The clinical aspects of mirror therapy in rehabilitation: a systematic review of the literature

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The objective of this study was to evaluate the clinical aspects of mirror therapy (MT) interventions after stroke, phantom limb pain and complex regional pain syndrome. A systematic literature search of the Cochrane Database of controlled trials, PubMed/MEDLINE, CINAHL, EMBASE, PsycINFO, PEDro, RehabTrials and Rehadat, was made by two investigators independently (A.S.R. and M.J.). No restrictions were made regarding study design and type or localization of stroke, complex regional pain syndrome and amputation. Only studies that had MT given as a long-term treatment were included. Two authors (A.S.R. and S.M.B.) independently assessed studies for eligibility and risk of bias by using the Amsterdam–Maastricht Consensus List. Ten randomized trials, seven patient series and four single-case studies were included. The studies were heterogeneous regarding design, size, conditions studied and outcome measures. Methodological quality varied; only a few studies were of high quality. Important clinical aspects, such as assessment of possible side effects, were only insufficiently addressed. For stroke there is a moderate quality of evidence that MT as an additional intervention improves recovery of arm function, and a low quality of evidence regarding lower limb function and pain after stroke. The quality of evidence in patients with complex regional pain syndrome and phantom limb pain is also low. Firm conclusions could not be drawn. Little is known about which patients are likely to benefit most from MT, and how MT should preferably be applied. Future studies with clear descriptions of intervention protocols should focus on standardized outcome measures and systematically register adverse effects. *International Journal of Rehabilitation Research* 34:1–13 © 2011 Wolters Kluwer Health | Lippincott Williams & Wilkins.

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Introduction

In mirror therapy (MT), the patient sits in front of a mirror that is oriented parallel to his midline blocking the view of the (affected) limb, positioned behind the mirror. When looking into the mirror, the patient sees the reflection of the unaffected limb positioned as the affected limb. This arrangement is suited to create a visual illusion whereby movement of or touch to the intact limb may be perceived as affecting the paretic or painful limb. MT has been used to treat patients suffering from stroke (Altschuler *et al.*, 1999; Yavuzer *et al.*, 2008; Dohle *et al.*, 2009; Cacchio *et al.*, 2009b), complex regional pain syndrome (CRPS) (McCabe *et al.*, 2003; Moseley, 2004) and other pain syndromes such as peripheral nerve injury and following surgical interventions (Rosen and Lundborg, 2005; Gruenert-Pluess *et al.*, 2008). Three particular conditions that have been studied the most are stroke, CRPS and phantom limb pain (PLP) (Ezendam *et al.*, 2009).

The underlying mechanisms of the effects in these three patient groups have mainly been related to the activation of 'mirror neurones', which may also be activated when observing others perform movements and also during mental practice of motor tasks (Buccino *et al.*, 2006; Filimon *et al.*, 2007). Mirror neurons were found in areas of the ventral and inferior premotor cortex associated with observation and imitation of movements and in somatosensory cortices associated with observation of touch (Di Pellegrino *et al.*, 1992; Rizzolatti *et al.*, 1996; Keysers *et al.*, 2004). These cortical areas are supposed to be activated by MT (Stevens and Stoykov, 2003; Matthys *et al.*, 2009). Until now, direct evidence for the mirror-related recruitment of mirror neurons is lacking (Matthys *et al.*, 2009; Diers *et al.*, 2010; Michielsen *et al.*, 2010). Other potential mechanisms such as enhanced self-awareness and spatial attention by activation of the superior temporal gyrus, precuneus and the posterior cingulate cortex have been proposed (Rothgangel *et al.*, 2006; Matthys *et al.*, 2009; Michielsen *et al.*, 2010). The superior temporal gyrus is also thought to play an important role in recovery from neglect (Karnath, 2001; Karnath *et al.*, 2001), and is activated by observation of biological motion (Allison *et al.*, 2000).

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Recently three reviews on the topic of MT have been published (Ezendam *et al.*, 2009; Ramachandran and Altschuler, 2009; Seidel *et al.*, 2009), concentrating on the effectiveness of MT in different diseases. In contrast to these studies, our study focuses on the clinical aspects of MT interventions, which have not yet explicitly been addressed and in addition includes recently published papers. In addition, our study includes only those studies that had MT given as a long-term treatment, defined as more than two interventions. We defined 'clinical aspects' of MT interventions as a compound of clinically relevant factors that allow for reproduction of the intervention in daily practice. These include detailed information on treatment and patient characteristics, use of clinically relevant outcome measures and description of possible side effects of the intervention.

Thus, the main objective of this study was to conduct a systematic review on the clinical aspects of applying MT interventions after stroke, PLP and CRPS (Fig. 1).

Materials and methods

Criteria for considering studies for this review

Types of studies

The studies included in this review were all available articles published before August 2010 in English, German, French and Dutch. All randomized controlled trials (RCTs), nonrandomized controlled clinical trials (CCTs) and other studies (e.g. single-case studies or case series) evaluating the clinical aspects of MT were considered.

The articles were categorized according to their study design (Oxford Centre for Evidence-Based Medicine, 2009):

(1) Class I: randomized controlled studies;
(2) Class II: cohort studies and nonrandomized CCTs;
(3) Class III: case–control studies;
(4) Class IV: single-case studies and patient series.

Types of participants

All studies that involved adult patients (aged > 18 years) suffering from stroke, PLP or CRPS were included. No restrictions were made with regard to the type or localization of stroke, CRPS and amputation.

Types of interventions

To be included, studies had to have MT given as a long-term treatment, defined as more than two interventions, either as the only therapy intervention or in combination with other types of treatment strategies. Studies that included only one or two MT treatments to determine immediate effects were excluded.

For the purpose of this study, MT was defined as the use of a mirror reflection of unaffected limb movements superimposed on the affected extremity. Therefore, studies could use a parasagittal mirror or a modified mirror device (45°) suggesting movements made by the affected limb. Other illusory mechanisms such as using immersive virtual reality were excluded.

Types of outcome measures

According to the aim of this systematic study, trials were included only if they studied the effects of MT on at least one important clinical outcome, defined as measurements on the activity level in stroke patients and pain intensity in patients with CRPS and PLP, respectively. Studies that analysed only cortical mechanisms of MT using measurements such as functional magnetic resonance imaging (fMRI) or transcranial magnetic stimulation (TMS) were excluded.

Studies were also excluded if:

(1) Only the theoretical background of MT was investigated;
(2) Only the (conference) abstract was available.

Search strategy for identification of studies

Studies were identified by a computer-supported search through August 2010 using the following databases: Cochrane Database of controlled trials, PubMed/MEDLINE, CINAHL, EMBASE, PsycINFO, PEDro, RehabTrials and German databases such as DIMDI and Rehadat. The search strategy that was used for databases such as PubMed and Cochrane served as the main protocol and was then modified for searching other databases.

The following keywords were used: imagery, mirror, feedback/psychological, rehabilitation, therapy, stroke, amputation, phantom limb, complex regional pain syndromes and reflex sympathetic dystrophy. The detailed search strategies are available on request from the first investigator (A.S.R.).

Additional methods used included screening of the reference lists of identified articles, search on the investigators of identified studies and personal communication with experts in the field of MT.

