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MOTOR IMAGERY AND ACTION OBSERVATION AS AN ALTERNATIVE GAIT TRAINING INTERVENTION FOR THE ELDERLY

by

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A capstone project submitted to the Graduate Faculty in Physical Therapy in partial fulfillment of the requirements for the degree of Doctor of Physical Therapy (DPT), The City University of New York

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THE CITY UNIVERSITY OF NEW YORK

ABSTRACT

MOTOR IMAGERY AND ACTION OBSERVATION AS
AN ALTERNATIVE GAIT TRAINING INTERVENTION FOR THE ELDERLY

By

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Motor imagery (MI) is the mental representation of movement without any body movement. Action observation (AO) is a non-physical method of training, in which the learner observes the action of another individual. Eighteen subjects between ages 60-80 were randomly assigned to 3 training groups, the MI, AO and motor training groups. All subjects were assessed and measured with the Expanded Timed-Get Up and Go (TUG) test and Figure-8-Walk (F8W) test. All three groups yielded a significant improvement in difference in total TUG time ($p<0.05$). When individual aspects of the TUG were considered, the sit to stand component improved in the MI and Motor groups. The results of this study suggest that MI and AO can improve cadence and have an effect mirroring that of motor practice. If utilized properly, MI and AO may be indicated as a rehabilitation intervention adjunct to gait training, and potentially decrease the risk of falls in the elderly population.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Falls among older adults constitute a serious problem. Accidents are the fifth leading cause of death in older adults and falls make up two-thirds of such deaths (Rubenstein, 2006). Nearly 30 % of people aged 65 and over fall per year, with one-fifth of such incidents requiring medical attention (Salminen et al., 2009). As the elderly population continues to grow there has been a focus in the geriatric field to determine the risk factors for falls in order to implement preventative measures (Granacher et al., 2013). Among the focus of many such studies has been how gait can be a valid predictor for falls (Cesari et al., 2005; Luukinen et al., 1995; Montero et al., 2005).

As individuals age their fall risk and time to ambulate between two destinations significantly increases (Schrack et al., 2012). Quach et al. (2011) demonstrated that a decline in gait speed by 15 m/s every year would increase the risk of falls both indoors and outdoors. One trial by White et al. (2013) even concluded that as a healthy individuals' gait speed declined that their mortality rate increased. While gait has been a focal point among various studies as a prognosticator for falls, it is still unclear as to what the best method for improving gait is and whether or not gait training is even the best intervention to prevent falls (Jones & Whitaker, 2011). The studies that do examine gait intervention in the elderly are mainly related to different forms of physical exercise (VanSwearingen et al., 2011).

Motor imagery (MI) is the mental representation of movement without any body movement (Solodkin et al., 2004). Neurophysiological and cerebral imaging studies examining similarities between real and simulated locomotor activities have demonstrated that locomotor activities, either performed physically or imagined, are subject to common laws and principles. Physiological responses such as heart rate and respiratory rate increases were observed to be similar in healthy individuals when they would walk on a treadmill and then later imagine walking on the treadmill (Malouin & Richards, 2010). Another neurological study showed similar cortical activity in the brain of healthy individuals with active walking and imaginary walking (Miyai et al., 2001). Fadiga & Craighero (2004) demonstrated that the motor cortex is involved whenever the idea of an action is evoked. Regional blood flow has been seen to increase in various cortical motor areas and the cerebellum during imagery tasks (Decety et al., 1990; Grafton et al., 1996).

The involvement of the motor system during motor imagery was speculated to be "due to unspecific factors, such as intention or readiness to move rather than to a true internal dynamic simulation of movement" (Fadiga & Craighero, 2004). Recent studies have dismissed this notion via the use of transcranial magnetic stimulation (TMS) to measure the level of excitation and inhibition in the corticospinal system. Tremblay et al. (2001) showed increased motor-evoked potentials specific to the targeted muscle during motor imagery, supporting similar findings in previous studies (Abbruzzese et al., 1999; Rossini et al., 1999). Facchini et al. (2002) further elaborated on these findings and indicated that motor imagery during unilateral tasks are associated with increased contralateral primary cortex excitability, mirroring motor movement cortical activity.

