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THE EFFECT OF MOTOR IMAGERY PERSPECTIVE ON ACTIVITY OF THE BICEP BRACHII

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ABSTRACT

To investigate the effectiveness of imagery perspective (internal imagery and external imagery) on the ability to activate target muscle groups, 16 (8 male, 8 female) participants considered to be experienced weight lifters were examined in this study. The internal imagery perspective of a heavy weight was expected to produce larger electromyography (EMG) activity of the biceps brachii compared to internal light, external light, and external heavy conditions. However, the One-Way Within Subjects ANOVA suggests no significant main effect for trials, $F(3,45) = 0.117$, $p = 0.764 > 0.05$. While this study didn't result in any significant findings between imagery conditions, this research postulates important directions for future research.

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Chapter 1

1.1 Introduction

In recent decades, psychophysiologists have been interested in researching motor imagery in relation to muscle activity. Motor imagery (MI) is a mental process by which an individual rehearses a given action without physically engaging in the activity. There are two main types of imagery: internal, first person perspective, and external, third person perspective. Previous research reveals a long history to the question of whether or not specific patterns of efferent activity (motor response) are associated with type (i.e., internal or external) and content of imaginal activity. More specifically, psychophysiologists have conducted studies examining patterns in the responses of subjects given instructional cues to form an image. Evidence suggests that imaginal recall of a task that has recently been perceived results in “sense organ changes and muscular adjustments” which mimic the patterns during actual perceptions (Lang, 1979); simply stated, imagining the task can have a material effect on muscle activity. This research also provides evidence for the idea that responses in imagination are dependent upon specific cues relative to the original perceptual responses (Lang, 1979).

Based on his bioinformational theory that an “image is a functionally organized set of propositions stored by the brain,” Lang suggests that the two main types of cues in imagery are response and stimulus propositions. Response propositions are statements designed to elicit physiological responses that parallel the responses during the actual movement. Hence, for practical purposes, response propositions serve as the internal imagery perspective; they are responsible for creating similar physiological responses to the actual movement and create a first person point of view (inside the body looking out). On the other hand, stimulus propositions are statements that are descriptive of specific features of the scenario. Therefore, stimulus propositions serve as the external imagery perspective; being descriptive of the scenario, they create a third person point of view (outside the body looking in) for the imager.

Following Lang's bioinformational theory, research has shown imagery instructions that contain response propositions elicit greater physiological responses compared to scripts with only stimulus propositions. Response propositions are thought to elicit greater physiological responses because they describe the imager's response to a particular scenario and focus on what the imager would feel while actually completing a task. On the other hand, stimulus propositions are statements that are more descriptive of specific features of the scenario. Work to date therefore suggests that imagery scripts that only contain stimulus propositions are less effective than imagery scripts that only contain response propositions (Weinberg & Gould, 2015).

1.2 Purpose

Traditional studies of motor imagery have divided participants into a control and experimental group, where the experimental group engaged in some type of imagery intervention. These studies, which will be reviewed in Chapter 2, have looked into the effectiveness of internal (response propositions) versus external imagery (stimulus propositions) perspectives in performance ability of a simple task. Other studies, also discussed in Chapter 2, have evaluated the ability of imagery to produce muscle activity of target muscle groups. These studies have been particularly interested in the type of imaginal activity and the effects of imagery on muscle responses. With limited exceptions, studies have not looked at varying weights in conjunction with imagery in much detail. To date, there is a lack of studies that have examined the usefulness of combining different imagery perspectives alongside varied weight conditions to determine which conditions produce the greatest muscle activity. Therefore, the purpose of this experiment was to re-evaluate the type of imagery that is most effective in producing muscle activity in conjunction with which imagined weight condition produces the most muscle activity.

1.3 Experimental Overview

Participants first completed a warm up. Following the warm up, relaxation cues were read to participants and participants were instructed to relax their muscles. Depending on the given condition, the appropriate imagery script was read to participants. EMG was measured during each of the imagery conditions and a post-imagery questionnaire was filled out in order for participants to self-rate their ability to use the appropriate type of imagery dependent on the script they were read. Chapter 3 contains further details regarding the methods that were used in this study.

Chapter 2

Review of Literature

2.1 Overview

This chapter is a review of literature regarding imagery studies. It examines the following: the usefulness of imagery in everyday life (including the benefits of using imagery in rehabilitation settings post stroke); the benefits of using one imagery technique as opposed to the other (internal imagery perspective compared to external imagery perspective); muscle activity in response to motor imagery; and, lastly, differences in muscle activity when measured by electromyography (EMG) according to the types of imagery that will be discussed.

