BRIEF REPORT

Using Motor Imagery in the Rehabilitation of Hemiparesis

Jennifer A. Stevens, PhD, Mary Ellen Phillips Stoykov, MS, OTR/L

ABSTRACT. Stevens JA, Phillips Stoykov ME. Using motor imagery in the rehabilitation of hemiparesis. Arch Phys Med Rehabil 2003;84:1090-2.

Objective: To examine the effectiveness of using motor imagery training in the rehabilitation of hemiparesis.

Design: A before-after trial with clinical and behavioral analyses of single cases.

Setting: Academic-affiliated rehabilitation hospital.

Participants: Two survivors of embolic middle cerebral artery stroke that resulted in chronic hemiparesis.

Intervention: A motor imagery training program consisting of imagined wrist movements (extension, pronation-supination) and mental simulations of reaching and object manipulation making use of a mirror box apparatus. Twelve 1-hour experimental sessions were delivered, 3 times a week for 4 consecutive weeks.

Main Outcome Measures: Two clinical assessments, grip strength, 4 wrist functionality measurements, and 3 timed performance tests. All outcome measures were recorded before training began, at 3 times during the intervention month, with 2 additional long-term measurements.

Results: Performance of the paretic limb improved after the imagery intervention, indicated by increases in assessment scores and functionality and decreases in movement times. The improvements over baseline performance remained stable over a 3-month period.

Conclusions: These results demonstrate the potential for using motor imagery as a cognitive strategy for functional recovery from hemiparesis. The intervention targets the cognitive level of action processing while its effects may be realized in overt behavioral performance.

Key Words: Hemiparesis; Rehabilitation.

INDIVIDUALS WITH HEMIPARESIS typically demonstrate spasticity, muscle weakness, and a persistent deficit in movement coordination. Such incoordination occurs at least in part because the neural circuitry responsible for mediating an action intention, and an executed action that precisely reflects that intention, is no longer intact either as a consequence of brain injury or secondary to immediate disuse.[1] Traditional stroke rehabilitation therapies address this incompatibility by using behavior repetition. The hope is that repeated physical practice will improve motor activity, allowing for smooth and controlled movements to occur, acting as examples for the brain to use in reestablishing the circuitry that mediates voluntary movement. One disadvantage of this approach is that recovery is dependent on performance of an impaired limb.

Here, we examine the effectiveness of sending successful action signals to the brain through the use of motor imagery. Mental images of movement can be generated independent of overt behavioral output of a paretic limb. Humans are equipped with a simulation network that positions the motor system in anticipation of movement execution and provides the self with information about the possibility and meaning of upcoming actions.[2,3] The processes underlying motor imagery are similar to those active during actual movement. Actions generated using motor imagery adhere to the same movement rules and constraints that physical movements follow, and the neural network involved in motor imagery and motor execution overlap, primarily in the premotor and parietal areas, basal ganglia, and cerebellum.[4-7]

The motor imagery training in our study focused on 3 movements: reaching/object interaction, wrist extension, and pronation and supination of the wrist. We chose these movements because each is necessary for performance of activities for daily living, each comprises a major subset of movement problems faced by persons with hemiparesis, and performance of each can be measured explicitly for functional increases.

METHODS

Two individuals with chronic hemiparesis completed the study. Patient 1 was a 76-year-old, right-handed woman who survived a middle cerebral artery (MCA) embolism that resulted in multiple right hemisphere cortical and subcortical strokes. Patient 2 was a 63-year-old, right-handed man who survived a cardioembolic stroke to the left MCA. The lengths of time between the date of stroke and study participation were 14 months (patient 1) and 6 years, 2 months (patient 2).

