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# Outcomes of Combined Visual and Auditive Stimulation on Functions of Hand and Grip Strengths in Patients with Hemiplegia

Bhaswati Baishya[1] Kalidasan Varathan[1]

[1] Krupanidhi College of Physiotherapy, Bengaluru, Karnataka, India

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**Address for correspondence** Kalidasan Varathan, MPT, Krupanidhi College of Physiotherapy, Bengaluru, Karnataka, 560 035, India (e-mail: rvkalidasan@gmail.com; physio.kric@krupanidhi.edu.in).

## Abstract

**Background** Stroke is a major ailment that results from hypoxia, ischemia, blockage, or hemorrhage. The recovery of hand functions is an essential goal in stroke patients' recovery.

**Aim** This study aimed to analyze the outcomes of rhythmic auditory stimulation (RAS) and mirror therapy on hand functions, as well as grip strength, in stroke patients.

**Materials and Methods** A quasiexperimental study has been used based on criteria of inclusion, 30 patients were enrolled. The participants were assigned to two groups, 15 patients each. Group A (control group) underwent traditional physiotherapy. Group B (experimental group) underwent RAS and mirror therapy. Both the groups received 20 minutes of treatment, 20 sessions in 1 month. The Action Research Arm Test (ARAT) and hand-held dynamometer were used to evaluate results. Paired *t*-test has been used to analyze the data with the SPSS software tool.

**Results** The paired *t*-test results showed that notable distinctions in ARAT mean pretest scores between two groups were not found. A notable change in ARAT results was present between the two groups with mean posttest score and difference in pretest to posttest. No notable distinctions in grip strength results were seen with mean pretest results. But a notable change was found in grip strength results among two groups with mean posttest scores.

**Conclusion** Combining RAS and mirror therapy programs has shown beneficial effects on hand functions, as well as grip strength of stroke patients and can be used as adjunct interventions along with conventional physiotherapy to encourage restoration of hand functions in hemiparetic patients.

**Keywords**
- ► rhythmic auditory stimulation
- ► mirror therapy
- ► stroke
- ► the action research arm test
- ► grip strength

## Introduction

Stroke can be defined as evolving medical symptoms of principal disruption of cerebral function of which the symptoms can continue for 24 hours or more and can lead to death.[1] The neurological presentations relate to the extent of injury, site of the part engaged, as well as fundamental causes of brain dysfunction.[2] Globally, stroke results in 12.6 million individuals having a disability of which 8.9 million people belong to lower middle–income countries.[3]

Stroke accounted for 41% of deaths and 72% of disabilities in our country.[4] In India, the second leading cause of death is stroke, the most significant cause of disability.[5,6] Upper extremity function is damaged in approximately 70% of these

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individuals.[7] Damage to the upper extremity function of hemiplegic patients critically disrupts their ability to perform daily tasks independently.[8]

Following the onset of stroke, motor paralysis appears, and the recovery of finger extension function takes the longest period.[9] Given that many daily activities require using movements of fingers and hands, patients, who are not able to use their hands after the onset of stroke, experience a certain level of physical and mental pain.[10]

Mirror therapy is an easy and feasible intervention for upper limb training. The purpose is restoring the upper limb dexterity while asking the patient to emphasis on uninvolved extremity movements.[11]

Rhythmic auditory stimulation (RAS) is another treatment intervention that has shown to be beneficial in enhancing upper limb movements.[12] RAS enhances motor control by promoting organization and accomplishment by powerful entrainment and integrated outcomes of repeated rhythmic sensory signals on the motor system.[13]

Park et al stated stroke survivors accounting for 85%, undergo paralysis, and 69% of patients account for disrupted functioning of upper limbs.[8] The hand and digits dexterity recovery makes a crucial contribution to the rehabilitation of hemiplegic patients.[11] Because of the limited evidence of RAS on hand functions in hemiplegic patients, a need arises for looking into its uses together with mirror therapy in improving the hand functions, as well as strength, of the hemiparetic hand. The framed null hypothesis was that there would be no significant effect of RAS and mirror therapy on the hand functions and grip strength of the stroke patients. The alternate hypothesis was there would be a significant effect of RAS and mirror therapy on the hand functions and grip strength of the stroke patients.

