant improvement in subsequent motor performance (Feltz and Landers, 1983). In a recent imaging study (Ersland, Rosén, Lundervold, Smievoll, Tillung, Sunderberg and Hugdahl, 1996), hypnotic suggestions were used to evoke the subjective experience of tapping movements in the fingers of an amputated arm. When the patient 'tapped' his missing fingers, brain activations corresponding to those produced by actual finger movements were observed in contralateral motor cortex. Also relevant is another positron emission tomography (PET) imaging study involving eight amputees with phantom limb pain (Willoch, Rosén, Tolle, Oye, Wester, Berner, Schwaiger and Bartenstein, 2000). This study similarly found that the same brain areas were activated during hypnotically induced phantom limb movement as during movement of an intact limb. The movements of the phantom limb produced in response to suggestion in hypnosis were not 'as-if-feelings' but were 'vivid and real phantom sensations' similar to those the amputees experienced without hypnosis on an everyday basis. 'Comfortable movements' of the phantom limb in hypnosis were accompanied by a feeling of voluntary control, whereas 'uncomfortable' or painful movements resembled involuntary actions that the participants attempted to control. The same group also reported (Rosén, Willoch, Bartenstein, Berner and Rosjo, 2000) in a pilot study on two amputees that hypnotically suggested movement of the phantom into new positions could be incorporated successfully into a treatment package.

One potential problem with a simulated movement approach to treatment is that most patients with phantom limbs are unable to, or find it difficult to, move the phantom limb voluntarily (Ramachandran and Hirstein, 1998). It was for this reason (and not explicitly for pain relief) that Ramachandran originally devised his virtual reality mirror box. If congruent visual feedback of the 'paralysed phantom limb' could be provided then it might be possible to regain voluntary control over it. Mental rehearsal of movement may also lead to a reduction in the cramped and static postures of a phantom limb in cases where these appear to be associated with phantom pain. This approach stems in part from the cumulative evidence that imagery-based mental rehearsals, or mental training, can beneficially affect aspects of subsequent motor performance such as muscular strength (Yue and Cole, 1992), movement speed (Pascual-Leone, Nguyet, Cohen, Brasil-Neto, Cammarota and Hallett, 1995) and temporal consistency (Vogt, 1995). Moreover, the simulation theory proposed by Jeannerod (2001) suggests that covert actions, such as imagining limb movements, are considered by the brain as a form of action, save for the fact that the movement is not actually executed by the corresponding limb or body part. Jeannerod's (2001) theory obtains support from several sources. Behavioural findings have shown that imagined actions retain the same temporal characteristics as their corresponding real actions when it comes to execution (Decety, Jeannerod and Prablanc, 1989). Extended performance of tasks in the imagination can also lead to marked physiological changes.

Subjects performing and mentally simulating leg exercise increase their heart rate and respiration rate in both conditions (Decety, Jeannerod, Germain and Pastene, 1991). Finally, changes in brain activity associated with movements made in the imagination activate a subset of those activated during motor execution (see Decety, Perani, Jeannerod, Bettinardi, Tadary, Woods, Mazziota and Fazio, 1994; Stephan, Fink, Passingham, Silbersweig, Ceballos-Bauermann, Frith and Frackowiak, 1995).

How might such motor simulation modulate and eliminate the experience of pain in patients with phantom limbs? Ramachandran assumed that phantom limb pain arose (in part) from a disruption of the normal interaction between motor intention to move the limb and subsequent appropriate sensory feedback. Consequently, congruent visual feedback (such as via an appropriately positioned mirror) might also act to interrupt this pathological cycle that generated the painful phantom. Ramachandran set up a mirror box that enabled amputees to view the reflected image of their normal limb in the location where their missing limb would be, but did not allow them to see the stump or residual parts of the affected limb. With this apparatus the phantom spasms and associated pain were dramatically relieved during exercises involving the 'virtual limb' in six of 12 cases (Ramachandran and Hirstein, 1998). Viewing the reflection in the mirror permitted amputees to experience movement in their previously static phantom limb and a significant, albeit short-lived, reduction of pain. The phantom limb movement and its pain alleviating effects ceased, however, when patients closed their eyes. The efficacy of this method still awaits a prospective controlled trial.

