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The effect of focus of attention on heart rate and performance while performing the wall sit

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THE EFFECT OF FOCUS OF ATTENTION ON HEART RATE AND PERFORMANCE
WHILE PERFORMING THE WALL SIT

by

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B.S., Southern Illinois University, 2011

A Research Paper
Submitted in Partial Fulfillment of the Requirements for the
Master of Science in Education Degree

Department of Kinesiology
in the Graduate School
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RESEARCH PAPER APPROVAL

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TABLE OF CONTENTS

<u>CHAPTER</u>	<u>PAGE</u>
ACKNOWLEDGMENTS	i
LIST OF FIGURES.....	iii
CHAPTERS	
CHAPTER 1 – Literature Review and Introduction	1
CHAPTER 2 – Method.....	13
CHAPTER 3 – Results	17
CHAPTER 4 – Discussion.....	20
CHAPTER 5 –Conclusion	29
REFERENCES	31
VITA	34

LIST OF FIGURES

<u>FIGURE</u>	<u>PAGE</u>
Figure 1	14
Figure 2	18
Figure 3	19

CHAPTER 1

LITURATURE REVIEW AND INTRODUCTION

It has long been wondered by both athletes and health practitioners whether there is an optimal way of learning and developing motor skills. While this is a complex question, one such way of attempting to answer it is by examining what the individual is concentrating, or focusing, on while performing the motor skill at hand. One of the leading researchers in attentional foci, Gabriel Wulf, was attempting to find the answer to this exact question many years ago as she attempted to learn how to perform basic movements such as the power jibe on a wind surfing board. After hours of failed attempts and many falls into the water while focusing on where her feet were and the position and power she was exerting with her hands she decided to completely switch her focus to tilting and moving the surf board and the position of the handle and sail rather than concentrating on the movements of her body to accomplish these same maneuvers. Wulf was so impressed with her immediate and seemingly permanent improvements on the wind surfer that she decided to create an experiment to test her theory that shifting her attentional focus was what had resulted in her observed performance enhancement.

In her first experiment (Wulf, HoB, & Prinz, 1998, Experiment 1), Wulf and her colleagues used a ski simulator and asked participants to direct their attention to either the pressure they exerted on the platform on which they were standing (i.e., external focus), or to focus on their feet (i.e., internal focus) throughout the experiment. They found that on a retention test the external focus group performed superiorly compared with both the internal focus control groups. Wulf and colleagues went on to replicate their findings in a follow up study which entailed balancing on a stabilometer (Wuf, HoB, & Prinz, 1998, Experiment 2). The instructions

given to participants for that experiment was to either focus on keeping the markers on the balance platform horizontal (i.e., external focus) or to focus on keeping their feet horizontal (i.e., internal focus). It should also be noted that the participants' feet were placed in the exact same position throughout the experiment. The external focus group again performed superiorly compared to the internal focus group. The results of this study were eye opening to the entire field of motor behavior and were met with a certain amount of skepticism. The question researchers in the field began to ask was how is it possible for such a small attentional focus change to have such a powerful effect?

Wulf, Lauterbach, and Toole (1999) then devised an experiment to replicate the previous findings in a real world setting using novice golfers learning the pitch shot. A group of twenty-two participants with no golf experience were randomly assigned to an internal focus or external focus group. Each participant then received the exact same instructions explaining proper posture, stance, and grip. The only difference in instruction was on how to swing the club. The internal group was instructed to focus on swinging the arms and the external group was instructed to focus on swinging the club like a pendulum. During practice trials both groups became more accurate, however the external group significantly outperformed the internal group. During a retention test one day later this significant difference remained even when no additional instructions were given. To see if these results could be replicated Maddox, Wulf, and Wright (1999) conducted a similar study with participants learning the backhand stroke in tennis. The results of this study again demonstrated the significant advantage of adopting an external focus while learning a new skill.

The results of these aforementioned studies clearly demonstrate the relatively permanent learning benefit when instructions induce an external focus opposed to an internal focus. The

question then arose as to whether it was more important for participants to externally focus or just to not direct their attention internally. At the time, the Wulf et al. (1998, Experiment 1) experiment was the only study that included a control group. The results of that study demonstrated that the control practice performance was similar to the external group; however, during the retention test, the control was significantly worse (and nearly equal to the internal group). This brought up the basic theoretical questions; does adopting an external focus of attention enhance performance, or does directing attention internally depress performance?