2.2 The Importance of Imagery and Its Effects

Over the past few decades, imagery has rapidly and increasingly become a topic of concern to many psychophysiologists interested in improving motor function. Fuelscher and Hyde (2015) investigated the purported association between developmental changes in the efficiency of online reaching corrections and improved action representation. “Online” control simply refers to the ability to correct a movement mid-movement in response to unexpected changes. Participants were responsible for completing an online control task (that assessed reaction time and movement time) as well as a hand rotation task (that assessed response time and accuracy testing motor imagery). The online control task was completed using a double-step reaching task (DSRT) on a 40-inch touch screen monitor, DSRT simply meaning participants were responsible for a multistep reaching task. There were four circles located on the screen. The circle at the bottom center of the screen was referred to as “home base.” The remaining three circles fanned out and were located at -20 degrees, 0 degrees, and 20 degrees with respect to “home base.” Using their dominant index finger, participants were instructed to touch and hold “home base” until it darkened and the next circle lit up, at which point they were to move their dominant index finger to the center of the circle accordingly as quickly and accurately as possible. Jumping trials were also included as part of this task. Jumping trials are described as trials that involved the proceeding circle to rapidly change from one circle to another. This change of target circle required the nervous system to adapt mid-movement to correct the action. The hand rotation task tested motor imagery by displaying a hand on the screen in various orientations, requiring participants to determine whether the stimulus presented was a right or left hand as quickly and accurately as possible. The regression analysis showed that imagery ability significantly predicted reaching efficiency. This was the first study to provide empirical evidence that more efficient online control through development can partly be predicted by improved action representation ability. This research is supportive of current neurocomputational theories of human reaching and extends preliminary evidence from healthy adults.

2.2.1 Motor Imagery in Rehab Settings

As imagery has grown more popular and scientists concur that it is an effective way of eliciting a motor response, studies have been done to determine the usefulness of motor imagery in rehab settings, particularly involving stroke.

A study by Page, Levine, and Leonard (2005) investigated the use of mental practice (MP) (for practical purposes, MP can be considered the same thing as MI) in rehabilitation settings for stroke patients. Prior to completion of the experimental and control group interventions, participants were required to complete the Motor Activity Log (MAL) and the Action Research Arm Test (ARA). The MAL is a questionnaire assessing how patients use their affected limb during Activities of Daily Living (ADLs) and was completed by the participants as well as the therapist about completion of 30 ADLs in the past week. The ARA assesses one's ability of grasp, grip, punch, and gross movement on a 4-point scale. The control group received 30-minute therapy sessions twice a week for six weeks emphasizing ADLs, while the experimental group received the same therapy in conjunction with MP. As a result, the rating of affected limb use (MAL and ARA scores) for MP patients increased in patients and caregivers (1.55 and 1.66 respectively), as well as the increase in the quality of movement (2.33 and 2.15 respectively). This study provides evidence that MP may help in increasing a stroke patient's use of the affected limb. This study also shows a correlation between MP and motor function improvements. Although providing solid evidence that mental practice is useful for stroke patients to regain movement in rehabilitation settings, the definition of mental practice is loosely defined. For the purpose of this study, it is impossible to know whether mental practice includes the use of visual or kinesthetic imagery rather than simple cognitive rehearsal of the task the same way that MI is thought to do.

Liu, Chan, Lee, and Hui-Chan (2004) examined the effectiveness of mental imagery in encouraging relearning for patients after stroke. Participants were randomly assigned to a control group and experimental group; the control group participated in conventional functional training interventions to recover the ability to complete daily tasks while the experimental group participated in the mental imagery based intervention. Those receiving the imagery based intervention were trained in proper techniques of mental imagery to accurately practice the tasks. As a result of this study, the mental imagery intervention group showed greater relearning of both trained and untrained tasks compared to the control group (who did not have imagery intervention). The mental imagery group also demonstrated a greater ability to retain the trained tasks after one month and transfer the relearned skills to other untrained tasks. In its entirety, this study shows that mental imagery is a successful technique to promote relearning of daily tasks for people after an acute stroke. More specifically, this study demonstrates imagery with the ability to improve the planning and execution of both the trained and untrained tasks as well as relearning appearing to help patients retain and generalize the skills and tasks learned in the rehabilitation program. This study provides great insight into the usefulness of motor imagery in rehabilitation settings for stroke patients. However, limitations of this study include the small sample size, the short follow-up period, and the lack of control of patients' brain lesion sites. Another limitation to this study is the lack of control for the degree at which patients actively engaged in the imagery processes. Studies of a similar nature could be significantly improved by addressing these limitations.

A case report by Dickstein, Dunsky, and Marcovitz (2004) examined the effect of MI practice on extremity functions in a 69-year-old man with left hemiparesis following stroke. The patient received MI gait practice for six weeks. The MI intervention focused on task-oriented gait and on impairments of the affected lower limb. Pre-intervention, midterm, post-intervention, and follow-up measurements of temporal-distance stride parameters and sagittal kinematics of the knee joint were taken. After six weeks of MI gait practice, the patient increased gait speed by 23% and reduced double-support time by 13%, as well as displaying an increase in the range of motion of the knees. These results suggest that MI may be useful for enhancing walking ability in patients following stroke.

The studies mentioned in this section provide useful evidence that motor imagery can be used to effectively increase range of motion and movement in patients who suffer loss of movement as a result of stroke.

