Original Article

Evaluating the Effect of Mirror Therapy on Cognitive Neuroplasticity and Motor Recovery in Stroke Rehabilitation

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ABSTRACT

Background: Stroke commonly leads to significant motor impairments through cortical damage. Mirror therapy (MT), utilizing visual feedback to stimulate motor cortex activity, has shown promise as a neuroplasticity-enhancing intervention for motor recovery. This study investigated mirror therapy's effects on neuroplastic changes and functional motor outcomes in post-stroke patients during rehabilitation.

Methods: We conducted a randomized controlled trial with 40 post-stroke patients (ages 40–70) presenting upper limb motor deficits. Participants were randomly allocated to mirror therapy (Group A) or task-oriented training (Group B). Both groups received 6-week interventions, 5 sessions weekly. Cognitive neuroplasticity was measured using Trail Making Tests (TMT) assessing attention, visual search, and executive function. Motor function evaluation included Fugl-Meyer Assessment for Upper Extremity (FMA-UE) and Action Research Arm Test (ARAT).

Results: All 40 patients (mean age 58.7±7.9 years) completed the intervention. While both groups demonstrated significant within-group improvements ($p<0.001$), mirror therapy showed superior effectiveness over task-oriented training. TMT improvements significantly favored mirror therapy: TMT-A (-26.3±8.9 vs -14.4±7.2 seconds, $p<0.001$); TMT-B (-43.8±12.7 vs -19.5±9.8 seconds, $p<0.001$). Motor assessments similarly favored mirror therapy: FMA-UE (+15.8±4.3 vs +10.7±3.9 points, $p<0.001$); ARAT (+13.8±3.7 vs +8.8±4.1 points, $p<0.001$). Effect sizes were large across measures (Cohen's d: 1.25-2.12).

Conclusion: Mirror therapy demonstrated clear superiority over task-oriented training for enhancing cognitive neuroplasticity and motor recovery in stroke patients. These results suggest mirror therapy provides comprehensive benefits addressing multiple post-stroke impairment aspects simultaneously, supporting its integration into standard rehabilitation protocols for upper limb motor deficits.

Keywords: *Cognitive Neuroplasticity, Mirror Therapy, Motor Recovery, Stroke Rehabilitation, Upper Limb Function.*

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INTRODUCTION

Stroke affects approximately 15 million people worldwide annually, with one in four individuals experiencing stroke during their lifetime[1]. It's become one of the most challenging neurological conditions we encounter clinically, representing a major cause of long-term functional disability that significantly impacts quality of life even with comprehensive therapeutic interventions. The pathophysiology is complex, involving motor, sensory, and cognitive dysfunctions, though motor impairment often presents as the most prominent deficit[2].

What's particularly concerning is that roughly 50% of stroke survivors experience persistent disability in arm-hand performance. Research shows only 5% of individuals with complete paralysis regain full arm function, while 30-66% never recover functional use of the affected limb[3-4]. This creates substantial challenges for patients and their families, as upper motor neuron damage manifests through both positive symptoms (increased muscle tone, hyperactive reflexes, pathological signs) and negative symptoms (paresis, loss of fine motor control, decreased dexterity).

Spasticity affects more than one-third of patients within the first year post-stroke, contributing to decreased range of motion, joint stiffness, and complications in daily activities[6]. These statistics highlight why effective rehabilitation strategies are so critically needed.

Over recent years, stroke rehabilitation has evolved significantly from traditional analytical approaches toward task-oriented training methodologies. These newer approaches are grounded in principles of motor re-learning, motor control, and neuroplasticity[7−8]. However, challenges remain with long-term compliance and the observation that upper limb recovery is often more limited than lower limb recovery. This has led researchers to explore innovative approaches including constraint-induced movement therapy, mental practice, virtual reality training, and mirror therapy[9−10].

Mirror therapy represents a particularly interesting development. Originally developed by Ramachandran and Roger-Ramachandran for phantom limb syndrome, it works by providing false visual input to the brain, creating an illusion where patients perceive their healthy limb's movement reflected in the mirror as movement of the affected limb[11]. While we don't fully understand all the neurophysiological mechanisms involved, neuroimaging studies have revealed some fascinating insights. Mirror therapy appears to transform asymmetrical brain activation patterns toward more symmetrical configurations, shifts activation balance within primary motor cortices toward the affected hemisphere, and modulates interhemispheric transcallosal inhibition[12].

