SIGNIFICANCE OF MENTAL REHEARSAL ON HAND-EYE COORDINATION

A THESIS PRESENTED TO THE DEPARTMENT OF HEALTH, PHYSICAL EDUCATION, RECREATION, AND DANCE IN CANDIDACY FOR THE DEGREE OF MASTER OF SCIENCE

By
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SIGNIFICANCE OF MENTAL REHEARSAL
ON HAND- EYE COORDINATION

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THESIS APPROVED

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Thesis Advisor                                           Date

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Dean of Graduate School                                  Date
ABSTRACT

The purpose of this study is to investigate the effectiveness of Mental Rehearsal on Hand Eye Coordination. A total of 50 international students participated in this study. All the participants were randomly assigned into a control group (n=25) who traced the maze with no mental rehearsal before the task and experiment group (n=25) who performed mental rehearsal before starting the task. Both groups preformed two trials. The maze was scored with two variables. One was the number of times the participants touched the maze borders and the other was total distance in centimeters outside the maze borders. Repeated measures analysis of variance was utilized to examine the impact of mental rehearsal and gender across two trials on a hand eye coordination task. Results indicated that three-way interactions for both distance, $F(1, 46) = .10, p = .76$, and touch, $F(1, 46) = 0.09, p = .77$, were non significant. All two-way interactions for both variables were also non-significant. For distance, main effects for both trial and group were non-significant ($p > .025$); however, the main effect for gender was significant, $F(1, 46) = 10.86, p = .002$. For touch, main effects for both trial $F(1, 46) = 36.17, p \leq .01$ and group $F(1, 46) = 3.34, p = .28$ were significant. The significant effects observed on the touches variable suggest that mental rehearsal does improve hand eye coordination, as the experimental group demonstrated significantly better performance on hand eye coordination task than the control group. This implies that mental rehearsal combined with physical practice has greater effect than only physical practice. There was a significant gender differences in performance of both touch and distance variables. Females did better in both touch and distance variable when compared to male counterparts. It is recommended that future research investigate the gender effect on mental rehearsal.
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CHAPTER I

INTRODUCTION

Hand eye coordination is one of the salient skills that form the basis of perceptual motor functions associated with activities of daily living, sports skills, and various other movement based tasks. Perceptual motor skills can be disrupted in various pathological conditions like stroke, TBI, Parkinson's disease, autism, cerebral palsy, developmental disorders, and many others. For the developing child, disruptions of perceptual motor skills can make everyday tasks more and more difficult (Goyen et al., 2006). Examples of this impact include school-based tasks like learning to write, functional activities including dressing and using cutlery, and engaging with peers in play (Goyen et al., 2006).

Beyond the realm of typical motor development and daily activities, hand eye coordination has its implication on the acquisition of sport skill and coaches need to be aware of the developmental sequences of the children. There is also a need to identify effective training techniques to improve the perceptual motor skills to acquire the required sport skill and to enhance performance of those skills when the occasion arises.

Mental Rehearsal

Mental Rehearsal is the voluntary rehearsal of tasks in mind in the absence of physical movement with the goal of improving motor performance (Dickstein, & Detsch, 2007). The most popular theory regarding the theoretical basis of mental rehearsal is psycho neuromuscular theory, which dates back to Jacobson (1932). According to this theory, sub threshold activation of muscles during mental rehearsal is similar to that of
actual physical performance of the same skill. Although abundant evidence supports the positive impact of mental rehearsal on motor skill learning and performance (Bird, 1984; George, 1992; Lejeune, & Decker, 1994; Mendoza, & Wichman, 1978; Rawlings, 1972; Ryan, & Simons, 1982; Ryan, & Simons, 1983; Woolfolk, Murphy, Gottesfeld, & Aitken, 1985), the degree of its effectiveness depends on various factors such as the nature of the task, the expertise level of the participants, the retention interval between practice and performance of the skill, and duration of the mental practice session (Driskell, Copper, & Moran, 1994). In numerous studies, the combination of mental rehearsal and physical practice has been investigated. Most researchers suggest that physical practice is more effective than only mental practice; however, the combination of physical practice and mental practice is claimed to be the most effective form of training to acquire a new skill or to improve the performance of the learned task (Butler, & Page, 2006; Dickstein, & Deutsch, 2007; Sanders, Sadoski, Bramson, Wiprud, & Walsum, 2004).