There is a wealth of literature regarding the use of motor imagery and its application as a training tool. Studies of healthy individuals utilizing motor imagery techniques have demonstrated enhanced performance of various aspects of motor control including strength gains, improved speed, increased range of motion, and improved postural control (Dickstein & Deutsch, 2007). The majority of research on healthy individuals utilizing MI however is in younger populations, especially as a tool for athletes (Blair et al., 2000; Taktek, 2004). Sidaway and Trzaska (2005) demonstrated that twenty year olds without impairment increased ankle Dorsiflexion (DF) strength via mental practice. Ankle DF strength was chosen because of its importance in gait and stair climbing. Another trial of healthy 20 year olds demonstrated that motor imagery training improved dynamic balance similarly to physically training balance (Choi et al., 2010). Motor imagery in the elderly has an intense focus as a rehabilitation tool post CVA, but the exploration of MI in healthy elderly populations is minimal. In a study by J.E. Deutsch (2012) with patients recovering from stroke, motor imagery training resulted in improvements with gait (walking) and balance ability and when compared with on-site manual therapy the motor sessions resulted in less therapist travel time and cost, as well as shorter therapy sessions. A randomized control trial by Cho et al. (2013) showed that motor imagery training with gait training was more effective than sole gait training to enhance balance and gait in chronic stroke patients. Another case study suggested the usefulness of MI to enhance the walking abilities of a patient post CVA (Dickstein et al., 2004).

An additional finding during earlier MI studies was the thought that observing the actions of someone else or oneself facilitated the same corticospinal areas during the physical execution of the observed movements (Fadiga et al., 1995). For consistency throughout the paper this concept is defined as action observation (AO). Action observation (AO) is another non-physical method of training, in which the learner observes the action of another individual (Van Tilborg et al., 2011). Patuzzo et al. (2003) proposed the specific motor facilitation during action observation, showed no differences were present when subjects observed actions performed by themselves or others. The most recent literature has revealed a ‘mirror-neuron system,’ a class of neurons in the ventral pre-motor cortex and inferior parietal lobule that respond during the execution and the observation of goal-directed motor acts (Casile, 2013). Interestingly, the initial beliefs that the mirror neuron system simply “mirrors” observation activity and execution activity may not be true. Baldissera et al. (2001) demonstrated that not only are the same cortical areas active during AO and physical movement, but there is also an opposing signal generated in the spinal cord during AO not present in MI or movement. Vigneswaran et al. (2013) produced evidence that within the mirror neuron system, facilitating neurons were only half as active for action observation as for action execution, and that suppression neurons reversed their activity pattern and were also facilitated during execution of observation. This is believed to be an inhibitory mechanism preventing execution of the observed actions and explained by Fadiga & Craighero (2004) to “leave free the cortical motor system to ‘react’ the observed action without the risk of overt movement generation.” There is an ongoing debate in regards to these findings and their implications on motor learning.

The majority of research in action observation’s use as a motor learning tool has been in relation to its ability to be used as a teaching technique, especially in an academic or work environment in which a teacher or employer demonstrates proper techniques (Magill, 1993). Considering that motor training requires a learning process, the theory that action observation has clinical benefits in a rehab setting and to society as a whole is a useful proposal that has yet to be explored in detail versus physically practicing the observed techniques.

It is important to note that not all individuals are candidates for motor imagery or action observation. A study of patients with a right hemisphere stroke resulting in unilateral neglect revealed they were less capable of performing visual and mental tasks, impairing the potential benefits of such training techniques (Vromen et al., 2011). Other studies have demonstrated that action observation did not necessarily correlate to the learning of motor skills (Kelly & Burton, 2001).