## Objective

This study aimed to evaluate the (1) effect of conventional therapy on hand functions and grip strength of stroke patients, (2) combined effects of RAS and mirror therapy on the hand functions and grip strength of the stroke patients, and (3) compare the effects of conventional therapy against the combined effects of RAS and mirror therapy on the hand functions and grip strength of the stroke patients

## Materials and Methods

The study design is a pre–post quasiexperimental study involving patients clinically diagnosed with a stroke, duration of 6 months from onset, both the genders, aged 50 to 65 years for 4 weeks.[8,11] A total of 30 patients were conveniently selected as per the inclusion criteria. Patients with anterior cerebral artery (ACA) and middle cerebral artery (MCA) involvement with the affected side being the dominant side and those with Brunnstrom's recovery stages of 3 and 4 took part.[8] Patients with dementia, depression, or productive psychosis were not included.[2] Patients having any visual or auditory impairments were excluded.[14] The patients were grouped into the following: the control group receiving traditional physiotherapy and the experimental group receiving exclusively mirror therapy plus RAS. The purposive sampling technique was used to group the patients into control and experimental group.

### Procedure

►**Fig. 1** shows the flowchart for the procedure. Overall, 20 treatment sessions were given for 1 month for both the groups. Assessments were made before and after the treatment sessions using hand-held dynamometer and ARAT. Conventional physiotherapy was provided for 20 minutes to the control group in each session.

### Conventional Physiotherapy

#### Tone Normalization of Spastic Muscles

Slow sustained stretching of the agonist spastic muscles through range of motion (ROM). Active exercises focused on the activation of the weak antagonist muscles using slow and controlled movements were performed. Local facilitation techniques, such as stretching, tapping, and light resistance, were added to enhance the action of the weak

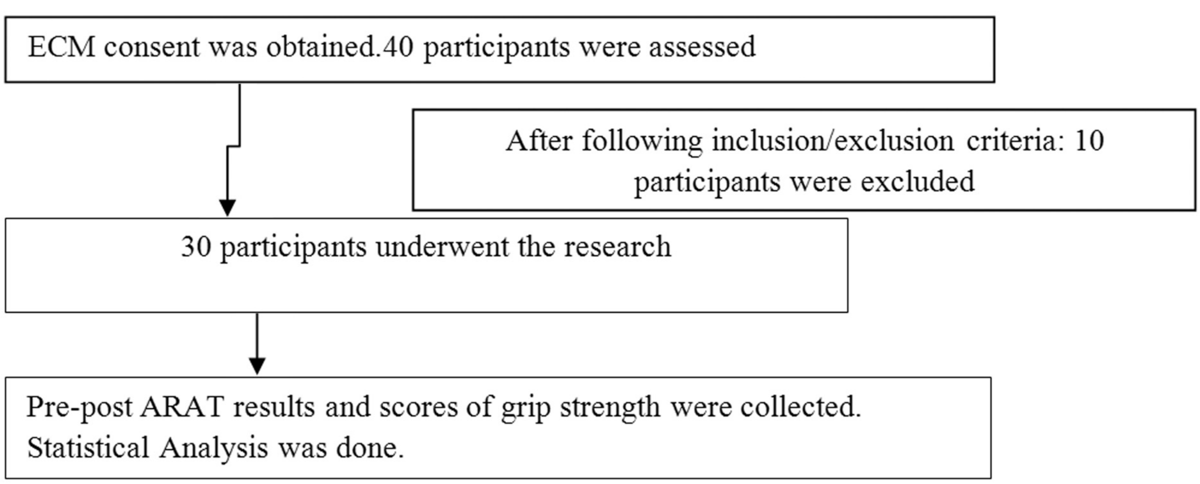


**Fig. 1** Flowchart for the procedure. ARAT, action research arm test.

antagonist muscles.[15] Tapping to the antagonist muscle was given to facilitate voluntary movement out of synergy pattern which caused reciprocal inhibition of the spastic muscle. Tone normalization was provided for 5 minutes.

#### To maintain Range of Motion

ROM exercises were given for 5 minutes.

#### Sensory Reeducation

Stroking through thenar, as well as hypothenar, eminences five times to achieve purposeful muscular contractions. Superficial and deep pressure were applied. Localization to touch was to allowing patients to touch objects of various sizes, shapes, and materials. Sensory re-education was given for 5 minutes.

#### Encouraging Voluntary Movement

Patients were encouraged to make use of their involved hand for performing daily activities such as grooming and dressing. The patients performed all the voluntary activities for 5 minutes. Integrated mirror therapy and RAS for 20 minutes were rendered to the experimental group in each session.

