Mirror therapy with bilateral arm training for hemiplegic upper extremity motor functions in patients with chronic stroke

KNK Fong *, KH Ting, CCH Chan, LSW Li

KEY MESSAGES

1. Mirror therapy has an incongruent visual feedback induced by mirror, which makes it different from bilateral arm training.
2. Mirror therapy and bilateral arm training are useful in enhancing hemiplegic arm functions in patients with chronic stroke, with significant benefits to the distal hand functions in mirror therapy.
3. In an electroencephalographic study to observe a mirror illusion attributed to mirror neuron system for stroke and healthy participants, event-related desynchronisation in beta bands particularly the Beta rhythm (17-35 Hz) in both contralateral and ipsilateral motor cortices reflected that action observation for motor preparation in stroke patients was much reduced and might affect motor learning.

Hong Kong Med J 2019;25(Suppl 3):S30-4
HMRF project number: 01121966

[1] KNK Fong, [1] KH Ting, [1] CCH Chan, [2] LSW Li

[1] *Department of Rehabilitation Sciences, The Hong Kong Polytechnic University*
[2] *Tung Wah Hospital*

* Principal applicant and corresponding author: rsnkfong@polyu.edu.hk

Introduction

We hypothesised that a mirror visual feedback illusion enhanced hemiplegic arm functions in mirror therapy (MT) compared with bilateral arm training (BAT), and that there was recruitment of the mirror neurons, as reflected by event-related desynchronisation (ERD), mediating the recognition of the mirror illusion during MT, in patients with chronic stroke. We aimed (1) to compare the effects of MT with those of BAT on improving the motor functions of the hemiplegic upper extremity for patients with chronic stroke; and (2) to examine, using electroencephalography (EEG), whether recruitment of the mirror neurons, as reflected in the form of ERD, mediated recognition of the mirror visual feedback during MT, and to compare with that in BAT, in patients with chronic stroke and their healthy counterparts.

Methods

The study was divided into two parts. Part 1 was a single-blinded randomised controlled trial comparing the MT and BAT groups. Data were collected at baseline, at 6 weeks after treatment, and at 3-month follow-up. Part 2 involved cross-sectional EEG measurement for consenting participants in both groups to investigate the instant brain response on MT compared with that in BAT.

Patients with chronic stroke from community self-help groups or referred from outpatient clinics in the Hong Kong Hospital Authority West Cluster were recruited by convenience sampling. Inclusion criteria were: (1) neurological condition with unilateral hemiparesis, (2) a Functional Test of Hemiplegic Upper Extremity – Hong Kong version score of levels 2 to 6, (3) chronic stroke with onset of neurological condition >6 months previously, (4) ability to understand and follow simple verbal instructions, (5) ability to participate in a therapy session lasting at least 30 minutes, and (6) community ambulant with or without aids. Individuals with severe neglect and severe spasticity were excluded. In part 2 of the study, similar numbers of healthy counterparts matched to the stroke group in terms of demographics were recruited as controls. The study was performed in accordance with the principles of the Declaration of Helsinki. Only participants who had given written informed consent were included.

Part 1

For both groups, the training programme consisted of 12 sessions (two per week for 6 weeks), each lasting for 30 minutes. The mirror box apparatus (406 × 432 mm) was placed at the midsagittal plane of the participant. The movement practice involved five table-top tasks. Participants were instructed to perform a maximum of 30 trials per task in each session, giving a total of 150 trials per session. The period of each training session (activities graded according to the levels of severity of affected arm impairment in the Functional Test of Hemiplegic

Upper Extremity) lasted for 30 minutes. The only difference between the two groups was the use of a mirror.

All participants had to complete the 6-week training programme delivered by two occupational therapists. In the MT group, each participant practiced the movements with the unaffected arm (including elbow, wrist, and hand). While watching the reflection of the unaffected arm in the mirror, the participant was asked to move the affected arm at the same time to imitate/synchronise the movement with the mirror reflection of the unaffected arm. If the participant was unable to move the arm, the therapist would passively assist the movement of the affected hand so as to synchronise it with the reflection of the unaffected hand. In the BAT group, the participant practiced bimanual arm exercises using the same movement strategies but without a mirror; a direct view of the affected hand was allowed.