2.3 Internal and External Motor Imagery

As described by Mahoney and Avener (1977) external imagery is imagery in which a person views himself/herself from the perspective of an external observer (much like in home movies). Internal imagery, on the other hand, requires an approximation of the real-life phenomenology such that the person imagines being inside his/her body and experiencing the sensations that would be expected in real situations. In one study, Mahoney and Avener (1977) found that higher skilled gymnasts tended to think about gymnastics in everyday situations. These gymnasts described “talking to themselves” considerably during training and competition. The Olympic team qualifiers also reported varying reliance on types of mental imagery. All finalists reported using imagery extensively, but the better athletes reported a higher frequency of “internal” rather than “external” images. Although it provided good evidence for internal imagery being more effective than external imagery, this study was limited by the small sample size as well as the strict sample of people that were investigated. All things considered, these limitations make it difficult to apply the results from this sample to the general population.

A few years later Epstein (1980) examined the relationship of internal and external imaginal rehearsal and imaginal style to a skilled motor behavior, in this case, dart throwing.

Participants were split into three groups; the internal imagery condition (N=30), the external imagery condition (N=30), and the control group (N=15). Initially, all of the subjects were given an imagery-style questionnaire involving picturing four images and rating their ability to do so as well as the clock test; the clock test involved tracing a clock on the participants' forehead and tracing the hands at either 3 or 9 o'clock. Depending on the response of the individual, they were either scored with an internal or external response. Each participant then underwent baseline dart-throwing where they threw 30 darts before being read their instructional cues according to imagery condition. After imagery training, participants once again threw 30 darts in the same fashion while engaging in the instructed imagery. The control group was instructed to count backwards by sevens prior to throwing the darts in the hopes of controlling for self-initiated mental rehearsal of the dart throwing task. Post experimentation, participants were given another questionnaire to assess their ability to engage in the appropriate rehearsal, while the control group was given a questionnaire to assess the efficacy of the counting task. As a result, males who had reported tactile imaginal sensations, thought to mimic the internal imagery perspective, were more skilled at dart throwing than males who did not report tactile sensations. These results parallel the results of Mahoney and Avener and suggest that internal imagery may be more beneficial to performance than external imagery as external imagery items yielded many negative coefficients. From this we can suggest that external imagery negatively affects one's ability to concentrate on the appropriate cues for success. Rather than successful cues of a task, external imagery may be related to focusing on mistakes and recalling previous failures rather than success. In an attempt to explain why external imagery may be associated with lower performance, Epstein proposed that external imagery may not provide the imager with useful kinesthetic cues to focus on the skill and rather may focus the imager's attention on irrelevant or distracting aspects of the skill. Epstein also suggests that external imagery allows the imager to take on the role of a critical, evaluative observer, possibly increasing self-consciousness and nervousness. These reasons, however, are only speculative and cannot serve to explain why external imagery is associated with lower performance compared to internal imagery being associated with improved performance.

Once again examining the effects of imagery on muscle movement, Hale (1982) hypothesized that subjects engaging in internal imagery would produce greater EMG activity of the biceps during a biceps curl compared to subjects engaging in external imagery. Participants were classified as “experienced” weight lifters or “inexperienced” weight lifters and were randomly assigned to either a delayed imaginary lifting condition or an immediate imaginary lifting condition. A 7-point Imagery Exercise Questionnaire was completed alongside the kinesthetic and visual subscales of the Betts QMI Vividness of Imagery Scale prior to completion of the imagery interventions. The immediate imagery group completed a 1-minute prerelaxation baseline to assess tonic activity level at muscular and ocular sites and then a 20-minute abbreviated progressive relaxation tape was played in order to reduce residual muscle tension. Each participant viewed five filmed trials depicting the dumbbell curl from either a first-person or third-person visual perspective. In the internal imagery condition, participants were encouraged to “imagine what it feels like in your biceps to lift the 25-pound dumbbell,” and before the external imagery condition the emphasis was to “visualize what it looks like to lift the 25-pound dumbbell.” A significant within-subjects main effect for imagery was found as a result of this study, suggesting that internal imagery did, in fact, produce greater biceps activity than the external imagery perspective. The relaxation procedure incorporated into this study attempted to control for extraneous muscle movement that would alter EMG results. The relaxation procedure helped to ensure a stable baseline during imagery by reducing muscular activity, allowing us to attribute the EMG activity of the biceps to the imagery perspectives.