A basic expanded timed walking test (TUG) that accounts for speed and smoothness of ambulation will be used as the basis for grading the improvements of each experimental group. Botolfsen et al. (2008) demonstrated the usefulness to analyze subtasks of the traditional TUG and higher reliability and validity than traditional TUG to identify impaired mobility. Van Swearingen et al. (2011) indicated in a randomized control trial that improvements in gait speed led to functional gains in other areas and also increased physical activity and function. To test if training in the TUG would lead to improved speed in another walking task, a Figure-8 Walk (F8W) test, in which subjects walk in a figure 8 pattern around 2 cones, also will be included without practice. Hess et al. (2010) showed that walking skill in older adults could be assessed validly via the F8W. It is our goal to determine if similar improvements in walking speed and smoothness in both the motor imagery and passive observation group are found in comparison with the physically practicing group. The scale for grading smoothness of gait uses the same criteria as a previous study by Brach et al. (2011). This would be a significant finding and can be a useful tool in the gait training of elderly individuals. Motor practice and observation are a much more practical means of training that can be utilized at any moment of the day regardless of the presence of a healthcare assistant. With many of the aforementioned articles mentioning gait training as a way to decrease fall risk, both MI & AO may have the additional benefit to reduce the occurrence of falls, injury and death among elderly populations similar to the way physical practice appears to.

METHODS

Twenty subjects between the ages of 60-80 participated in this study. Of these subjects, 2 were men and 18 were women. All subjects were residents of Shore Road Facility of the

Lutheran Medical Center in Brooklyn, NY. All testing took place in the recreation room. Subjects were included if they were ≥ 60 years old, a resident of Shore Road Facility of Lutheran Medical Center, they ambulated with either no assistive device or a unilateral assistive device such as a cane, and scored > 24 score on Mini Mental State Exam (MMSE). The MMSE is a brief 30-question test that focuses on mathematics, memory and orientation to screen for cognitive impairment. Subjects were excluded if they had a previous diagnosis of Diabetes Mellitus, hypertension, any neurological disorders including CVA or Parkinson's disease, used a walker, two canes or two crutches for ambulation. Other general information was also obtained, including each subject's name, age, resident room number, any history of neurological disease, and if they could safely ambulate without or with an assistive device (cane or quad cane). Each participant was given a detailed oral and written explanation of the study, and each signed an informed consent form. The experimental protocol was approved by the Institutional Review Board (IRB) committees of the City University of the New York and Lutheran Medical Center. A translator was present for Chinese-speaking participants.

Subjects were interviewed for inclusion/exclusion criteria. All subjects were assessed with the Expanded Timed-Get Up and Go (TUG) test and Figure-8-Walk (F8W) test. The Timed-Get Up and Go (TUG) performance has six components. They were to stand up from a chair, walk 10 meters, turn around, walk another 10 meters, and sit down in the chair. The stopwatch was started on the word 'go' and times were recorded at the six following stages: sit-to-stand, as the subject passed the 2 meter mark (gait initiation), as the subject passed the 8 meter mark (walk 1), as the subject passed the 8 meter mark when returning (Turn), as the subject reached the chair again (walk 2), and stand-to-sit. The 10-meter course was measured using the same meter stick at each session and a marker was placed at each point to delineate where each measurement was.

A black cone was placed at the end of the course in which subjects used to turn around. The TUG test was measured by three skilled movement components; speed (time to complete the course), amplitude (the number of steps taken to complete the course) and smoothness (three-item component scale). The three-item smoothness component scale included the subjects' ability to complete the course without stopping, hesitation, and changing pace. A grade of 0 or 1 was given for each test; 0 indicating any difficulty or 1 indicating no difficulty. This gives a total smoothness scale of 0 (not smooth) to 3 (smooth).

The Figure-8-Walk (F8W) test was also administered to the subjects in order to determine if training for active observation and motor imagery would also yield improvements in this non-associated task. In the F8W the subject starts between cones placed five feet apart from each other. The F8W test was shown and verbally explained to the subjects prior to them starting the course. The subjects were to begin to walk in a figure 8 pattern around the cones in whichever direction they choose. The same measurements used for the TUG, was applied to measure the F8W test (speed, amplitude and smoothness).