**Summary And Purpose Statement**

Despite these investigations that have examined the effectiveness of mental rehearsal, many questions still remain unanswered. Since different studies use different types of tasks, it is difficult to arrive at a conclusion on the effect of mental rehearsal on hand eye coordination. Thus the purpose of this study was to further evaluate the significance of mental rehearsal on hand eye coordination. The following research question was considered:

Q1: Do the Participants who completed mental rehearsal demonstrate greater hand eye coordination than those who do not take part in mental rehearsal?
Hand Eye Coordination

Hand eye coordination is use of vision to guide movements of the hand for many human activities like eating, sports, using tools etc. (Goyen et al., 2006). To aim at a target location or, reach and perform a task, each sequence of events requires a complex integrated coordination of the hand movement and eye (Rand & Stelmach, 2010). Normal hand eye coordination involves synergistic function of several sensorimotor systems vision, touch, motor control, attention, and memory all contribute to even the simplest tasks involving, hand eye coordination (Crawford, medendorp, & Marotta, 2004). The mechanism is dauntingly complex and can potentially involve much of the brain, as well as many recurrent feedback loops (Crawford et al., 2004). However, the brain must implement certain fundamentals transformations in a certain sequence, and it appears to do so in a modular fashion (Crawford et al., 2004). Hand eye coordination is one of the more salient and vital human capabilities and can disrupt various aspects of daily life including school, activities of daily living and social interaction (Goyen et al., 2006).

Hand Eye Coordination & Sports Skills

Hand eye coordination plays a significant role in the process of acquiring sports skills. The rate of the skill development varies for each individual but skills are attained in a sequential manner like other milestones (Stricker, 2002). For example, the skill of tracking moving objects and judging velocity often has not fully matured until the age of 6 or 7. From ages 10-12 strategies like selective attention and use of complex memory
mature allowing the individuals of this age to participate in sports that require complex hand eye coordination.

As the children progress through such stages, developmental disturbances in physiologic, neuromuscular, and musculoskeletal system can hinder hand eye coordination. For example, preterm children are more likely to have difficulties in eye hand coordination and motor skills, which can impact successful learning and participation in sports and everyday life (Goyen et al., 2006). Understanding the natural skill progression of a young athlete is crucial for the coaches to prevent unrealistic expectations and to adapt training programs that are more appropriate and specific for certain age ranges and sports (Stricker, 2002). There is also a need for developing appropriate effective training programs to improve hand eye coordination with respect to the specific sport (Stricker, 2002).

Hand Eye Coordination In Pathologies

In the realms of pathologies, there is evident degeneration in the quality of life following developmental disorders, stroke, Parkinson's disease, TBI and many other conditions that compromise hand eye coordination (Goyen et al., 2006). For example, a recent study has shown that the severity of perceptual motor dysfunction increases in children with developmental coordination disorder and learning disorder (Jongmans, Mercuri, Vries, Dubowitz, & Henderson, 2003).

When considering the number of individuals who at some point in their life experience an injury or illness that disturbs hand-eye coordination, the need for strategies and interventions for regaining and enhancing such skills becomes evident. An average
of one in six children are born every year with any developmental disability in America, which has increased by 17.1% from 1997-2008 (Center For Disease Control And Prevention, 2011). According to a report from the American heart association, 795,000 people experience stroke every year. This is only a fraction of individuals who could benefit from techniques for enhancing hand eye coordination. As mentioned earlier, such abilities play a critical role in the sports realm and in daily life. One potential technique for enhancing the development and recovery of hand eye coordination across various areas of practice is mental rehearsal.

**Defining Mental Rehearsal**

According to Driskell, Copper and Moran (1994) mental rehearsal is defined as "the cognitive rehearsal of the task in the absence of overt physical movement" (p. 489). The term mental practice has been applied to variety of interventions and training techniques which are conceptually different (Driskell et al., 1994). Mental rehearsal is a form of mental practice. Other forms include positive imagery and self-talk. Mental rehearsal can potentially be used in variety of ways including but not limited to learning a new skill, improving an existing skill, and developing performance strategies (Shanks & Cameron, 2000). Likewise, there are several theoretical approaches regarding the technique of mental rehearsal and how it is to be used.

**Psycho Neuromuscular Theory**

The possible theoretical explanations regarding how mental practice operates have been summarized by Grouios and George (1992). The most popular theory among those is the psycho neuromuscular theory. According to Jacobson (1932), there is a minimal sub threshold activation of the respective muscles due to mental practice that are
used during the actual performance. This activation is sufficient to give kinesthetic feedback through which learning a new skill is enhanced. This theory is supported by the EMG research conducted by Gandevia, Gazit-Grunwald, Plax, Dunsky and Marcovitz in 1997; however, the result of Shanks and Cameron's sequential reaction time experiment in 2000 is inconsistent with psycho neuromuscular theory.

