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Mental Attention: Improving Motor Imagery by Adding Focus

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Abstract

Research has delineated the values of motor imagery for physical tasks; subjects consistently outperform control groups when mentally rehearsing a task and transferring it to a physical medium. Additionally, an external focus of attention has been shown to increase accuracy and performance while performing a physical task as compared to an internal focus. There had been no previous research addressing a focus of attention while mentally rehearsing a task. Therefore, the objective of this study was to see if varying foci of attention during practice of a dart-throwing task could enhance mental rehearsal. Consistency was significantly depressed for mental internal and control conditions in the first test block.

Mental Attention: Improving Motor Imagery by Adding Focus

“Picture yourself on a boat in a river...” (Lennon & McCartney, 1967).

Imagery evokes a sensory experience. This sense, however, involves nothing tangible. It is a mental depiction that can create a picture where no visual cue is present. Motor imagery, also referred to as visualization and mental rehearsal, is defined as an experience that resembles perceptual experience, but occurs without the appropriate stimuli for the relevant perception (Plessinger, n.d.). Motor imagery involves imagining a performance without overt physical performance. Specifically, motor imagery has been shown to increase the power and distinctiveness of memories and cognitive tasks (Murray, 2007) and has been found effective for improving performance in physical tasks (Lohse, Healy, & Sherwood, 2010a; Wohldmann, Healy, & Bourne, 2007). The acquisition of physical knowledge through motor imagery is an integral part of these findings and has been shown to be effective in athletic settings, via positive visualization utilized to focus on the goal of a task before commencing the activity (Isaac, 1992).

Imagery and Performance

Imagery has been widely researched as a crucial component for elite athletes. Jowdy, Murphy, and Durtschi (1989) reported that 90% of athletes qualifying for the 1988 Olympics used mental imagery during training and competition. Orlick and Partington (1988) interviewed 235 Olympic athletes and found that 99% of them relied on some form of mental imagery. More recent surveys of athletes have looked to quantify the type of imagery that leads to the best performance. The Sports Imagery Questionnaire was developed to assess the effectiveness of four

types of imagery: cognitive general, motivational general, cognitive specific, and motivational specific (Hall, Mack, Paivio, & Hausenblas, 1998). Orlick and Partington (1998) concluded that “attentional focus and the quality and control of performance imagery were the most important statistically significant athlete skills directly related to high level performance at the Olympic Games” (p. 129).

The majority of mental imagery research has focused on cognitive specific imagery, where a certain task is rehearsed and performed. Research typically follows three standard conditions: a physical practice condition, a mental imagery condition, and a control condition. Subjects perform a baseline task, practice the task using one of the three conditions, and are measured on performance of the task following the practice session. The mental and physical conditions involve the same number of trials of the task, whereas the control condition either rests or performs a distractor task. Most research has reported that the mental task is significantly better than the control condition, yet not as effective as physical practice (Isaac, 1992; Singer, Hausenblas, & Janelle, 2001). Based on these findings, it is generally accepted that imagery “facilitates the learning and performance of motor skills” (Singer et al., 2001, p. 531).

Brain mapping techniques such as functional magnetic resonance imaging have allowed investigators to examine the cortical structures that are activated during mental rehearsal. Motor cortex mapping while mentally imagining finger movements showed a 27% difference in the suppression of post stimulus 20-Hz rhythmic activity over rest. Full finger movements show a complete suppression of the 20-Hz signal. Slight physical movements of the fingers showed activity similar

to that occurring during the mental imagery (Schnitzler, Salenius, Samelin, Jousmaki, & Hari, 1997). Suinn (1980) found that elite skiers, when asked to visualize a ski run, exhibited slight muscle activity due to motor imagery. The muscle activity, in fact, corresponded with specific sections of the course or type of turn that the skiers were describing. Murphy (2005) states that any physical skill has a specific neural pathway in the brain and is strengthened with repetition. Motor imagery is able to activate this pathway and strengthen it in ways similar to physical practice.