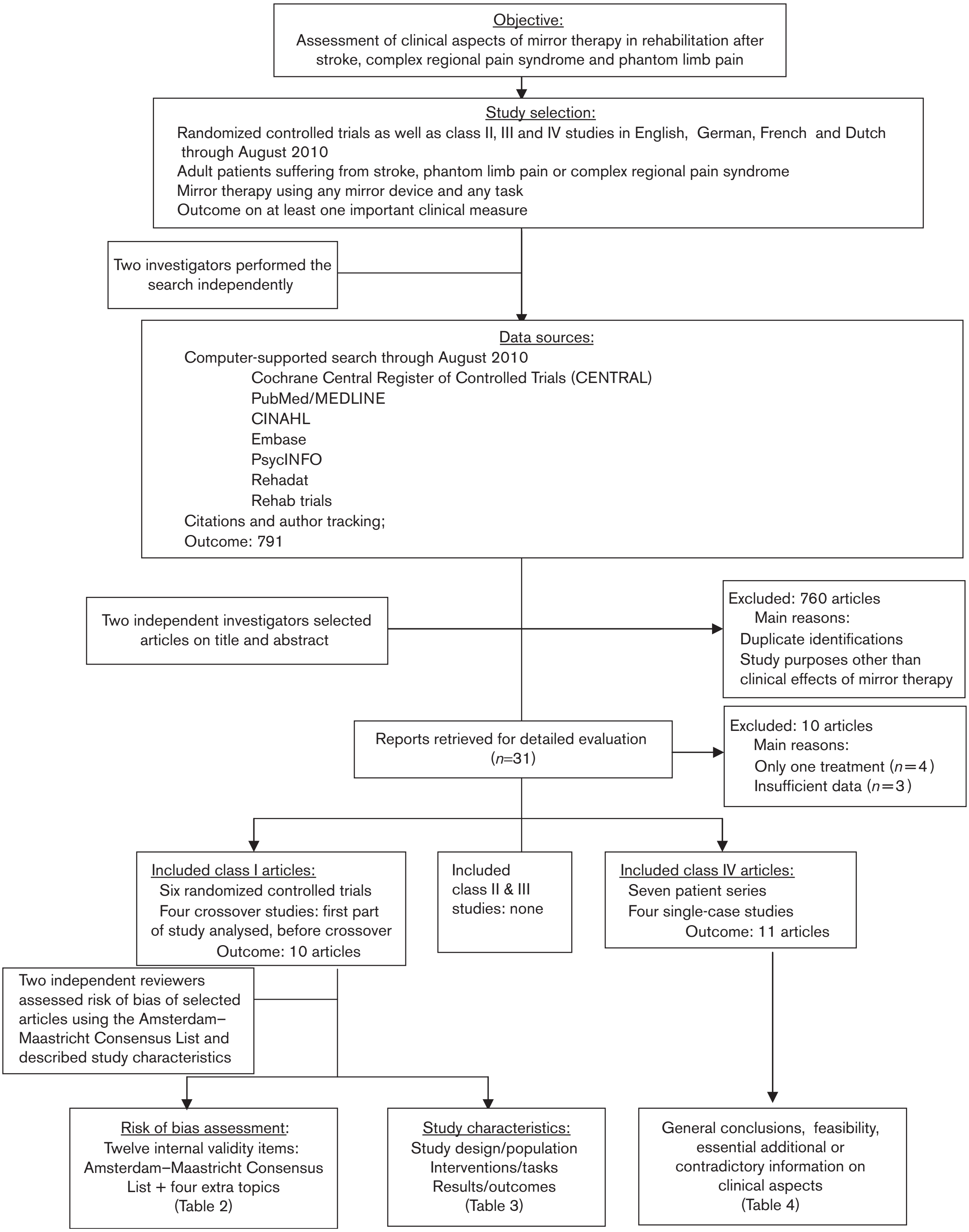
Data collection and analysis

All sources were searched independently by two investigators [A.S.R. (researcher) and Marsha Jussen (librarian)] by applying the stated selection criteria. Disagreement with regard to the study selection was resolved by consensus, and in the case of persisting disagreement a third investigator (S.M.B.) was consulted.

Assessment of risk of bias and clinical aspects

To assess the methodological quality of included RCTs and CCTs, we used the Amsterdam–Maastricht Consensus List (AMCL) for Quality Assessment (Van Tulder *et al.*, 2003) coupled with four additional items on quality

Fig. 1



Overview of study selection and risk of bias assessment.

Table 1 Risk of bias assessment of selected randomized trials with the Amsterdam–Maastricht consensus list for quality assessment

	Stroke							CRPS and PLP		
Items	Cacchio *et al.* (2009b)[a]	Cacchio *et al.* (2009a)	Sutbeyaz *et al.* (2007)	Yavuzer *et al.* (2008)	Dohle *et al.* (2009)	Rothgangel *et al.* (2004)	Altschuler *et al.* (1999)[a]	Moseley (2006)	Moseley (2004)[a]	Chan *et al.* (2007)[a]
1a Method of randomization	+	?	+	+	+	+	+	+	+	+
1b Concealment of allocation	?	?	+	+	+	?	?	+	?	?
2 Comparable subgroups at baseline	?	+	+	+	+	−	?	+	?	?
3 Blinded care provider	−	−	−	−	−	−	−	−	−	−
4 Correction for attention; same treatment (dose); cointervention	?	+	+	+	+	+	+	+	-	?
5 Acceptable compliance	?	+	+	+	+	+	+	+	?	?
6 Blinded patient	−	?	−	−	−	−	−	−	−	?
7a Acceptable withdrawals during intervention period	+	−	+	+	−	+	?	+	+	−
7b Lost to follow-up	NA	−	−	−	NA	+	−	+	+	NA
8 Blinded outcome assessor	+	+	+	+	+	+	+	+	+	?
9 Relevance measures	+	+	+	+	+	+	?	+	+	+
10a Timing assessment	+	+	+	+	+	+	+	+	+	+
10b Follow-up	NA	+	+	+	NA	−	−	+	+	NA
11 Intention to treat analysis	−	+	+	+	−	−	?	−	+	−
Total	3.5/11	7/11	8.5/11	8.5/11	6.5/11	6/11	4/11	8/11	5.5/11	2/11
Additional quality and clinical relevance items										
Intervention in detail	−	?	?	?	?	+	?	+	+	−
Side effects	−	−	−	−	?	+	−	?	−	+
Sample size *a priori*	−	+	+	+	+	−	−	+	+	−
Adequate statistics	+	+	+	+	+	+	?	+	+	?

Range: 0–11 points.
+, 1 point; −, 0 points; ?, 0 points; NA, not applicable.
Items 1a/b; 7a/b and 10a/b are scored as 0.5 points.
[a]Crossover studies rated as randomized controlled trials by analyzing the first part of the study only; before patients crossed over groups.

and clinical aspects (Van der Velde *et al.*, 2007; see Appendix). These can be seen in Table 1. Assessment of these clinical relevance factors is also recommended by the Cochrane Back Review Group (2010). Each criterion was checked for the availability of complete information and if insufficient information was given the criterion was scored as unclear (?, 0 points). If sufficient information was available the criterion was scored as either positive (+, 1 point) or negative (−, 0 points), leading to a maximum score of 11 points per study. We defined a study to have sufficient methodological quality if the score on the AMCL was equal to or above six points (Van Tulder *et al.*, 2001; Van Tulder *et al.*, 2003). Quality items were discussed by the two investigators (A.S.R., S.M.B.) beforehand, and a consensus method was used to resolve disagreements. If disagreements persisted, a third review investigator (A.J.B.) was consulted. The included studies were not blinded for investigators, institution or journal because the investigators who assessed the risk of bias were familiar with the literature.

Data extraction

Two investigators (A.S.R., S.M.B.) independently extracted data on study design, population, interventions and outcomes using a standardized extraction form. Disagreement between the reviewers with regard to the study characteristics was resolved before data were extracted.

Results

Study selection

Seven hundred and ninety-one articles were identified in the Cochrane Central Register of Controlled Trials ($n = 428$), PubMed/MEDLINE ($n = 193$), EMBASE ($n = 113$), PsycINFO ($n = 26$) and PEDro ($n = 31$). Seven hundred and sixty articles were rejected on the basis of their title and abstract, the main reasons being duplicate identifications and study purposes different from analysing clinical aspects of MT.

Thirty-one articles remained, of which the full-text was obtained. After reading the full-text versions of these studies, 10 articles were excluded due to the following reasons:

(1) Only one treatment (Ramachandran *et al.*, 1999; Brodie *et al.*, 2003; Brodie *et al.*, 2007; Sumitani *et al.*, 2008);
(2) Insufficient information on intervention and/or outcomes (Karmarkar and Lieberman, 2006; Altschuler and Hu, 2008; Gruenert-Pluess *et al.*, 2008);
(3) Orthopaedic conditions (Rosen and Lundborg, 2005);
(4) Control and intervention conditions too similar (Moseley, 2005);
(5) Two references to same study dataset (Stevens and Stoykov, 2004; Rothgangel *et al.*, 2007).