**Mental Rehearsal And EMG Responses**

In 1984 a study by Evelyn Bird demonstrated that there is a definitive quantification of EMG response to the imagined tasks. The participants of this experiment were all champion performers in different sports including national rower, breaststroker, and international water skier. All the participants were instructed to imagine the event which requires precision and intensity of the performance while their EMG is recorded. The result supports that mental rehearsal feedback helps to improve the sense of timing of the event.

The fusimotor drive during the voluntary muscle contraction and the selective recruitment of alpha motor neuron is essential to improve motor performance (Gandevia et al., 1997). Although mental practice activates fusimotor neuron selectively, any such activation is not functionally significant. Thus, mental rehearsal is unlikely to improve performance via fusimotor drive alone (Gandevia et al., 1997). However mental rehearsal of movements activates multiple cortical areas associated with the movement and also causes increased skeletomotor activity and reflex excitability. Thus mental rehearsal produces small contractions of relevant muscles that aid the development of motor performance (Gandevia et al., 1997).
Another study in 2005 indicated that even though there is an activation of motor units in the target muscles, the EMG activity in all the target muscles of a performance are not the same. Furthermore, the magnitude of the EMG is very low, but still identifiable during motor imagery (Dickstein et al., 2005). Based on this research there, is evidence to suggest that mental rehearsal does activates the associated areas of brain and does physically engage the body in a low level state of physical practice.

Factors That Influence Effectiveness Of Mental Rehearsal

Many factors can influence the effect of mental rehearsal such as the nature of the task, the expertise level of the participants, the retention interval between practice and performance of the skill, and duration of the mental practice session (Driskell et al., 1994). Furthermore, a single task involves both cognitive and motor components. Researchers have found that, although mental practice in general can be effective for both cognitive and physical tasks, mental rehearsal is more effective with tasks that involve more of cognitive component (Driskell et al., 1994).

Among novice participants there is a strong effect of mental rehearsal on performing a new skill, which naturally involves more of cognitive component than performing a familiar skill (Shanks & Cameron, 2000). In contrast, participants conducting a familiar task may not benefit as much from mental rehearsal, as there is less of a cognitive element (Shanks & Cameron, 2000). This result is in consistent with Ryan and Simon's (1983) claim that, once a participant has learned the physical component of the skilled task, then mental rehearsal alone is adequate to continue to improve performance, without additional physical practice.
Regarding the retention interval, the effectiveness of mental practice is noted to decline over a period of time (Shanks & Cameron, 2000). The beneficial effect of mental rehearsal on performance reduced by one-half of its original magnitude by the end of 2 weeks. Mental rehearsal has been found to be more effective when the performance is tested immediately (Shanks & Cameron, 2000). If mental rehearsal is an intervention to improve performance, then it should be implemented as training at least 1 to 2 weeks prior to task performance (Driskell et al., 1994). In addition research indicates that the optimal duration of mental rehearsal intervention to be approximately 20 minutes in duration (Shanks & Cameron, 2000). A Meta analysis done by Driskell and his colleagues in 1994 also supports the claim that extended mental practice without physical practice produce diminishing performance. When a participant physically practices, they receive feedback via their performance that leads to an increase in the proficiency, whereas during extended mental rehearsal there is no knowledge of result or opportunity for feedback. Thus, the motivation starts to degrade and thereby causing boredom and decrease in the performance (Driskell et al., 1994; Ryan & Simons, 1983).

**Mental Practice Vs. Physical Practice**

Numerous studies have examined the effects of the mental rehearsal, but due to different types of tasks with different types of subjects, it is very difficult to draw firm conclusions on the effectiveness of mental rehearsal. Studies suggest that mental rehearsal improves performance when compared to conditions involving no practice (Driskell et al., 1994). Many studies supports that physical practice enhances the
performance more than only mental rehearsal (Mendoza & Wichman, 1978; Ryan & Simons, 1982; Shanks & Cameron, 2000); however, there is adequate evidence found in the literature that mental rehearsal combined with physical practice is more effective than only physical practice of a task.

The result of the experiment done by Rawlings in 1972 supports the hypothesis that mental rehearsal can improve performance. It also suggests that mental rehearsal when combined with physical practice as an intervention is more effective than only physical practice as an intervention.

Mendoza and Wichman (1978) studied the effectiveness of mental practice on performance of dart throwing skill. Thirty two college undergraduates were recruited for the study and were assigned into one of the four testing conditions: no practice/control group, mental rehearsal only, and mental rehearsal with simulated dart throwing, motor practice. The performance of dart throwing was assessed after 6 days of mental or physical practice. The result from this experiment suggests that all form of practice differ significantly from no practice group. However, the physical practice group's performance on dart throwing improved significantly compared to all other forms of practice.