It seems from the above that previous attempts to employ hypnotically induced movements of the phantom limb may have engaged brain areas responsible for normal movements of the phantom limb with a resultant reduction in phantom limb pain. One of the main methodological differences between previous hypnotic approaches and the non-hypnotic procedures of Ramachandran is that none of the hypnotic studies employed the additional 'prosthetic' imagery of a 'virtual mirror' with which to facilitate the reality of the imagined experience. In view of the reported success of mirror feedback in eliminating phantom limb pain in some patients, an attempt was made to recreate the mirror box effect in hypnosis in a phantom limb patient. The aim was to confirm and replicate Ramachandran's original finding and also to see if his technique could be extended by simplifying it even further (by replacing the actual mirror with a virtual one).

Reports of the emotional reaction of phantom limb pain patients on their first exposure to the mirror apparatus or to hypnotically suggested movements of the phantom limb indicate that they involve subjectively quite similar experiences. This further encouraged the view that the mirror movement effect might be replicable by appropriate hypnotic suggestions. Our own phantom limb pain patient, NB, was already experienced with the effects of the mirror apparatus from home practice before we tested him. He reported that his initial reaction on first experiencing movement in his phantom arm had been one of both surprise and delight. These feelings were heightened by the associated pain reduction, which he had specifically not been told about at the time of carrying out the initial trials with the mirror. Personal experience by the second author of several other cases of phantom limb pain over the years confirm that the first experience of movement in the phantom limb is often exhilarating and a highly emotional occasion. Ramachandran and Blakeslee (1998) described the first exposure of their patient, Philip, to the mirror apparatus. Philip had been involved in a motor cycle accident 10 years before and, like our patient NB, had suffered a brachial avulsion though in Philip's case the paralysed and useless limb had since been surgically removed. Ever since the acci-

dent he had never had the experience of movement in his phantom limb, which he felt was constantly 'frozen' in an awkward position. Once positioned with his right arm inside the mirror Philip was asked to attempt to make synchronous movements of both arms. As he had the experience of his left arm moving he exclaimed, *'Oh my God! This is unbelievable. It's mind-boggling! My left arm is plugged in again. It's as if I'm in the past. All these memories from so many years ago are flooding back into my mind. I can move my arm again. I can feel my elbow moving, my wrist is moving. Its all moving again!'*

Similarly, Le Baron and Zeltzer (1996) described the case of Tom, previously reported in Hilgard and LeBaron (1984). Tom was an 18-year-old whose left leg had been amputated following the diagnosis of a malignant bone tumour. In hypnosis, as part of a relaxation routine, he was asked to visualize his missing limb and to contract and relax the muscles in both legs together. He found the sensation strange but was able to experience his missing leg responding in the same way as the other one. His comments were, *'Kinda weird. But it was great! First I wiggled my toes, then I moved my leg a little, then I tightened the muscles, then all of a sudden both my legs felt more relaxed.'*

Case report

NB is a 46-year-old mechanic and racing driver who had experienced phantom limb pain ever since an accident five years previously in which he had suffered an avulsion of his left brachial plexus (that is, his left arm had been pulled out of his shoulder joint with sufficient force to tear the nerves leading to and from his spinal cord, though the arm itself had remained attached to his shoulder). He had previously been left-handed but now his immobile and insensitive left arm was supported in a leather sling. The positions he reported for his phantom arm and hand rarely corresponded to the actual position of the deafferentated limb. NB described two types of phantom limb pain. The first was an intense cramp-like experience, which occurred intermittently, approximately once per day, and lasted for 20 minutes. It commenced in the upper part of his denervated left arm and spread down into his lower arm. During this pain he felt his left hand become clenched and he experienced a burning sensation in the hand. The second type of pain consisted of a constant throbbing sensation in the knuckles of his left hand, which was accompanied every two to three minutes by what he described as 'small electric shocks' which shot down from his upper arm into the lower part of his arm and terminated in the little finger of his phantom hand. In an effort to establish whether the mirror method had a beneficial effect on this second form of pain, NB had used the mirror apparatus at a rehabilitation centre and at home two years before the current investigations. He had found it helpful in reducing his phantom limb pain during its use but afterwards the pains always returned within a few hours. NB had no prior experience of hypnosis.