A blinded assessor carried out outcome assessments of upper limb performance using the Fugl-Meyer Assessment, the Action Research Arm Test, and the Wolf Motor Function Test.

Part 2

Each participant sat in a comfortable chair and placed both arms on a table in front of them. EEG was recorded with a 64-channel cap referenced to left mastoid connected to SymAmps2 amplifier (Neuroscan, Charlotte [NC], USA). There were two task conditions for EEG capturing: (1) with the affected arm at rest while the unaffected arm is moving, and (2) viewing the unaffected arm while the mirror was covered (ie, sham mirror).

TABLE. Baseline characteristics of the study population*

Variable	Part 1				Part 2		
	Total (n=101)	Mirror therapy (n=51)	Bilateral arm training (n=50)	P value	Mirror therapy (n=11)	Bilateral arm training (n=9)	P value
Age, years	58.3±10.0	58.2±9.5	58.4±10.6	0.927	56.6±10.5	54.7±16.9	0.970
Sex				0.352			0.199
Male	65 (64.4)	35 (68.6)	30 (60.0)		8 (72.7)	4 (44.4)	
Female	36 (35.6)	16 (31.4)	20 (40.0)		3 (27.3)	5 (55.6)	
Duration from onset, months	26.8±38.9	30.2±46.8	23.3±29.1	0.371	63.6±85.4	54.0±41.9	0.676
Hemiplegic side				0.609			0.964
Right	56 (55.4)	27 (52.9)	29 (58.0)		5 (45.5)	4 (44.4)	
Left	45 (44.6)	24 (47.1)	21 (42.0)		6 (54.5)	5 (55.6)	
Recruitment site				0.756			-
Hospital	17 (16.8)	8 (15.7)	9 (18.0)		0 (0)	0 (0)	
Self-help groups	84 (83.2)	43 (84.3)	41 (82.0)		11 (100)	9 (100)	
Arm functioning				0.886			0.964
Higher	33 (32.7)	17 (33.3)	16 (32.0)		5 (45.5)	4 (44.4)	
Lower	68 (67.3)	34 (66.7)	34 (68.0)		6 (54.5)	5 (55.6)	
Functional Test for Hemiplegic Upper Extremity – Hong Kong version score	3.9±1.6	4.0±1.7	3.8±1.5	0.564	4.4±1.6	4.3±1.2	0.876
Fugl-Meyer Assessment score	29.0±16.4	29.3±17.1	28.6±15.9	0.829	29.5±13.1	27.7±18.6	0.704
Upper limb subscore	19.4±9.2	19.2±9.6	19.5±8.8	0.868	18.9±7.8	18.8±11.2	0.970
Hand subscore	9.6±8.3	10.0±8.6	9.1±8.0	0.572	10.6±6.4	8.8±7.8	0.401
Action Research Arm Test score	18.3±19.9	19.2±20.4	17.3±19.5	0.646	23.4±21.3	19.3±22.1	0.337
Grasp subscore	5.6±6.9	6.0±7.1	5.3±6.8	0.649	7.7±7.7	6.1±6.9	0.503
Grip subscore	4.2±4.7	4.3±4.7	4.0±4.6	0.729	5.3±5.2	4.8±5.2	0.781
Pinch subscore	4.0±6.4	4.2±6.6	3.9±6.4	0.842	4.8±6.9	4.8±7.4	0.714
Gross subscore	4.4±3.5	4.7±3.4	4.1±3.6	0.376	5.5±3.1	3.7±3.9	0.278
Wolf Motor Function Test							
Functional ability subscore	28.6±18.8	28.5±19.5	28.7±18.2	0.949	28.8±15.9	26.1±18.1	0.594
Grip subscore	5.7±6.4	6.1±6.4	5.3±6.4	0.482	5.1±4.5	6.0±3.6	0.594

