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Commentary Article

Mirror therapy applied to functional recovery of post-stroke patients: An overview.

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Abstract

Mirror therapy emerged from the use of visual feedback to induce kinesthetic sensations and has since been explored as a simple, low-cost, and non-invasive strategy for neurorehabilitation. Although the neurophysiological mechanisms underlying its effects remain incompletely understood, they are likely related to interactions between visual feedback, somatosensory processing, motor imagery, mirror neuron activity, and cortical sensorimotor plasticity. In post-stroke hemiparesis, mirror therapy may help restore the disrupted relationship between intended movement and visual perception, potentially reducing learned non-use and facilitating motor relearning. This commentary provides an overview of the theoretical basis and clinical relevance of mirror therapy for functional recovery after stroke, highlighting its potential as an adjunctive rehabilitation strategy while recognizing the need for clearer patient selection criteria and more rigorous mechanistic investigation.

Keywords: Stroke, Visual Feedback, Rehabilitation.

1. Commentary

Three somewhat artificial dichotomies have plagued neurology from its origins. First, there was a debate as to whether different mental capacities are clearly located in modules or are they mediated in a holistic way? Second, do specialized modules exist, do they work autonomously, or do they interact substantially? Third, are they flexible or can they be modified by changing input, even in adult brains, that is, is brain damage in adults irreversible or is some recovery possible? Countless generations of medical professionals have been taught that functions are localized and fixed and that damage is usually permanent; although there are always dissenting voices. However, there has been a paradigm shift in neurology with an increase in rejection of this classic dogma [1].

This shift had its beginnings in the work of Patrick Wall, through his evidence for the new view of brain function. Evidence of both intersensory interactions as well as the plasticity of brain modules was taken into account. Of course, all this evidence comes from investigations in adult brains; contradicting the dogma of immutable brain communications [1,2]. Based on these principles, in an attempt to attenuate sensorimotor deficits and accelerate the process of functional recovery, currently the mirror therapy technique (mirror visual feedback), introduced by Ramachandran and Rogers in 1992 [2] for the treatment of patients with pain phantom, is used for the treatment of post-stroke hemiparesis. Mirror therapy consists of a technique that uses a 2 x 2 m mirror, vertically supported sagittally in the middle of a rectangular box. The technique suggests that a neural network responsible for controlling one hand in a given task can be used in the movements of another hand, referring to the ability to memorize a procedure [3]. The idea is to re-educate the brain through a simple task, where the individual performs a series of movements with the healthy arm, which is seen in the mirror as if it were the injured arm. In this way, it is intended to “trick” the brain, making it imitate the movements of the injured arm through the reflection of the uninjured arm in the mirror [2,4].

After this initial work, carried out by Ramachandran and Rogers [2,4], other subsequent studies were inspired by these findings using mirror therapy [1]. Much is speculated about the effectiveness of the technique, due to the good results observed in recent clinical studies. Thus, it is suggested that the technique has great potential for future applications and implications in the field of neurology. Even if only a small proportion of patients are helped, these results would already be of great value, given the high incidence of strokes, as about a tenth of the world's population will suffer some type of stroke-related sensorimotor deficit. Furthermore, even if the technique benefits a minority of patients, it is able to pave the way for a more complete future of effective therapies once we know the variables involved.

In a placebo-controlled pilot study [1] conducted with 9 patients, moderate functional recovery was observed in 3 patients, mild in another 3, and almost none in the last 3. Subsequently, a number of cases reports 4-6 found benefits for post-operative hemiparesis. More recently, 2 randomized and controlled studies found significant improvement in hemiparesis [5,6]. Both studies used 40 patients with hemiparesis, the first with hemiparesis of the lower limbs [5] and the second with hemiparesis of the upper limbs [6] enrolled up to 12 months after stroke. Subjects were randomized into mirror therapy (leg movements for the first study and movements of both hands and arms for the second) or control group, with all subjects receiving a physical therapy protocol as a control intervention. A statistically significant improvement in sensorimotor deficits was verified using the Brunnstrom scale and the FIM scale in favor of the group that received mirror therapy when compared to the control group. These results indicate that many patients show substantial recovery of function using mirror therapy. But the variability suggests the technique may help some patients more than others. This variability may depend in part on the exact site of injury and duration of post-stroke deficits. Once these variables have been understood, it may be possible to administer mirror therapy to those patients who are able to benefit the most (although the technique's simplicity, it has the potential to be routinely implemented as an additional therapy).