The intervention consisted of three 1-hour sessions for 4 consecutive weeks. Two kinds of motor imagery tasks were used. The first task, computer-facilitated imagery, focused on wrist extension and wrist pronation-to-supination. Computer-generated movies provided visual cues to the subjects, depicting the movements made by a left arm (or right, for patient 2) from 3 angles (arm pointed to the left, arm straight ahead, arm pointed to the right), and at 4 different speeds (roughly 3, 6, 9, 12s for each movement). For each trial, the movie was presented, then a blank screen appeared, during which time the subject was instructed to explicitly imagine his/her own hand completing the movement just observed. After the movement was imagined, the subject depressed the space bar on the computer to advance to the next movie trial. We were able to obtain the amount of time, or imagined movement time (IMT), the individuals used to complete each movement image by measuring the time between onset of the black screen and depression of the space bar. Computer-facilitated motor imagery training lasted roughly 25 minutes. Patient 1 completed 24-trial blocks and patient 2 (who completed the image generation faster) completed 36-trial blocks.

The second task was mirror box–facilitated imagery. This idea is adapted from the work of Ramachandran and Rogers-Ramachandran,[8] who used mirror images of limbs to examine

From the Sensory Motor Performance Program, Rehabilitation Institute of Chicago, Chicago, IL (Stevens, Stoykov); and Department of Physical Medicine & Rehabilitation, Northwestern University Medical School, Chicago, IL (Stevens).

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Reprint requests to Jennifer A. Stevens, PhD, 345 E Superior St, Ste 1406, Chicago, IL 60611, e-mail: *j-stevens3@northwestern.edu.*

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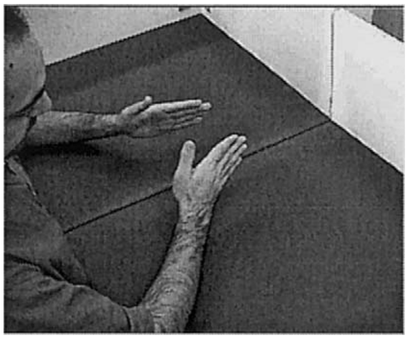

Fig 1. The model demonstrates the mirror box apparatus for simulation of a left limb moving about successfully. The right (unaffected) limb moves around in the workspace resulting in a reflection of the left (paretic) limb moving about successfully in space. Individuals were instructed to "imagine the reflected limb actually is your limb moving about."

phantom kinesthetics and, in some cases, treat phantom limb pain. The mirror box apparatus is depicted in figure 1. The observation of the reflected limb provided a direct perceptual cue of the paretic limb completing a smooth and controlled movement. The imagery component was reinforced by then instructing the individual to "imagine that the reflected limb is in fact your limb moving about physically in space." During the first week of intervention, patients focused on learning to identify the hand reflected in the mirror as his/her own paretic limb moving around freely. In subsequent weeks, relatively simple object manipulation tasks were presented. In the final week, complex manipulation tasks were presented. For example, a stylus was held in the right hand and drew geometric shapes while the individual observed the left hand (the reflection in the mirror) drawing geometric shapes. Mirror box imagery training lasted about 30 minutes.

Behavioral and clinical assessments were completed before the intervention began, at 3 intermittent times during the intervention, and at 1 and 3 months after intervention completion. A battery of assessments was used to better understand the scope of the effects mental practice might have on functional improvements. The battery included: 3 subtests from the Jebsen Test of Hand Function[9] (lift light cans onto a low shelf, lift heavy cans onto a low shelf, turn over 5 cards); the Fugl-Meyer Upper Extremity Motor Function Test[10]; grip strength; range of motion[11] measurements of wrist extension, flexion, pronation, and supination; and the arm and hand dimensions of the Phys-