Subjects were randomly assigned to three training groups: motor imagery, active observation and motor training. The motor imagery training consisted of the subject relaxed, seated and eyes closed while one of our team members recited from a script a step-by-step walkthrough of the TUG. This was then followed by the subject imagining themselves performing the TUG for however long it took them to go through the course. There were no time constraints for this however some did it faster than others. This was performed for 3 cycles and once the subject was done imagining themselves performing the course, the next cycle began. The action observation group consisted of the participant relaxed and seated while viewing a video of one of our team members from the camera screen performing the TUG at a fast and smooth pace. Subjects were advised to actively watch the tape with no verbal cues. Verbal cues were not given to ensure the subject was not biased as to where they focused. Concentration on the 'particulars' of the TUG was freely determined by the subject. This video was viewed 3 times with a 15 second rest period, which was used to rewind the videotape. The motor training group practiced navigating the TUG course 3 times with a 2-minute rest period in-between cycles.

The experiment lasted three weeks. On day one, all subjects performed the TUG and F8W tests to assess baseline values for speed, amplitude and smoothness. Each subject trained for two weeks (four consecutive days per week). On the final day (10) in week three, the participants were assessed on the TUG and F8W tests. Only 18 subjects (2 subjects were unavailable for personal reasons) were reassessed again with the TUG and F8W tests six months later without treatment. This was used to compare the subjects to themselves (as their own control) to determine if any improvements were made with training. Subjects were paid $30 in cash and signed a confirmation form that they received $30 cash for their full participation in our study. This study was supported by the Doctoral Student Research Grant (DSRG) via the CUNY Graduate Center in competition round #8.

Table 1. Treatment Protocol

	Motor Imagery	Active Observation	Motor
Day 1 (pre-test)	TUG & F8W	TUG & F8W	TUG & F8W
Day 2-9	Treatment	Treatment	Treatment
Day 10 (post-test)	TUG & F8W	TUG & F8W	TUG & F8W

Table 2. Control Protocol (6 month gap)			
	Motor Imagery	Active Observation	Motor
Day 1 (pre-test)	TUG & F8W	TUG & F8W	TUG & F8W
Day 2-9	No Treatment	No Treatment	No Treatment
Day 10 (post-test)	TUG & F8W	TUG & F8W	TUG & F8W

DATA ANALYSIS

SPSS version 20.0 was utilized for data analysis. The threshold for significance for p-values was set at < 0.05. A 2-level repeated measures ANOVA was used to analyze all the factors of the data. The within subject levels were (sit to stand, initiation, walk 1, turn, walk 2, stand to sit, smoothness, number of steps, and figure 8 time) control and treatment. The between factor (motor, imagery, observation) aspect of the ANOVA was for the whole group. In addition the Bonferroni post-hoc test was run to evaluate any interaction between groups.

In order to determine the change in time of each variable, the Post test times were subtracted from the pre-test time. Therefore, a positive number indicates improved speed after training. A negative number indicates decreased speed after training.

RESULTS

Figure 1 indicates the difference (Pre/Post) of the total TUG time (in seconds) for each group (Imagery, Observation, Motor) tested. For each group, a significant improvement in speed after training was found Imagery p = 0.033 ($F_{1,6} = 7.66$, $p < .05$); Observation p = 0.030 ($F_{1,4} = 40.43$, $p < .05$) ; Motor p = 0.038 ($F_{1,5} = 7.85$, $p < .05$).