2.4 Effects of Motor Imagery on Muscle Activity

A study conducted by Guillot, Lebon, Rouffet, Champely, Doyon, and Collet (2007) investigated the muscular responses during actual lifting of a dumbbell and motor imagery (MI) of the same movement. Thirty right-handed (15 men and 15 women) sports students between 18 and 25 participated in this study. Before testing, maximum concentric capacity of a bicep curl was measured and each participant completed the MIQ-R. Each subject was assigned a score regarding the ease/difficulty of representing each movement mentally. Participants completed a warm up dumbbell curl and were then strapped in a chair with a goniometer and EMG electrodes on the active arm and non-dominant hand to eliminate extraneous movement. Participants were asked to lift or imagine lifting the weighted dumbbell for four different conditions. Results revealed that motor imagery was accompanied by not only a subliminal specific EMG activity of muscles acting as prime movers during the actual movement, but also EMG activity of the antagonist, synergist, and fixator muscles. Further, the statistical analysis revealed greater EMG activity during MI than during the rest condition, regardless of the subjects' gender, the muscles, and the type of contraction. This study was the first to provide evidence for an effect of the contraction type, as the EMG was found to be larger during the heavy concentric contraction than during both the light concentric and eccentric conditions. This study also provided evidence that MI and motor execution share common neural mechanisms.

2.5 Effectiveness of Internal and External Imagery Evaluated by EMG

White and Hardy (1995) investigated the effects of different imagery perspectives on aspects of motor performance. Participants were instructed to use their preferred type of imagery, internal or external, to complete a slalom course. Five blocks of three trials of the slalom course were completed. The time it took for each participant to complete the course, the number of missed gates, and the number of times participants hit the gates with the wheelchair were all assessed. Results revealed that the internal visual imagery (IVI) group completed the transfer trial with significantly fewer errors than the external visual imagery (EVI) group. This suggests that internal visual perspective might have allowed rehearsal of required responses at each gate, thus improving the 'readiness' of the system by centering attention on the cues to be used in order to negotiate each slalom gate accurately. Results also revealed that the EVI group completed all of the learning trial blocks and transfer block course significantly faster then the IVI group. Mainly, this study suggests that internal and external imagery are both useful in different ways as they had different speed/accuracy trade-offs in the transfer trial (IVI being accuracy based and EVI being speed based).

Wilson, Smith, Burden, and Holmes (2010) examined whether movement imagery results in greater physiological responses depending on who generates the imagery script: the participant or the experimenter. Twenty postgraduate university students and staff members (10 male and 10 female) were recruited to participate in this study. Each participant completed the Movement Imagery Questionnaire – Revised (MIQ-R) and were each given a score to indicate the ease/difficulty of the imagined activity. An EMG was used to evaluate muscle activity and the electrode sensors were placed over the midpoint of the distal half of the belly of the biceps brachii and the lateral head of the triceps while a reference electrode was placed over the dorsal surface of the wrist. Results revealed a significant effect for the self-rated imagery being higher in a participant-generated imagery script compared to an experimenter-generated imagery script. These results supported both of the studies' proposed hypotheses: that an imagery intervention using participant generated imagery scripts would produce a greater task-relevant muscle activity (therefore indicating greater imagery ability than experimenter-generated scripts) and that muscle activity in non-task-relevant muscles would not be significantly greater before baseline activity. This study has given useful insight to the effects of motor imagery on muscle activity. This study, however, lacks definitive evidence of whether or not participants moved during the imagery. It is a possibility that participants tensed their muscles during the imagery, which would be picked up by the EMG without knowledge of it being a result of actual movement or the imagery itself. Use of sensitive tools such as motion sensors or strain gauges would improve the reliability of this study and should be used in future research. According to the participants' MIQ-R scores, participants in this study could use imagery reasonably well, which creates another limitation. This is important when generalizing this information to other populations who may not have as much ease in imagining something. Also, the sample tested in this experiment included three participants who had no prior experience of imagery tasks while others were familiar with the idea. Lastly, among the sample in this study, there were two left-handed participants but the imagery was a right-handed task (making it a non-dominant movement for these individuals). Taken together then, improvements to the limitations of this study would provide further, possibly more accurate, knowledge about the effects of motor imagery on muscle activity.

2.6 Purpose of Study

The purpose of this study is to investigate the usefulness of imagery in everyday life by examining the effects of different imagery perspectives on EMG activity of the bicep. This study will also investigate the difference in EMG activity of the bicep according to different imagined weight conditions regarding the different imagery perspectives used.

Chapter 3

Methods

3.1 Participants

Eight males and eight females (ages 18-39) volunteered to participate in this study. Volunteers were recruited from a sample of weight lifters who regularly participated in weight lifting in the Penn State Berks Campus Beaver Community Center. The Pennsylvania State University Institutional Review Board for Human Subjects approved this study and, as per university policy for a study of this nature, all participants provided verbal consent.

3.2 Apparatus

A Delsys Trigno Wireless EMG System (Figure 1) was used for this study. This high-performing system is designed to make physiological measurements in movement science like surface electromyography (EMG) easy to assess by providing reliable recordings of the signal.