Focus of Attention

Research has shown that adopting a focus of attention can increase performance in a motor-based task. Specifically, an external focus involving the effects of an outcome can produce better results than internally focusing on the action itself. When thinking about an action's effect, one influences the environment, whereas thinking about an action's internal mechanisms only influences the participant. Wulf, Höß, and Prinz (1998) demonstrated that an external focus of attention produced greater improvement in learning a complex task than an internal focus. In their experiment, subjects were trained to perform a slalom-type movement on a ski-simulator. Subjects stood on a wheeled platform along a track and were told to direct their attention to either their outer foot (internal) or the wheels of the apparatus (external). The externally focused group was able to improve their amplitude, the distance they could successfully balance on the ski simulator, better than the internally focused group, even though attention was focused in a similar area. This result was replicated using a stabilometer and

directing participants to maintain a horizontal position and their balance while directing attention to their feet (internal) or the platform (external). The results again confirmed that participants who practiced with external focus performed significantly better than participants who focused internally (Wulf et al., 1998). Athletic accuracy has also shown performance gains through the use of an external focus of attention. This advantage has been demonstrated in volleyball serves and soccer kicks (Wulf, McConnel, Gartner, & Schwartz, 2002), pitch shots in golf (Wulf & Su, 2007), and basketball free throws (Zackry, Wulf, Mercer, & Bezodis, 2005). In each experiment, the externally focused group outperformed the internal group.

Attention data have also examined the effect of focusing attention, either externally or internally, on neuromuscular coordination (both motor unit recruitment within a muscle, and the pattern of activation between muscles). Electromyography (EMG) data recorded during a bicep curl showed better performance by the externally focused group and less EMG activity than the internal group (Vance, Wulf, Tollner, McNevin, & Mercer, 2004). This finding suggests that an external focus recruits muscles more efficiently and is able to produce better results with less exertion. Zachry et al. (2005) also showed increased performance and reduced EMG activity during a free throw task for the external group. These results suggest that an external focus imparts skill in a task rather quickly. Skilled movement is defined by Guthrie (1952) as “the ability to bring about some end result with maximum certainty and minimum outlay of energy, or of time and energy” (p. 136). An external focus can improve the efficiency and effectiveness of motor tasks.

Present Study

Research has looked at the effectiveness of mental practice and the benefits of an external focus of attention, and both have been proven to increase performance of motor skills. It is hypothesized that a focus of attention could have an effect on the efficacy of mental practice. Lohse, Sherwood, and Healy (2010b) investigated focus of attention and achieved results consistent with previous research that an external focus is able to increase accuracy over an internal focus during a dart-throwing task. A dart-throwing task has been utilized in the present study for examining the combination of motor imagery and focus of attention.

Method

Participants

Data were collected from 120 University of Colorado students, 67 from the Fall 2010 semester and 53 from the Spring 2011 semester. Of these, 74 subjects were female and 46 subjects were male. One subject's data were removed because her accuracy was greater than 3 standard deviations from the overall mean. Subjects were recruited from the University of Colorado PSYC 1001 student pool, and participation in the experiment fulfilled course credit requirements. The University of Colorado IRB approved the study protocol, and all subjects signed a consent form.

Apparati and Measurements

A standard bristle dartboard was attached to a 2-m plywood stand and positioned 1.73 m off the ground and 2.37 m from the throwing line. The dartboard was of official size, and the distance was a standard official competition length.

Subjects threw regulation steel tip darts that weighed 22 g. Error was measured as the linear distance from the center of the dartboard (bulls-eye) to the dart, and served as the behavioral measurement of performance.

Procedure

Subjects were assigned to one of five conditions. The condition order was chosen pseudorandomly using a random number generator in Excel. Each subject participated in only one condition, and the order of conditions was constrained so that all conditions were tested in every set of five successive subjects.