Wulf knew from her own personal windsurfing experience, as well as her experimental findings, that adopting an external focus was indeed superior to adopting an internal focus of attention. This led her to wonder about the mechanisms of why this was occurring. Is just not focusing internally the key to optimal performance or is there something deeper going on when people externally focus? Wulf specifically wondered whether it mattered most if participants focused externally or just didn't focus at all.

In an experiment designed to explore this question, Wulf, McNevin, Fuchs, Ritter, and Toole (2000, Experiment 1) compared two types of external foci on inexperienced individuals while learning a forehand shot in tennis. In the first group, the external focus instructions were to focus on the trajectory of the ball coming towards the racket (i.e., antecedent group), while the second external group received the instructions of focusing on the anticipated trajectory of the hit ball (i.e., movement effect group). If all that mattered was the fact that participants were not focusing their attention internally then both groups should equally improve and show no differences throughout practice and retention (Wulf et al., 2000). Throughout the practice trials both groups showed equal improvements. During the 24-hour retention test though, it was observed that the movement effect group had significantly better scores. This finding indicated

the advantage of adopting an external focus of attention was specifically the result of the learner focusing on the outcome of the movement opposed to externally focusing on its antecedent.

These aforementioned studies (Maddox et al., 1999; Wulf et al., 1998; Wulf et al., 1999; Wulf et al., 2000) clearly demonstrate an advantage of adopting an external versus an internal focus of attention in relation to performance and learning in balance tasks, golf shots, and tennis strokes, but no valid explanation existed at that time for this effect in the experimental literature (Wulf, McNevin, & Shea, 2001).

In an attempt to explain the benefits of adopting an external focus of attention, Wulf and colleagues proposed the constrained action hypothesis (McNevin, Shea, & Wulf, 2003; Wulf, McNevin, & Shea, 2001; Wulf, Shea, & Park, 2001). In essence, this hypothesis suggests that when individuals adopt an internal attentional focus, they tend to consciously interfere with the control processes that regulate the coordination of their movements. As a result, when individuals attempt to actively control their movements, they inadvertently disrupt the automatic control processes that would otherwise occur, which compromises motor behavior. This is in contrast to the more automatic type of control that occurs when individuals adopt an external focus of attention. Directing attention externally allows the communication process of the motor control system to occur in a reflexive manner that produces effective and efficient movements. The result is that the desired outcome is achieved almost as a by-product of the external focus itself. By adopting an external focus, the processes of controlling the movement occurs more automatically and efficiently, resulting in enhanced performance and learning.

Since the constrained action hypothesis proposes that focusing externally encourages more automatic control, Wulf and her colleagues proposed that this form of motor control would result in quicker and more reflexive actions. In contrast, by focusing internally individuals may

inadvertently intervene in the control process which would disrupt these otherwise automatic reflexive actions (Wulf, Shea et al., 2001). To test this prediction, Wulf, Shea et al. (2001) designed an experiment in which participants executed a primary task of balancing on a stabilometer, and a secondary task of responding to a randomly occurring auditory stimulus (i.e., probe reaction time) by pressing a button on a hand held device. The internal group was instructed to keep their feet horizontal, and the external group was instructed to keep the markers on the balance platform horizontal. Participants in both groups were given the hand held device and instructed to press the button every time the random auditory cue was sounded. The results of the study revealed that on the retention test the external group produced lower error balance scores and faster probe reaction times. The results suggest that focusing internally “slows down” neurological processes by utilizing a greater amount of attentional requirements, whereas focusing externally encouraged more automatic movements. It would seem that even novices can coordinate a movement automatically similar to experts by focusing externally (Wulf, Shea et al., 2001). This study along with similar ones such as McNevin and Wulf (2002) and McNevin, Shea, and Wulf (2003), provided strong evidence for an external focus promoting more automatic movements and an internal focus restricting or constraining those automatic processes. The proposed constrained action hypothesis provided a valid theoretical explanation for the observed performance and learning differences.

Up until this point in the experimental lineage almost all experiments conducted were either balancing or sport specific tasks. In the first study of its kind Vance, Wulf, Tollner, McNevin, and Mercer (2004) used a within subject design with a counterbalanced trial order between internal and external conditions while performing biceps curls to measure force production differences. Participants in the internal group were instructed to concentrate on the

biceps muscles and participants in the external group were instructed to concentrate on the bar. Electromyography (EMG) activity of the biceps and triceps brachii was measured during the bicep curls. As expected, EMG activity was significantly lower in both the biceps and triceps brachii muscles while performing the bicep curls in the external condition even though the same amount of weight was lifted. This suggests that when participants externally focused on the bar their movements and muscle activation patterns became more efficient. An unexpected outcome of the study was that bicep curls were executed faster during the external focus condition even though no speed instructions were given. This result is in accordance with the constrained action hypothesis since a more automatic mode of control typically results in a more fluid and smoother movement and thus may lead to a faster movement execution.