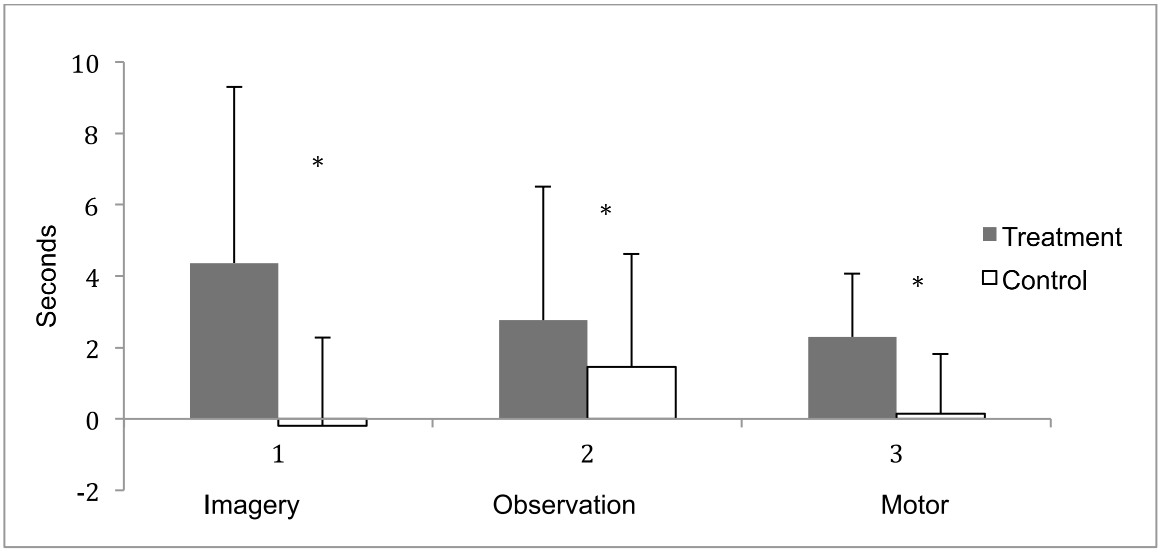

Figure 1. Difference in Total TUG time (Post-Pre times).(* $p < 0.05$ between Treatment and Control groups)

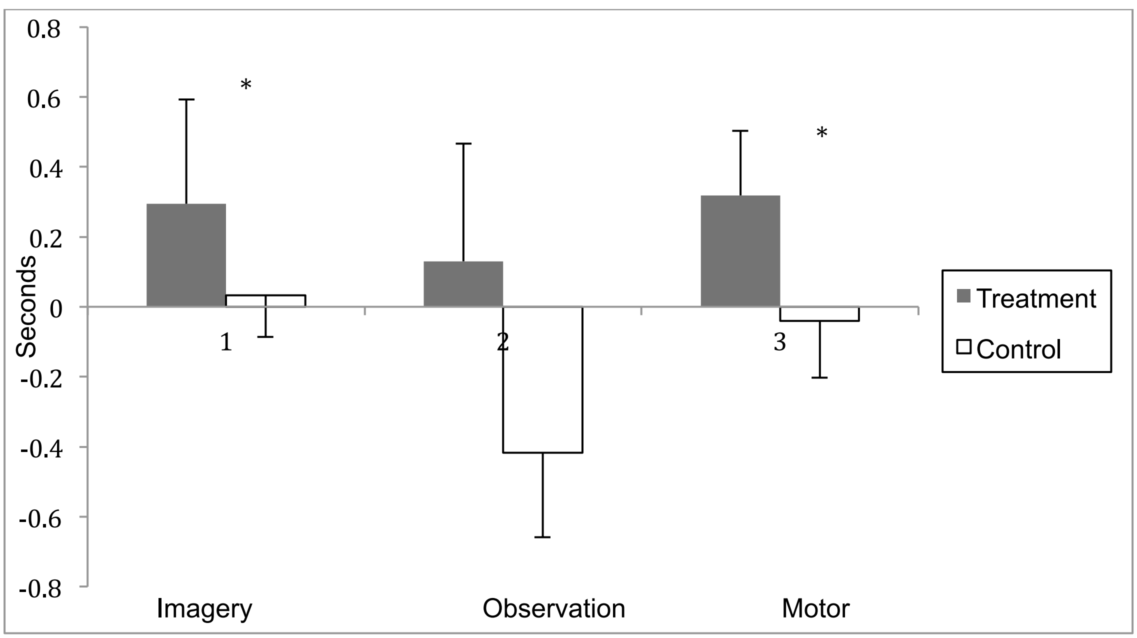

Figure 2. Difference in Sit-Stand time.(* $p < 0.05$ significant difference between Treatment and Control.)

