Scand J Plast Reconstr Surg Hand Surg, 2005; 39: 104–108

Taylor & Francis
Taylor & Francis Group

CASE REPORT

Training with a mirror in rehabilitation of the hand

BIRGITTA ROSÉN & GÖRAN LUNDBORG

Department of Hand Surgery, Malmö University Hospital, Malmö, Sweden

Abstract
Treatment with a mirror gives an illusion of function in a missing or non-functioning hand. The method is based on the concept that the central representation of phantoms and body image can change rapidly, and has been described in the treatment of phantom pain and stroke. We show in three pilot cases new applications for the use of the mirror in rehabilitation after hand surgery.

Key Words: *Nerve repair, sensory re-education, mirror visual feedback, brain plasticity, rehabilitation*

Introduction

The use of mirrors for the prevention and treatment of phantom pain was first described by Ramachandran and Hirstein to restore the disruption of normal interaction between intention to move the limb and the absence of appropriate sensory feedback [1]. A mirror is placed vertically in front of the patient to reflect the non-injured hand in the place of the injured hand and the patient gets a mirror visual feedback. The amputated arm is positioned behind the mirror, and through the visual system the amputated hand looks – through an illusive effect – to be intact. During repeated sessions the pain can be reduced, presumably because the changed cortical organisation, which is induced by the amputation, is modified and influenced towards normalisation. The principle has also been used in studies to improve mobility of the hand in patients who have had strokes [2], and there are single reports about using mirrors in training programmes for musicians with dystonia [3]. Recent studies have described the successful use of mirrors in the treatment of complex regional pain syndrome (CRPS) type I [4,5].

Using mirrors in patients who have had hand surgery

There are several implications of the mirror concept in rehabilitation of hands, for instance to facilitate mobilisation of dyscoordinated hands after reconstructive surgery when the "motor programme" must be re-acquired. Severe lack of coordination, with a non-functioning hand, is sometimes seen after trauma, particularly when pain is a problem. We have used the mirror concept also for treatment of severe hyperaesthesia after hand injuries in cases in which standard desensitisation programmes are not applicable because the injured hand cannot be touched because of excessive hypersensitivity. In such cases touching the *intact* hand gives a visual and perceptual illusion of touching the injured hand, and repeated training sessions seem to result in a central desensitisation effect with reduced hypersensitivity.

Treatment with a mirror also has a potential role in sensory re-education after repair of a major nerve trunk – before the hand has become reinnervated. In such cases *observation* of a tactile stimulus applied to the injured insensible hand may hypothetically activate neurons within the somatosensory cortex. In such cases the aim is to preserve the cortical

Correspondence: Birgitta Rosén, Department of Hand Surgery, Malmö University Hospital, SE-205 02 Malmö, Sweden. Tel: +46-40-33 19 34. Fax: +46-40-92 88 55. E-mail: birgitta.rosen@hand.mas.lu.se

(Accepted 9 September 2004)

ISSN 0284-4311 print/ISSN 1651-2073 online
DOI: 10.1080/02844310510006187

representation of the injured hand and to reduce or inhibit the profound reorganisation of the somatosensory cortex which would otherwise occur [6–8].

We present three cases in which the concept has been successfully used combined with traditional hand training.

Case reports

Case 1: Training with a mirror in a dyscoordinated hand after a cat bite

A 26-year-old right-handed woman presented with an infection secondary to a cat-bite dorsal to the second metacarpophalangeal joint of the right hand. At exploration of the joint a haematoma was drained. Despite training of the finger the patient did not regain active flexion. When she was first seen at our department one year after the injury she had a painful and dyscoordinated index finger, which could not be actively flexed (Figure 1*a*). Grip strength was 45% of the left hand, flexion of the thumb and index finger were not possible, and she was still on sick leave from her nursing work. The predominant problem was that the index finger was not used functionally and was not involved in gripping. A standard home programme with exercises to promote active and passive mobility and grip strength was combined with mirror training four times a day including a programme of bilateral exercises (Figure 2). After two weeks of intensive training, active flexion was regained to the extent of the passive mobility (Figure 1*b*), and the problematic digit was now a part of functional gripping. The mirror training was gradually withdrawn. Grip strength increased rapidly and after another four weeks was 85% of left hand. Pain during loaded activity was still a problem but the patient managed to handle that with transcutaneous nerve stimulation and she went back to work after three months.