Mirror testing

NB was first tested using a mirror following the method described by Ramachandran and Hirstein (1998). This provided him with the illusion of being able to view symmetrical movements of his 'left' (phantom limb) hand when he moved his right hand. During testing his actual left arm was taken out of the sling and placed out of sight on the tabletop in front of him. The apparatus was then set up in such a way as to prevent direct observation of his right hand but nevertheless allowed him to see its reflected image (now lateralized) in a position where his left hand would be. Throughout he

reported experiencing the reflected image as his phantom left hand, which he described as moving normally in synchrony with his right hand movements. Pain ratings were taken on a scale of 0–10 before, during and after the mirror box test (Table 1). Prior to the onset of the experiment his pain rating was 7. He was also able to experience sensations in his phantom left arm. For example, when he touched the mirror surface with his right hand he experienced a sensation of pressure in the fingertips of both hands, although, interestingly, only the intact right hand felt the coldness of the glass. Whilst viewing the mirror image and 'moving his phantom limb' his phantom limb pain totally disappeared (pain was rated as 0). However, when NB closed his eyes the sensation of moving his left hand was lost, even though he continued to move his right hand as before. In contrast to the experience of movement the phantom limb pain did not return immediately when he closed his eyes and some residual effect remained after testing with the mirror was complete (a phantom limb pain rating of 2).

Table 1. Ratings of pain in the phantom left hand before, during and after a session with the real mirror apparatus or a virtual (hypnotically hallucinated) mirror apparatus*

	Before	During	After
Real mirror	7	0	2
Virtual (hypnotic) mirror	4	0	2.5

* 0 = no pain; 10 = worst pain.

'Virtual mirror' testing

One hour after testing with the real mirror apparatus, NB's phantom limb pain had begun to build up again and had reached a rating of 4. He was seated at a bare wooden table which had previously held the mirror apparatus and was then taken through an eyes-closed hypnotic induction procedure commencing with general relaxation, followed by descent imagery (garden and steps) as a deepening, and finally by special place imagery of his own choosing (the Lake District in winter with the smell of fir trees, etc.). From postural signs and the slowness of his speech, it appeared that he had responded positively to the hypnotic procedure. NB was asked to keep his eyes closed and then was instructed as follows, *'Please imagine, and then see, the mirror box in front of you. When you see the mirror box clearly please nod your head so that I know.'* When the head nod signal was given the instructions continued, *'Now, please place your right hand in the mirror box as usual and look into the mirror.'* (NB's eyes remained closed throughout but he made actual movements with his right hand), *'Tell me what you see'*. NB claimed that he could see the 'reflection of his hand' clearly and was subsequently asked to try to move both hands in synchrony. He reported that he felt his left hand moving though the feeling was 'not as strong' as it had been on the previous occasion in the mirror apparatus. Moreover, he had the sensation of his left hand floating two inches above the tabletop and feeling unusually heavy. When one of the experimenters touched his right hand, NB reported a tingling sensation in his left hand.

With further encouragement to watch closely 'the reflected hand in the mirror' while he continued to make movements with his right hand, NB reported that the sensation of movement in his left hand and in the fingers of his left hand became clearer, though he

still claimed that it was not as strong as in the earlier mirror apparatus test. More importantly, however, he again reported freedom from pain (rated 0) in his phantom left arm and hand as he 'watched' the mirror hand moving. When he was asked to reach forward with his right hand and feel the surface of the table with his fingers he also described a 'stretching' sensation in his left hand and was able to feel the wooden surface with the fingers of his left hand. With his right hand resting on the table, NB felt that his left hand was still 'floating two inches above the surface'. NB was asked to raise his right hand to the same height as he felt his left hand to be. When one of the experimenters then gently pushed NB's right hand back down onto the table surface, NB said he felt his left hand being crushed. Similarly, when he was asked to make a fist of his right hand and to observe that in the mirror he said his left hand felt as if it was being squashed and he could 'see' that it looked like a fist.