Description of studies

The 21 included studies consisted of 10 randomized trials, of which six were parallel group RCTs and four

Table 2 Overview of study characteristics of included randomized controlled trials

Stroke

Study/score	Design/participants	Interventions	Results/outcomes
Cacchio *et al.* (2009b) Score: 3.5/11	RCT Poststroke CRPS type I upper limb *n*=8 *n*=8, control group I *n*=8, control group II Median age: 62 years (range: 53–71 years) Chronic phase (median time poststroke: 14 months; range: 7–21 months)	Experimental group: parasagittal mirror Frequency: 30 min daily; 4 weeks Tasks: all cardinal movements of the affected arm (proximal-to-distal) 'How': not specified Control group I: Same movements; same duration but using covered mirror Control group II: Mental practice of the same movements with same duration	VAS (pain on movement), WMFT, brush-induced allodynia, edema Moments: once pretest; once after every week; once post-test after 4 weeks Significant reduction of pain intensity on movement (median change: −51 mm) in 88% of patients compared with 12% in control group I and 25% in control group II Improvement in motor function; allodynia and edema in favor of MT group (data not shown)
Cacchio *et al.* (2009a) Score: 7/11	RCT Poststroke CRPS type I upper limb *n*=22, experimental group *n*=20, control group Mean age: 57.9 years (SD=9.9 years) Subacute phase (<6 months; average time poststroke; 5.1 months; SD=2.5 months) Average duration of CRPS: 2.8 months (SD=1.3 months)	Experimental group: parasagittal mirror Frequency: first 2 weeks once daily for 30 min; second 2 weeks daily 60-min sessions; 4 weeks; add-on to conventional care Tasks: flexion/extension movements of shoulder, elbow and wrist, pronation and supination forearm Speed of movements self selected by patients 'How': moving only unaffected limb while watching mirror-reflection; without verbal feedback Control group: Same movements; same duration but using covered mirror All patients used no analgesics during study period	WMFT, MAL, VAS (at rest; during shoulder flexion movement and tactile allodynia with brush) Moments: once pretest; once post-test 1 week after termination of treatment; follow-up at 6 months Significant reduction of pain intensity at rest (mean change 3.3 in MT group vs. 0.3 in control group); during movement (mean change 3.6 in MT group vs. 0.1 in control group) and tactile allodynia (mean change 3.0 in MT group vs. 0.5 in control group) in favor of MT group Significant improvement on arm functioning and amount of daily arm use on WMFT (mean change 1.5 in MT group vs. −0.2 in control group) and MAL (mean change 2.2 in MT group vs. 0.1 in control group) in favor of MT group Effects still observed at 6 months follow-up
Sutbeyaz *et al.* (2007) Score: 8.5/11	RCT Stroke-lower extremity *n*=20, experimental group *n*=20, control group Mean age: 62.7 years Subacute phase (<12 months; average time poststroke; 3.5 months)	Experimental group: parasagittal mirror Frequency: once daily for 30 min; 5 days/week; 4 weeks; add-on to conventional care Tasks: flexion/extension movements of nonparetic ankle 'How': moving nonaffected ankle while watching mirror-reflection; without verbal feedback Control group: Same treatment protocol and frequency but with observation of nonreflective side of mirror	FAC, FIM, MAS; Brunnstrom stages Moments: once pretest; once post-test 4 weeks after end of intervention period; follow-up at 6 months Significant differences between groups at follow-up on FIM (mean improvement +21.4 in MT group vs. +12.5 in control group) and Brunnstrom stages (mean improvement +1.7 in MT vs. +0.8 in control group) in favor of MT group No significant differences on MAS and FAC
Yavuzer *et al.* (2008) Score: 8.5/11	RCT Stroke upper extremity *n*=20, experimental group *n*=20, control group Mean age: 63.2 years (range: 49–80 years) Subacute phase (<12 months; average time poststroke; 5.4 months; range: 3–12 months)	Experimental group: parasagittal mirror Frequency: once daily for 30 min; 5 days/week; 4 weeks; add-on to conventional care Tasks: flexion/extension movements of wrist and fingers 'How': symmetrically moving nonaffected and affected limb 'as good as possible' while watching mirror-reflection Control group: Same treatment protocol and frequency but with observation of nonreflective side of mirror	FIM, MAS, Brunnstrom stages (upper limb) Moments: once pretest; once post-test after 4 weeks therapy; follow-up at 6 months Significant differences between groups at follow-up on FIM (mean improvement +8.3 in MT group vs. +1.8 in control group) and Brunnstrom stages (mean improvement +1.5 in MT vs. +0.4 in control group) in favour of MT group No significant differences on MAS
Dohle *et al.* (2009) Score: 6.5/11	RCT Stroke upper extremity *n*=18, experimental group *n*=18, control group Mean age: 54.9 years Postacute phase (<8 weeks; average time poststroke=26.2 days)	Experimental group: parasagittal mirror Frequency: once daily for 30 min; 5 days/week; 6 weeks; add-on to conventional care Tasks: different arm-, hand- and finger-postures indicated by numbers provided by verbal feedback of therapist 'How': symmetrically moving nonaffected and affected limb 'as good as possible' while watching mirror-reflection Control group: Same treatment protocol and frequency but with direct observation of affected arm	ARAT, FIM, Fugl-Meyer, neglect scores: BIT and TAP Moments: once pretest; once posttest after 6 weeks therapy; no follow-up Significant differences between groups on Fugl-Meyer sensory subscale (mean improvement +0.8 in MT group vs. 0.2 in control group) and neglect score (mean improvement +0.9 in MT group vs. +0.2 in control group) in favor of MT group No significant differences between groups after 6 weeks therapy on ARAT; FIM and Fugl-Meyer score; tendency regarding finger function in initial plegic patients (mean improvement Fugl-Meyer +4.4 in MT group vs. +1.5 in control group; ARAT: +2.5 vs. +0.4) No effect regarding lesion locus or latency of stroke on outcomes

Table 2 (*continued*)

Study/score	Design/participants	Interventions	Results/outcomes
Stroke			
Rothgangel *et al.* (2004) Score: 6/11	RCT Stroke upper extremity *n*=8, experimental group *n*=8, control group Two subgroups: inpatient (*n*=10) and outpatient (*n*=6) group Median age: 73.0 years; range: 62–87 (outpatient group) and 79.0 years; range: 49–87 (inpatient group) Chronic phase (>3 months; median time poststroke: 12 months)	Experimental group: parasagittal mirror Frequency: (a) inpatient group: twice daily for 30 min; 4 days/week; 5 weeks; (b) outpatient group: twice daily 30 min; 2 days/week; 5 weeks Tasks: gross arm/hand movements; patient-specific functions (grasping and reaching); fine motor movements of fingers 'How': (a) patients with higher muscle tone: active movements with nonparetic arm; paretic arm facilitated by therapist; (b) patients with lower muscle tone: bilateral active movements; assisted by therapist Control group: Same treatment protocol and frequency but without using a mirror; direct observation of affected arm	ARAT, PSK, MAS Moments: once a pretest; once after 2.5 weeks therapy and once a post-test after 5 weeks therapy; follow-up 10 weeks after pretest Significant differences on ARAT outcome between inpatient groups in favour of MT group after 5 weeks (mean change score +8.4 in MT group vs. +1.2 in control group) but groups differed at baseline Clinically relevant differences on ARAT outcome also between outpatient groups Significant differences on PSK between groups in favor of MT; but 'flawed' by patients' perspective Less effect of MT on MAS
Altschuler *et al.* (1999) Score: 4/11	RCT Stroke upper extremity *n*=4, experimental group *n*=5, control group Mean age: 58.2 years Chronic phase (>6 months; average time poststroke: 4.9 years)	Experimental group: parasagittal mirror Frequency: twice daily for 15 min; 6 days/week; 4 weeks Tasks: starting with movements patients could perform, followed by movements they could not (not specified) 'How': bilateral symmetrical arm and hand movements (moving the affected arm 'as good as possible') Control group: Same treatment protocol and frequency but using transparent plastic instead of mirror	Videotapes of cardinal movements of upper extremity rated by two blinded senior neurologists; (scale range: −3 to +3; assessing change in ROM; speed and accuracy) Subjective comments of treated patients Moments: once a pretest; once after 2 weeks therapy; once a post-test after 4 weeks intervention No follow-up Slightly more improvement of cardinal movements of upper extremity in MT group than in control group Patients reported increased motivation through MT
Complex regional pain syndrome and phantom limb pain			
Moseley (2006) Score: 8/11	RCT CRPS type I upper and lower extremities; amputation of upper and lower extremities and brachial plexus avulsion injury *n*=17, experimental group; *n*=20 control group (CRPS) *n*=5, experimental group; *n*=4 control group (amputation) *n*=3, experimental group; *n*=2 control group (brachial plexus avulsion injury) Mean age: 41 years Chronic phase (mean duration of symptoms: 14 months)	Experimental intervention: graded motor imagery Frequency: daily home training; 6 weeks; additionally weekly consultation of PT to monitor home exercises Tasks: different postures of hand or foot 'How': GMI consisting of three stages (each stage lasting 2 weeks) as home training (a) Recognition of limb laterality: 107 pictures per day (mean) of hand/foot postures shown on monitor (b) Mental practice: mentally adopting 40 different hand/foot postures per day (mean) shown on photographs (c) Mirror therapy: 45 pictures of unaffected hand/foot per day (mean); adopting posture shown on picture with both limbs while observing mirror reflection Control intervention: At least one PT intervention/week; 6 weeks; additional home training with comparable training load as experimental group; Restrictions: no exercises similar to GMI Both groups received interventions in addition to usual medical care; patients were advised not to change type or dosage of medication	Patient-specific functions on NRS; pain severity on VAS; MPQ Evaluation of home exercises: log Moments: once a pretest; once a post-test; after 6 weeks therapy and once follow-up at 6 months Significant differences between groups in favour of GMI group on VAS (mean improvement +24 mm in GMI group vs. +10.5 mm in control group) and function on NRS (mean improvement +2.2 points in GMI group vs. +0.6 points in control group) after 6 weeks therapy and at follow-up No effect of duration of symptoms on pain outcome
Moseley (2004) Score: 5.5/11	RCT CRPS type I upper extremity after noncomplicated wrist-fracture *n*=7, experimental group *n*=6, control group Mean age: 35 years Chronic phase (>6 months; average duration: 51 weeks)	Experimental intervention: graded motor imagery Frequency: each waking hour; daily; 6 weeks Tasks: different postures of hand or foot 'How': GMI consisting of three stages (each stage lasting 2 weeks) (a) Recognition of hand laterality: three sets of 56 pictures of hand postures shown on monitor (approximately 10 min) each waking hour; (b) Imagined hand movements: mentally adopting 28 hand postures three times shown on pictures (approximately 15 min) each waking hour (c) Mirror therapy: 20 pictures of unaffected hand; adopting posture shown on picture with both hands 10 times while observing mirror reflection; each waking hour	NPS; circumference of second and third digs by hand measuring tape; hand laterality recognition time by software Evaluation of home exercises: log Moments: once a pretest; once after 2 and 4 weeks therapy; once a post-test after 6 weeks intervention No follow-up Significant differences between groups regarding pain intensity and quality on NPS; distal edema and hand laterality recognition time after 6 weeks therapy in favour of GMI group Effect sizes after 6 weeks therapy: NPS points: 20; NPS intensity: 3; finger circumference (millimetre): 9