The evidence from the study done by Ryan and Simons (1982) supports that mental rehearsal is more effective in regard to learning a new motor skill when compared to learning a new motor skill with no mental or physical practice. However, this study also qualifies the claim that physical practice is much more effective than any other form of practice.
Furthermore, mental rehearsal combined with physical training and observation of the correct technique was found to be more effective in table tennis performance than only physical training or no training (Lejeune et al., 1994). In 2004, a study was conducted to find the cost effective method of training medical students in learning basic surgical skills. The results indicated that mental imagery was equally effective compared to physical practice following an initial physical practice (Sanders et al., 2004). The program combining mental and physical practice was found to be more effective in stroke patients than a program composed of only physical practice or mental rehearsal (Butler, & Page, 2006). Mental practice is useful when complemented with physical practice in healthy individuals, athletes and population with pathologies (Dickstein, & Deutsch, 2007).

**Synthesis Of Literature**

Hand eye coordination is an essential skill in day to day life and almost in all sports. When this perceptual motor skill is affected due to any pathological conditions, performing functional activities become difficult. Thus finding ways to effectively improve hand eye coordination is of prime importance. Mental rehearsal is one of the intervention techniques that can be possibly used to improve hand eye coordination. Since different studies have examined the effects of mental rehearsal with different types of tasks and with different types of subjects, it is very difficult to draw firm conclusions on the effectiveness of mental rehearsal on hand eye coordination (Driskell et al., 1994). The purpose of this study is to further examine the impact of mental rehearsal on hand eye coordination. The following research hypotheses were examined:
H1 - Participants who complete 1 minute mental rehearsal activity will demonstrate greater hand eye coordination than those who do not take part in mental rehearsal.

H2 – Participants will demonstrate improvements in hand eye coordination when provided an opportunity to physically the prescribed task.
CHAPTER III

METHODS

Population

The population of this study was made up of healthy individuals over the age of 18 years. The accessible population consisted of international students attending a State University in the Midwest part of the United States. At the time of study, the University had a total student population of 7,142 with 6,193 undergrad students and 949 grad students. A total of 3.8% of the total student population were international students.

Sample

A total of 50 participants (24 males and 26 females) took part in the study. The age range of the participants was 21-28 years with an average age of 22.48 years. This was a convenience sample of volunteers. All participants were citizens of Republic of India.

Instrumentation

To measure hand-eye coordination, the experiment required the participant to draw a line from a start point to the end point in a maze picture (see appendix A). The maze picture was attached to a vertical surface at the participant's eye level.

Participants were asked to directly position themselves in front of the maze picture and start drawing the line inside the maze from beginning point to the end point. They completed the task with their dominant hand. A 10 second time limit was given, and was counted down verbally by the researcher as the maze was being completed by the participant. All the participants were asked not to support their hand on the vertical surface while drawing the line. Directions regarding maze completion as stated: “Now we will complete the maze posted on the wall in front of you. You will have 10 seconds to
trace the maze with your pencil. Do not place your hand on the wall surface. You must hold the pencil like this “demonstrated proper hand position”. Avoid going outside of the maze or touching the edges. Do your best to finish the maze within 10 seconds, I will count down your time like this “10, 9, 8, 7, and so on. OK, let’s begin, go ahead and pick up your pencil and get ready. Ready…Begin”…. (count down). If participants were unable to complete the maze in the given 10 sec period, the participants were asked to stop the line where ever they were in the maze.

The completed maze was then graded in two ways. One was by counting the number of points at which the line drawn by the participant touched the maze borders. The total numbers of such points were recorded as total touches. The second was, if the participant crossed the border line and returned inside the maze, the total distance of the line outside maze borders was measured in centimeters. The total distance was recorded for each participant. If the participant was unable to complete the maze in given 10 sec duration, the participants were asked to stop at the point where they had completed and each incomplete section of the maze was considered 1cm distance outside the maze.

**Procedures**

Approval was obtained from the university Institutional Review Board for conducting the experiment. Individuals who expressed an interest in participating in the study were provided with the contact information for the researcher to arrange the time for the testing session. Initial participation recruits were acquaintances of the researcher, through involvement in the campus international student organization. These initial recruits then referred the researcher to additional individuals who were part of the accessible population. Participants were given a consent form at the beginning of the
testing session. Those who agreed to participate signed a copy of the consent form for the researcher, and each participant was given a copy for their own records. Once the consent was granted, the study began. Those who consented were then randomly assigned to one of two study groups. Only general demographic information was collected (age and gender) and no specific identifying information was obtained (e.g., name, student id numbers). To protect identities, participants were assigned a three digit ID number that began with a 1 or a 2. This number was used to track which group they were in. Each participant performed two trials of the same task. The 2nd and 3rd digit (e.g., 01, 02) was used to identify the participants forms for first and second trials so that they could be matched at a later time.