* Data are presented as mean±standard deviation or No. (%) of participants

Results

Part 1

A total of 101 patients with stroke (17 from Tung Wah Hospital, 75 from self-help groups) were randomised to either the MT (n=51) or BAT (n=50) group. Two participants in the MT group and three participants from the BAT group dropped out who were eventually included in intention-to-treat analysis. The two groups were comparable in terms of baseline characteristics (Table). Both groups improved significantly after training, except for gross subscore of Action Research Arm Test in MT (P=0.069) and BAT (P=0.199). Repeated measures ANOVA showed a significant between-group treatment effect (F=4.360, P=0.050) and a significant group-time interaction (F=3.527, P=0.033) for the Fugl-Meyer Assessment hand subscore; there were no significant between-group differences for other outcome measures.

Part 2

Of 20 patients (11 with left hemiplegia and 9 with right hemiplegia from the self-help groups), 11 from the MT group and 9 from the BAT group voluntarily participated in EEG measurement. The two groups were comparable in terms of baseline characteristics.

Twenty (12 men and 8 women) healthy counterparts (mean age, 61.3 years) were recruited by convenience sampling from social networks in the community. They were asked to use their dominant hands (all right-handed) as active hands to move; therefore, only stroke patients with left hemiplegia were compared with the healthy counterparts for evaluation of instant training effects. After pre-processing, data of six healthy participants and one stroke patient with left hemiplegia were excluded, owing to insufficient clean epochs for further analysis. Data of 10 stroke patients with left hemiplegia and 14 normal healthy counterparts were analysed.

Event-related spectrum perturbations at C3 and C4 during 400-1100 ms were averaged in 8-10 Hz (alpha-1 band), 10-12 Hz (alpha-2 band), 12-16 Hz (sensorimotor rhythm [SMR] band), and the new beta band defined as 17-35 Hz. A mixed effects ANOVA was performed with the within-subject factor of task condition (real mirror vs covered [sham] mirror), hemisphere (contralateral vs ipsilateral to the trained hand), and the between-subject factor of group (normal heathy participant vs stroke patient) in the alpha-1, alpha-2, sensorimotor rhythm, and beta bands separately. In alpha-1 band, there was neither a significant main effect nor an interaction effect. In alpha-2 band, the ANOVA only revealed a marginal significant main effect of group [F (1, 22)=4.026, P=0.057]. The three-way ANOVA also failed to reveal any significant effect in sensorimotor rhythm band (12-16 Hz). However, in beta band (17-35 Hz), there was a significant interaction effect of hemisphere*group [F (1,22)=10.546, P=0.004] and a significant main effect of hemisphere [F (1, 22)=27.156, P<0.0001]. These findings suggest that stroke patients showed significantly less suppressed in beta band compared with healthy controls, and that both groups showed greater suppression on the contralateral motor area (C3). Further examination on the effect of mirror*group in contralateral and ipsilateral motor area found that there was a significant task condition effect at the contralateral motor area (C3) with a F ratio of F (1,22)=4.989, P=0.036, showing that both groups have more suppression at C3 in the covered mirror condition. Figure 1 shows the topography of the alpha and beta rhythm in unimanual hand movement task with mirror and covered mirror task conditions in the group of stroke patients and normal healthy participants.

An asymmetry index was calculated from the subtraction of the event-related spectrum perturbations between C3 (contralateral motor area) and C4 (ipsilateral motor area) to account for the difference of activity between contralateral and ipsilateral motor areas. ANOVA analysis was carried out to explore the effect of task condition and group on this index in alpha-1, alpha-2 and beta bands. Significant main effects of group on the asymmetry index were found in the beta band [F (1, 22)=8.680, P=0.007] (Fig 2).