Table 2 (*continued*)

Complex regional pain syndrome and phantom limb pain			
Study/score	Design/participants	Interventions	Results/outcomes
		Control intervention: Ongoing management; no limitations on treatment (waiting list control) Patients were advised not to change type or dosage of medication	
Chan *et al.* (2007) Score: 2/11	RCT Traumatic amputation of lower limb; military hospital $n=6$, experimental group $n=6$, control group I $n=6$, control group II	Experimental intervention: parasagittal mirror Frequency: 15 min daily; 4 weeks Tasks: different movements of feet (not specified) 'How': observing mirror reflection while attempting to move both feet Control intervention I Same frequency and movements while observing nonreflective side of mirror Control intervention II Mental practice with comparable frequency: imaging moving the amputated limb with eyes closed	VAS; number and duration of pain episodes Moments: once a pretest; once after every week of therapy and once a post-test after 4 weeks therapy No follow-up Significant differences between groups in favour of MT group on VAS (median improvement +24 mm; range: +13 to +54 mm; data in control groups not specified) Decreased number and duration of pain episodes; all patients in MT group reported decrease in pain (vs. 17% in control group I; 33% in control group II; respectively) 33% of patients in experimental group reported 'adverse effects' (grief)

ARAT, action research arm test; BIT, behavioral inattention test; CRPS, complex regional pain syndrome; FAC, functional ambulation categories; FIM, functional independence measure; GMI, graded motor imagery; MAL, motor activity log; MAS, modified Ashworth scale; MPQ, McGill pain questionnaire; MT, mirror therapy; NPS, numeric pain scale; NRS, numeric rating scale; PSK, patient specific functional scale; PT, physical therapy; RCT, randomized controlled trials; ROM, range of motion; SD, standard deviation; TAP, tests of attentional performance; VAS, visual analogue scale; WMFT, Wolf motor function test.

were crossover studies. The data from the studies are shown in Table 2. We analysed the crossover studies as RCTs because we only extracted data from the first part of the studies, before participants crossed over to the control conditions, to avoid methodological problems associated with crossover study designs (Friedman *et al.*, 1998). No class II and III studies were identified but we retrieved eleven class IV studies (Table 3). Studies were very heterogenous in design, size, conditions studied and outcomes measured, as shown in Table 4.

The methodological quality also varied as shown in Table 1, and few were high quality; methodological quality scores ranged from 2 to 8.5 points on the AMCL; most of the higher quality randomized studies were conducted in stroke patients regarding upper limb functions, with four studies scoring equal to or higher than six points on the AMCL. In patients with CRPS (including two studies on poststroke CRPS) only two RCTs (Moseley, 2006; Cacchio *et al.*, 2009a) and in patients with PLP only one randomized study (Moseley, 2006) showed satisfactory methodological quality. All studies failed in blinding care providers and patients, and only 40% of the trials reported adequate concealment of allocation. With regard to the clinical aspects of MT interventions, the lack of attention to potential adverse effects from the therapy and the sparse description of the treatment protocol are notable.

Stroke

All six randomized trials investigating the effects of MT as an additional therapy involving stroke patients showed similar results in a positive direction for arm function. Individual studies suggested positive effects on leg function (Sutbeyaz *et al.*, 2007) and on sensation and neglect (Dohle *et al.*, 2009), whereas two studies showed that MT reduced pain intensity and tactile allodynia in patients with CRPS type I after stroke (Cacchio *et al.*, 2009a, 2009b).

Three different intervention characteristics were identified: the patient was encouraged to move the affected limb 'as good as possible' (Altschuler *et al.*, 1999; Yavuzer *et al.*, 2008; Dohle *et al.*, 2009), movements were only performed by the unaffected limb (Sutbeyaz *et al.*, 2007; Cacchio *et al.*, 2009a) or movements of the affected limb were facilitated by the therapist (Rothgangel *et al.*, 2004). The time between stroke and onset of the intervention varied from 26 days (Dohle *et al.*, 2009) to 27 months (Altschuler *et al.*, 1999), with the majority of trials including patients of no more than 12 months poststroke. The study carried out by Dohle *et al.* (2009) suggests a correlation between the severity of paresis and amount of functional improvement by MT. Nevertheless, it was not possible to discern any firm evidence that patient characteristics or specific treatment characteristics had any influence.

Complex regional pain syndrome

In patients with CRPS type I (including two studies on poststroke CRPS), MT alone (Cacchio *et al.*, 2009a, 2009b) or in combination with limb laterality recognition and mental practice, also called as 'graded motor imagery' (Moseley, 2004, 2006), showed positive results in all four randomized studies. It should be noted that the study carried out by Moseley (2006) included CRPS patients and patients suffering from PLP, without presenting separate results for each patient group.