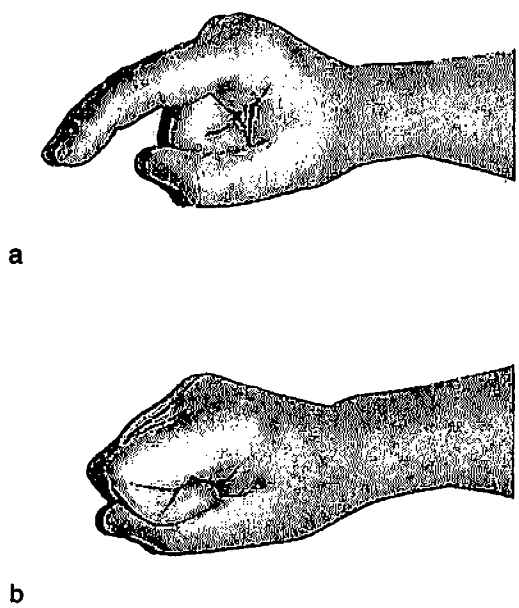

Figure 1. Case 1. Active flexion (*a*) before and (*b*) after two weeks training with the mirror.

Case 2: Training with a mirror after tendon transfers

A 58-year-old right-handed woman with rheumatoid arthritis had several operations on her dominant hand during a three-year period including decompressions of the median nerve and several tenosynovectomies. In addition, because the tendons ruptured, the flexor digitorum superficialis (FDS) tendon of the ring finger was transferred to the flexor pollicis longus (FPL) tendon, and the ruptured flexor digitorum profundus (FDP) tendons 2 and 3 were bridged by a palmaris longus (PL) graft. At a later stage the grafted FDP 2 and 3 tendons were sutured side-to-side to the FDP 4 and 5 tendons. Traditional early mobilisation was initiated but failed to achieve successful mobility of the thumb and index finger. After 18 months there was good passive motion but the hand was severely uncoordinated with no active function in the IP-joint of the thumb or PIP/DIP joints of the index finger, and no useful grip in those fingers.

At this point the patient was put on a practice schedule of mirror therapy twice a day. The training took place in a quiet environment and included moving both hands symmetrically in coordinated exercises according to a predefined programme, and with instructions to concentrate on the hand in the mirror. The specific exercises were followed by standard isolated active exercises and, between

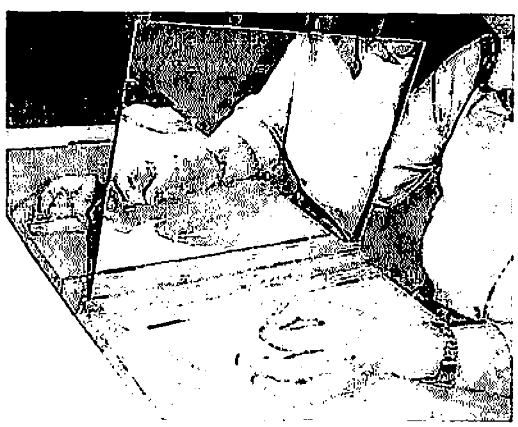

Figure 2. Case 1. Bilateral training with the mirror.

practice, a buddy-strap between digit II and the better functioning digit III was used. Ten days after initiation of the mirror training the patient could initiate flexion in the thumb and index fingers with good coordination, and after four weeks there was good active flexion in the interphalangeal (IP) joint of the thumb, and the proximal interphalangeal (PIP) joint of the index finger. After eight weeks the active flexion in these specific joints had increased to 50° and 45°, respectively, and the patient had pinch grip between digits I and II. During the next three months her mobility improved further with better coordination and she could use her hand for light activities of daily living.

Case 3: Training with a mirror to facilitate sensory re-education after repair of the median nerve

The right median nerve, transected to 95% at wrist level, was repaired in a 38-year-old left-handed man. Active mobilisation was started four weeks postoperatively. No motor deficits were noted (intact APB function), but perception of touch/pressure with Semmes-Weinstein monofilaments (SWM) was not testable in areas of the hand innervated by the median nerve. He had disturbing hyperaesthesia that required desensitisation exercises. At this time mirror-training was introduced based on a home programme twice daily consisting of bilateral and unilateral (uninjured hand) exercises: active movements of the hand including pinching; sensory re-education during concentration on the "mirror-hand" with localisation exercises, that is, active touch of a texture with single fingers (uninjured hand); and active touching of every-day objects such as sandpaper of varying roughness, cutlery and working tools (Figure 3*a*–*c*).