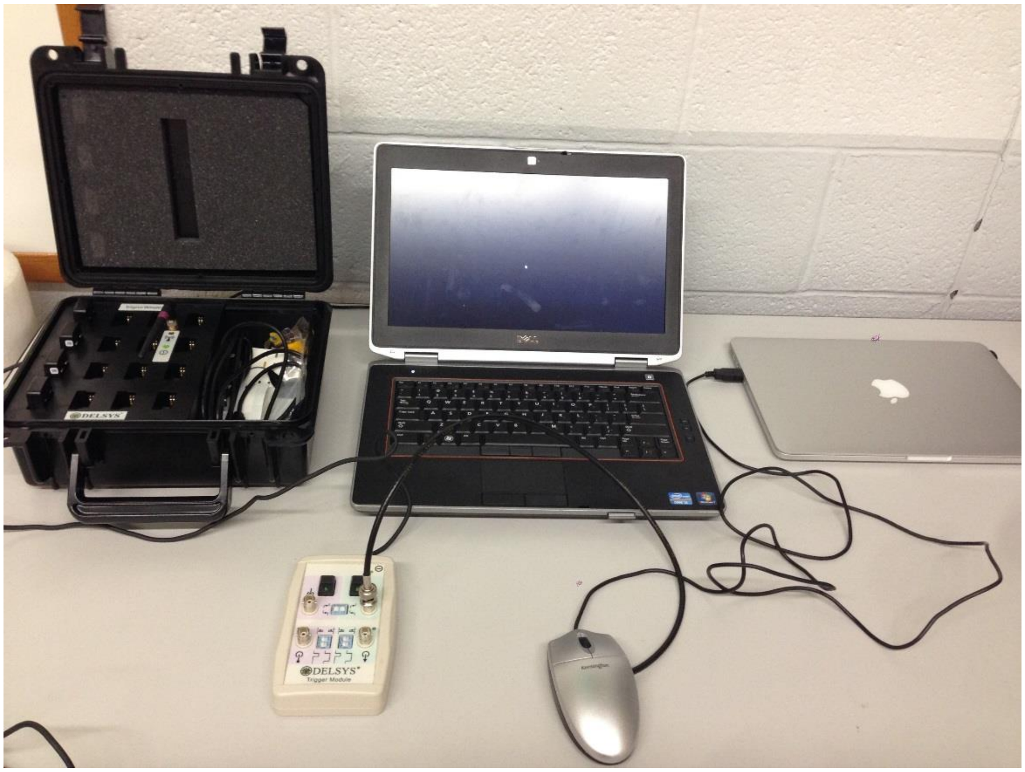

Figure 1. Delsys Trigno Wireless EMG System

Along with the Wireless EMG machine, a Delsys Trigger Module (Figure 2) was used in this experiment. The Trigger Module can be used in two different types of triggering schemes: Primary/Secondary Triggering and Independent-Signal Triggering. The Primary/Secondary Triggering scheme involves a Primary Data Acquisition System used to control a Secondary Data Acquisition System. The Independent-Signal Triggering scheme involves an independent trigger device being used to generate a signal to start both Data Acquisition Systems. In this experiment, the Trigger Module was used to start recording EMG activity on the Delsys Trigno Wireless EMG System simultaneously with the start of the recorded imagery scripts.

Figure 2. Delsys Trigger Module

3.3 Tasks and Procedures

Participants were first randomly assigned an order in which to complete the imagery conditions: internal heavy, internal light, external heavy, and external light. Next, participants completed a two-part general warm up. The first part of the warm up consisted of 2-3 repetitions of a dumbbell curl exercise using an 8-pound dumbbell (used for the light conditions) and the second part of the warm up consisted of 2-3 repetitions of a dumbbell curl exercise using a 20-pound dumbbell (used for the heavy conditions). During the warm up, subjects were instructed to focus on what their arm looked like when lifting the light weight compared to lifting the heavy weight. Participants were also instructed to focus on the physiological sensations experienced in the arm when lifting the weight. These instructions were intended to give participants enough information to follow the imagery trials proficiently as the physiological sensations were representative of the internal imagery perspectives and the visualization was representative of the external imagery perspectives. The 8-pound dumbbell was representative of the light conditions while the 20-pound dumbbell was representative of the heavy conditions, therefore making the differentiation between the two weights important for imagery conditions as well. Following the warm up, subjects denoted their "dominant" arm; alcohol pads were used to clean the upper arm and an electrode was placed on the belly of the bicep (Figure 3) using an adhesive sticker once the area dried completely.