Control

Mental rehearsal Internal focus

Mental rehearsal External focus

Physical practice Internal focus

Physical practice External focus

The experiment consisted of one session with three phases: pre-test/baseline, acquisition, and post-test. In the pre-test phase each participant threw six darts. This short pre-test attributes more of the practice to the acquisition phase and demonstrates a general sense of each subjects' dart-throwing skill without allowing for additional practice before the acquisition phase. Research has shown that a combination of physical practice and mental rehearsal can enhance physical performance (Corbin, 1972). However, separating mental and physical rehearsal can attribute a more specific effect to mental rehearsal on its own. A typical mental rehearsal study involves the subject standing motionless and mentally rehearsing the task from start to completion (Driskell, Copper, & Moran,

1994). For the acquisition phase, participants in the mental rehearsal cohort had their dominant arm placed in a sling to prevent rehearsal movement or recruitment of muscle. Each subject was asked to stand on the throwing line and mentally rehearse throwing darts, either with an internal or external focus. Research has shown that mentally rehearsing the negative outcome of a task, such as thinking about missing a golf putt or missing the target in darts, can be significantly detrimental on post-test performance (Powell, 1973; Woolfolk, Parrish & Murphy, 1985), so each participant was told to be as accurate as possible. Each cohort mentally “threw” 45 darts. Physical practice has shown that at least 20 trials are needed to see an effect, and because mental rehearsal has generally been reported as having a weaker performance boost than physical practice (Driskell et al., 1994), more throws were used to elicit an effect. The physical practice group also threw 45 darts during the acquisition phase.

For the mental rehearsal external focus group, subjects were told: “For this phase, we will have you mentally practice throwing darts. Please only imagine throwing darts with your dominant hand and only imagine throwing each dart as accurately as possible. While mentally throwing each dart, focus on the imagined *flight of the dart*. If you mentally feel inaccurate, try to fix it or change it on the next mental throw by refocusing on the imagined *flight of the dart*. After you have finished mentally throwing each dart, say ‘done’ to complete the trial.”

For the mental rehearsal internal focus group, subjects were told: “For this phase, we will have you mentally practice throwing darts. Please only imagine throwing darts with your dominant hand and only imagine throwing each dart as

accurately as possible. While mentally throwing each dart, focus on the imagined *movement of your arm*. If you mentally feel inaccurate, try to fix it or change it on the next mental throw by refocusing on the imagined *movement of your arm*. After you have finished mentally throwing each dart, say 'done' to complete the trial."

The physical conditions also involved either external or internal foci during practice. For the physical practice external focus group, subjects were told:

"For this phase, we will have you practice throwing darts. Please only throw darts with your dominant hand and only throw each dart as accurately as possible. While throwing each dart, focus on the *flight of the dart*. If you feel inaccurate, try to fix it or change it on the next throw by refocusing on the *flight of the dart*. After you have finished throwing each dart, say 'done' to complete the trial."

For the physical practice internal focus group, subjects were told: "For this phase, we will have you practice throwing darts. Please only throw darts with your dominant hand and only throw each dart as accurately as possible. While throwing each dart, focus on the *movement of your arm*. If you feel inaccurate, try to fix it or change it on the next throw by refocusing on the *movement of your arm*. After you have finished throwing each dart, say 'done' to complete the trial."

The condition's focus was restated every three throws during the acquisition phase. This reminder served to reinforce the focus of attention. This reminder was used in both the physical and mental practice conditions.

The control group participated in an irrelevant letter detection task in the acquisition phase and did not practice throwing any darts, mentally or physically. The letter detection task consisted of participants reading two passages and circling

every occurrence of the letter “G”. This task took the equivalent amount of time that it took the mental and physical groups to complete their repetitions.

The post-test phase involved each of the five groups throwing 30 darts at the dartboard. There was no instruction on attention, and each subject was told to “...be as accurate as possible” after every three throws.

Accuracy was measured as absolute error from the center of the target. Each circumference number around the board was recorded to measure the distribution of throws and to determine whether there was a horizontal or vertical bias. The board is divided into 20 sections, so each section represents 18 degrees. This measurement allowed an assessment of how the placement of the different throws varied relative to each other.

Design

This study followed a 2 x 2 x 5 mixed factorial design. The four factors were the practice type (mental vs. physical), the focus of attention (internal vs. external), and the test phase (block 1-5), where accuracy was measured for improvement across the test phases. The first two factors were between-subjects and the last factor was within-subject. An alternative 5 x 5 design replaced the first two (between-subjects) factors with a single five-level factor of condition to enable comparisons of the control condition with the other conditions. Blocks consisted of two sets of three throws each, for a total of six throws per block. The mean accuracy was computed as the average of all six throws in the pre-test and each block of six throws in the post-test.