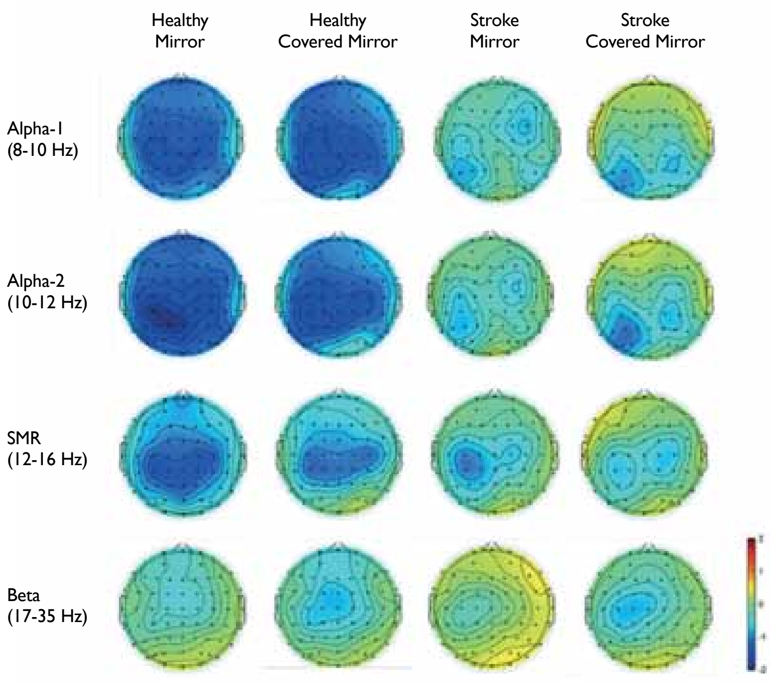

FIG 1. Topography of the alpha and beta rhythm in unimanual hand movement task with mirror and covered mirror task conditions in stroke and healthy participants

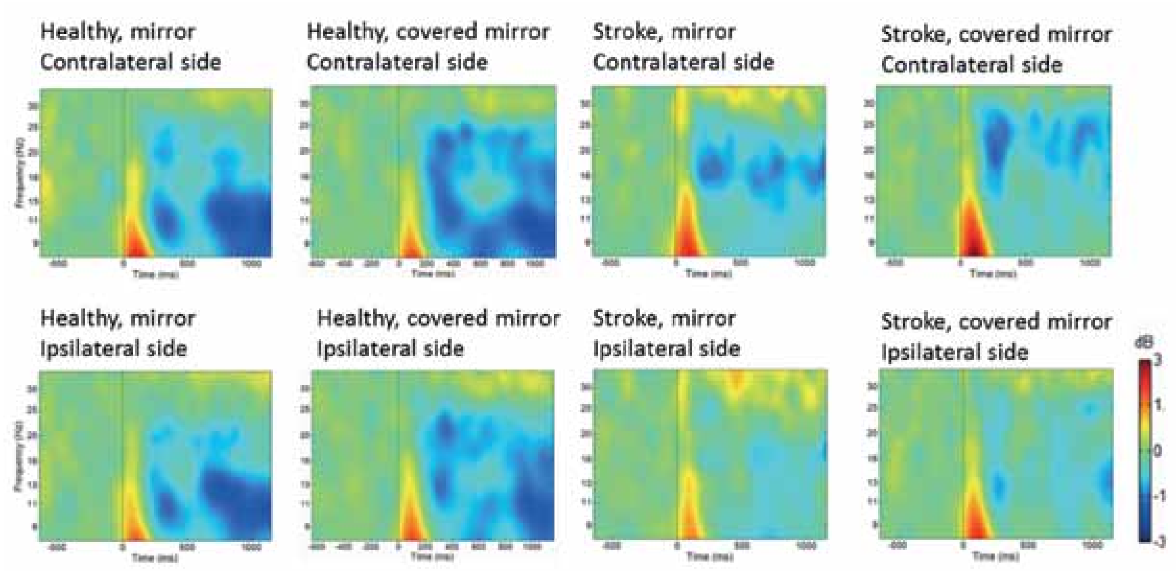

FIG 2. Comparison of event-related spectral perturbation at electrode C3 (contralateral motor area) and C4 (ipsilateral motor area) in unimanual hand movement task with mirror and covered mirror in the groups of stroke patients and healthy participants