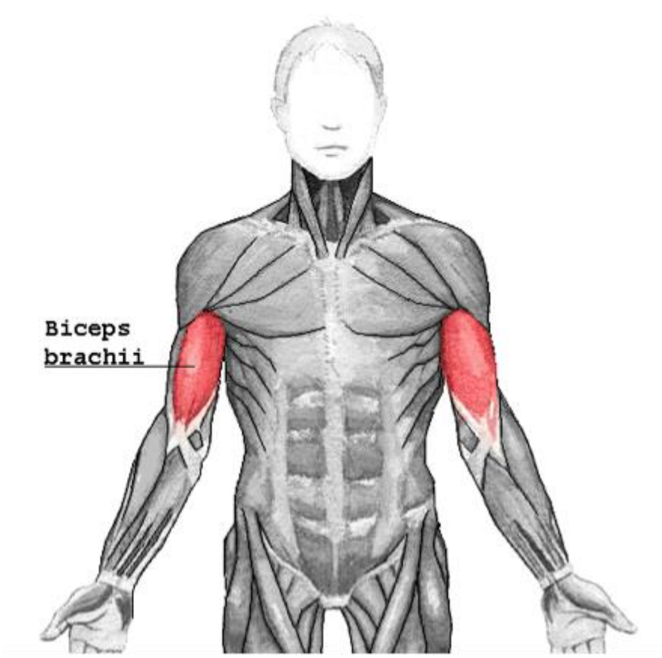

Figure 3. Biceps Brachii

A signal preview was examined to assure there was a clear signal on the EMG system. Following the signal preview, maximum voluntary contraction (MVC) was assessed to normalize the data for testing. The MVC was explained to participants; as a baseline for measurement, participants completed the MVC to normalize the data collected during imagery conditions.

Participants were told the system would start counting down from three, at which point the examiner would place support underneath the elbow with one hand and provide resistance motion by pushing down on the arm with the opposite hand while subjects sat in an upright position. Participants were to hold the maximum contraction for 3 seconds before relaxing and were then given a minute break in between trials. Three MVCs were taken for each participant. At this point, subjects were instructed to lay back on the experimenter table and relax. A relaxation script (Appendix A) was read twice to participants while a second signal preview ran simultaneously. This step was done to assure participants were not moving and were completely relaxed prior to testing imagery conditions.

The Delsys Trigger Module was connected to the Delsys Trigno Wireless EMG System and a Kensington two-tailed mouse (Figure 4) was connected to the trigger module and a second computer. Recorded scripts for each condition were played off of a second computer. The recordings (Appendix B) started in conjunction with the beginning of the EMG recording, and the recordings were played through three times for each condition. Post-imagery, subjects were instructed to continue lying down and were read a series of questions assessing their ability to use the proper type of imagery as well as the ease or difficulty of imagining according to the given condition (Appendix C). Participants were given a minute to rest between conditions, and the procedures for the external light condition were subsequently repeated for the other conditions: internal heavy, internal light, and external heavy. Each participant completed the four imagery conditions using the recorded imagery scripts.

Figure 4. Two-Tailed Mouse

Chapter 4

Results

Although we expected the internal imagery perspective of lifting a heavy weight to produce more EMG activity compared to all other conditions, results of the One-Way Within Subjects ANOVA suggest no significant main effect for trials, $F(3,45) = 0.117$, $p = 0.764 > 0.05$.

Table 1. Means and Standard Deviations Among Imagery Conditions

Conditions	Mean	SD	N
Internal Light	1.71	.822	16
Internal Heavy	1.68	.780	16
External Light	1.70	.917	16
External Heavy	1.72	.823	16

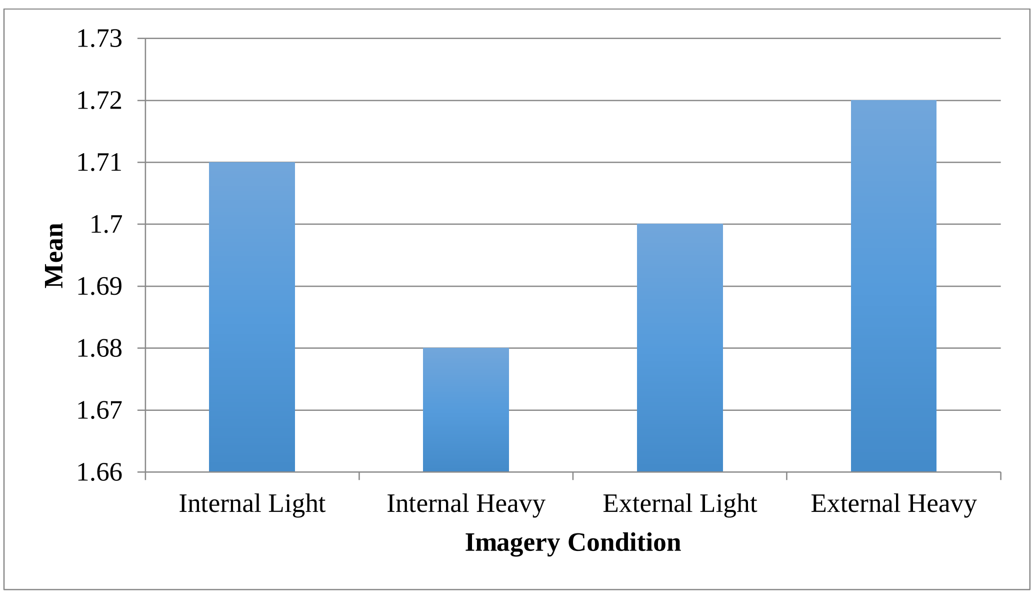

Figure 5. Mean EMG Activity of Imagery Conditions

Chapter 5

Discussion/Conclusion

As a result of this experiment and in accordance with previous research, it was expected that the internal imagery perspective of lifting a heavy weight would produce higher EMG signal compared to all other imagery conditions. However, statistical analysis shows no significant difference in average EMG activity among the imagery conditions.