Additionally, mirror therapy increases activity in brain regions associated with self-awareness and spatial attention, including the precuneus and posterior cingulate cortex[13]. This broader neural activation suggests potential benefits beyond just motor recovery.

Recent systematic reviews have shown growing research interest in mirror therapy, with evidence suggesting beneficial effects on upper limb function, impairment, and activities of daily living[14−15]. However, several limitations persist in current literature. Many studies examine mirror therapy combined with other therapeutic approaches rather than as a standalone intervention, making it difficult to isolate specific therapeutic effects[16]. Furthermore, most clinical trials focus on chronic-phase stroke patients, with limited investigation across different recovery phases when neuroplasticity patterns may vary[17].

Perhaps most importantly, the relationship between mirror therapy and cognitive neuroplasticity remains understudied, despite growing recognition that cognitive processes play crucial roles in motor recovery and functional outcomes[18]. This gap in our understanding represents a significant opportunity for advancing stroke rehabilitation.

Given these limitations and the potential for enhanced understanding of neuroplasticity mechanisms in stroke recovery, we saw a compelling need to evaluate mirror therapy's specific effects on both motor recovery and cognitive neuroplasticity. Our study aims were threefold: assess mirror therapy's effect on cognitive neuroplasticity using Trail Making Tests; evaluate motor recovery through established assessments; and directly compare mirror therapy effectiveness versus task-oriented training in stroke rehabilitation.

METHODOLOGY

Study Design

We designed a randomized controlled trial to evaluate mirror therapy versus task-oriented training effects on cognitive neuroplasticity and motor recovery in stroke patients. The study used a parallel-group design with pre- and post-intervention assessments over 6 weeks, following established stroke rehabilitation research guidelines[19].

Study Setting

To ensure adequate recruitment and generalizability, we conducted the study across multiple clinical sites. Participating centers included the Physical Therapy Clinic of Foundation of Medical Forum Karachi, Physical Therapy Outpatient Department of Liaquat University Hospital Jamshoro, and SK Clinic Islamabad. We selected these settings based on their established stroke rehabilitation programs and availability of qualified physical therapists.

Sample Size

Our sample size calculation determined 40 participants would be needed to detect clinically meaningful differences between intervention groups. We based calculations on previous studies examining mirror therapy effectiveness on Fugl-Meyer motor assessment for upper extremity in stroke patients[20], considering mean values for mirror therapy intervention (28.3±18.1) and virtual reality mirror therapy (43.4±14.5). Calculations used 95% confidence interval and significance level >0.05.

Participants

Our target population comprised post-stroke patients with upper limb motor deficits seeking rehabilitation services at participating centers. We included adults aged 40-70 years who had experienced stroke and demonstrated upper extremity functional limitations requiring therapeutic intervention.

Inclusion Criteria:

- Age 40-70 years
- Confirmed stroke diagnosis (ischemic or hemorrhagic)
- Upper limb motor deficits present
- Medically stable condition
- Ability to sit upright ≥30 minutes
- Cognitive ability to understand and follow simple instructions

Exclusion Criteria:

- Severe cognitive impairment preventing assessment/intervention participation
- Uncontrolled medical conditions interfering with rehabilitation
- Previous neurological disorders (other than stroke)
- Visual impairments preventing mirror therapy participation
- Severe upper limb contractures limiting range of motion
- Participation in other experimental rehabilitation programs
- Inability to attend regular therapy sessions

Interventions

- ***Mirror Therapy Group (Group A)***

  Participants received mirror therapy intervention 5 days weekly for 6 weeks. Each 30-45 minute session was supervised by qualified physical therapists trained in mirror therapy protocols. We based our intervention on Ramachandran's original principles, utilizing visual feedback to stimulate neuroplasticity and motor recovery through mirror neuron system activation[11].

  Our setup involved placing a standard therapeutic mirror (40cm x 30cm) vertically on a table between participants' arms, positioned at midline. The affected limb was placed behind the mirror (completely obscured from view), while the unaffected limb was positioned in front where its reflection could be clearly observed. Participants sat comfortably with both arms supported at table height, ensuring optimal viewing angles and postural stability throughout sessions.

- **Task-Oriented Training Group (Group B)**

  Group B received task-oriented training following established stroke rehabilitation protocols based on motor learning principles and neuroplasticity concepts[21]. Sessions were conducted 5 days weekly for 6 weeks, each lasting 30-45 minutes under qualified physical therapist supervision. The intervention focused on repetitive practice of meaningful functional tasks relevant to activities of daily living, emphasizing whole-task practice rather than component-based exercises.