Results

Between-Subject Analysis

Behavioral performance measures. The absolute error from the center of the target for all throws was 9.24 cm. Mean accuracy improved significantly in all conditions across all blocks from 9.79 cm in Block 1 to 8.97 cm in Block 5, $F(4, 460) = 2.910$, $MSE = 5.408$, $p = .0213$. The main effect of condition was not significant, $F(4, 115) = 0.888$, $MSE = 32.235$, $p = .4734$; however, means did improve from the control (10.10 cm) to all other conditions (9.02 cm) across all blocks. When separately examining practice type and focus of attention, means improved for physical practice (8.94 cm), mental practice (9.08 cm), external focus (9.02 cm) and internal focus (9.00 cm). The main effect of practice type (physical vs. mental) was not significant, $F(1, 92) = 0.080$, $MSE = 30.861$, $p = .7781$, nor was the main effect of focus of attention (external vs. internal), $F(1, 92) = 0.002$, $MSE = 30.861$, $p = .9660$.

All conditions improved from baseline to the test averaged across blocks. Physical practice improved by 4.08 cm, mental practice improved by 3.42 cm, external focus improved by 3.88 cm, and internal focus improved by 3.63 cm. Control subjects improved by 2.43 cm from baseline. Mean accuracy improvement from the pre-test to post-test is shown in Table 1.

These data trend in the direction desired. The physical conditions performed best, whereas the mental conditions performed better than the control condition.

Standard deviation of performance. Standard deviation improved across blocks from 5.45 to 4.75, $F(4, 460) = 3.191$, $MSE = 4.389$, $p = .0133$. The standard deviation interaction of block and condition was significant, $F(16, 460) = 1.688$, $MSE = 4.389$, $p = .0456$. The decrease in variability was similar for the mental external

and physical external conditions, whereas the mental internal condition resembled the control. The physical internal condition exhibited an increase in variability across block.

The physical external group had the least variation across all five post-test blocks (4.654), and the mental external group had the second least variation (4.870). The physical internal group had variation of 4.907 over the five post-test blocks, the mental internal group had variation of 4.955 over the five post-test blocks, and the control condition exhibited the greatest variability, at 5.263 (see Figure 1). By combining practice type and focus type, results resemble the hypotheses. The physical practice and the external focus had the least variability. These data are presented in Tables 2 and 3.

Matched Group Within-Subjects Analysis

Research has shown that mental rehearsal performance gains are more evident with subjects who are already familiar with a task (Driskell et al., 1994; Mulder, Zijlstra, Zijlstra, & Hochstenbach, 2003). Therefore, subjects were matched based on their baseline performance, and analyses were conducted as a within-subjects design. Additionally, this method increased the power of the analyses.

Behavioral performance measures. The main effect of block was significant, $F(4, 92) = 2.617$, $MSE = 6.014$, $p = .0401$. The main effect of condition was not significant, $F(4, 92) = 1.448$, $MSE = 19.772$, $p = .2245$, and the interaction between block and condition was not significant, $F(16, 368) = 0.716$, $MSE = 5.257$, $p = .7780$. In Fisher's PLSD post-hoc tests, the control was significantly different from the physical external condition, $p = .0417$.

Standard deviation of performance. The main effect of block for variation was significant, $F(4, 92) = 3.037$, $MSE = 4.612$, $p = .0212$. The main effect of condition for variation was not significant, $F(4, 92) = 0.796$, $MSE = 7.231$, $p = .5306$. The interaction between block and condition was significant, $F(16, 368) = 1.710$, $MSE = 4.334$, $p = .0428$.

Percent improvement. Subjects were analyzed based on their percent improvement from the baseline phase to each of the five post-test blocks. There were no significant effects or interactions for the percent improvement. In a Fisher's PLSD post-hoc test, the control condition was significantly different from the physical external condition, $p = .0205$.