As early as 1910, psychophysiologists have explored physiological patterns evoked by instructional cues to form an image in subjects who had no prior experience of that image. Perky examined the effects of asking subjects to generate an image from various cues on eye movement (1910). In a similar study, Jacobson recorded ocular movements in subjects asked to visualize specific things and found more ocular activity during imagery compared to relaxation (1930). He furthered his study by splitting subjects into two groups where he either asked them to “visually” imagine or “muscularly” imagine bending their right arm. Subjects who “visually” imagined the action showed more ocular activity while subjects who “muscularly” imagined the action showed more EMG activity, revealing that the efferent activity was affected by how subjects were instructed to imagine the experience (Jacobson, 1931). These results suggest that motor imagery is part of a broader phenomenon (the motor representation) related to intending and preparing movements (Jeannerod, 1995).

More recently, several studies have investigated the usefulness of motor imagery. These studies have found similar results that motor imagery can be beneficial. Mahoney and Avener (1977), Epstein (1980), and Hale (1982) all found comparable results that internal imagery is a more effective type of imagery compared to external imagery. EMG activity of a target muscle (agonist) has been found to be higher in internal imagery conditions than external imagery conditions; therefore, these studies suggest that to improve performance, internal imagery should be the preferred method of imagery. Not only is EMG activity of the agonist seen in these studies during imagery, but Guillot, Lebon, Rouffet, Champely, Doyon, and Collet (2007) found that imagery conditions resulted in EMG activity of synergist and fixator muscles as well.

Implications of this study involve motor imagery as an effective tool in changing or relearning behavior. As previously discussed in Chapter 2, Fuelscher and Hyde (2015) found that the higher the imagery ability of an individual, the more efficient their reaching ability. In simple terms, the easier it is for an individual to imagine a movement the easier it is to correct that movement mid-action. More realistically, Page examined the effectiveness in reacquisition of functioning post-stroke and found that patients who received imagery in conjunction with occupational therapy (OT) had significantly greater arm recovery than individuals who only received OT (2000). Another study investigated the effect of MI on functional recovery and found that there was a greater improvement on the training tasks for the MI group compared to the control group (Dijkerman, Letswaart, Johnson, & MacWalter, 2004). Similarly, Page, Levine, and Leonard (2005), Liu, Chan, Lee, and Hui-Chan (2004), and Dickstein, Dunsky, and Marcovitz (2004) also studied the recovery of motor functioning in stroke patients. These studies found comparable results of motor imagery being effective in regaining lost movement. Therefore, these studies suggest motor imagery can be used to regain lost motor function in patients who have suffered from stroke.

As motor imagery continues to prove useful in being able to enhance movement, skill level, or performance ability, it is important to understand how this imagery can be used in every day life. The studies mentioned above prove that motor imagery can help patients regain movement after stroke, which allows for advances in simple rehabilitation. In other terms, by simply imagining the accuracy in the completion of ADLs, an individual can improve upon their ability to perform these ADLs after stroke has impaired their ability to do so. Feedback obtained from executing targeted movements during physical rehabilitation would help produce more realistic and efficient motor imagery, hence increasing the potential of mental practice and possibly accelerating the rate of recovery (Jackson, Lafleur, Malouin, Richards, & Doyon, 2001).

Considering the results of previous studies and the insignificant results of this study, limitations must be considered. A difficulty in conducting this experiment was the availability of lab space. Due to the high demand for lab space, there were often interruptions that occurred during testing because of the multiple studies going on. This could have prevented an accurate reading of EMG activity for some participants between conditions based on their inability to properly focus on the imagery scripts during imagery conditions. Secondly, the placement of the electrodes could have prevented the best EMG signal. Some individuals had bigger, more pronounced biceps brachii therefore making it easier to accurately find the belly of the bicep to assure the clearest, most accurate reading of the EMG signal. Also, alcohol was the only substance used to clean the skin before applying the electrode. Debriding must occur in order to apply the electrode closest to the muscle allowing for the least signal interference from dead skin cells on the surface of the skin. The debriding of the skin was not completed during this experiment to assure participants were not injured in any way during testing.

Considering these limitations, future studies should incorporate debriding of the skin prior to applying the electrode to achieve a greater signal. This step will help determine a more accurate magnitude of EMG during imagery trials, which is important especially due to the fact that EMG signal during imagery trials will most likely be negligible compared to actual movement. Similarly, future studies should assure that testing can be completed in a quiet setting without interruptions to give participants the tools they need to appropriately follow the imagery scripts under total concentration. It may also be useful for future studies to give participants visual enhancements. Giving participants a visual of what the imagery scripts are descriptive of may help participants visualize the imagery appropriately; for example, showing participants a video of the bicep curl from different viewpoints. A video from the side of the bicep curl would represent the third-person external imagery perspectives while the video from above the shoulder would represent the first-person internal imagery perspectives.