Table 3 **Study characteristics of included class IV studies**

Study	Design/participants	Interventions	Results/outcomes
Stroke			
Miltner *et al.* (2000)	Patient series $n=23$, stroke $n=14$, TBI Mean age: 52.9 years (stroke); 35.9 years (TBI) Chronic phase (>6 months; average time post-stroke: 44.5 months; range = 6–122 months; average time post-TBI: 28.5 months; range = 8–103 months)	Experimental intervention: MT + AO + MP Frequency: 20-min daily; 4 weeks in addition to conventional care Tasks: grasping and reaching a cup in 12 different positions 'How': affected arm facilitated by therapist during grasping and reaching movements (part I approximately 10 min) Part II: AO + MP: video observation of movements of unaffected arm from a first-person perspective combined with MP (approximately 10 min)	Three experts rating videos of patients performing grasping movements on a 11-point-Likert Scale Muscle strength (MRC grading); MAS; sensory assessment (mirroring and NIH grading) Moments: once a pretest; once a post-test after 4 weeks therapy No follow-up Significant improvement in grasping movements and muscle tone in stroke patients Less effect on muscle strength and sensory domain More improvement in stroke patients than in patients with TBI and in moderate paresis than in severely or slight affected patients
Stevens and Stoykov (2003)	Patient series Left and right MCA infarction; cortical and subcortical stroke $n=2$ Man aged 63 years and women aged 76 years Chronic phase (14 months and 6 years 2 months poststroke)	Experimental intervention: AO + MP + MT Frequency: three times per week 60 min MIP; 4 weeks Tasks: reaching/object interaction; extension; pronation and supination; movements of wrist 'How': observation of computer-generated movies depicting movements of affected arm from three different angles + speeds; followed by MP of observed movements (part I = approximately 25 min) Part II: mirror-box facilitated MP: 1 week identifying mirror reflection as affected limb; 2–3 weeks: simple object manipulation tasks; week 4: complex object manipulation (approximately 30 min)	Jebsen Test of hand function; Chedoke McMaster Stroke Scale; Fugl-Meyer; grip strength; wrist ROM Moments: once a pretest; once after 1 and 2.5 weeks; once a post-test after 4 weeks therapy and two times follow-up at 1 and 3 months after termination of treatment Improvements on Fugl-Meyer; grip strength; ROM and performance times on Jebsen during intervention period; less during follow-up Better movement imagery ability in both patients after the intervention
Sathian *et al.* (2000)	Single-case report; thalamus and internal capsule infarction left hemisphere; neglect and sensory loss Man: aged 57 years Chronic phase (6 months poststroke)	Experimental intervention: MT + MP + CIMT Frequency: weekly PT visits over approximately 3 months period aimed at directing and monitoring home program Tasks: different bimanual movements (not specified) 'How': attempting bimanual upper extremity movements using a mirror box followed by MP of somatosensory cues from both limbs with eyes closed (phase I) Phase II: forced-use of upper limb soon after motor functions improved by phase I Patient kept on practicing several hours/day with the mirror on his own during phase II	Performance times of tasks 'cup to mouth'; 'picking up a pen'; 'folding towel in quarters' and 'draping towel over shoulders'; functional reach test; grip strength; release time; flexion; abduction and external rotation of glenohumeral joint Moments: once a pretest; once a post-test approximately after 3 months therapy Functional arm improvement (extended functional reach and performance times on functional tasks) Improvement in grip strength; release time and shoulder abduction ROM No effect on somatosensory functions on neurological testing
Pott (2001)	Single case report; subcortical haemorragic stroke right hemisphere; neglect and sensory loss Lower extremity Man Chronic phase (5 years poststroke)	Experimental intervention: MP + MT + FT Frequency: three times per week 50 min complex PT intervention incl. MT; 5 weeks add-on to standard care Tasks: knee flexion and foot dorsiflexion movements 'How': MP by visualizing movement tasks followed by active bilateral movements of lower limb using a mirror; additional facilitation by therapist. At the end of each intervention training of functional tasks (gait; steps) without mirror	Motor Function Assessment Scale; ankle ROM; muscle force (MRC); sensory assessment (mirroring); gait assessment using video analysis and 10 m walking test Moments: once a pretest; once a post-test after 12 weeks No follow-up Positive effects on functional abilities; active ROM; muscle tone and -force and sensory domain
Complex regional pain syndrome and phantom limb pain			
McCabe *et al.* (2003)	Patient series CRPS type I of upper and lower limb $n=3$, acute phase (<8 weeks) $n=2$, intermediate duration (5 months and 1 year) $n=2$, long-standing disease (>2 years) Mean age: 33 years; range: 24–40 years	Experimental intervention: parasagittal mirror Frequency: ongoing PT interventions + daily MT sessions as often as patients wished to use mirror; maximum 10 min/session; 6 weeks Tasks: bilateral circular and flexion/extension movements; speed and range of movement dictated by patient's pain	VAS; pain diary; vasomotor changes with IRT; log Moments: once pretest; once post-test after 6 weeks intervention No follow-up Significant reduction of pain intensity on VAS in five out of eight patients (acute-intermediate duration)

Table 3 (*continued*)

Complex regional pain syndrome and phantom limb pain			
Study	Design/participants	Interventions	Results/outcomes
	Average disease duration: 1 year 5 months (range: 3 week–3 years)	'How': if possible movements of unaffected and affected limb in a congruent manner; while observing mirror reflection Two 'control phases' before experimental intervention (approximately 5 min): (a) visualizing both limbs (direct visual feedback) (b) viewing covered mirror with painful limb hidden; same movements as in experimental condition	Normalization in vasomotor changes of affected limb Three out of eight patients were pain-free after 6 weeks therapy Five out of eight patients significantly reduced their analgesic requirements correlation between MT frequency and duration of analgesic effect Three out of eight patients (chronic phase) stopped after 3 weeks therapy because of no effect
Tichelaar *et al.* (2007)	Patient series CRPS type I upper and lower limb $n=3$ Man: aged 23 years; women: aged 42 and 46 years Chronic phase (8 months, 2 years 6 months and 9 years)	Experimental intervention: MT + CBT Frequency: second week 3 × daily two sessions for 5 min in addition to desensitization therapy; third week: 5 × daily two sessions for 5 min Tasks: first week: detoxification; second and third week: little; pain-free movements only of unaffected limb; if some movements were possible with affected limb; patients performed tasks also with affected limb 'How': affected limb hidden by mirror; watching mirror reflection of unaffected limb with imagination of bilateral movements	VAS (at rest and after strength testing and allodynia); hand-held dynamometer; goniometer; brush and monofilament Moments: once a pretest; once a week during therapy and once a post-test after the intervention period (at 5; 8 and 14 weeks respectively) No follow-up Only one patient improved on pain; ROM; strength and area of allodynia Less or no effect in other two patients Correlation between duration of symptoms, extend of 'foreignness' of affected limb and outcome Reduced medication intake in two out of three patients at the end of intervention
Selles *et al.* (2008)	Patient series CRPS type II (causalgia) upper limb after traumatic nerve injury $n=2$ Women: aged 33 and 36 years Chronic phase (6 months and 3 years 2 months)	Experimental intervention: parasagittal mirror Frequency: after initial PT session home delivered MT; 3–5 × daily for approximately 15 min/session; 3 weeks (patient 1) and 5 months (patient 2) Tasks: no standardized protocol; self-chosen movements 'How': phase I: only moving unaffected hand with imagination that both hands are moving; Phase II: bilateral hand movements; PT touched unaffected limb while patients focused mirror reflection	Short-term pain relief on VAS (patient 1), long-term pain relief on VAS (patient 2) Moments: once presession; once during each session and once after each session (patient 1); once a pretest; once a post-test after 5 months therapy (patient 2) Significant short-term pain relief (for approximately 30–45 min) in patient 1 and long-term pain relief in patient 2 Reduction in medication intake in both patients at the end of intervention Patients reported increased arm functioning
Mercier and Sirigu (2009)	Patient series; single-case multiple baseline study, $n=6$, brachial plexus avulsion injury $n=2$, amputation upper extremity Mean age: 37 years; range: 19–54 years Chronic phase (mean duration of symptoms 6.75 years; range: 1–16 years)	Experimental intervention: inverted image of unaffected arm in a 45° oriented mirror Frequency: two sessions (30–60 min) per week; 8 weeks; each session consisted of 10 tasks; 10 repetitions each Tasks: gross arm and hand movements (e.g. flexion/extension movements of elbow and wrist); fine motor tasks (e.g. precision grip with small objects) and functional tasks (grasping a glass; dialing phone number) 'How': movements of unaffected limb filmed; inverted and projected on computer screen. Reflection of computer screen image in a 45° oriented mirror is superimposed on affected limb	Short-term pain relief at every session; long-term pain relief over intervention period; daily pain diary (background pain; paroxysms during day; number and duration) Moments: at the end of every week; baseline period before intervention (varying from 1 to 5 weeks); during 8 weeks therapy and during 4 weeks follow-up Significant pain relief in five out of eight patients (30% pain reduction or more); average pain relief 38% (range: −13.8 to 93.5%) No correlation between long-term pain relief and duration of symptoms No association between type of phantom limb sensation and outcome
Giraux and Sirigu (2003)	Patient series Brachial plexus avulsion injury, $n=3$ Men: aged 18, 40 and 41 years Chronic phase (6 months; 2 years and 5 years)	Experimental intervention: inverted image of unaffected arm in a 45° oriented mirror Frequency: three sessions per week; 8 weeks; each session consisted of 100 arm and hand movements Tasks: opening/closing hand; finger-opposition movements; grasping various objects; sessions started with simple and slow movements; then speed and complexity increased 'How': movements of unaffected limb filmed; inverted and projected on computer screen Reflection of computer screen image in a 45° oriented mirror is superimposed on affected limb; patients attempted to move both limbs while watching the mirror reflection	Average pain on VAS; percentage of pain relief on VAS; fMRI Moments: once a pretest; once a post-test after 8 weeks therapy No follow-up Significant pain relief in two out of three patients (80 and 40% pain relief respectively) One patient showed no improvement; fMRI revealed increased activity of M1 in affected hemisphere in the two patients who improved Significant reduction of medication intake at the end of intervention