Once a time was scheduled with each participant, the session was conducted. Then, trial 1 procedures were implemented. Participants in the mental rehearsal group were asked to take part in a 1 minute mental rehearsal activity as described in the below protocol, and to then complete the maze task. Those in the control group immediately completed the maze task, with no mental rehearsal. Once trial 1t was done, the participants were either asked to follow the mental rehearsal protocol again (experimental group), or to simply wait one minute and then complete trial two of the maze task (control group). The maze diagram was placed out of the sight of the control group participants during this break to prevent them from mentally rehearsing the task on their own.

This process resulted in two trials for the control group and two trials for the mental rehearsal group. Both trials for mental rehearsal group were preceded by the 1 minute mental rehearsal task.
Mental Rehearsal Protocol

During the mental rehearsal period, members of the experimental group were positioned before the maze and were asked to mentally rehearse the successful completion of the task for 1 minute while looking at the maze picture. Directions for mental rehearsal involved the following simple statement. “Look at the maze on the wall and imagine yourself successfully drawing a line through the entire maze without touching or crossing any lines. Please continue to mentally practice this task until you are told to stop”. After 1 minute of mental rehearsal, the participant was asked to complete the maze task. This protocol was followed by all experimental group participants prior to each trial on the maze task.

Research Design & Data Analysis

This study involved an A x B x (C x S) design. The primary between subjects factor in the design was group (control vs. visualization – designated as A). This factor reflected research hypothesis 1. Gender (men vs. women) was included in the design as a moderator variable (designated as B). Trial (trial 1 vs. trial 2) was the primary within subjects variable in the study, and reflected research hypothesis 2 (designated as C x S).

Internal Validity

The following sections summarize potential threats to internal validity. These threats include subject characteristics, mortality, location, instrumentation, instrument decay, testing, history, maturation, and subject attitude.
Subject characteristics. Subject characteristics refers to individual nature of participants that could affect the result of the study. Subject characteristics threat was minimized by random assignment to group. This procedure helps ensure that the two study groups are similar in nature.

Mortality. Mortality refers to dropping out of subjects during a study. Mortality was not a threat as this study. All the data was collected within a very short period of time and no participation withdrew during study session.

Location. Location difference across study groups or participants in general can influence the study result. This was controlled in this study by having a standardized testing location. All the participants in the study were tested at the same location.

Instrumentation. The internal validity may also be affected by the way the instrument is used in the study. In this study the instrument was standardized. All the participants in the control and study groups followed the same respective procedures throughout the study. All data was collected by the researcher, which helps ensure consistency across participants. This procedure does present the possibility of data collector bias. This was controlled by strict adherence to the established procedures for implementing the hand eye coordination task.

Instrument decay. Instrument decay can a threat if the nature of the instrument is changed in some way or another during the study. Instrument decay threat was minimized in this study by utilizing a standardized testing procedure.

Testing. Testing refers to practice or fatigue effect when multiple trials take place. Fatigue was not a threat in this study due to the short duration of the testing protocol. Practice was actually one of the independent variables controlled for in this
study and expected to lead to significant gains in hand eye coordination. The research design accounted for any effect from practicing the hand eye coordination task.

**History.** The response of the participants could possibly be altered due to unanticipated and unplanned events during the study. As the testing location and the instrument were standardized, there were no unanticipated or unplanned events occurred during the study.

**Maturation.** Sometimes changes noted in the study may be a result of passing of time rather than intervention itself. Maturation was not a threat to internal validity in this study as the two trials are performed back to back within a very short time period.

**Subject attitude.** Subject attitude refers to the view of the participant about the study. In this study, participants were not told about the research hypothesis or the expected outcome of the mental rehearsal exercise. It is possible that attitudes toward mental rehearsal may have impacted the extent to which participants in the experimental group actually performed the mental rehearsal.
CHAPTER IV

RESULTS

Descriptive Statistics

Examining descriptive statistics is a useful process for understanding the general trends within the findings of this study. Raw means and standard deviations for each variable can be viewed in Tables 1 and 2. In addition, Table 3 and 4 display estimated marginal means and standard errors and are referred to in the following summary of results as they correspond with hypothesis testing.