Figure 2 indicates the difference in Sit-to-Stand time for each group (Imagery, Observation, Motor). Imagery p = 0.014 ($F_{1,6} = 11.57$, $p < .05$) and Motor p = 0.04 ($F_{1,5} = 25.91$, $p < .05$) demonstrated significant improvement in speed after training. Imagery significant when compared with Observation group (p = 0.004). Motor significant when compared with Observation group (p = 0.01)

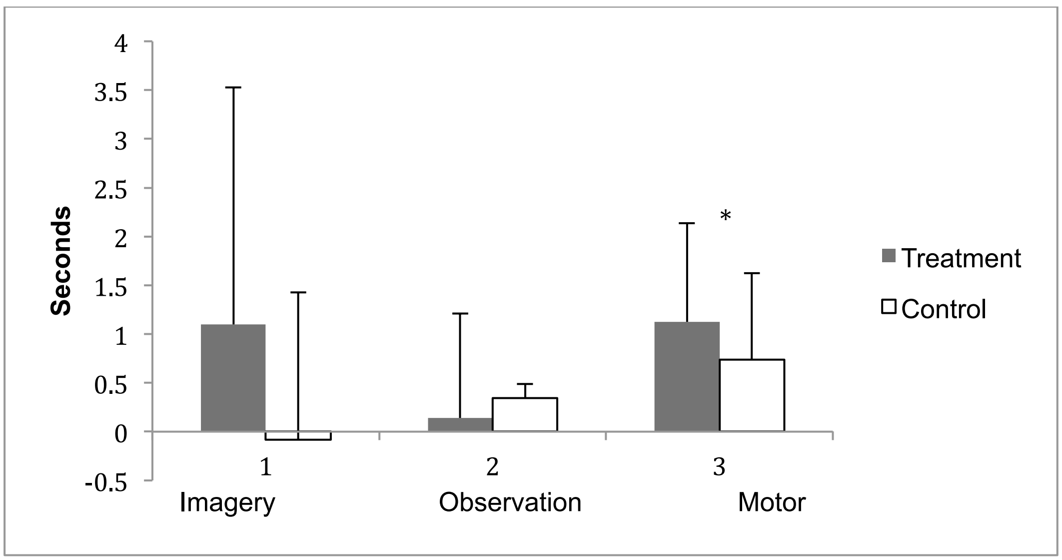

Figure 3. Difference in Turn. (* p < 0.05 significant difference between Treatment and Control.)

Figure 3 represents the values of difference in Turn times for each group (Imagery, Observation, Motor). Motor p = 0.046 ($F_{1,5} = 6.95$, $p < .05$) demonstrated significant improvement in speed after training.