The way in which the restoration of the link between vision and movement is established can lead to a resolution of learned paralysis in post-stroke patients, and with this in mind, a possible clinical explanation for the results presented above would be the neuron system. mirror (SNE) [7]. This system of neurons is found in both the frontal and parietal lobes, areas rich in neurons responsible for motor commands, which trigger the production of simple skillful movements, such as if someone were to pick up a peanut or put an apple in their mouth [8,9]. Remarkably, a subset of these neurons, “mirror neurons”, also fire when someone just watches another person perform the same movement. Mirror neurons allow one subject to put himself in another's shoes, seeing the world from the other's perspective, not only physically but also mentally, in order to deduce the other's imminent action [7,10].

Mirror neurons necessarily involve interactions between multiple modalities, vision, motor commands, proprioception, which suggest that they could be involved in the effectiveness of mirror therapy in post-stroke patients. When it comes to stroke, body image reorganizations in the sensory and motor cortex can generate real movement limitations, but also limitations that can be classified as “learned paralysis”. This is due to a clogged blood vessel in the brain, the fibers that extend from the brain to the spinal cord run out of oxygen and suffer damage, causing real paralysis; however, in the early stages of a stroke, the brain swells, also temporarily leaving some nerves simply dazed and disconnected. During this period, when the limb does not function, the brain receives negative visual feedback. After the edema subsides, due to the experience of negative visual feedback, it is possible for the patient's brain to have a form of “learned paralysis” [2]. One possibility is that if there is a residue of surviving and latent mirror neurons, through mirror therapy a supply of visual information through mirror therapy could revive the motor neurons.

This possibility was investigated and confirmed by a group of researchers who used, in an experimental group, a protocol composed of mirror therapy and also of videos in which patients watched movements performed by healthy people, so that soon after they tried to use their paretic arm to perform the movements. Compared to the control group that performed a conventional physical therapy protocol and watched a video with geometric symbols, the experimental group showed superior results. The authors also point out that this protocol can be used by patients with bilateral post-stroke hemiparesis, through the movement of an arm by the patient while watching the reflection of the physical therapist's arm in the mirror [11].

Assuming that in addition to the corticospinal tracts that travel contralaterally from the motor cortex, there are also some ipsilateral ones. For example, the right motor cortex sends its outputs not only to the left side of the spinal cord as is still thought, but also to the spinal cord contralaterally. Within this context, we argue whether these pathways are excitatory or inhibitory? Would be functional or remaining vestiges of some ancient road not crossed before? When commands are sent to the contralateral side of the body, why don't any commands go simultaneously to the ipsilateral muscles? Would these repressed ipsilateral movements therefore be mirrored on the left side? And lastly, if information from the right hemisphere to the left side, spinal cord, and body is damaged by stroke, then why can't the ipsilateral pathway from the left side to the spinal cord take over and move the paralyzed limb? None of these questions have been satisfactorily answered, but with a more meticulous investigation, it would be possible to take advantage of these connections in a clinical setting, as perhaps visual feedback acts by reactivating these latent ipsilateral connections [11].