During the first training session, while he watched the illusion in the mirror of using and touching the injured hand, the patient spontaneously expressed a "strange feeling" in the digits that lacked sensibility. The injured hand was at this time just resting behind the mirror. After nine weeks SWM-testing at the tip of digits I, II, and III showed a response to filament number 6.65 (450 g), not testable, and number 6.65, respectively. At this point the patient started to work full time (construction work) and the specific training with the mirror was reduced to 2–3 times a week.

After 12 weeks the hand was fully mobile. Total score according to the *Model instrument for outcome after nerve repair* was unusually good; 1.8 (max: 3) [9], SWM at the tip of digits I, II, and III were number 6.65 (only perception of deep pressure was present being normal at this point), and there was of course no measurable tactile discrimination (2PD) or tactile identification: shape texture identification test (STI-test). However, the patient could localise accurately moving hard touch at each phalanx of digits I, II, and III.

Discussion

Cases 1 and 2 are examples of a classic dyscoordination, and the training was similar to that described in studies in which the mirror concept was used to treat musicians with dystonia [3] (bimanual symmetrical exercises). The objectives were to re-establish voluntary motor behaviour. The illusive effects of "correct" motor function from the mirror were probably increased by the fact that there was an intact sensory input in the injured hand. An afferent sensory inflow is necessary to perform well-coordinated movements. The cortical motor system is well-integrated with sensory cortical areas in the parietal lobe and the cerebellum, and humans can imagine making a movement without actually executing it, a phenomenon called *motor imagery* [10].

Case 3 was different. Four weeks after a nerve repair at wrist level there was no sensory function in the digits. The purpose of this early sensory relearning at a time point when the adjacent areas in the somatosensory brain cortex rapidly expand to occupy areas with no input [7], was to preserve the cortical "hand map", so making the re-learning easier for the patient once the affected parts of the hand were reinnervated [8]. Treatment with the mirror may also improve the motor recovery. It also seemed that in the initial unilateral exercises the patient could experience a "strange feeling" in the insensible digits. This illusive stimulation of an uninjured hand after a nerve repair may hypothetically give rise to contralateral and ipsilateral activation of the somatosensory cortex, and the ipsilateral activity might additionally strengthen the visual illusion of touch of the denervated hand in the mirror. An experience that the injured hand is touched – in reality an illusion based on touching the contralateral non-injured hand – may even strengthen the effect of the mirror.

A mirror-induced illusion of "being touched", mediated through the visual system, may be based on neurons in the somatosensory cortex activated by tactile stimulation of the hand as well as observation of tactile stimulation applied to the hand. This hypothesis is based on the occurrence of *mirror neurons* in the premotor cortex, which are activated at actions of the hand as well as by "observation" of hand actions, performed by others [11]. Such mirror phenomena have been reported to involve also areas within the somatosensory cortex [12]. In animal experiments the *execution* of such hand actions as well as *observation* of them done, performed by

