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Doing It with Mirrors: A Case Study of a Novel Approach to Neurorehabilitation

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Arm amputees can experience the perception of movement of a phantom limb while looking at a mirror reflection of the moving, intact arm superimposed on the perceived phantom. Such use of a mirror to provide illusory visual feedback of movement can be useful in rehabilitation of hemiparetic patients. In this case report, we describe the successful application of "mirror therapy" to the post-stroke rehabilitation of a patient with poor functional use of an upper extremity, due mainly to somatosensory deficits. Mirror therapy facilitated employment of a motor copy strategy (bimanual movements) and later progression to "forced use" of the affected arm. The end result was increased functional use of the affected upper limb.

Ramachandran and colleagues (1,2) described the use of a mirror to induce kinesthetic sensations in the phantom limbs of arm amputees. The mirror was placed vertically in front of the subject, who moved the intact arm while looking at its reflection, visually superimposed on the phantom arm. The reflected movement led to vivid perception of movement of the phantom limb, even in individuals with phantoms that were previously perceived as immobile. The mechanisms mediating this cross-modal phenomenon remain unclear but may be related to normal convergence of visual and somatosensory feedback signals in parietal cortex (2). Thus visual input may be sufficient to evoke kinesthetic percepts in certain circumstances. In a subsequent study from Ramachandran's laboratory (3), similar use of the mirror was reported to be helpful in the rehabilitation of patients rendered hemiparetic by strokes. Patients' comments and neurologists' blinded ratings of videotaped observations indicated improvement in motor function after daily practice with the mirror over an 8-week period. The investigators speculated that the illusory visual feedback substituted for inadequate proprioceptive input and recruited premotor cortical areas, which receive visual input and contribute importantly to the corticospinal projection.

Mirror therapy is potentially a very attractive technique in stroke rehabilitation because of its simplicity. We therefore began to investigate its efficacy in our outpatient rehabilitation program. In this case study we describe the beneficial effect of mirror therapy in the rehabilitation of a patient with profound sensory deficits contralateral to a subcortical infarct, resulting in marked incoordination and poor functional use of his upper extremity. Improvement was documented using objective measures of motor function. We thought that providing illusory visual input of limb movement might be particularly effective in this patient, who lacked somatosensory input and consequently relied on vision.

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Case Report

The patient was a 57-year-old, right-handed white male who, on the day after coronary artery bypass grafting, was noted to be unable to move his right upper extremity. The next day a neurologic consultant found right-sided neglect with sensory loss and mild weakness, more in the upper extremity than the lower extremity. A CT scan without contrast revealed a lucency of about 1 cm diameter in the left thalamus and posterior limb of the internal capsule. An echocardiogram was unrevealing. Carotid duplex scanning revealed bilateral carotid stenosis of 50% or less. He spent 2 weeks in inpatient rehabilitation and 4 weeks in outpatient rehabilitation in a day program and made a good recovery with regard to motor strength.

Approximately 6 months after the stroke, the patient was referred to our program because of continuing difficulty with using his right side. He reported that this problem was particularly marked in the absence of vision, associated with inability to locate his right upper and lower limbs in space. In addition, he experienced right-sided paresthesias. Right-sided problems on neurologic examination included mild weakness (grade 4 out of 5) and spasticity (Ashworth grade 1.5–2); hyperreflexia; profound, pan-modal sensory loss; dystonic posturing of the arm and hand; and substantial incoordination on the finger-nose-finger test.

We constructed a simple apparatus of the type used by Ramachandran and coworkers (1–3; see Figure in ref. 3). It consisted of a wooden box, open at the top and containing a central partition, both sides of which were mirrored. The patient was asked to insert one arm on either side of the central partition and to attempt to perform synchronous bimanual movements while looking at his unaffected left arm and its reflection in the mirror (masquerading as his affected right arm, which was out of sight on the other side of the partition). Initial testing showed some improvement of coordination and fluidity of right upper extremity movement under these conditions. The patient was therefore started on a program consisting of weekly physical therapy visits that were used to direct and monitor a home program. Initial therapy involved use of the mirror to facilitate a "motor copy" strategy (i.e., attempting bimanual upper extremity movements) (4). This approach began by using the mirror and was later expanded to include practice independent of the mirror, with the eyes closed to focus on somatosensory cues from the intact limb as well as residual ones from the affected limb. Once the patient's motor function began to improve with this regimen, the therapeutic strategy progressed to "forced use" (5,6) of the right arm in daily activities. The program proved to be strikingly beneficial. The patient was so convinced of the value of the mirror that he constructed a similar apparatus at home and practiced using it for hours each day, even after progressing to the other approaches.