Outcome Measures

- **Cognitive Neuroplasticity Assessment**

  We used the Trail Making Test (TMT) to assess cognitive neuroplasticity through attention, visual search, and executive functioning measurements[22]. The TMT consists of two parts: Part A requires connecting numbered circles sequentially, while Part B involves alternating between numbers and letters in sequential order. Trained assessors administered assessments in standardized manner, recording completion times and errors. Pre-intervention assessments occurred within one week before treatment initiation; post-intervention assessments occurred within one week after completing the 6-week intervention.

- **Motor Function Assessment**
  We evaluated motor function using two validated instruments. The Fugl-Meyer Assessment for Upper Extremity (FMA-UE) assessed sensorimotor impairment across multiple domains: motor function, sensation, joint range of motion, and joint pain[23]. This assessment includes 33 items scored on 3-point ordinal scales, with higher scores indicating better motor function. The Action Research Arm Test (ARAT) evaluated upper limb functional ability through four subtests: grasp, grip, pinch, and gross movement[24]. ARAT comprises 19 items scored on 4-point scales, with maximum possible scores of 57 points. Trained, blinded assessors administered both assessments following standardized protocols at pre- and post-intervention timepoints.

Statistical Analysis

We conducted statistical analysis using SPSS version 25.0. Descriptive statistics summarized demographic characteristics and baseline measures. We used paired t-tests for within-group comparisons and independent t-tests for between-group comparisons. Effect sizes were calculated using Cohen's d. Statistical significance was set at $p<0.05$.

Ethical Considerations

The Institutional Review Board of Foundation of Medical Research and Laboratories Karachi approved this study (FMRL-IRB/2025/013), an organization registered with NIH ClinicalTrials.gov. All participants provided written informed consent after receiving detailed explanations of study procedures, potential risks and benefits, and their rights as research participants. We maintained participant confidentiality throughout the study, and participants retained rights to withdraw anytime without affecting clinical care. The study was conducted according to Declaration of Helsinki and Good Clinical Practice guidelines.

RESULTS

Demographics

Forty post-stroke patients participated in this randomized controlled trial, with 20 participants allocated to each intervention group. We recruited participants from three clinical centers: 20 (50%) from Karachi, 10 (25%) from Hyderabad, and 10 (25%) from Islamabad. All participants completed the 6-week intervention with no dropouts recorded.

Table-1: Demographic Characteristics of Study Participants

Characteristic	Group A (Mirror Therapy) n=20	Group B (Task-Oriented Training) n=20	P-value
Age (years), Mean ± SD	58.4 ± 8.2	59.1 ± 7.6	0.782
Gender, n (%)			0.739
Male	12 (60%)	11 (55%)	
Female	8 (40%)	9 (45%)	
Time since stroke (months), Mean ± SD	4.3 ± 2.1	4.7 ± 2.4	0.567
Affected side, n (%)			0.645
Right	11 (55%)	12 (60%)	
Left	9 (45%)	8 (40%)	
Stroke type, n (%)			0.892
Ischemic	16 (80%)	15 (75%)	
Hemorrhagic	4 (20%)	5 (25%)	
Education level, n (%)			0.701
Primary	6 (30%)	7 (35%)	
Secondary	9 (45%)	8 (40%)	
Higher	5 (25%)	5 (25%)	
Study center, n (%)			0.823
Karachi	10 (50%)	10 (50%)	
Hyderabad	5 (25%)	5 (25%)	
Islamabad	5 (25%)	5 (25%)	

Demographic characteristics showed homogeneous distribution between groups, ensuring baseline comparability for outcome analysis. Both groups had similar mean ages (Group A: 58.4 years; Group B: 59.1 years), comparable gender distribution with slight male predominance in both interventions, and similar time since stroke onset, indicating comparable chronicity of stroke-related deficits.

Within-Group Analysis

Both intervention groups demonstrated significant improvements across all outcome measures following the 6-week treatment period. Mirror therapy and task-oriented training groups both showed statistically significant pre-to-post intervention changes in cognitive neuroplasticity and motor function assessments, consistent with established literature on neuroplasticity and motor recovery[3].