Studies on mirror therapy demonstrate that this technique has major implications, both for clinical practice and for our theoretical understanding of the brain. From a clinical point of view, studies suggest that mirror therapy can accelerate functional recovery from a wide range of sensorimotor disorders, such as post-stroke hemiparesis or other brain injury [6,12-15]. On a theoretical level, the findings are also of great relevance to our understanding of normal and abnormal brain function. The old view of brain function (standard model), dating back to the last century and on which neurology is still based, is the notion that the brain consists of a large number of highly specialized autonomous modules that interact very little with each other at birth. Neurological disorders, in this view, result from relatively irreversible and permanent damage to a single or a small subset of modules, which would not exactly explain the localization specificity of signals and deficits, but also why there is generally so little recovery of function. after injury or brain damage. By automatically deleting a module a function is deleted forever.

The results presented here have major implications, both for clinical practice and for the theoretical understanding of brain functioning. From a clinical point of view, the results suggest that mirror therapy can accelerate the recovery of functions in hemiparetic patients who have suffered a stroke and possibly other brain injuries or damages, such as traumatic brain injury, or even peripheral injuries, such as complex regional pain syndrome [10,14,16,17]. It remains to be seen whether patients with other diseases, such as Parkinson's or focal dystonia's, could benefit from the use of this therapy. Although it seems unlikely, this issue deserves to be explored. In fact, these findings unequivocally demonstrate that using very simple procedures, barriers between modules (e.g. between vision and proprioception) and, more remarkably, between one brain and another, a patient literally experiences another pain in their limb [2,4], can be overcome [1]. Such findings suggest that it is necessary to rethink the view that the brain works in a serial and hierarchical way with its modules and replace it with a new, more dynamic view. Rather than thinking of brain modules as inflexible and autonomous, they should be seen as being in a state of dynamic equilibrium with each other and with the environment (including the body), with connections constantly being formed and reformed in response to necessary environmental changes. A neurological dysfunction, at least in some instances, could be caused not so much by irreversible damage to a module as by a functional shift in balance. Within this context, perhaps the equilibrium point can be changed to its normal state by pressing a "reset" key using a relatively simple and non-invasive procedure such as mirror therapy [1-17]. Figure 1 shows the proposed mechanism and clinical rationale of mirror therapy for post-stroke functional recovery.