At follow-up visits over the next 3 months, the patient's motor function demonstrated progressive improvement and a corresponding gain was noted in functional use of his right arm. Despite lack of improvement in sensory deficits on neurologic testing, he acquired the ability to grade pressure appropriately to objects that were picked up. Moreover, he no longer needed "to stare at his right arm" when he was using it but was able to use his peripheral vision and remote somatosensory cues (e.g., from the shoulder girdle) to guide movement. He even developed a pincer grasp and was able to pick up coins and other small objects. Overall, he could use his right arm to assist consistently in activities such as dressing. Primary use of this arm was less consistent (e.g., he was able to use his right hand to insert a key and unlock a door about 60% of the time, without having to assist with his left hand). His dystonia and appendicular incoordination also improved. Objective measurements confirmed his improvement in motor function (Table 1).

Table 1. *Performance of patient before and after rehabilitative training. All scores refer to the affected right arm.*

Test	Pretraining Performance	Posttraining Performance
Grip strength	17 kg	24 kg
Release time	0.78 sec	0.45 sec
Max. shoulder flexion	140°	140°
Max. shoulder abduction	70°	90°
Max. shoulder external rotation	40°	40°
Functional reach	0.28 m	0.38 m
Cup to mouth time	5.2 sec	3.1 sec
Time to drape towel over shoulders	7.2 sec	4.3 sec
Time to pick up pen	8.9 sec	7.1 sec
Time to fold towel in quarters	15.1 sec	11.2 sec

Discussion

Use of a mirror was beneficial in our patient's rehabilitation after stroke. The capability of illusory visual feedback to influence kinesthesis during active movement in this patient is consistent with the observations of Ramachandran and coworkers on amputees (1,2). In our patient, as in the previous report on hemiparetic patients (3), it is remarkable that manipulating sensory inputs led to significant motor recovery, which was objectively documented in the present study. We cannot completely exclude a contribution from spontaneous recovery to our patient's improvement. However, the speed of his progress during approximately 3 months of intervention, relative to the extent of recovery he had experienced in the preceding 6 months, strongly suggests that his dramatic improvement was indeed a result of our intervention. Moreover, use of the mirror was a critical factor in facilitating use of more established strategies such as motor copy and forced use.

Of note, our patient had a profound somatosensory deficit and was reliant on vision to guide movement. This may account for his impressive response to the provision of illusory visual feedback. Interestingly, the patient's functional gains occurred despite persistent somatosensory impairment. It is likely that learning to use peripheral vision and indirect somatosensory cues contributed to his gains. Areas crucial to functional recovery in this patient probably include those known to have both multimodal sensory representations and a role in motor control, such as posterior parietal and premotor cortical areas (7). The neural mechanisms underlying the efficacy of mirror therapy are not clear, but the resulting improvement in motor function is an instantiation of use-dependent neural plasticity, which has been demonstrated in the form of expansion of topographic maps in a variety of situations. These include nonhuman primate investigations of perceptual learning (8) and motor learning after experimental stroke (9), as well as human studies of blind Braille readers (10) and players of stringed musical instruments (11). Use-dependent neural plasticity can also be manifested as nontopographic changes in neuronal coding characteristics (12,13) and may involve mechanisms ranging from synaptic plasticity (14) to axonal sprouting (15,16).

It is well known that patients with sensory loss are among the most difficult to rehabilitate. Rehabilitative interventions focus largely on the motor system. Patients with impaired somatic sensation may constitute the most appropriate group for mirror therapy because of their dependence on visual input. Our anecdotal observations support this view, since patients with predominantly motor deficits did not appear to benefit during testing with the mirror at their initial visit. However, it remains possible that such patients could respond if intervention is prolonged (3). Further investigation is required to identify the types of deficits that would be most responsive to mirror therapy.

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