One of the effects reported with the real mirror was the loss of movement sensation in his left hand when NB closed his eyes and could no longer see his reflected right hand. In hypnosis NB was reporting his experience of the mirror apparatus as if he had his eyes open (though they remained physically closed throughout). To test the effects of 'eye closure' during the virtual mirror testing he was asked to 'close' his eyes while continuing to move his right hand — when he did so he said he was 'holding a cup' in his left hand, that he could see it clearly and that he had distinctly felt his left hand move to pick it up. After the test session NB said that the hallucinated cup was full of water and commented that he had been feeling very hot and thirsty at that point.

Collectively, these observations suggest that NB was experiencing in hypnosis something very similar to the experience generated by the 'real' mirror apparatus. Not only did he report experiencing similar movements in his 'left' hand, albeit not so strongly, but also a variety of sensory and postural changes. Significantly, both approaches appeared to eliminate phantom limb pain. In the post-session interview NB said that the virtual mirror experience had felt 'real' to him, that it was like actually being there with the mirror and that he could clearly 'see' the mirror reflection of his right hand. It was interesting that when NB was asked to 'close his eyes' he seemed to lose the usual experience of synchronous movement in his left hand. What was even more interesting was that he nevertheless continued to experience some movement in his left hand but now independently of the right and apparently driven by his need for a drink of water. This suggests that once the constraints of synchronous movement by the right hand had been removed the experience of the phantom limb was free to be shaped by environmental influences and NB's own motivational state.

Age regression

The comments made by Ramachandran and Blakeslee's (1998) phantom limb pain patient, Philip, on first exposure to the mirror apparatus (see earlier) indicated that he felt transported back to a time before his accident when both arms were able to move normally. That is, he experienced a form of age regression. In order to explore directly the potential of time reversal suggestions for reducing pain outside the context of a mirror apparatus the hypnotic condition was maintained and NB was asked simply to *'Go back to an appropriate time before your accident when you could use both your hands'*. He described vividly the experience of being 'in a workshop full of race cars' and said he was building an engine and working normally with both hands (he was not making actual movements with his right hand). When he was asked to look at his hands he said he could see both of them and that they looked and felt normal. He reported that he had no pain (a scale score of 0) but when he was asked to move both arms independently he

said the movements of his left arm felt 'sluggish and heavy' compared to the movements of his right arm.

Pain rating after hypnosis

Shortly after the end of the hypnosis session NB rated his pain at 2.5 on the 10-point scale.

Discussion

NB's experiences in hypnosis and his reporting of them were clearly influenced by his prior familiarity with the 'real' mirror apparatus. Nevertheless, the mirror experience, including the elimination of phantom limb pain, was successfully replicated by use of hypnotic imagery alone. The only significant difference between the two conditions was the qualitatively more powerful experience of movement in the phantom left hand with real visual feedback. Interestingly, despite this, both methods achieved total elimination of phantom limb pain (albeit from different baselines), indicating that phantom limb sensation and phantom limb pain may have different cortical origins, as recently suggested by Grusser, Winter, Muhlmickel, Denke, Karl, Villringer and Flor (2001) and that the effectiveness of mirror feedback in reducing pain is not dependent upon the quality of the actual visual/imagined representation of the movement *per se*. It may thus be that a high level of imagery ability is not required for the pain reduction effect to occur. A similar question arises in relation to hypnotizability, although in this case the available evidence would suggest a positive relationship between pain reduction and hypnotizability (Montgomery et al., 2000). We do not have measures of either imaginative ability or hypnotizability for NB and these should be included in future studies.

It would be interesting to see whether similar results would be found in a phantom limb pain patient who was mirror-naïve. Even if it were to consistently produce a less powerful effect on the experience of movement in the missing limb, there are obvious advantages of an hypnotic mirror procedure for phantom limb pain control compared to the use of a real mirror assuming pain reduction is equivalent. First, it does not rely on the physical presence of the mirror; second, the pain relief created by the hypnotically produced mirror might prove longer lasting as patients could customize the imagery for themselves and use it on a continuous ongoing basis.