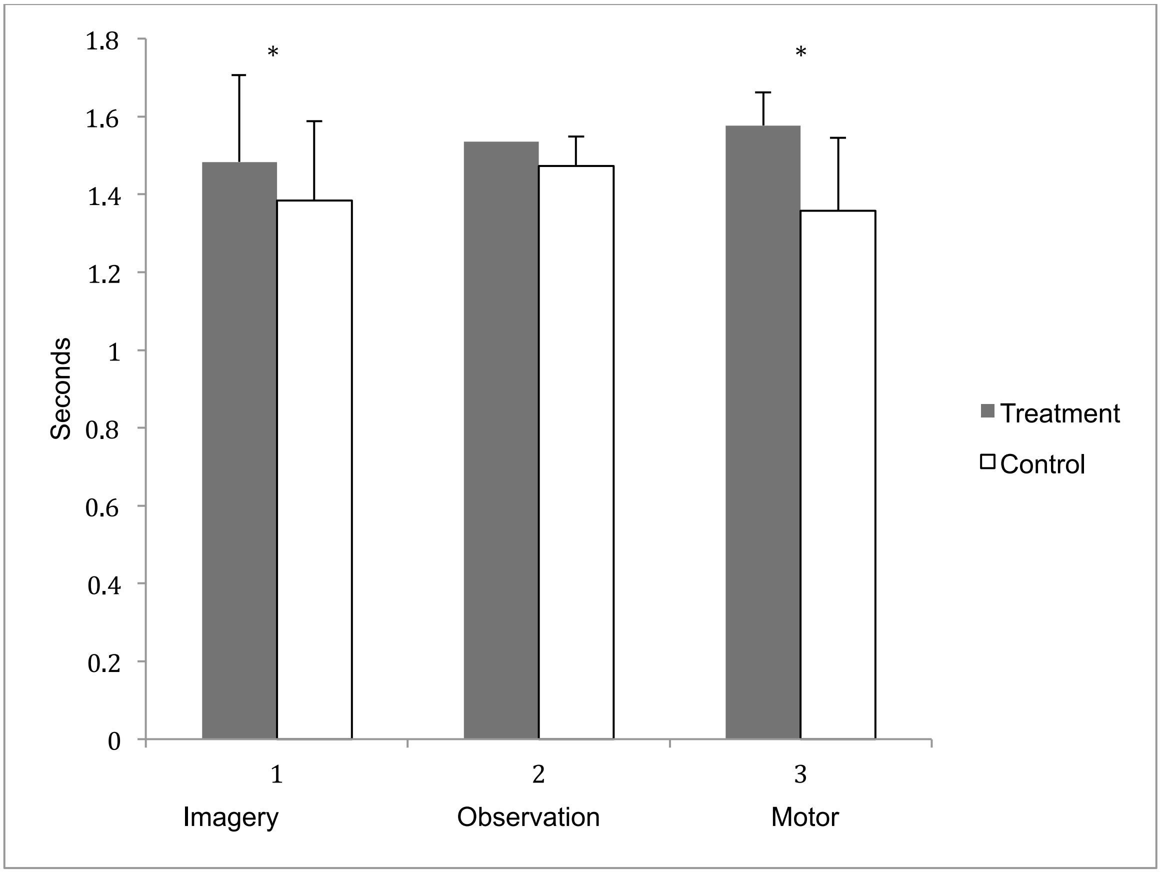

Figure 4. Cadence(* $p < 0.05$ significant difference between Treatment and Control groups.)

Figure 4 represents the values of Cadence for each group (Imagery, Observation, Motor). Imagery p = 0.014 ($F_{1,6} = 11.56$, $p < .05$) and Motor p = 0.019 ($F_{1,5} = 11.55$, $p < .05$) showed significant improvement in speed after training. No significant change was found in Initiation, Walk1, Walk2, or Sit when comparing Post-test times compared with the Pre-test times. In addition there were no significant changes in F8W, step number, or smoothness.

DISCUSSION

All three interventions, motor imagery, physical practice, and action observation had significantly improved total TUG times compared to the control group. This is consistent with findings from previous studies including Cho et al. (2013), who found that gait training with motor imagery significantly improves the balance and gait abilities in stroke patients compared to gait training alone. Furthermore, the results were also consistent with previous findings from Tia et al. (2010), who established that action observation improved motor abilities in elderly subjects in walking. When the 3 groups were compared against each other, there was no significant difference noted between the intervention groups. This is consistent with a previous study by Kim & Lee (2013) in which both action observation and motor imagery training significantly improved TUG times as well as gait speed and cadence compared to a control group. That study also found no significance between the action observation and motor imagery groups.