### Rhythmic Auditory Stimulation

Participants were made to sit in a back-supported chair, with the affected hand placed on the desk.[14] RAS using an electronic smartphone-based metronome was given. Patients performed hand movements such as grasping a ball and releasing it, rolling the ball from the tip of fingers to the palm, pinching a ball, stacking coins, and other physiological movements of the hand. Patients executed the repeated movement sequence with the metronome beats in time.[14] To find out the preferred auditory stimulation frequency, each patient was asked to perform a repetition of each task for 1 minute using the affected hand.[14] The advantage of using a smartphone is that it can be easily operated and is instantly available (►**Table 1**).[16]

### Mirror Therapy

A mirror box training session followed this. The involved hand of the patient was asked to place at the back of the box while the uninvolved extremity ahead of the box. Participants performed various physiological forearm and hand movements, viewing the uninvolved extremity image, thereby watching the reflection of movements of the hand projected over the affected hand.[10,16] The patients performed the same physiological activities simultaneously using the paretic hand (►**Table 1**).[17]

### Outcome Measures

- Primary outcome measure was ARAT and secondary outcome measure was
- hand-held dynamometer.

### Statistical Analysis

Statistical analyses are listed in ►**Tables 2–7**.

## Results

Notable changes among the groups were not found: control (57.07 ± 4.079) and experimental (57.87 ± 4.824) groups with the distribution of age and mean age ($p = 0.666$) and gender distribution and mean ($p = 0.719$).

A notable difference in ARAT scores between the groups was not seen: control (27.07 ± 8.852) and experimental (27.33 ± 10.560) groups with mean pretest scores ($p = 0.937$). But notable changes in ARAT results were present in the groups: control (32.20 ± 8.986), and experimental (39.07 ± 8.345) groups with mean posttest scores ($p = 0.021$) and change from pretest to posttest ($p = 0.0001$) scores.

This shows that the experimental group is showing maximum changes in ARAT results compared with the control group.

No notable distinctions in grip strength results were observed among groups: control (14.20 ± 4.329) and experimental (14.67 ± 3.773) groups with mean pretest scores ($p = 0.753$). Notable distinction was observed: control (17.00 ± 4.375) and experimental (20.33 ± 4.923) groups with mean posttest scores ($p = 0.059$); change from pretest to posttest was noted ($p = 0.0001$).

It shows that the experimental group shows maximum changes or improvement in grip strength scores than the control group.

Thus, it shows that the integrated visual and auditory stimulation (RAS and mirror therapy) improved functions of the hand and grip strength among hemiparetic patients. Statistically significant values were observed for the experimental group.

**Table 1** Duration, frequency, and activities for the treatment interventions

| Treatment interventions | Duration | Frequency | Activities to be performed |
|---|---|---|---|
| Rhythmic auditory stimulation | 10 minutes | 5 days/week | • Grasping a ball and releasing it<br>• Rolling the ball from the tip of the fingers to the palm<br>• Pinching a ball<br>• Stacking coins<br>• Other physiological movements of the hand |
| Mirror therapy | 10 minutes | 5 days/week | • Supination and pronation<br>• Flexion–extension of wrist and finger, finger movements<br>• Sponge squeezing<br>• Swiping a table with a towel etc. |

**Table 2** Comparison of the groups by age

| Variable | Paired differences | | | | | *t* | df | Significance (two-tailed) |
|---|---|---|---|---|---|---|---|---|
| | Mean | Standard deviation | Standard error mean | 95% confidence interval of the difference | | | | |
| | | | | Lower | Upper | | | |
| AGE_E AGE_C | 0.800 | 7.022 | 1.813 | −3.089 | 4.689 | 0.441 | 14 | 0.666 |

Note: Notable distinctions were not present among the two groups (experimental group and control group) in age distribution and mean age ($t = 0.441$ and $p = 0.666$; ►**Table 2**).

**Table 3** Comparison of the groups by gender

| Variable | Paired differences | | | | | *t* | df | Significance (two-tailed) |
|---|---|---|---|---|---|---|---|---|
| | Mean | Standard deviation | Standard error mean | 95% confidence interval of the difference | | | | |
| | | | | Lower | Upper | | | |
| Gender | 0.067 | 0.704 | 0.182 | −0.323 | 0.456 | 0.367 | 14 | 0.719 |

Note: Notable distinctions were not present among the two groups (experimental and control group) in gender distribution and mean age ($t = 0.367$ and $p = 0.719$; ►**Table 3**).