Table 3 (*continued*)

Complex regional pain syndrome and phantom limb pain			
Study	Design/participants	Interventions	Results/outcomes
Maclachlan *et al.* (2004)	Single-case study Through hip amputation after necroting facilities $n=1$ Man: aged 32 years Chronic phase (NS)	Experimental intervention: MT + MP Frequency: 2–3 × daily 10 × 10 movements of leg and foot; 3 weeks Tasks: standardized movements of knee; foot and toes (e.g. flexion/extension movements; pronation/supination; abduction/adduction) 'How': first week MT under supervision of PT; during week-end self-delivered; second week reduced supervision of PT; 3–4 × daily self-delivered during week-end; third week: exercises without mirror and supervision (MP)	NRS; motor control over phantom limb (0–100%) Moments: once pretest and once post-test after 3 weeks therapy No follow-up Significant reduction of pain intensity (patient had no longer phantom limb pain) and improved control over phantom limb Patient reports straightening of phantom limb from a shrinked position at the end of the intervention
Darnall (2009)	Single-case study Traumatic above knee amputation $n=1$ Man: aged 35 years Chronic phase (approximately 1 year postamputation)	Experimental intervention: MT + MP Frequency: home delivered MT: 3 × /week 20–30 min; later 30 min daily over 3 months; in addition five 60 min psychology sessions for information and supervision during 3 months Tasks: no standardized protocol; self-chosen movements (mainly movements of foot; flexion/extension; rotation; touching big toe); in addition daily breathing and PMR techniques (25 min) Patient did MP for 3 months before intervention to relief pain; he kept on doing MP at work during intervention period 'How': mirror placed longitudinally against a table; exercises of intact foot while watching mirror reflection	BPI; NRS Moments: once a pretest; once a post-test after 3 months therapy No follow-up Significant improvement on pain intensity and impairments (patient was pain-free and had no longer impairments in ADL at the end of intervention period) Patient reported strong correlation between MT frequency and pain intensity Significant reduction of medication intake at the end of intervention

ADL, activities of daily living; AO, action observation; BPI, brief pain inventory; CBT, cognitive behavioral therapy; CIMT, constraint induced movement therapy; fMRI, functional magnetic resonance imaging; FT, functional training; IRT= infrared thermography; M1, primary motor cortex; MAS, modified Ashworth scale; MCA, middle cerebral artery; MP, mental practice; MRC, medical research council; MT, mirror therapy; NIH, National Institute of health; NRS, numeric rating scale; NS, not significant; PMR, progressive muscle relaxation; PT, physical therapy; ROM, range of motion; TBI, traumatic brain injury; VAS, visual analogue scale.

Table 4 Summary of selected class I and IV studies

Class I studies	Pathology	Site	Type of intervention	Effects	Total *n* (patients)
Altschuler *et al.* (1999); Rothgangel *et al.* (2004); Yavuzer *et al.* (2008); Dohle *et al.* (2009)	Stroke	UE	Parasagittal mirror	Functions, sensibility, neglect	101
Cacchio *et al.* (2009a; 2009b)	Poststroke CRPS	UE	Parasagittal mirror	Pain, functions	66
Sutbeyaz *et al.* (2007)	Stroke	LE	Parasagittal mirror	Functions	40
Moseley (2004; 2006)	CRPS type I	UE; LE	GMI	Pain, functions, edema	50
Chan *et al.* (2007); Moseley (2006)	PLP	UE; LE	Parasagittal mirror (Chan *et al.*; 2007) GMI (Moseley; 2006)	Pain, functions	32
Class IV studies	**Pathology**	**Site**	**Type of intervention**	**Effects**	**Total *n* (patients)**
Miltner *et al.* (2000); Stevens and Stoykov (2003); Sathian *et al.* (2000)	Stroke	UE	MT and MP and AO or CIMT	Functions, muscle tone, grip strength, ROM	26
Pott (2001)	Stroke	LE	MT, MP and FT	Functions, ROM, muscle tone, sensibility	1
McCabe *et al.* (2003); Tichelaar *et al.* (2007)	CRPS type I	UE; LE	MT and MT + CBT	Pain, vasomotor changes, ROM	10
Selles *et al.* (2008)	CRPS type II	UE	Parasagittal mirror	Pain	2
Mercier and Sirigu (2009); Giraux and Sirigu (2003); Maclachlan *et al.* (2004); Darnall (2009)	PLP	UE; LE	MT and MT + MP	Pain, impairments	13

AO, action observation; CBT, cognitive behavioral therapy; CIMT, constraint induced movement therapy; CRPS, complex regional pain syndrome; FT, functional training; GMI, graded motor imagery; LE, lower extremity; MP, mental practice; MT, mirror therapy; PLP, phantom limb pain; ROM, range of motion; UE, upper extremity.

In contrary to the studies of stroke patients, trials in patients with CRPS did not include active movements of the affected limb in their treatment protocols during the first weeks. Instead, unilateral pain-free movements of the unaffected limb were used (Cacchio *et al.*, 2009a, 2009b), or MT was preceded by other cognitive treatment strategies such as limb laterality recognition or mental practice (Moseley, 2004, 2006). Compared with the studies including stroke patients, a higher treatment frequency (several sessions per day) was used in CRPS trials.

Phantom limb pain

The two studies that investigated the effects of MT (Chan *et al.*, 2007) and graded motor imagery (Moseley, 2006) on PLP in patients following amputation of the upper or lower limb or brachial plexus avulsion, found positive results regarding patient-specific functions (Moseley, 2006) and pain intensity and number and duration of pain episodes (Moseley, 2006; Chan *et al.*, 2007). Unfortunately, the description of study characteristics in the publication of Chan *et al.* (2007) was sparse.

Additional information from class IV studies

The uncontrolled studies support the findings from the class I studies. In contrary to the randomized trials in stroke patients, the intervention used in all class IV studies consisted of a combination of MT with other cognitive treatment strategies such as mental practice or action observation (Sathian *et al.*, 2000; Miltner *et al.*, 2000; Stevens and Stoykov, 2003). Outcomes from CRPS trials further suggest that the degree of 'foreignness' of the affected limb as perceived by the patient and the duration of symptoms of CRPS could play an important role as a prognostic factor regarding the success of a MT intervention (McCabe *et al.*, 2003; Tichelaar *et al.*, 2007).

Discussion

Ten randomized studies are included in this systematic review. Studies are heterogenous in design, use different measures at different times and often include small numbers of unrepresentative patients. In addition, important clinical aspects of MT interventions such as a detailed description of the treatment protocol and possible side effects are only insufficiently addressed. Thus, meta-analysis and completing a GRADE-table was not possible, and the results could be overturned by upcoming trials; all conclusions should thereby be considered with caution. For systematic reviews and meta-analysis, the Cochrane Collaboration recommends presenting the overall quality of evidence using the GRADE-approach (Grading of Recommendations Assessment, Development and Evaluation). Because of the heterogeneity of included studies this was not possible in our study. In stroke patients, we found a moderate quality of evidence that MT as an additional therapy improves recovery of arm function after stroke. The quality of evidence regarding the effects of MT on the recovery of lower limb functions is still low, with only one RCT (Sutbeyaz *et al.*, 2007) reporting effects. In patients with CRPS and PLP, the quality of evidence is also low (Guyatt *et al.*, 2008).