When analyzing the components of the TUG, only one individual component had a significantly improved time versus the control. This was the sit-stand portion of the test. Both the motor practice and motor imagery interventions revealed significantly improved sit-stand times versus the control. Action observation had no significant individual component gains compared to the control. The literature to compare this finding to is sparse. It may be possible to attribute this to Vigneswaran et al.'s (2013) finding that neurons facilitated during AO were only half as active as those during action or MI. However the fact that the overall TUG times did significantly decrease with AO leaves doubt around that possibility. Another explanation could be that the subjects were not fully engaged with the task in the beginning of AO training. Villiger et al.'s (2011) study revealed that cortical activity during AO increased as the subject was engaged and focused on the task and decreased when their attention drifted from the task. AO training subjects could potentially be at a higher risk of distraction compared to the motor practicing group and motor imagery group because the latter two groups are forced to engage in the activity otherwise nothing would happen. The actions observed during AO training will take place regardless of the subjects' level of activity, as someone else is performing the actions. There is also evidence of initial strength gains during training resulting from neural adaptations that enhance motor unit activity patterns (Hakkinen et l., 1996; Moritani, 1993). Rising from a seated position to standing may be the most demanding strength requirement during the TUG test, which may explain why the motor practice and motor imagery group both saw significant gains in this area. The training interventions for MI and motor practice target similar corticospinal pathways with no evidence of a suppressing effect. Although Tia et al. (2010) established that action observation and physical practice activate a common cortical network, it is not fully understood yet how action observation's mirror neuron system creates learning in the brain. It is possible that the initial improvements in neuromuscular control may not be replicated with action observation, another possible explanation as to why the gain in the first TUG component (sit-stand) may have similar gains with motor imagery and motor practice, but not with action observation.

The Figure-8 Walk Test was performed to determine if there was a transfer effect in training. Subjects in all intervention groups had improved Figure-8 walk test times but they were not significantly different from the control group. This is inconsistent with VanSwearingen et al.'s (2011) study demonstrating improved performance in other areas and increased physical function. In that study, however, multiple transfer scales were used, including subject questionnaires regarding activity level and standardized scales measuring gait efficiency. It would have been useful to use the same scales in our evaluations in order for consistency when comparing.

Retesting the intervention groups 6 months after their training revealed that gains were not maintained, and their TUG times reverted to the pre-intervention times. Other studies with longer training interventions have revealed maintained gains up to 3 months post (Deutsch et al., 2012). Testing the subjects again 2 weeks after this point (the same time period used in the intervention group) allowed for the subjects to act as their own control. Ideally, the control testing would be done first, but due to the fear of time constraints and the small number of participants the intervention was performed first. This was in order to ensure at the very least a comparison between interventions. Future studies examining the effects of the three interventions provided (MI, AO, and physical practice) should be performed simultaneously with a separate control group.

Standard deviations for the overall TUG times in intervention groups were higher than the average time improved. Furthermore the majority of participants were female. These are weaknesses that may have been remediated with a larger, more diverse subject pool. Additionally, no standard reference is available for how often or for what duration participants needed to watch the recording during the action observation portion of the study. Future studies need to investigate the minimal level of repetition for active observation to result in improved performance, and whether there is a ceiling at which time no additional amount of repetition will improve performance. The interventions took place in an open area, and all distractions could not be controlled, however the control subjects were also evaluated in the same area. Ideally, all distractions would be eliminated. Further research should focus on the carry over of motor imagery and action observation interventions in gait training, including their influence on balance, coordination, and ability to decrease fall risk. It has already been demonstrated that gait training and motor performance can improve community participation, performance of ADL's, and quality of life. (Tia et al., 2010) Those findings, however, did not utilize motor imagery and action observation as training techniques.

The results of this study are clinically applicable to therapists who provide care to elderly patients in need of interventions to improve gait parameters. The findings suggest motor imagery and action observation have an effect mirroring that of motor practice. This allows the patient to mobility train in any setting without having to physically perform the action. If utilized properly, the interventions may aid in decreasing the time needed to rehabilitate the patient, improve gait training, and further decrease the risk of falls.

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