**Table 4** Pre–post action research arm test (ARAT) scores

| Variable | | Paired differences | | | | | *t* | df | Significance (two-tailed) |
|---|---|---|---|---|---|---|---|---|---|
| | | Mean | Standard deviation | Standard error mean | 95% confidence interval of the difference | | | | |
| | | | | | Lower | Upper | | | |
| Pair 1: experimental group | Pre–post scores of ARAT | −11.73 | 4.35 | 1.123 | −14.14 | −9.324 | −10.45 | 14 | 0.000 |
| Pair 2: control group | Pretest scores of ARAT, posttest scores of ARAT | −5.133 | 1.685 | 0.435 | −6.066 | −4.2 | −11.8 | 14 | 0.000 |

Note: The mean of paired difference of pre-post ARAT scores in the control group was −5.133 with standard deviation of 1.685, which is statistically significant ($p < 0.0001$; ►**Table 4**).

**Table 5** Pre–post grip strength scores

| Variable | | Paired differences | | | | | *t* | df | Significance (two-tailed) |
|---|---|---|---|---|---|---|---|---|---|
| | | Mean | Standard deviation | Standard error mean | 95% confidence interval of the difference | | | | |
| | | | | | Lower | Upper | | | |
| Experimental group | Pretest scores of grip strength (kg), posttest scores of grip strength | −5.667 | 2.289 | 0.591 | −6.934 | −4.399 | −9.589 | 14 | 0.000 |
| Control group | Pretest scores of grip strength, posttest scores of grip strength | −2.8 | 1.612 | 0.416 | −3.693 | −1.907 | −6.725 | 14 | 0.000 |

Note: The mean of paired difference of pre–post grip strength scores in the control group was −2.880 with standard deviation of 1.612 which is statistically significant ($p < 0.0001$; ►**Table 5**).

**Table 6** Paired differences of pretest scores of action research arm test (ARAT) and grip strength

| Variable | Paired differences | | | | | *t* | df | Significance (two-tailed) |
|---|---|---|---|---|---|---|---|---|
| | Mean | Standard deviation | Standard error mean | 95% confidence interval of the difference | | | | |
| | | | | Lower | Upper | | | |
| Pretest scores of ARAT between the experimental and control group | 0.267 | 12.87 | 3.323 | −6.861 | 7.394 | 0.08 | 14 | 0.937 |
| Pretest scores of grip strength (kg) between the experimental and control group | 0.467 | 5.643 | 1.457 | −2.658 | 3.591 | 0.32 | 14 | 0.753 |

Note: The values obtained show that the subjects were homogenous in both groups (►**Table 6**).

**Table 7** Paired differences of posttest scores of ARAT and grip strength

| Variable | Paired differences | | | | | *t* | df | Significance (two-tailed) |
|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Standard error mean | 95% confidence interval of the difference | | | | |
| | | | | Lower | Upper | | | |
| Posttest scores of ARAT between the experimental and control group | 6.867 | 10.19 | 2.631 | 1.224 | 12.51 | 2.61 | 14 | 0.021 |
| Posttest scores of grip strength between the experimental and control group | 3.333 | 6.275 | 1.62 | −0.142 | 6.809 | 2.057 | 14 | 0.059 |

Abbreviations: ARAT, action research arm test; SD, standard deviation.
Note: The mean of paired differences of scores of ARAT posttest was 6.867 with SD = 10.19 ($p = 0.021$). The mean of paired differences in grip strength score was 3.333 with SD = 6.275 ($p = 0.059$), which is statistically significant (►**Table 7**).

## Discussion

Stroke often results in a paretic hand. After 6 months from the duration of stroke, patients regaining dexterity in manipulative tasks accounted for 38%, while only 11.6% achieved complete functional recovery in hand dexterity.[18]

Differences in hand functions and grip strengths were evaluated and compared. The application of RAS by a smartphone-based metronome application showed improvements in grip strength, as well as various physiological hand functions, while mirror therapy provided the appropriate visual feedback.