Discussion

Analyses of variance on variation (SD) and accuracy showed a main effect of block. The post-test consisted of the average of six throws in five sets. The first block showed the worst accuracy (where zero would be perfect) and the greatest variability, and Block 5 showed the best accuracy and least variability. This finding shows that subjects' improved during the course of the post-test. The interaction of block and condition with respect to variability shows that the external focus of attention decreased variability in both physical and mental practice conditions. In analyzing the slope of the variation from Block 1 to Block 5, the mental and physical external conditions exhibited a relatively flat and stable slope. Additionally, variation in Block 1 for mental external and physical external was less than in the other conditions. Therefore, most of what was learned was acquired during the practice phase, not the testing phase. The slope of the variation for the mental

internal condition decreased across the five blocks of the post-test phase, and in a similar fashion to the control condition, suggesting that improvement can be attributed to the number of throws in the post-test, not what was learned during practice. Additionally, variation in the physical internal condition increased over the post-test phase (see Figure 2).

Variation in performance across subjects was discussed and a matched group design was used to reduce variability between subjects. Self-report on previous skill involved in this task was difficult to ascertain, and subjects varied widely in pre-test performance. Mental rehearsal has shown improvement for subjects familiar with a task (Mulder et al., 2003); therefore baseline testing could be used to determine skill level before practice condition is administered. Additionally, the quality of imagery and familiarity with mental rehearsal led to better performance for athletes (Jowdy et al., 1989), yet subjects may not be familiar with mental rehearsal and not derive maximum benefit. There is no tangible measurement or physical feedback involved with imagery. Self-report for mental imagery was tenuous; some subjects reported a high number on a scale of 1 (worst) to 10 (best) but suggested that they visualized poorly, whereas other subjects reported a low number and said they visualized well. Future design should incorporate multiple training sessions involving mental rehearsal to improve subjects' use of imagery.

Future analyses will look at the accuracy bias between groups. Subjects' darts were recorded vertically (top vs. bottom halves of board) and horizontally (left vs. right halves of the board). Preliminary analyses showed less vertical bias away from the center of the board for the external conditions.

This research is the first to look at the combinatory effects of mental rehearsal and focus of attention. The data trended according to previous research involving mental rehearsal and focus of attention; however, significance was not found in the accuracy data to support the hypothesis. Variation data were significant to an extent, but further research is required to acknowledge whether there is a true crossover interaction between practice type and focus of attention. It is entirely possible one could derive greater benefit from an internal focus of attention while mentally rehearsing. Focus of attention involves an external and physical event; external focus influences the environment, whereas internal focus influences the participant. Both include physical movement. Mental rehearsal, contrarily, eliminates movement. Therefore, an internal focus of attention, where one considers the precision of their movements, could connect better with a mental representation of action. Research has showed that mental rehearsal affects the motor cortex; therefore, EEG data may prove to be insightful in expanding this research.

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Table 1

Pre-test, Post-test, and Improvement for Accuracy

CONDITION	PRE-TEST AVG	POST-TEST AVG	IMPROVEMENT
CON	12.52 cm	10.09 cm	2.43 cm
ME	12.35 cm	9.14 cm	3.21 cm
MI	12.65 cm	9.08 cm	3.63 cm
PE	13.45 cm	8.90 cm	4.54 cm
PI	12.61 cm	8.99 cm	3.62 cm

Table 2

Means and Standard Deviations of Distance in Centimeters as a Function of Practice Type and Focus Type Averaged Across all Post-Test Throws

Focus Type	Physical Practice		Mental Practice	
	M	SD	M	SD
External	8.90	4.65	9.14	4.87
Internal	8.99	4.91	9.08	4.96

Table 3

Mean Accuracy and Standard Deviation of Distance in Centimeters for Main Effects of Practice Type and Focus Type

Practice Type		M	SD
	Mental	9.08	4.91
	Physical	8.94	4.78
Focus Type			
	External	9.02	4.76
	Internal	9.00	4.93

Figure Captions

Figure 1. Standard deviation as a function of block and condition.

Figure 2. Trend lines for standard deviation from Block 1 to Block 5 as a function of condition.