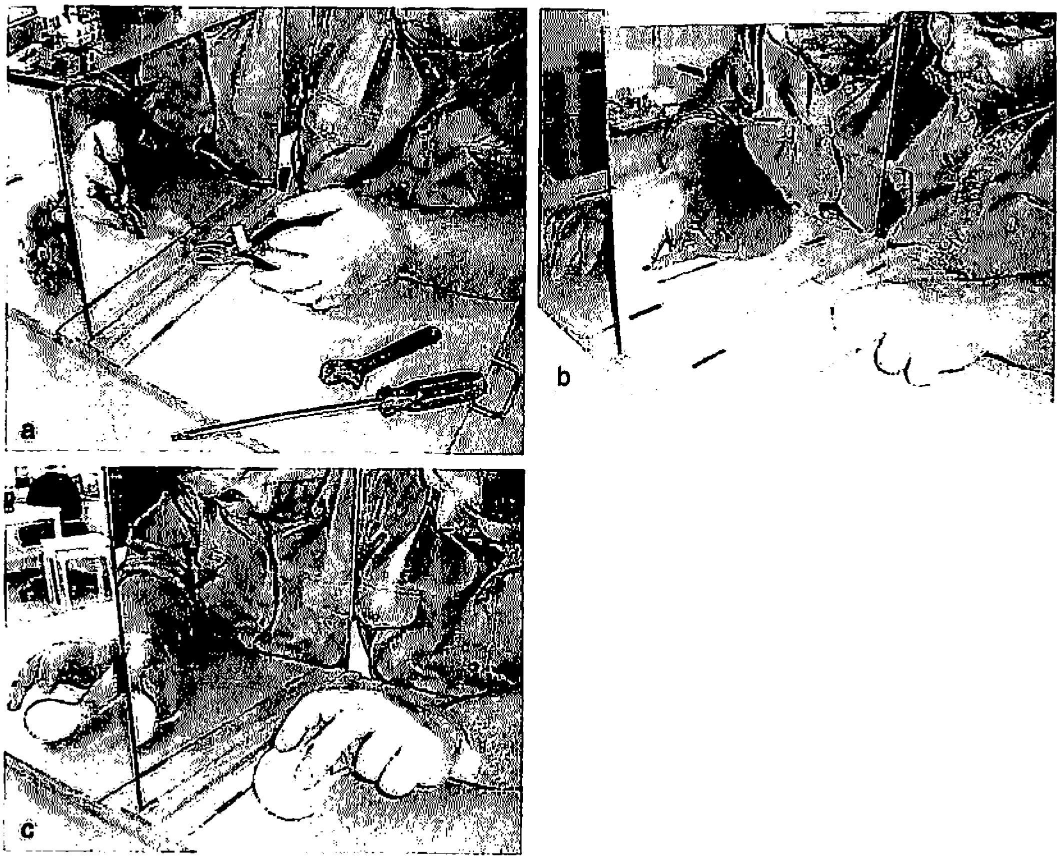

Figure 3. Case 3. (*a*) Unilateral training with working tools. (*b*) Unilateral active training with different textures of sandpaper. (*c*) Bilateral training for coordination and training with textures.

others, activate neurons in the premotor cortex [13]. It has been hypothesised that the frontal mirror-neuron system, known to facilitate motor output during observations of actions, may also modulate those somatosensory inputs which are directed to precentral areas [14].

We here demonstrate new applications of the "mirror therapy", and we feel that it has a place among the training strategies in the rehabilitation process after hand surgical interventions.

Acknowledgements

Our research on artificial sensibility is supported by grants from the Swedish Medical Research Council no 5188, The Swedish Brain Foundation, and Malmö University Hospital. We thank Dr Peter Kalén who operated on two of the patients.

References

[1] Ramachandran VS, Hirstein W. The perception of phantom limbs, The DO Hebb lecture. Brain 1998;121:1603–30.

[2] Altschuler E, Wisdom S, Stone L, Foster C, Galasko D, Llewellyn D, et al. Rehabilitation of hemiparesis after stroke with a mirror. Lancet 1999;353:2035–6.

[3] Byl NN, McKenzie A. Treatment effectiveness for patients with a history of repetitive hand use and focal hand dystonia: a planned, prospective follow-up study. J Hand Ther 2000;13:289–301.

[4] McCabe CS, Haigh RC, Ring EF, Halligan PW, Wall PD, Blake DR. A controlled pilot study of the utility of mirror visual feedback in the treatment of complex regional pain syndrome (type 1). Rheumatology 2003;42:97–101.

[5] Moseley GL. Graded motor imagery is effective for long-standing complex regional pain syndrome: a randomised controlled trial. Pain 2004;108:192–8.

[6] Lundborg G, Richard P. Bunge memorial lecture. Nerve injury and repair–a challenge to the plastic brain. J Peripher Nerv Syst 2003;8:209–26.

[7] Merzenich MM, Jenkins WM. Reorganization of cortical representations of the hand following alterations of skin inputs induced by nerve injury, skin island transfers, and experience. J Hand Ther 1993;6:89–104.

[8] Rosén B, Balkenius C, Lundborg G. Sensory re-education today and tomorrow: a review of evolving concepts. British Journal of Hand Therapy 2003;8:48–56.

[9] Rosén B, Lundborg G. A new model instrument for outcome after nerve repair. Hand Clin 2003;19:463–70.

[10] Naito E, Ehrsson HH. Kinesthetic illusion of wrist movement activates motor-related areas. Neuroreport 2001;12: 3805–9.

[11] Grezes J, Armony JL, Rowe J, Passingham RE. Activations related to "mirror" and "canonical" neurones in the human brain: an fMRI study. Neuroimage 2003;18: 928–37.

[12] Avikainen S, Forss N, Hari R. Modulated activation of the human SI and SII cortices during observation of hand actions. Neuroimage 2002;15:640–6.

[13] di Pellegrino G, Fadiga L, Fogassi L, Gallese V, Rizzolatti G. Understanding motor events: a neurophysiological study. Exp Brain Res 1992;91:176–80.

[14] Rossi S, Tecchio F, Pasqualetti P, Ulivelli M, Pizzella V, Romani GL, et al. Somatosensory processing during movement observation in humans. Clin Neurophysiol 2002;113: 16–24.