Discussion

We found that effects of MT and BAT were similar and able to improve all clinical outcomes except for the gross subscore of the Action Research Arm Test. Although we could not find any significant difference in clinical effects between MT and BAT, our findings are in congruent to those reported in a recent Cochrane review[1] that most studies with significant effects between experimental and control groups might have been influenced by the type of control treatment. The effects on motor function are robustly significant in studies that compared MT with a sham intervention that used a covered mirror, thus avoiding any view of the affected limb. However, there is no advantage in effects when the experimental group is compared with no mirror or a transparent window with an unrestricted view (ie without the use of mirror) in the control group. Our clinical study did not use a sham mirror for comparison, but instead adopted a comparable intervention: bimanual arm training with the same customised movement tasks but without a mirror, which should be viewed as more powerful than a sham mirror condition. The only difference with or without mirror visual feedbacks between the two group possibly accounts for the significant between-group difference and the significant group-time interaction for the distal hand functions. This is consistent to a study that reported significant and larger effects of MT benefited the distal hand functions[2].

There was a significant main effect of groups in both contralateral and ipsilateral motor areas, particularly the contralateral motor area (C3) in both healthy and stroke participants in the alpha-2 band. Bilateral alpha/mu suppression during movement execution was expected; however, the findings of ERD in both hemispheres reflected that the problem of motor learning after stroke might be explained by reduced ability in action observation, leading to a poorer preparation in movement execution.

There was ERD in beta band, an overall more pronounced suppression over the contralateral hemisphere than the ipsilateral hemisphere, in both healthy and stroke participants. A magnetoencephalographic study reported similar results of movement-related beta desynchronisation in patients and healthy controls.[3] However, another study reported that more pronounced suppression in EEG analysis was found over the right than left hemisphere sites during action observation, regardless of the hand that moved.[4] Our findings are consistent to our previous review article that suggested mirror visual feedback may contribute to stroke recovery by revising the interhemispheric imbalance caused by stroke due to the activation of the mirror neuron system and that action observation may promote motor relearning in stroke individuals by activating the mirror neuron system and motor cortex[5].

Conclusion

MT is more useful than BAT in improving distal arm functions, and that mirror visual feedback is likely to activate the contralateral sensorimotor cortex, making the brain more symmetrical during the course of motor recovery after hemiplegia in stroke.

Acknowledgements

This study was supported by the Health and Medical Research Fund, Food and Health Bureau, Hong Kong SAR Government (#01121966). We thank the participants and staff of the Hong Kong Stroke Association and the Self Help Group for the Brain Damaged. In particular, we thank Lau Kim-hung and Yuen Siu-lam for their administrative support throughout the study.

References

1. Thieme H, Mehrholz J, Pohl M, Behrens J, Dohle C. Mirror therapy for improving motor function after stroke. Cochrane Database Syst Rev 2012;3:CD008449.
2. Deconinck FJ, Smorenburg AR, Benham A, Ledebt A, Feltham MG, Savelsbergh GJ. Reflections on mirror therapy: a systematic review of the effect of mirror visual feedback on the brain. Neurorehabil Neural Repair 2015;29:349-61.
3. Rossiter HE, Borrelli MR, Borchert RJ, Bradbury D, Ward NS. Cortical mechanisms of mirror therapy after stroke. Neurorehabil Neural Repair 2015;29:444-52.
4. Frenkel-Toledo S, Bentin S, Perry A, Liebermann DG, Soroker N. Dynamics of the EEG power in the frequency and spatial domains during observation and execution of manual movements. Brain Res 2013;1509:43-57.
5. Zhang JJQ, Fong KNK, Welage N, Liu KPY. The activation of the mirror neuron system during action observation and action execution with mirror visual feedback in stroke: a systematic review. Neural Plast 2018;2018:2321045.