The first issue to be addressed in this study is the impact of mental rehearsal on hand eye coordination. Both distance and total touches were considered as indicators of hand eye coordination. In regard to distance, the estimated marginal means for the visualization group was 1.57 (SE = .37), whereas the overall mean of the control group was 1.76 (SE = .37). A more noticeable difference occurred when considering total touches. The visualization group had an estimated marginal mean of 7.26 (SE = .50), compared to a control group estimated marginal mean of 9.02 (SE = .49).

The second factor to be considered in this study was the difference between trial 1 and trial 2. This comparison essentially reflects the effect of physical practice on hand eye coordination (trial 1 is practice for trial 2). Again, both distance and total touches were considered. For distance the estimated marginal means of trial 1 and trial were 1.64 (SE = 2.50) and 1.66 (SE = 2.17) respectively. For touches, the estimated marginal mean of trial 1 and trial 2 were 9.64 (SE = 2.65) and 6.60 (SE = 3.80), indicating improvement in the number of times participants failed to stay within the maze.
Finally, gender differences were considered and represent the third main effect that was examined. Men had an overall estimated marginal mean of 8.94 (SE = .50) for touch and 2.42 (SD = .37) for distance, whereas women had an overall estimated marginal mean of 7.35 (SE = .48) for touch and .82 (SE = .36) for distance.

**Hypothesis Tests**

An A x B x (C x S) design was utilized in this study and data was analyzed with Repeated Measures Analysis of Variance. Within this analysis, trial was examined as a within subjects factor (trial 1 vs. trial 2), whereas group (visualization vs. non-visualization) and gender (male vs. female) were considered as between subjects variables.

Dependent variables of distance and touch were analyzed separately using the above approach. To control for inflation of Alpha (type 1 error), Bonferonni’s correction was utilized to identify a cutoff for significant probability values of .025. Three-way interactions for both distance, $F(1, 46) = .10, p = .756$, and touch, $F(1, 46) = 0.09, p = .766$, were non-significant. Likewise, all two-way interactions for both variables were also non-significant ($p \leq .025$). These findings allowed for interpretation of main effects.

In regard to distance, main effects for both trial and group were non-significant ($p > .025$); however, the main effect for gender was significant, $F(1, 46) = 10.86, p = .002$. This finding did not support the research hypotheses predicting that both practice and visualization would lead to improvements in hand eye coordination.

In regard to touch, main effects for both trial $F(1, 46) = 36.17, p \leq .001$ and group $F(1, 46) = 6.35, p = .015$ were significant, with the main effect for gender being non-significant. This finding supported both research hypotheses, suggesting that both
visualization and practice led to improvements in the number of touches occurring as the hand eye coordination task was completed.
Table 1

Means and Standard Deviations for Distance across Trials, Groups, and Gender

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>SD</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Trial 1 Control</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>2.79</td>
<td>2.57</td>
<td>13</td>
</tr>
<tr>
<td>Female</td>
<td>.59</td>
<td>1.19</td>
<td>12</td>
</tr>
<tr>
<td>Total</td>
<td>1.73</td>
<td>2.28</td>
<td>25</td>
</tr>
<tr>
<td><strong>Trial 1 Exp.</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>2.09</td>
<td>3.67</td>
<td>11</td>
</tr>
<tr>
<td>Female</td>
<td>1.13</td>
<td>1.60</td>
<td>14</td>
</tr>
<tr>
<td>Total</td>
<td>1.55</td>
<td>2.69</td>
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</tr>
<tr>
<td><strong>Trial 1 Overall</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>2.47</td>
<td>3.07</td>
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</tr>
<tr>
<td>Female</td>
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<td>1.42</td>
<td>26</td>
</tr>
<tr>
<td>Total</td>
<td>1.64</td>
<td>2.47</td>
<td>50</td>
</tr>
<tr>
<td><strong>Trial 2 Control</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>2.94</td>
<td>2.72</td>
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</tr>
<tr>
<td>Female</td>
<td>.72</td>
<td>1.61</td>
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</tr>
<tr>
<td>Total</td>
<td>1.88</td>
<td>2.49</td>
<td>25</td>
</tr>
<tr>
<td><strong>Trial 2 Exp.</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>2.26</td>
<td>2.27</td>
<td>11</td>
</tr>
<tr>
<td>Female</td>
<td>.82</td>
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Table 2
Means and Standard Deviations for Touches across Trials, Groups, and Gender

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Table 3

Estimated Marginal Means on Distance for Group and Gender Comparisons

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<table>
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<th>Standard Error</th>
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<td>Male</td>
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### Table 4

