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Topical review

Is mirror therapy all it is cracked up to be? Current evidence and future directions

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1. Introduction

That viewing oneself through a mirror can evoke peculiar experiences has intrigued researchers for more than a century [34]. The typical approach involves placing one limb behind a mirror that is situated along an observer's midline. The observer who looks at the mirror's surface will perceive the reflected limb to be the limb that is hidden behind the mirror. People subjectively report the experience of 'seeing through' the mirror's surface, as though it were actually transparent. This approach exploits the brain's predilection for prioritising visual feedback over somatosensory/proprioceptive feedback concerning limb position. For the amputee who 'places' their phantom behind the mirror, it may feel as though the phantom has 'come alive' [30]. This has led to a novel approach to pain reduction in this notoriously difficult to treat population [30], one that has understandably received a great deal of attention in the scientific, clinical, and popular press. We critically evaluate the current state of the evidence that mirror therapy reduces pain, summarise relevant findings concerning the other effects on the human brain of using mirrors, and suggest implications for clinical practice and research.

2. Does mirror therapy reduce pain?

Case studies and anecdotal data are overwhelmingly supportive of mirror therapy, or 'virtual' mirror therapy, in which a virtual reality environment is used instead of a mirror [29], to relieve phantom limb pain, complex regional pain syndrome (CRPS), and for post-surgical rehabilitation. Complete relief is often reported in these studies [2,12,19,23,30,33,35], but case studies are, for obvious reasons, likely to present an overly optimistic picture. More convincing are the results of a recent clinical trial in which 22 patients with phantom limb pain were randomly allocated to four weeks of mirror therapy, a covered-mirror control group, or to the mental imagery of movement, for 15 min daily [4]. All patients (6/6) in the mirror therapy group, 1/6 of the control group, and none of the imagery group reported a decrease in pain. Unfortunately, that paper did not address potential sources of bias and the pain scale used was not sufficiently well defined. No information was provided on the ~20% of the subjects who dropped out, potentially weakening the final results.

A high quality clinical trial in patients with CRPS reported a good analgesic effect in those with acute symptoms, but no effect in those with chronic CRPS [25]. However, many cases of acute CRPS resolve spontaneously regardless of the intervention, which makes interpretation of that result rather difficult as well. Finally, three clinical trials that incorporated mirror therapy into a three-stage motor imagery program, demonstrated a reduction of pain and disability in those suffering from CRPS and phantom limb pain [26–28].

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Those trials were judged to constitute very good evidence of efficacy for CRPS [6]. Mirror therapy constitutes only one component of graded motor imagery, so we still do not know how great a contribution mirror therapy made to the effect.

Perhaps the most robust trial of mirror therapy undertaken thus far found it to be no better for the immediate reduction of phantom limb pain than motor imagery without a mirror [3]. In that trial, which was part of a larger investigation ($n = 80$) of mirror therapy and phantom experiences, 15 patients with phantom limb pain were randomly allocated to mirror therapy or to a covered-mirror control group. About 50% of each group reported complete pain relief.

Such contrasting conclusions are possible when studies involve different interventions and measure the effects of those interventions in different ways. The most parsimonious conclusion of the data published to date would therefore appear to be that mirror therapy does not provide any greater immediate pain relief than motor imagery alone [3], but that a program of daily mirror therapy might [4,25], particularly if it constitutes part of a wider graded motor imagery program [28]. In short, the assertion made over a decade ago, that robust experimental trials are required to determine if the visual feedback is indeed an important part of mirror therapy [30], still holds true today.

3. Other effects on the human brain of using mirrors

Many studies have investigated the effect of seeing oneself in a mirror, in both neurologically impaired patients and healthy volunteers (see [16], for a review). Much has been elucidated, but four observations bare particular relevance to the use of mirrors in pain rehabilitation and management. For convenience sake, we will describe each as though participants have their right hand behind a mirror while watching the reflected image of their left hand.

(i) *Visual feedback dominates somatosensory feedback for cortical proprioceptive representation.* When the mirror is adjusted so that the visually specified location of the right arm differs from its proprioceptively specified position, the perceived location of the right hand is shifted toward its visually specified location [13]. The magnitude of this effect is linearly related to the size of the visual-proprioceptive conflict [17].

(ii) *Mirror therapy increases cortical and spinal motor excitability.* This has also been reported for motor imagery and while observing others move [10,11,12]. This effect depends on the so-called mirror–neuron system [31], which constitutes neurons that are active both during the observation of a task and during the execution of the task itself. Thus, by watching the right hand move, the mirror–neuron system may activate those motor processes that would be involved in moving the right hand. Perhaps, when both arms are moved, the mirror–neuron system serves to fine-tune the motor command, a possibility supported by evidence of enhanced spatial coupling during bimanual tasks when using a mirror [9].

(iii) *Sensory experiences can be evoked on the basis of visual information alone.* Brushing only the left hand imparts visual information that both hands are, in fact, being brushed. After about three minutes of such brushing, many people perceive the brushing on both hands, even though they know the right hand has not been brushed [32]. This type of phenomenon has also been observed in amputees, who sometimes perceive a touch on their intact limb as also occurring on their missing limb's phantom [18], and in neglect patients, who perceive a touch to their affected side as occurring on their unaffected side [14]. In patients with unilateral CRPS (but not non-CRPS neuropathic pain [21] touching the unaffected limb can evoke pain and paraesthesia in the affected (untouched) limb [1]. In a different paradigm, participants watch a light flash on a rubber hand placed in front of them and begin to feel the touch at the location of the light, that is, on the rubber hand [7]. In each case, the visual input overrides the (lack of) tactile input and is sufficient to produce the sensation of touch. These findings imply modulation of tactile processing upstream from S1 (Fig. 1).