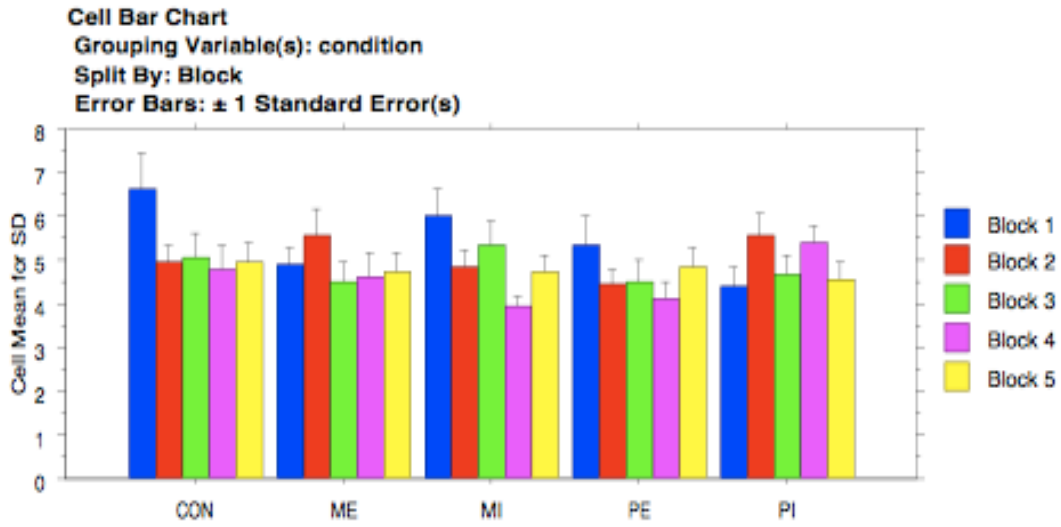


Figure 1.

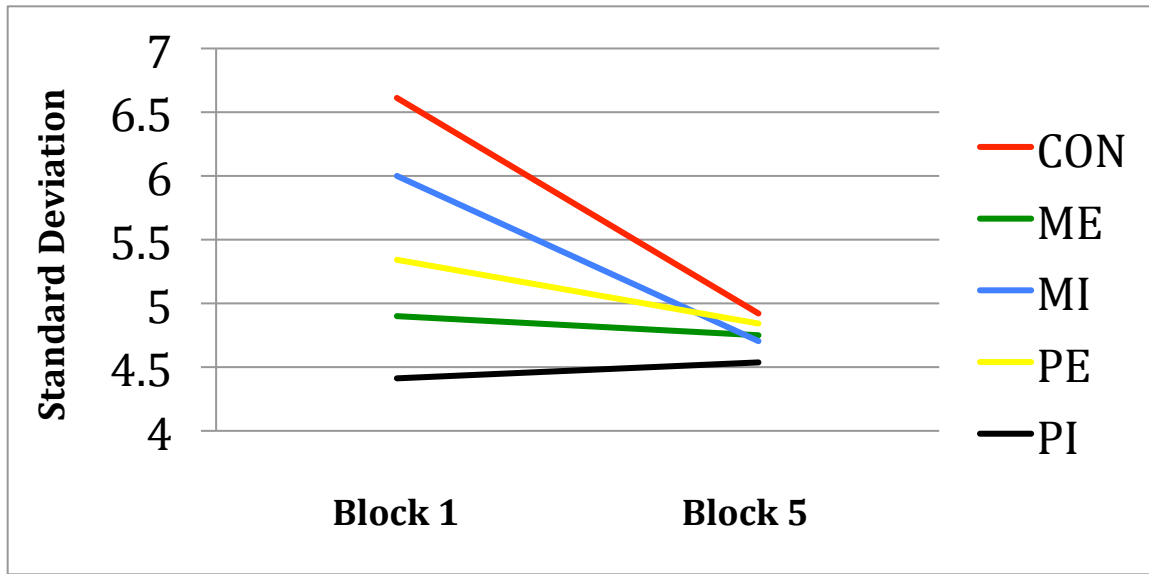


Figure 2.