Table 1: Functional Improvements After Motor Imagery Training

	Performance					
		Intervention			Follow-Up	
Test	Baseline	1wk	2.5wk	4wk	1mo	3mo
Fugl-Meyer (max score, 66)						
P1	34	37	44	44	49	50
P2	NA	44	51	56	51	51
Grip strength (lb)						
P1 Left limb	6	15	19	19	19	22
Right limb	39	54	42	53	40	45
P2 Left limb	79	79	83	90	80	95
Right limb	23	12	27	22	26	34
Wrist movement (deg)						
P1 E/F	30/55	40/55	47/68	50/50	40/65	45/65
S/P	15/80	21/80	35/80	45/80	35/85	35/85
P2 E/F	43/70	49/45	50/55	53/50	50/55	45/50
S/P	22/90	38/92	15/73	35/90	28/80	25/85
Chedoke-McMaster score						
P1 Arm	3	4	5	5	4	5
Hand	3	3	4	4	4	4
P2 Arm	5	5	5	5	5	5
Hand	4	5	5	5	4	4
Jebsen: light objects (s)						
P1 Left limb	43.02	17.27	13.35	14.92	17.82	12.98
Right limb	7.56	5.08	4.89	5.36	5.52	4.91
P2 Left limb	6.38	5.13	6.45	4.96	5.69	4.79
Right limb	18.75	15.66	16.61	11.92	14.62	15.8
Jebsen: heavy objects (s)						
P1 Left limb	18.96	18.7	18.23	15.66	18.14	14.38
Right limb	6.34	6.10	5.48	5.51	5.83	5.95
P2 Left limb	6.90	5.67	5.04	5.43	4.80	4.81
Right limb	16.04	17.0	12.7	12.62	13.19	10.54
Jebsen: card turning (s)						
P1 Left limb	34.4	28.48	25.74	20.41	25.27	30.52
Right limb	6.70	6.15	9.30	6.29	8.93	6.68
P2 Left limb	NA	8.27	5.83	5.49	6.56	6.80
Right limb	NA	20.90	26.33	13.12	17.18	18.09

Abbreviations: E, extension; F, flexion; NA, not available; P, pronation; P1, patient 1; P2, patient 2; S, supination.

ical Impairment Inventory of the Chedoke-McMaster Stroke Assessment.[12]

DISCUSSION

Patient 1's ability to imagine movements in time frames proportional to the speeds at which they were depicted in the movies improved over the 4-week training period. Linear regression analyses showed a significant linear trend between IMT and speed in the second half of the 4-week intervention ($F_{1,94}=12.63$, $P<.001$), but not in the first ($F_{1,94}=1.30$, $P=.25$). Movement times for patient 2 were substantially faster, and his ability to imagine movements in time frames similar to those presented was significant in the first half of the training ($F_{1,142}=96.20$, $P<.001$) as well as in the second ($F_{1,142}=137.60$, $P<.001$).

RESULTS

The clinical assessment scores are listed in table 1. Fugl-Meyer scores consistently increased during the 4 weeks of intervention with modest increases during the 3 follow-up months. Patient 1 had appreciable consistent increases in grip strength for the affected left limb, while patient 2 displayed overall gains; however, the pattern of change was irregular. Goniometric measurements of wrist function revealed increases in range of motion during the intervention month, with minor losses in movement range occurring after the intervention was complete. There were 1-point increases in the Chedoke-McMaster Stroke Assessment during the intervention for both participants that diminished during the first month postintervention. For both participants, notable decreases in movement times for the Jebsen tests were found even though the motor imagery training focused on simulation of accurate, not speedy, movements. During the follow-up months with patient 2, there were increases in his movement times (movements completed at a slower pace), however, the 3-month movement time reports were faster than the baseline evaluation scores.

CONCLUSION

We present the effects of using mental simulation of action to facilitate functional recovery of a paretic limb. Despite a limited number of patients, our report highlights a potential use of mental imagery as an innovative and effective therapy augmentation for the clinician and patient. We believe the performance improvements are linked to a priming of the motor system at a central command level, which translates to a downstream effect of more controlled and faster movements. A 1-month course of motor imagery movement training was used, but a longer course of training may be more beneficial. The greatest increases in function generally occurred during the month of intervention, suggesting that the behavioral effects were associated with the actual practice of mental simulation. It is also possible that use of motor simulation therapy strategies in acute or subacute stages of recovery (ie, <6mo) may increase the size of this effect. Patient 1's improvements were notably greater and longer lasting than those occurring with patient 2, who had experienced his stroke more than 6 years before participation in the study.

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