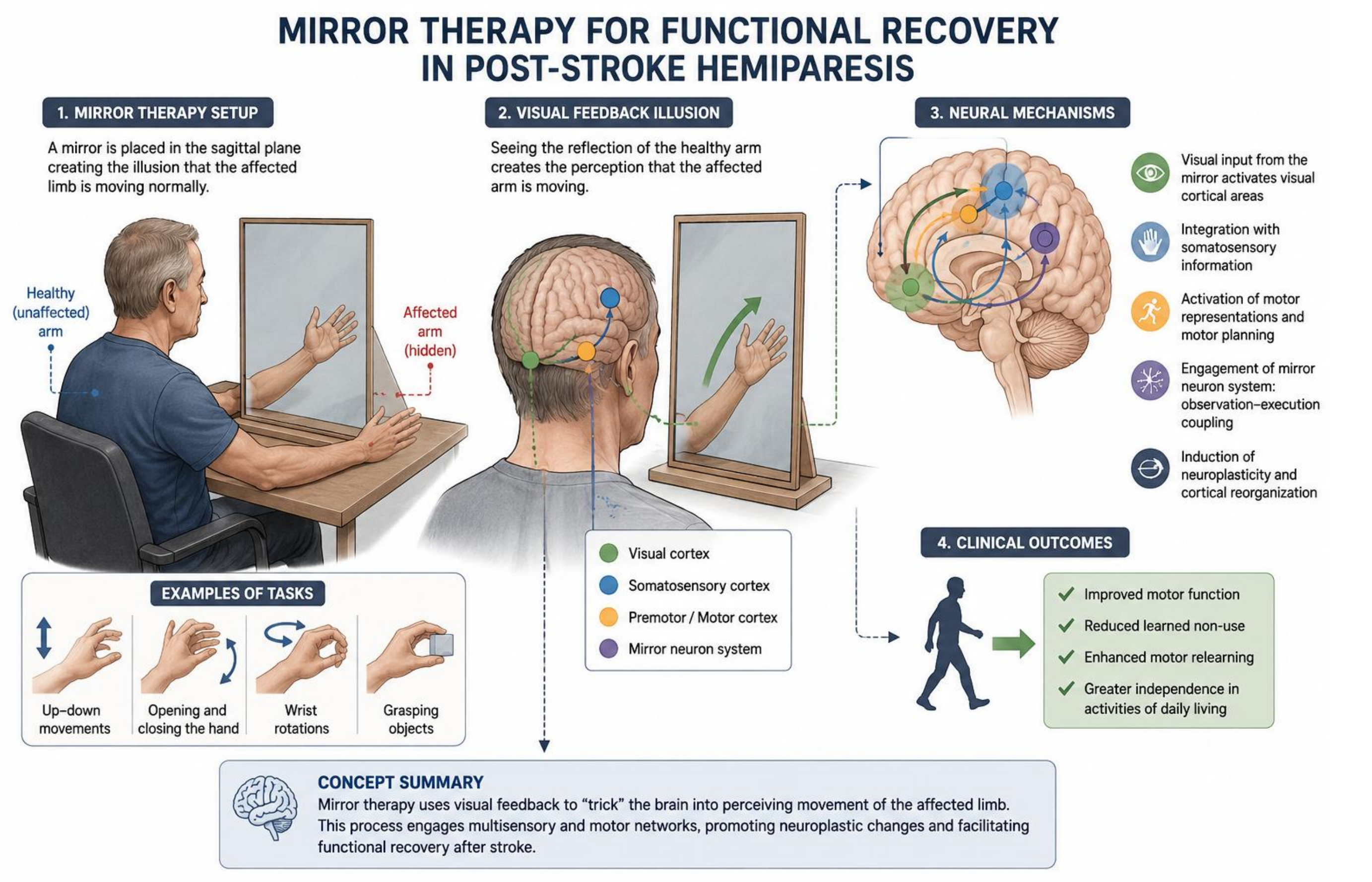

Figure 1. Proposed mechanisms and clinical rationale of mirror therapy for post-stroke functional recovery.

Mirror therapy is based on the placement of a mirror in the sagittal plane, allowing the reflection of the unaffected limb to create the visual illusion that the affected limb is moving normally. This visual feedback may help restore the disrupted relationship between motor intention and sensory perception after stroke. The proposed mechanisms include activation of visual cortical areas, integration of somatosensory information, recruitment of premotor and motor representations, engagement of the mirror neuron system, and induction of neuroplastic changes in sensorimotor networks. Through repeated task-oriented movements, such as hand opening and closing, wrist rotations, and grasping exercises, mirror therapy may contribute to motor relearning, reduced learned non-use, improved functional performance, and greater independence in activities of daily living.

2. Conclusions

Mirror therapy represents an adjunctive rehabilitation strategy for post-stroke hemiparesis, standing out as a low-cost, minimally invasive intervention with simple clinical applicability. Although the neurophysiological mechanisms underlying its benefits have not yet been fully elucidated, available evidence suggests that the visual feedback generated by the technique may modulate sensorimotor cortical areas, stimulate motor imagery, and activate neural networks related to the mirror neuron system, thereby contributing to neuroplastic reorganization of the central nervous system.

Thus, the use of a mirror may act as a resource capable of partially restoring the relationship between motor intention and sensory perception, favoring motor relearning and functional recovery. However, the literature also shows considerable variability in patients' clinical responses, reinforcing the need for more rigorous future investigations. Such studies should aim to more precisely identify the profile of patients with the greatest potential for benefit, as well as establish optimal dose-response parameters, specific therapeutic protocols, and the most appropriate timing for initiating the intervention throughout the post-stroke recovery process.

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