The results obtained after the paired *t*-test analysis showed that there was a recommendable improvement in both the outcome measures in the experimental group: ARAT score (39.07 ± 8.345) and grip strength score (20.33 ± 4.923). The findings matched the results of Street et al where significant mean values of ARAT (29.80 ± 18.75) were observed on the application of auditory stimulation which was designed for home-purpose for stroke patients with hemiparesis of the arm.[13,19] Raglio et al found recommendable recovery in grip strength (24.91 ± 11.55) in their study.[20] The improvements in the strength of grip functions observed are similar to the improvements observed in El Shemy and Abd El-Maksoud in which strength of grip functions improved profoundly (10.63 ± 1.49 vs. 5.7 ± 1.42, $p < 0.05$) were observed.[21] The obtained results also come in agreement with Sathian et al.[22]

After the analysis of the paired *t*-test, the results showed improvement in both the outcome measures in the control group: ARAT score (32.20 ± 8.986) and grip strength score (17.00 ± 4.375).

Recommendable improvement in ARAT scores postassessment was noted. A significantly higher effect in ARAT scores was seen among the experimental group. The positive results in the ARAT scores were due to the improvement of considerable dexterity which emphasized four aspects, that is, pinch, grip, grasp, and gross movements of the hand.

A significantly higher effect in grip strength scores was seen in the experimental group than in the control group. Grip strength improvement is related to improvements in complicated motor functions which shows that grip strength can be used as an indicator of the functional recovery of the hand and arm.

Conventional physiotherapeutic approaches are influenced by the ability of central nervous system (CNS) to reorganize itself to relearn and perform various cognitive and motor functions. Hence, the results can be ascribed to repetitions of specific tasks and exercises, local facilitation techniques, and motor relearning strategies.[23]

The outcomes show the improvement in quality of movement and enhanced motor control using RAS in stroke patients. The programmed movements produced by RAS were smooth, effective, and bought about wider ROM. The study results show that rhythmic cueing improves the quality of movement and motor control in stroke patients. RAS allowed for a programmed movement that was more efficient and smoother and had wider ROM. The results are likely the result of auditory rhythms transmitted to the motor system which provided constant feedback while performing the various exercises. The auditory and motor system have rich connectivity across various cortical, subcortical, and spinal levels. The auditory system projects into motor structures in the brain, creating entrainment between the rhythmic signal and the motor response.

Rhythmic auditory cueing has three advantages. First, holding frequency constant ensures that the same movement is actually repeated. The auditory cueing may entrain the motor system to its beat. Second, matching the sound with full extension or flexion of fingers provides an attentional goal for the patient. Goal setting is also known to promote motor learning. Third, receiving feedback is fundamental to motor learning. In this study, sensory information from the audio cues and visual and somatosensory sources provided intrinsic feedback to the patient regarding the movement goal.[14] The profound effects of RAS on movement have been explained by the auditory-motor entrainment which means innate synchronization of movement rhythm to the regular beat of music/sounds.[24]

The experimental group demonstrated better results in accomplishing the daily tasks of living compared with the control group. These results support the study of Stevens and Stoykov[25] study, stating that observing movements through mirror therapy generates positive feedback. Observation of normal movement provided positive visual feedback and improved the function of their affected limb without it being moved. Normal movement is thought to be induced due to activating the premotor cortex by recalling the proprioception (individual perception) that was reduced or removed when normal visual feedback was provided.[19] Mirror therapy, when used with daily functional activities, enhanced the motor recovery of the paretic upper extremity in stroke patients. Mirror therapy provides sustained regular visual input of movement which may better promote central brain remodeling.[26]

## Limitations and Recommendations

Stroke patients within 6 months from onset were taken into account, hence the homogeneity among the patients hence the homogeneity among the patients were maintained. The long-term effect of the interventions is not known as the research was conducted only for a month without follow-ups. Also, patients with Brunnstrom's stages 3 and 4 were included in the study, leading to nonuniformity in the pre–post test scores between and among the groups. Interventions according to various Brunnstrom's stages and individualized to the patients' functional needs should be developed.

## Conclusion

The study can be concluded by stating that integrated visual and auditory stimulation has beneficial effects on hand functions and strength in hemiparetic stroke patients. However, when compared with the conventional approach, the results of research conclude that combined effects of RAS and mirror therapy have beneficial effects on restoration and improvement of the hand functions. Both these treatment interventions can be used as suitable adjuncts along with conventional physiotherapy to encourage and facilitate the restoration of hand functions in hemiparetic patients.

**Conflict of Interest**
None declared.

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