Patient characteristics

Because of the limited evidence of included studies, no firm conclusions could be drawn regarding the important question of which patients might benefit more than others from this kind of treatment. The studies were too small and data were not provided in a way that allowed firm conclusions. But it seems reasonable that patients with insufficient attention and information processing are less capable for this kind of treatment, as focusing on the mirror image demands adequate cognitive capacities. Whether MT is more effective for stroke patients with severe paresis, as proposed by Dohle *et al.* (2009), has to be further evaluated.

Treatment characteristics

In addition, the evidence did not allow any conclusions to be drawn with regard to specific details of treatment, what may be more or less effective. As still several clinical methods are used in treating stroke and pain patients with MT interventions, future studies have to identify which treatment characteristics are more effective than others, enabling the design for clinical protocols. Remarkably, only two studies have reported on adverse effects of an MT intervention (Chan *et al.*, 2007; Casale *et al.*, 2009), finding them to be clinically significant and not infrequent. In the retrospective study of Casale *et al.* (2009), 29 out of 33 patients with PLP withdrew from MT treatment because of side effects such as grief, confusion or dizziness. These results show the potential adverse reactions that can be induced by the intervention and are in line with the results as that of Moseley *et al.* (2008), who showed that motor imagery led to increased pain and swelling in patients with chronic arm pain. Similar observations were made in other studies (Fink *et al.*, 1999; McCabe *et al.*, 2005). Consequently, given the moderate quality of evidence for beneficial effects one cannot support widespread uncritical clinical use of this technique until there is stronger evidence of benefit and evidence that it outweighs any risk or harm.

Strength and weaknesses of this study

The main strength of our study is that we focused on important clinical aspects regarding a relatively new intervention, and used systematic and explicit methods in identifying relevant trials. Furthermore, we think that we provided a comprehensive overview on the topic, adding recently published trials that have not been assessed before. This study also has some limitations. Owing to the heterogeneity of identified studies and the small number of patients it was impossible to give precise guidance on the right target group for MT. Furthermore, conclusions about which particular method of MT in which phase of recovery might be more effective, were not possible. It was not easy to define MT, because a mirror is simply one way of achieving a visual illusion. Moreover, although it is likely that using the search term 'mirror' would result in identifying all studies that used mirrors to achieve a visual illusion, it is possible that some studies were missed. It is also difficult to distinguish clearly between studies that focus on immediate or short-term effects, often neurophysiological, and those that study long-term and clinical effects. Despite these limitations, we probably identified most of the randomized trials to give an informative overview on the clinical aspects of MT.

Conclusion

The work on MT needs to be considered in the context of any new treatment modality. Early enthusiasm attracts many researchers to experiment on small groups of selected patients, often with weak study designs and a variety of measures. This can be seen, for example, in the use of mental imagery and practice (Braun *et al.*, 2006) and in the application of new drugs such as cannabis extracts (Hosking and Zajicek, 2008). The benefit of a relatively early systematic study, such as this, is that it may draw attention to some important points that should be considered in the design of future research. Future studies should try to identify patients who might profit more by MT than others, to guide more specific intervention through MT. Included studies did not provide sufficient information on the clinical protocols used. Therefore, detailed clinical protocols are urgently needed. The assessment of potential risks of a new intervention is mandatory in patient-reported outcomes to decide on the clinical utility of a treatment. Future studies must systematically register adverse effects. One possibility to weigh risks and benefits could be the use of standardized assessments as proposed by Boers *et al.* (2010). To answer these questions there is a need of multicentre studies using a smaller number of standardized and clinically relevant outcome measures that investigate the effects of MT in routine clinical settings (Langhorne *et al.*, 2009).

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References

Allison T, Puce A, McCarthy G (2000). Social perception from visual cues: role of the STS region. *Trends Cogn Sci* **4**:267–278.

Altschuler EL, Hu J (2008). Mirror therapy in a patient with a fractured wrist and no active wrist extension. *Scand J Plast Reconstr Surg Hand Surg* **42**:110–111.

Altschuler EL, Wisdom SB, Stone L, Foster C, Galasko D, Llewellyn DM, Ramachandran VS (1999). Rehabilitation of hemiparesis after stroke with a mirror. *Lancet* **353**:2035–2036.

Boers M, Brooks P, Fries JF, Simon LS, Strand V, Tugwell P (2010). A first step to assess harm and benefit in clinical trials in one scale. *J Clin Epidemiol* **63**:627–632.

Braun SM, Beurskens AJ, Borm PJ, Schack T, Wade DT (2006). The effects of mental practice in stroke rehabilitation: a systematic review. *Arch Phys Med Rehabil* **87**:842–852.

Brodie EE, Whyte A, Waller B (2003). Increased motor control of a phantom leg in humans results from the visual feedback of a virtual leg. *Neurosci Lett* **341**:167–169.

Brodie EE, Whyte A, Niven CA (2007). Analgesia through the looking-glass? A randomized controlled trial investigating the effect of viewing a 'virtual' limb upon phantom limb pain, sensation and movement. *Eur J Pain* **11**:428–436.

Buccino G, Solodkin A, Small SL (2006). Functions of the mirror neuron system: implications for neurorehabilitation. *Cogn Behav Neurol* **19**:55–63.

Cacchio A, De Blasis E, De Blasis V, Santilli V, Spacca G (2009a). Mirror therapy in complex regional pain syndrome type 1 of the upper limb in stroke patients. *Neurorehabil Neural Repair* **23**:792–799.

Cacchio A, De Blasis E, Necozione S, Di Orio F, Santilli V (2009b). Mirror therapy for chronic complex regional pain syndrome type 1 and stroke. *N Engl J Med* **361**:634–636.

Casale R, Damiani C, Rosati V (2009). Mirror therapy in the rehabilitation of lower-limb amputation: are there any contraindications? *Am J Phys Med Rehabil* **88**:837–842.

Chan BL, Witt R, Charrow AP, Magee A, Howard R, Pasquina PF, *et al.* (2007). Mirror therapy for phantom limb pain. *N Engl J Med* **357**:2206–2207.

Cochrane Back Review Group (2010). Clinical relevance assessment form [online resource]. *http://www.cochrane.iwh.on.ca/pdfs/Clinrel_assess_April2008.pdf* (Accessed 8 February 2011).

Darnall BD (2009). Self-delivered home-based mirror therapy for lower limb phantom pain. *Am J Phys Med Rehabil* **88**:78–81.

Di Pellegrino G, Fadiga L, Fogassi L, Gallese V, Rizzolatti G (1992). Understanding motor events: a neurophysiological study. *Exp Brain Res* **91**: 176–180.

Diers M, Christmann C, Koeppe C, Ruf M, Flor H (2010). Mirrored, imagined and executed movements differentially activate sensorimotor cortex in amputees with and without phantom limb pain. *Pain* **149**:296–304.

Dohle C, Pullen J, Nakaten A, Kust J, Rietz C, Karbe H (2009). Mirror therapy promotes recovery from severe hemiparesis: a randomized controlled trial. *Neurorehabil Neural Repair* **23**:209–217.

Ezendam D, Bongers RM, Jannink MJ (2009). Systematic review of the effectiveness of mirror therapy in upper extremity function. *Disabil Rehabil* **31**:2135–2149.

Filimon F, Nelson JD, Hagler DJ, Sereno MI (2007). Human cortical representations for reaching: mirror neurons for execution, observation, and imagery. *Neuroimage* **37**:1315–1328.

Fink GR, Marshall JC, Halligan PW, Frith CD, Driver J, Frackowiak RS, Dolan RJ (1999). The neural consequences of conflict between intention and the senses. *Brain* **122 (Pt 3)**:497–512.

Friedman LM, Furberg CD, DeMets DL (1998). *Fundamentals of clinical trials*. 3rd ed. New York: Springer.

Giraux P, Sirigu A (2003). Illusory movements of the paralyzed limb restore motor cortex activity. *Neuroimage* **20 (Suppl 1)**:S107–S111.

Gruenert-Pluess N, Hufschmid U, Santschi L, Gruenert J (2008). Mirror therapy in hand rehabilitation: a review of the literature, the St Gallen protocol for mirror therapy and evaluation of a case series of 52 patients. *Br J Hand Ther* **13**:4–9.

Guyatt GH, Oxman AD, Vist GE, Kunz R, Falck-Ytter Y, Alonso-Coello P, Schunemann HJ (2008). GRADE: an emerging consensus on rating quality of evidence and strength of recommendations. *BMJ* **336**:924–926.