NB's experience of pain relief when he was age-regressed to a time before his injury could be interpreted either as a product of the experience of movement in his phantom limb or as an indirect suggestion to return to a pain-free state. It may be that an age regression strategy of this sort would be more effective than a hypnotic mirror approach in patients with no prior experience of actual mirrors. It would also seem profitable to explore the effects of hypnotic 'age-progression' to a time when the phantom limb is mobile, pain-free or has shrunk.

There is an indication from both the virtual mirror and the regression procedures that the imagery employed for producing the moving arm experience is still modulated by the current central representation of the left limb. In particular, the imagined movement seemed to interact with the reality of the paralysed left arm to produce what was described as a 'sluggish movement'. If imagery were somehow unrelated or independent of the current motor representation there seems no reason (in principle) why the movement of the left arm should not have been experienced as completely normal (as was the imagined movement of the good arm in the regression experience).

Our observations with NB were not carried out as part of a formal therapeutic intervention and consequently no information is available on long-term effects. They do,

however, support the view that movement or imagery-based strategies in hypnosis might be used in the treatment of phantom limb pain. Initially they might be employed for alleviating phantom limb pain during self-hypnosis routines but ultimately the therapeutic aim would be to extend the effect into everyday situations.

Acknowledgements

We are grateful to NB for his co-operation. Peter W. Halligan is supported by the Medical Research Council.

References

Carlen, P.L., Wall, P.D., Nadvorna, H., Steinbach, T. (1978) Phantom limbs and related phenomena in recent traumatic amputations. Neurology 28: 211–17.

Cedercreutz, C., Uusitalo, E. (1967) Hypnotic treatment of phantom sensations in 37 amputees. In: Lassner, J. (Ed.), Hypnosis and Psychosomatic Medicine. New York, NY: Springer Verlag; 65–6.

Chaves, J.F. (1989) Hypnotic control of clinical pain. In: Spanos, N.P., Chaves, J.F. (eds), Hypnosis: The Cognitive–Behavioral Perspective. Buffalo, NY: Prometheus Books; 242–72.

Chaves, J.F. (1993) Hypnosis in pain management. In: Rhue, J.W., Lynn, S.J., Kirsch, I. (eds), Handbook of Clinical Hypnosis. Washington DC: American Psychological Association; 511–32.

Decety, J., Jeannerod, M., Prablanc C. (1989) The timing of mentally represented actions. Behaviour and Brain Research 34: 35–42.

Decety, J., Jeannerod, M., Germain, M., Pastene J. (1991) Vegetative response during imagined movement is proportional to mental effort. Behaviour and Brain Research 42: 1–5.

Decety, J., Perani, D., Jeannerod, M., Bettinardi, V., Tadary, B., Woods, R., Mazziotta, J.C., Fazio F. (1994) Mapping motor representations with positron emission tomography. Nature 371: 600–2.

Ersland, L., Rosén, G., Lundervold, A., Smievoll, A.I., Tillung, T., Sunderberg, H., Hugdahl, K. (1996) Phantom limb imaginary finger tapping causes primary motor cortex activation: an fMRI study. NeuroReport 8: 207–10.

Feltz, D.L., Landers, D.M. (1983) The effects of mental practice on motor skill learning and performance a meta-analysis. Journal of Sport Psychology 5: 27–57.

Flor, H., Elbert, T., Knecht, S., Wienbruch, C., Pantev, C., Birbaumer, N., Larbig, W., Taub, E. (1995) Phantom-limb pain as a perceptual correlate of cortical reorganization following arm amputation. Nature 375: 482–4.

Grouios, G. (1999) The phantom limb. Physical Therapy Reviews 4: 29–36.

Grusser, S.M., Winter, C., Muhlnickel, W., Denke, C., Karl, A., Villringer, K., Flor, H. (2001) The relationship of perceptual phenomena and cortical reorganization in upper extremity amputees. Neuroscience 102: 263–72.

Halligan, P.W., Marshall, J.C., Wade, D.T., Davey, J., Morrison, D. (1993) Thumb in cheek? Sensory reorganization and perceptual plasticity after limb amputation. Neuroreport 4: 233–6.

Halligan, P.W., Zeman, A., Berger, A. (1999) Phantoms in the brain. British Medical Journal 319: 587–8.

Hilgard, J.R., Le Baron, S. (1984) Hypnotherapy of Pain in Children with Cancer. Los Altos, CA: William Kaufmann.