For most participants in this study, external imagery was much more difficult to imagine compared to internal imagery. However, one participant said it was very simple. This particular participant was a body builder; she alluded to the fact that for the external imagery condition she pictured watching herself in the mirror completing the bicep curl the same way she does when lifting. She also displayed noticeably greater EMG activity during imagery conditions compared to all other participants. This information begs an interesting question as to whether or not body builders are better at motor imagery than other populations. If this were the case it could be due to the bigger, more defined muscles that we tend to see in bodybuilders (simply having a stronger muscle will produce more EMG activity than a weaker muscle) or because of the practices they use while lifting such as watching the muscles in the mirror during the movement and intensely focusing on the feelings in the muscles. Future studies may want to investigate such questions.

In conclusion, this study did not find any significance between imagery conditions even though EMG activity for internal imagery of lifting a heavy weight was expected to be the greatest. However, this study had limitations and minor changes to the study as mentioned above can improve the results to make stronger studies for the future. Motor imagery can still be seen as an effective tool in changing or relearning behavior and further research should be done to get a better understanding. This study affirms the potential for motor imagery as a tool for relearning specific movements. By recommending simple changes, this study provides direction and paves the way for future studies.

Appendix A

Relaxation Script

Take a deep breath as you make a tight fist with your dominant hand, then tense the muscles of your dominant hand, forearm, and upper arm. Squeeze until your muscles tremble or shake. Feel the muscles pull tight. Now relax.

Appendix B

Imagery Scripts

Light External

You are outside your body and you are watching from the side of your preferred hand holding the light dumbbell. You see your fingers curled around the light dumbbell as it rests on the chair. You see yourself grip the dumbbell and begin lifting it toward your shoulder. You can see the muscles of your wrist, forearm, and biceps contracting as you begin to raise the dumbbell toward your shoulder. You can see the dumbbell moving quickly upwards. As it moves closer to your shoulder you see the black dumbbell slowing down. Imagine what it looks like to see your bicep muscles lifting the light dumbbell toward the shoulder.

Heavy External

You are outside your body and you are watching from the side of your preferred hand holding the heavy dumbbell. You see your fingers curled around the heavy dumbbell as it rests on the chair. You see yourself grip the dumbbell and begin lifting it toward your shoulder. You can see the muscles of your wrist, forearm, and biceps contracting as you begin to raise the dumbbell toward your shoulder. You can see the dumbbell moving slowly upwards. As it moves closer to your shoulder you see the dumbbell slowing down. Imagine what it looks like to see your biceps muscles lifting the heavy dumbbell toward your shoulder.

Light Internal

You are inside your body and you see your preferred hand holding the light dumbbell. You see your fingers curled around the light dumbbell as it rests on the chair. You grip the dumbbell and begin lifting it toward your shoulder. You can feel your wrist, forearm, and biceps muscles contracting as you quickly begin to raise the dumbbell toward your shoulder. You can feel the muscles lightly exerting as you lift the dumbbell upwards. As it quickly moves closer to your shoulder you can feel the biceps slightly contracting in your arm. Imagine what it feels like to quickly lift the light dumbbell toward your shoulder.

Heavy Internal

You are inside your body and you see yourself holding the heavy dumbbell in your preferred hand. You see your fingers curled around the heavy dumbbell as it rests on the chair. You tightly grip the heavy dumbbell and begin lifting it toward your shoulder. You can feel your wrist, forearm, and biceps muscles contract strongly as you begin to raise the dumbbell toward your shoulder. You can feel the muscles exerting hard as you lift the dumbbell upwards. As it moves closer to your shoulder you feel the biceps and flexor muscles straining in your arm. Imagine what it feels like in your biceps muscles to lift the heavy dumbbell toward your shoulder.

Appendix C

Imagery Questionnaire

Subj. # ______ Name ________________________________ Condition _________

The following exercise is designed to measure various aspects of your experience in imagining things. After concluding your imagery condition, please answer the questions on your imagery experience.

People vary widely in their imaginary experiences and there are, therefore, no right or wrong answer to these exercises. Report your experience as accurately as possible.

Exercise	Results
Remember the image you just did of sitting down and "curling" a dumbbell up towards your shoulder by contracting your biceps and bending the elbow. (Take your time).	
a. Were you able to imagine any part of the scene? (If not, ignore the remaining questions).	Yes No
b. How clear or real was your mental picture of lifting the weight?	Not at all Very much 1 2 3 4 5 6 7
c. Did you "feel" the dumbbell in your hand?	1 2 3 4 5 6 7
d. How difficult was it to control your imaginary pictures and actions?	1 2 3 4 5 6 7
e. Did you "see" any part of your body other than your hand, legs, and the dumbbell? Did you feel like you were inside your own body when you sat and lifted the weight? (1st person perspective).	Yes No
f. Was it like standing outside your body and watching yourself sit and lift the dumbbell? (3rd person perspective).	Yes No

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