Estimated Marginal Means on Touches for Group and Gender Comparisons

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ANOVA for Distance

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### Table 6

ANOVA for Touch

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CHAPTER V
DISCUSSION

The research reported in this paper was designed to examine the impact of mental rehearsal on hand eye coordination. Two separate independent variables were considered as indicators of hand eye coordination (touches and distance), both of which pertained to the participants ability to trace a maze with a pencil. For the touches variable, the findings of this study suggest that practice of the activity (trial 1) had a significant influence on the subsequent performance in trial 2, irrespective of group and gender. However, significant improvement in the performance also was observed when physical practice along with briefly imagining the activity immediately prior to performing the activity was compared to practice alone (no mental rehearsal). There was not a significant interaction between trial and group; however, the experimental group did show greater gains from trial 1 and trial 2 than the control group. This tendency also supports that combined mental rehearsal and physical practice can have a greater effect than practice alone. This was consistent with the findings of Rawlings (1972), and Lejeune, and Decker (1994).

This study agrees with Rawlings, who examined 24 female undergraduate volunteers to test the hypothesis that mental rehearsal facilitates learning of rotary pursuit tracking. There were two experiments conducted by Rawlings. In first experiment, the participants were assigned to one of the three groups of no practice, practice and mental rehearsal. Participants in the mental rehearsal group improved on par with the practice group. During the second experiment, the group which engaged in combined mental and physical practice performed better than only physical practice group. Similar support was
evident from the study by Lejeune and Decker in 1994, which investigated the table tennis performance of 40 participants. Their results were that mental rehearsal combined with physical and observational techniques improved table tennis performance both qualitatively and quantitatively. Both these study demonstrate a positive gain in performance as a result of both physical practice and mental rehearsal.

When considering distance variable, the above mentioned significant differences did not occur. The results were surprising and contradicted the results on the touches variable. One potential explanation of this effect possibly could be the participants failed to realize the importance of returning to the maze as soon as possible once they went over the line, and were more focused on getting to the end. Post hoc consideration of the proportion of participants who failed to complete the maze indicated a notable difference in the distance covered with in 10 sec between the control and experimental group. 3 out of 25 completed the full maze in control group, whereas 9 out of 25 completed the full maze in the group who practiced visualization. This post hoc observation suggests that visualization does improve performance, which is consistent with previous studies (Bird, 1984; Driskell, 1994; George, 1992; Lejeune, & Decker, 1994; Mendoza, & Wichman, 1978; Rawlings, 1972; Ryan, & Simons, 1981; Ryan, & Simons, 1982; Woolfolk, Murphy, Gottesfeld, & Aitken, 1985). This observation was not an original aspect of the current study and should be examined through future research.

An interesting finding in this study that there was a significant gender differences in performance of both touch and distance variables. Females did better in both touch and distance variable when compared to male counterparts. Females tend to stay within the maze and avoided touching the maze borders more successfully than males. One possible
explanation for this finding might be that males tend to be more concerned with reaching the end of the maze within the 10 seconds on rather paying close attention to the details. Among females 20 out of 26 did not complete the maze, whereas among male participants 19 out of 24 did not complete the maze. This implies that men and women were fairly equal on the level of completion of the maze. Even though the instructions were the same for both genders, gender tendencies might have played a role. Some research suggests that gender difference related to motor development and hand eye coordination may be biological, especially in early in life. As people mature, cultural and social norms may be more of a factor. In 2009, Kenneth, Leonard, and List investigated any gender differences in competition between two distinct societies named Matrilineal and Patriarchal society. The result indicates that Maasai men were twice as competitive compared to Maasai women. However, Khasi (India) women were more competitive in nature than Khasi men and Maasai men. In 1993, Ruff and Parker investigated the gender and age specific changes in motor speed and hand eye coordination in a sample of 370 stratified according to gender. All the participants performed a variety of tasks that required hand eye coordination. Women performed slower on some tasks than men and men performed slower than women on other tasks. Their results indicated that there was a significant difference in gender. Similar significant gender differences were noted in the meta-analysis of 64 studies related to gender difference in motor performance (Jerry, & Karen, 1985)

Limitations

One of the major limitations of this study was that to ensure a standardization of conditions, the study utilized a time limit. This time limit may have impacted the result in
two ways. One, it might have created a competitive environment, which may have created the gender effect that was noticed in the study. Two, it may have impacted the effectiveness of the visualization.

The generalization of this study is limited to individuals who are members of the accessible population, which consisted of international students studying in the United States who were citizens of Republic of India. It may be that other ethnic groups or cultures would demonstrate a different result pattern. This particularly concerning in light of the observed gender differences. It may be that these gender differences were associated with cultural trends or norms. One other limitation within this study that pertained to sample was the relatively small number of participants. Another limitation concerning the generalization of this study was the task itself. The task in this study was easy to visualize because the only factors that would vary were related to the participant (their talent, for example). But in sports, for example, many variables may be undetermined to the individual, so their ability to imagine a hypothetical situation and the complexity of the task may come into play.