Jeannerod, M. (2001) Neural simulation of action: a unifying mechanism for motor cognition. Neuroimage 14: S103–9.

Jensen, T.S., Krebs, B., Nielsen, J., Rasmussen, P. (1983) Phantom limb, phantom pain and stump pain in amputees during the first six months following amputation. Pain 17: 243–56.

Kew, J.J., Halligan, P.W., Marshall, J.C., Passingham, R.E., Rothwell, J.C., Ridding, M.C.,

Marsden, C.D., Brooks, D.J. (1997) Abnormal access of axial vibrotactile input to deafferented somatosensory cortex in human upper limb amputees. Journal of Neurophysiology 77: 2753–64.

LeBaron, S., Zeltzer, L.K. (1996) Children in pain. In: Barber, J. (Ed.), Hypnosis and Suggestion in the Treatment of Pain: A Clinical Guide. New York, NY: Norton; 305–40.

Melzack, R. (1973) The Puzzle of Pain. New York, NY: Basic Books.

Merzenich, M.M., Nelson, R.J., Stryker, M.P., Cynader, M.S., Schoppmann, A., Zook, J.M. (1984) Somatosensory cortical map changes following digit amputation in adult monkeys. Journal of Comparative Neurology 224: 591–605.

Montgomery, G.H., DuHamel, K.N., Redd, W.H. (2000) A meta-analysis of hypnotically induced analgesia: how effective is hypnosis? International Journal of Clinical and Experimental Hypnosis 48: 138–53.

Oakley, D.A., Gracey Whitman, L., Halligan, P.W. (2002) Hypnotic imagery as a treatment for phantom limb pain: two case reports and a review. Clinical Rehabilitation 16: 368–77.

Pascual-Leone, A., Nguyet, D., Cohen, L.G., Brasil-Neto, J.P., Cammarota, A., Hallett, M. (1995) Modulation of muscle responses evoked by transcranial magnetic stimulation during the acquisition of new fine motor skills. Journal of Neurophysiology 74: 1037–45.

Pons, T.P., Garraghty, P.E., Mishkin, M. (1988) Lesion-induced plasticity in the second somatosensory cortex of adult macaques. Proceedings of the National Academy of Science, USA 85: 5279–81.

Ramachandran, V.S., Blakeslee, S. (1998) Phantoms in the Brain: Human Nature and the Architecture of the Mind. London: Fourth Estate.

Ramachandran, V.S., Hirstein, W. (1998) The perception of phantom limbs. Brain 121: 1603–30.

Ramachandran, V.S., Stewart, M., Rogers-Ramachandran, D.C. (1992) Perceptual correlates of massive cortical reorganization. Neuroreport 3: 583–6.

Rosén, G., Willoch, F., Bartenstein, P., Berner, N., Rosjo, S. (2000) Neurophysiological processes underlying the phantom limb pain experience and the use of hypnosis in its management: an intensive examination of two patients. International Journal of Clinical and Experimental Hypnosis 49: 38–55.

Stephan, K.M., Fink, G.R., Passingham, R.E., Silbersweig, D., Ceballos-Baumann, A.O., Frith, C.D., Frackowiak, R.S.J. (1995) Functional anatomy of the mental representation of upper extremity movements in healthy subjects. Journal of Neurophysiology 73: 373–86.

Vogt, S. (1995) On relations between perceiving, imagining and performing in the learning of cyclical movement sequences. British Journal of Psychology 86: 191–216.

Willoch, F., Rosén, G., Tolle, T.R., Oye, I., Wester, H.J., Berner, N., Schwaiger, M., Bartenstein, P. (2000) Phantom limb pain in the human brain: unraveling neural circuitries of phantom limb sensations using Positron Emission Tomography. Annals of Neurology 48: 842–9.

Yue, G., Cole, K.J. (1992) Strength increases from the motor program: comparison of training with maximal voluntary and imagined muscle contractions. Journal of Neurophysiology 67: 1114–23.

Address for correspondence:
Dr David Oakley,
Hypnosis Unit,
Department of Psychology (Remax House),
University College London,
Gower Street,
London,
WC1E 6BT,
UK.