Table-2: Within-Group Analysis - Pre and Post Intervention Outcomes

Outcome Measure	Group A (Mirror Therapy) n=20			Group B (Task-Oriented Training) n=20		
	Pre-intervention Mean ± SD	Post-intervention Mean ± SD	P-value	Pre-intervention Mean ± SD	Post-intervention Mean ± SD	P-value
TMT-A (seconds)	78.6 ± 18.4	52.3 ± 12.7	<0.001*	76.2 ± 16.9	61.8 ± 14.2	<0.001*
TMT-B (seconds)	142.5 ± 28.3	98.7 ± 19.6	<0.001*	138.9 ± 26.7	119.4 ± 22.1	0.002*
FMA-UE (points)	31.4 ± 8.9	47.2 ± 9.3	<0.001*	32.1 ± 9.2	42.8 ± 8.7	<0.001*
ARAT (points)	18.7 ± 6.2	32.5 ± 7.8	<0.001*	19.3 ± 6.8	28.1 ± 7.4	<0.001*

**Statistically significant at p<0.05*

In the mirror therapy group, we observed substantial improvements in Trail Making Test performance, with notable reductions in completion times for both TMT-A and TMT-B, indicating enhanced attention, visual search, and executive functioning. Motor function assessments revealed significant gains in both FMA-UE scores and ARAT performance, demonstrating meaningful functional recovery. The task-oriented training group similarly showed significant improvements across all measures, though with different patterns of change compared to mirror therapy intervention, particularly in relative magnitude of cognitive versus motor function improvements.

Between-Group Analysis

Between-group analysis revealed significant differences in treatment effects between mirror therapy and task-oriented training interventions. Mirror therapy demonstrated superior effectiveness in improving cognitive neuroplasticity markers and motor function outcomes compared to task-oriented

Table-3: Between-Group Analysis - Change Scores and Treatment Effects

Outcome Measure	Group A (Mirror Therapy) Change Score Mean ± SD	Group B (Task-Oriented Training) Change Score Mean ± SD	Mean Difference (95% CI)	P-value	Effect Size (Cohen's d)
TMT-A (seconds)	-26.3 ± 8.9	-14.4 ± 7.2	-11.9 (-16.8 to -7.0)	<0.001*	1.48
TMT-B (seconds)	-43.8 ± 12.7	-19.5 ± 9.8	-24.3 (-31.2 to -17.4)	<0.001*	2.12
FMA-UE (points)	+15.8 ± 4.3	+10.7 ± 3.9	+5.1 (+2.6 to +7.6)	<0.001*	1.25
ARAT (points)	+13.8 ± 3.7	+8.8 ± 4.1	+5.0 (+2.7 to +7.3)	<0.001*	1.29

**Statistically significant at p<0.05; TMT-A: Trail Making Test Part A; TMT-B: Trail Making Test Part B; FMA-UE: Fugl-Meyer Assessment Upper Extremity; ARAT: Action Research Arm Test; CI: Confidence Interval*

The most pronounced differences were observed in cognitive assessment measures, particularly in Trail Making Test performance, where mirror therapy showed significantly greater improvements in both attention and executive function domains. Motor function assessments also favored mirror therapy intervention, with significantly greater improvements in both FMA-UE and ARAT scores. Effect sizes for between-group differences were moderate to large across all outcome measures, indicating clinically meaningful differences in treatment effectiveness. These findings suggest mirror therapy may offer superior therapeutic benefits for both cognitive neuroplasticity enhancement and motor recovery in stroke rehabilitation compared to traditional task-oriented training approaches.

DISCUSSION

Our study demonstrated significant superiority of mirror therapy over task-oriented training in improving both cognitive neuroplasticity and motor recovery in stroke patients. These findings add to growing evidence supporting mirror therapy's effectiveness as a neuroplasticity-enhancing intervention in stroke rehabilitation[14–15].

The substantial improvements we observed in Trail Making Test performance following mirror therapy intervention align well with recent neuroimaging studies investigating cognitive effects of mirror therapy[12–13]. Research examining mirror therapy effects on brain activation patterns found that mirror presence changed initial asymmetrical activation patterns elicited during bimanual tasks in stroke patients to more symmetrical patterns. Our findings of 33.5% improvement in TMT-A and 30.7% improvement in TMT-B scores in the mirror therapy group support this neuroplasticity enhancement concept.

Mirror therapy increases activity in primary and secondary visual and somatosensory areas, enhancing attention and conscious awareness of sensory feedback, which directly corresponds to cognitive domains assessed by the Trail Making Test. In another investigation utilizing Trail Making Test as a cognitive assessment tool, researchers found that attention and neuropsychological status measured by TMT were significant predictors of mirror therapy response.