Another limitation was the duration of the visualization task, as well as the fact that there was no way to verify that the participants in the experimental group were actually visualizing or that those in the control group were not visualizing.

According to Driskell et al. (1994) extended mental practice is not necessarily better. Extended mental practice may lead to loss of concentration and boredom, thus no increase in the performance. An optimal duration of mental practice is needed to gain effective results; however, the optimal duration of mental practice was unclear for the nature of the task used in this study. Another limitation of this study was the inability to
account for the extent to which the task involved cognitive performance. Mental rehearsal is more beneficial for the task, which has more of a cognitive component compared to the motor component. While this study did hold the task constant across all participants, the degree to which the task is cognitive or motor is uncertain and there was no attempt to manipulate this variable within the research design.

The nature of the scoring system used in this study was a limitation as well, particularly in regards to those who did not finish the maze in the allotted 10 seconds. For example, if a participant did not complete the test in 10 sec, the uncompleted section of the maze was scored as 1 touch for each session. There are approximately 15 sections in the maze. If a person decided to complete 4 sections without touching or crossing the line in 10 sec, the participant would get the score of 11 for remaining uncompleted sections. However, the distance variable was given a score of 0 in case of not crossing of boarders (line drawn outside the maze), even if the participant did not complete the maze in given 10 seconds. In contrast, if a participant decided to complete the whole maze in 10 sec, then there were additional chances to touch/cross the borders of the maze. This time limit was implemented to standardize the difficulty of the task, but the scoring system used for those who did not reach the end of the maze was untested.

**Recommendations For Research**

This study highlights the need to examine the gender effects in future mental rehearsal studies, as there was an unexpected significant difference in the performance between male and female participants. In addition, the frequency and the quality of the mental rehearsal are still unclear. Researches in the future should focus determining the optimal duration of mental rehearsal for producing effective gains in performance. When
conducting future research on this topic, all the known factors that affect mental rehearsal such as but not limited to type of task, duration of mental rehearsal, and previous experience of the participant within the task should be taken into consideration. Due to the nature of the sample in the study, the generalizations of the results are limited to International students studying in the United States who are of Indian decent. Therefore future research should include participants from different ethnic and age group to have better generalization and to reduce cultural differences. The maze task used in this study was easy to visualize since there is no hypothetical situation demanding many undetermined variables into consideration as in that of sports. The obtained results in this study may be explained using memory organization theory. According to which there is an association between chief memory and response selection process. The Mental practice facilitates performance by creating an additional memory organization which in turn influences the motor response operations and thus increases the performance of that particular task. Continuing investigation is needed to understand the underlying theoretical framework which mediating mental practice.

**Recommendations For Practice**

Mental rehearsal is in close overlap with physical practice and potentially more effective when combined with physical practice. This effect of mental practice would be more beneficial to therapists who rehabilitate patients following various physiological abnormalities such as stroke, TBI, developmental disorders, etc. For example, consider a therapist training for opening an overhead cupboard activity with a patient following stroke. This activity involves hand eye coordination. It would be more beneficial for the patient's improvement in function if the activity is mentally rehearsed and physically
practiced rather only physical practice or only visualization. For hand eye coordination tasks that are dangerous or seldom offer chances to physically practice, mental practice should be considered as an alternative. Coaches can encourage the athlete to combine mental practice and physical practice for better performance. They also can encourage athletes to use mental rehearsal during the rehabilitation period after injury to stay in touch with their coordination skills necessary for the game and have the feel of control. Due to the finding that females tend to perform better than males when mental rehearsal is used as an intervention, this technique may be especially effective when used to improve hand eye coordination among female athletes and women sports teams. Again, this possibility should be examined with future research as the presented task here was not sport oriented and very structured.

**Conclusion**

In summary, the study was designed to address the research question "Do the participant who completed mental rehearsal demonstrated greater hand eye coordination than those who do not take part in mental rehearsal?". The results supports that mental rehearsal is an effective means to improve hand eye coordination. It also indicates that mental rehearsal when combined with physical practice has greater effects in enhancing hand eye coordination than just practice alone. There was also an interesting finding that the mental rehearsal technique is more effective in females than males. These results mean that mental rehearsal is an effective technique that can be used as a supplement to physical practice to effectively enhance hand eye coordination skill.
References


Appendix A

Maze For Hand Eye Coordination Test

Participant # ______________________  Date ____________

Trial Number
☐ Trial 1
☐ Trial 2
☐ Trial 3

Accuracy
Boundary
Touched/Crossed______________