Hosking RD, Zajicek JP (2008). Therapeutic potential of cannabis in pain medicine. *Br J Anaesth* **101**:59–68.

Karmarkar A, Lieberman I (2006). Mirror box therapy for complex regional pain syndrome. *Anaesthesia* **61**:412–413.

Karnath HO (2001). New insights into the functions of the superior temporal cortex. *Nat Rev Neurosci* **2**:568–576.

Karnath HO, Ferber S, Himmelbach M (2001). Spatial awareness is a function of the temporal not the posterior parietal lobe. *Nature* **411**:950–953.

Keysers C, Wicker B, Gazzola V, Anton JL, Fogassi L, Gallese V (2004). A touching sight: SII/PV activation during the observation and experience of touch. *Neuron* **42**:335–346.

Langhorne P, Coupar F, Pollock A (2009). Motor recovery after stroke: a systematic review. *Lancet Neurol* **8**:741–754.

Maclachlan M, McDonald D, Waloch J (2004). Mirror treatment of lower limb phantom pain: a case study. *Disabil Rehabil* **26**:901–904.

Matthys K, Smits M, Van der Geest JN, Van der LA, Seurinck R, Stam HJ, Selles RW (2009). Mirror-induced visual illusion of hand movements: a functional magnetic resonance imaging study. *Arch Phys Med Rehabil* **90**:675–681.

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

McCabe CS, Haigh RC, Halligan PW, Blake DR (2005). Simulating sensory-motor incongruence in healthy volunteers: implications for a cortical model of pain. *Rheumatology (Oxford)* **44**:509–516.

Mercier C, Sirigu A (2009). Training with virtual visual feedback to alleviate phantom limb pain. *Neurorehabil Neural Repair* **23**:587–594.

Michielsen ME, Smits M, Ribbers GM, Stam HJ, Van der Geest JN, Bussmann JB, Selles RW (2010). The neuronal correlates of mirror therapy: an fMRI study on mirror induced visual illusions in patients with stroke. *J Neurol Neurosurg Psychiatry* [Epub ahead of print].

Miltner R, Netz J, Hömberg V (2000). Cognitive treatment of sensomotor dysfunctions [in German]. *Pt Zeitschrift f Physiotherapeuten* **52**:954–964.

Moseley GL (2004). Graded motor imagery is effective for long-standing complex regional pain syndrome: a randomised controlled trial. *Pain* **108**:192–198.

Moseley GL (2005). Is successful rehabilitation of complex regional pain syndrome due to sustained attention to the affected limb? a randomised clinical trial. *Pain* **114**:54–61.

Moseley GL (2006). Graded motor imagery for pathologic pain: a randomized controlled trial. *Neurology* **67**:2129–2134.

Moseley GL, Zalucki N, Birklein F, Marinus J, Van Hilten JJ, Luomajoki H (2008). Thinking about movement hurts: the effect of motor imagery on pain and swelling in people with chronic arm pain. *Arthritis Rheum* **59**:623–631.

Oxford Centre for Evidence-based Medicine (2009). Levels of evidence [online]. *http://www.cebm.net/index.aspx?o=1025* (Accessed 8 February 2011).

Pott C (2001). Integration of mirror therapy in an ADL-oriented approach for outpatient neurological rehabilitation of a patient following stroke [in German]. *Pt Zeitschrift f Physiotherapeuten* **8**:1314–1332.

Ramachandran VS, Altschuler EL (2009). The use of visual feedback, in particular mirror visual feedback, in restoring brain function. *Brain* **132**:1693–1710.

Ramachandran VS, Altschuler EL, Stone L, Al-Aboudi M, Schwartz E, Siva N (1999). Can mirrors alleviate visual hemineglect? *Med Hypotheses* **52**:303–305.

Rizzolatti G, Fadiga L, Gallese V, Fogassi L (1996). Premotor cortex and the recognition of motor actions. *Brain Res Cogn Brain Res* **3**:131–141.

Rosen B, Lundborg G (2005). Training with a mirror in rehabilitation of the hand. *Scand J Plast Reconstr Surg Hand Surg* **39**:104–108.

Rothgangel AS, Morton A, Van den Hout JWE, Beurskens AJHM (2004). Phantoms in the brain: mirror therapy in chronic stroke patients; a pilot study. *Ned Tijdschr Fys* **114**:36–40.

Rothgangel A, de Bie RA, Bastiaenen CHG, Van Oostenbrugge R, Backes W, Hofman P (2006). The role of the mirror neuron system in rehabilitation with mirror therapy following middle cerebral artery infarction: a pilot fMRI study-51. Annual Meeting of the German Society of Medical Informatics, Biometry and Epidemiology (GMDS), Leipzig.

Rothgangel AS, Morton A, Van den Hout JWE, Beurskens AJHM (2007). Mirror therapy in rehabilitation after stroke: effectiveness on upper limb functioning in chronic stroke patients. *Neur Rehab* **13**:271–276.

Sathian K, Greenspan AI, Wolf SL (2000). Doing it with mirrors: a case study of a novel approach to neurorehabilitation. *Neurorehabil Neural Repair* **14**:73–76.

Seidel S, Kasprian G, Sycha T, Auff E (2009). Mirror therapy for phantom limb pain: a systematic review. *Wien Klin Wochenschr* **121**:440–444.

Selles RW, Schreuders TA, Stam HJ (2008). Mirror therapy in patients with causalgia (complex regional pain syndrome type II) following peripheral nerve injury: two cases. *J Rehabil Med* **40**:312–314.

Stevens JA, Stoykov ME (2003). Using motor imagery in the rehabilitation of hemiparesis. *Arch Phys Med Rehabil* **84**:1090–1092.

Stevens JA, Stoykov ME (2004). Simulation of bilateral movement training through mirror reflection: a case report demonstrating an occupational therapy technique for hemiparesis. *Top Stroke Rehabil* **11**:59–66.

Sumitani M, Miyauchi S, McCabe CS, Shibata M, Maeda L, Saitoh Y, *et al.* (2008). Mirror visual feedback alleviates deafferentation pain, depending on qualitative aspects of the pain: a preliminary report. *Rheumatology (Oxford)* **47**:1038–1043.

Sutbeyaz S, Yavuzer G, Sezer N, Koseoglu BF (2007). Mirror therapy enhances lower-extremity motor recovery and motor functioning after stroke: a randomized controlled trial. *Arch Phys Med Rehabil* **88**:555–559.

Tichelaar VYIG, Geertzen JHB, Keizer D, Van Wilgen CP (2007). Mirror box therapy added to cognitive behavioural therapy in three chronic complex regional pain syndrome type I patients: a pilot study. *Int J Rehab Res* **30**:181–188.

Van der Velde G, Van Tulder M, Cote P, Hogg-Johnson S, Aker P, Cassidy JD, *et al.* (2007). The sensitivity of review results to methods used to appraise and incorporate trial quality into data synthesis. *Spine* **32**:796–806.

Van Tulder MW, Ostelo R, Vlaeyen JW, Linton SJ, Morley SJ, Assendelft WJ (2001). Behavioral treatment for chronic low back pain: a systematic review within the framework of the Cochrane Back Review Group. *Spine* **26**:270–281.

Van Tulder M, Furlan A, Bombardier C, Bouter L (2003). Updated method guidelines for systematic reviews in the cochrane collaboration back review group. *Spine (Phila Pa 1976)* **28**:1290–1299.

Yavuzer G, Selles R, Sezer N, Sutbeyaz S, Bussmann JB, Koseoglu F, *et al.* (2008). Mirror therapy improves hand function in subacute stroke: a randomized controlled trial. *Arch Phys Med Rehabil* **89**:393–398.

Appendix

Criteria for positive scoring on additional quality items (see also Van der Velde *et al.*, 2007).

(1) Calculation of sample size *a priori*: for a positive scoring the authors of the study have to describe the procedure of sample size calculation and present the calculated numbers of participants.

(2) Intervention described in detail: the review author judges whether the intervention was described in detail to allow replication of the intervention.

(3) Side effects assessed: if the authors of the study described additional observed effects regarding the intervention (e.g. evaluation of the process, practicability, response of patients) this item is scored positive.

(4) Adequate statistics used: the review author judges whether appropriate statistical methods were used with regard to the outcome measurements and number of groups and patients studied.