The superior cognitive improvements we observed in the mirror therapy group compared to task-oriented training (TMT-A: -26.3 vs -14.4 seconds; TMT-B: -43.8 vs -19.5 seconds) suggest mirror therapy may offer enhanced cognitive neuroplasticity benefits beyond traditional rehabilitation approaches.

Recent studies examining mirror neuron system-based training on both motor and cognitive function in stroke patients found significant improvements in cognitive measures including reaction time and Wisconsin Card Sorting Test performance. Similarly, in comprehensive rehabilitation program studies, researchers reported that mirror therapy enhanced patient focus and attention, potentially favoring more cortical activation than traditional rehabilitation training. These findings support our observation of superior cognitive improvements with mirror therapy intervention.

The motor function improvements we observed demonstrate mirror therapy's effectiveness in enhancing upper limb recovery. FMA-UE scores showed mean improvement of 15.8 points in the mirror therapy group compared to 10.7 points in the task-oriented training group. In multicenter studies evaluating mirror therapy combined with task-oriented training, researchers found significant improvements in motor performance, with improvements in motor and functional recovery through mirror therapy use supported by similar research findings.

The effect size of 1.25 (Cohen's d) we observed indicates large clinically meaningful differences between interventions. Recent investigations have shown that mirror therapy activates brain areas related to cognitive processing, alertness, self-awareness and spatial attention, and seems to trigger several neuronal networks and induce brain reorganization and cortical rewiring by promoting neuroplasticity changes in the primary motor cortex.

ARAT improvements in our study (mirror therapy: +13.8 points vs task-oriented training: +8.8 points) align with findings from recent clinical trials. In studies examining sequential combination of mirror therapy with robot-assisted therapy, researchers found that mirror-induced visual illusion could facilitate neural activities in motor-associated network of the brain and serve as a priming technique for inducing neuroplasticity.

Our task-oriented training group showed significant within-group improvements across all measures, consistent with established literature supporting this intervention approach. Recent meta-analyses have demonstrated that task-oriented training significantly enhances rehabilitation of upper limb function and recovery of daily living skills in stroke patients[21]. However, our findings suggest that while task-oriented training remains effective, mirror therapy offers superior therapeutic benefits across both cognitive and motor domains.

Our choice of outcome measures aligns with current evidence-based recommendations for stroke rehabilitation assessment. Both the Fugl-Meyer Assessment and Action Research Arm Test are considered equally sensitive to change during rehabilitation and can be routinely used to measure recovery of upper-extremity motor function[23−24]. Our large effect sizes (Cohen's d: 1.25-2.12) across all outcome measures indicate clinically meaningful differences that exceed minimal clinically important differences established in previous research.

While our study provides valuable evidence for mirror therapy's superiority over task-oriented training, several limitations should be acknowledged. The 6-week intervention period, while consistent with many published studies, may not capture long-term retention effects. Recent reviews have identified that optimal duration, intensity, and content of mirror therapy interventions require further investigation[25]. Future studies should examine longer intervention periods and follow-up assessments to determine sustainability of observed improvements.

CONCLUSION

Our findings support integrating mirror therapy into standard stroke rehabilitation protocols, particularly for patients with upper limb motor deficits. The superior outcomes we observed across both cognitive neuroplasticity and motor recovery domains suggest mirror therapy may offer a comprehensive approach to stroke rehabilitation that addresses multiple aspects of post-stroke impairment simultaneously. The large effect sizes and statistically significant differences between interventions provide strong evidence for clinical implementation of mirror therapy as a primary intervention approach in stroke rehabilitation settings.

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None.

Author Contributions

Perkash Lal conceptualized the study, designed the methodology, and contributed to the original draft. **Satish Kumar** assisted with data analysis, literature review, and manuscript editing. **Jeetendar Valecha** supported statistical interpretation and critically revised the manuscript. **Mahrukh Warraich** contributed to data collection and helped in drafting the results. **Aneela Shoukat** supervised the project and provided technical guidance. **Safa Rafaqat** assisted in manuscript formatting, referencing, and final proofreading.

Ethical Approval

The Institutional Review Board of Foundation of Medical Research and Laboratories Karachi approved this study (FMRL-IRB/2025/013), an organization registered with NIH ClinicalTrials.gov

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None.

Conflict of Interests

None.

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