(iv) *Visual input enhances tactile sensitivity.* Tactile sensitivity imparted by watching the reflected image of one's arm being touched, is sustained beyond the cessation of the visual input [32], which is important because it implies longer-term changes in cortical processing.

4. Implications for clinical practice and research

Although there is good evidence that programs that *incorporate* mirror therapy can be helpful for patients with CRPS or phantom limb pain, the current evidence concerning mirror therapy *per se,* is uncompelling. The obvious implication is that we need more interpretational models and additional data – a robust blinded randomised controlled trial of daily mirror therapy for an extended period and with long-term follow-up, remains to be undertaken, despite calls for such trials more than a decade ago [30]. Furthermore, we also need to critically interrogate the theoretical bases for mirror therapy so that we might also come closer to determining who will benefit and who would not.

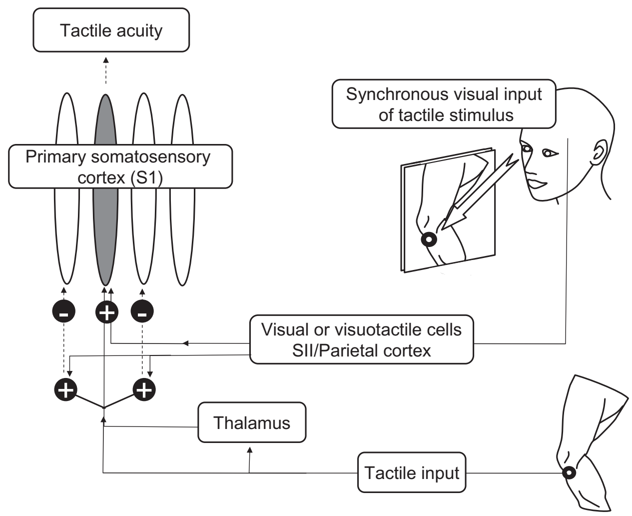

Fig. 1. Possible mechanisms for visual input to enhance or override tactile input. Seeing the touch, either directly or via watching the mirror image of touch to the corresponding point on the opposite limb, activates visual or bimodal visuotactile cells in secondary somatosensory (SII)/posterior parietal cortex, which facilitate the corresponding S1 neurons and enhances collateral inhibition in S1 and possibly in the thalamus.

Why is it taking so long? One clear barrier is the difficulty of accessing appropriate patients in sufficient numbers to satisfy the statistical power analysts. Another is ensuring the patients' participation throughout a trial in which many of them will not gain relief from what is often severe and unremitting pain. One approach that may overcome these barriers is to consider alternate experimental designs, for example, replicated case series, which, if undertaken within strict design constraints, can permit robust conclusions about the effects of treatment [15].

That looking in a mirror does impact on sensory and motor processes raises the possibility that mirrors might help relieve pain in hitherto unconsidered conditions, for example dystonia, in which muscle spasm holds joints within a painful range, or during serial casting. Alternatively, visual input might be used to expose patients to 'virtual' versions of movements of which they are afraid, before progressing to the movements themselves. Mirror therapy might provide a better means to do this than motor imagery, because although they may engage similar brain mechanisms, motor imagery requires greater deployment of cognitive resources, and would seem less likely to engage the interest of patients – any effect that novelty has on participation is certainly worth capturing. Perhaps mirror therapy is particularly suited to those who find motor imagery difficult.

Mirrors may have a more legitimate place in rehabilitation via their effect on tactile processing. The strong links between reorganisation at various levels of the sensory neuraxis, tactile acuity and pain, imply that improving tactile acuity, or normalising neural organisation, or both, may reduce pain [8]. Simultaneously seeing and feeling touch improves tactile acuity and there is already some precedent for this in patients with CRPS: tactile training with a mirror between the limbs is more effective than conventional approaches in terms of improving tactile function and decreasing pain (Moseley et al. unpublished data). In fact, the use of mirrors during sensory training is already advocated for enhancing sensory recovery after peripheral nerve injury or surgery, despite the lack of empirical support [22]. Furthermore, that visual input indicating that one's hand is being stimulated is sufficient to evoke the sensation of that hand being touched, raises the speculative (but not outrageous) possibility that this process might be sufficient to evoke descending inhibitory mechanisms – 'virtually rubbing it better'.

5. Summary

Despite widespread support of mirror therapy for pain relief in the peer-reviewed [2,4,12,19,23,24,25,30,33,35], clinical (e.g. [20] (and popular (e.g. [5]) literature, the overwhelming majority of positive data comes from anecdotal reports, which constitute weak evidence at best. Only two well described and robust trials of mirror therapy in isolation exist, on the basis of which we conclude that mirror therapy *per se,* is probably no better than motor imagery for immediate pain relief, although it is arguably more interesting and might be helpful if used regularly over an extended period. Three high quality trials indicate positive results for a motor imagery program that incorporates mirror therapy, but the role of mirror therapy in the overall effects is not known. Obviously, more robust clinical trials and experimental investigations are still required. In the meantime, the relative dominance of visual input over somatosensory input suggests that mirrors might have utility in pain management and rehabilitation via multisensory interactions. Indeed, mirrors may still have their place in pain practice, but we should be open-minded as to exactly how.

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