There is a notable limitation to the above study: the EMG activity was analyzed as integrated EMG (iEMG), which is a reflection of the combined influence of the temporal (i.e., movement time) and spatial (i.e., EMG amplitude) characteristics of muscle activity. Thus, the lower iEMG readings in the external condition could be a result of the shorter time frame in which it took the participants to complete the task. To address this concern, the researchers conducted a follow-up study in which a metronome was used and participants performed bicep curls in synchrony with the clicks produced (Vance et al., 2004, Experiment 2). The results of that study were nearly identical to their original bicep curl study except now the iEMG readings were more accurate in comparison. Thus, the adoption of an external focus resulted in a more efficient movement.

Marchant, Greig, and Scott (2009) sought to replicate these findings with two distinct differences in the experimental design. Opposed to using a metronome which places additional attentional demands on the participants, they standardized movement speed throughout each

repetition by using a Biodex system. The second change made was the addition of a control group to compare movement efficiency of the known benefits of an external focus to that of a more “natural” no focus condition. This was an interesting comparison because for a “simple” weightlifting task such as the bicep curl, one might not expect to find an improvement in performance by simply changing the focus of attention compared to what the performer usually does (Marchant et al., 2009). The results replicated those of Vance and colleagues (2004) demonstrating that instructing participants to focus externally on the movement of the weight bar resulted in significantly less iEMG and peak EMG activity than both the internal (i.e., focus on arms) and control (i.e., no focus) conditions. The most notable outcome of this study was that the external focus instructions were able to reduce muscular activity compared to the more natural control condition.

In a study designed to examine whether internal-external focus differences in EMG activity would also be found in tasks that have a clear goal and a measurable outcome, Zachry, Wulf, Mercer, and Bezodis (2005) measured movement accuracy relative to basketball free throw shooting. Using a within participant counterbalanced design, participants were required to perform basketball free throws while focusing either internally on their wrist motion or externally on the basket. EMG activity was recorded for various muscles of the shooting arm. The researchers proposed that greater EMG activity under internal focus conditions might add “noise” to the motor control system thereby constraining the system and hampering movement accuracy (Zachry et al., 2005). The authors also postulated that differences found within EMG activity in muscle groups that are not directly in the performer’s focus of attention would add support to the conclusion that interference, or noise, in the motor control system could be responsible for internal-external focus differences in movement effectiveness. As expected, the results of the

study indicated that the external focus group produced better accuracy scores compared to the internal focus group. Interestingly, the bicep and tricep EMG activity in the external group was significantly lower compared to the internal group. The authors concluded that since EMG activity differences occurred in muscle groups that participants were not instructed to focus on suggests that the effects of focus of attention on the motor system are rather general in nature and can “spread” to muscle groups that are not directly in the performer’s focus of attention (Zachry et al., 2005).

If increased “noise” throughout the system degrades movement efficiency and effectiveness, as proposed by the constrained action hypothesis, then endurance based tasks should also improve with an external focus of attention. In an experiment designed to investigate this hypothesis, Marchant, Greig, Bullough, and Hitchen (2011) measured the effects of focus of attention on three endurance tasks; Smith machine bench press, free weight bench press, and a free weight back squat. The exercises represented increasing complexity and difficulty with the Smith machine bench press representing the least complex and the free weight back squat representing the most difficult and complex. A modified version of the YMCA bench press protocol was used for the Smith machine bench press. The free weight bench press was performed at 75% of the participant’s one-repetition maximum (1RM). Finally, the free weight squat was performed at 75% of the participant’s 1RM. Each participant performed each of the three exercises in an internal, external, and no focus condition in a counterbalanced order until failure. The external instructions related to exerting force on and through the barbell and the internal instructions related to pressing with either the arms or the legs. The external focus resulted in a significantly greater number of repetitions to failure than the internal focus on the YMCA Smith machine bench press. There was no significant difference in the control condition

compared to both the internal and external conditions. There was a significantly greater amount of repetitions performed for the 75% 1RM free weight bench test between the external focus conditions and both the internal and control condition. The internal and control conditions were not significantly different. Finally, for the 75% 1RM free weight back squat the external focus group produced a significant higher number of repetitions compared to the internal and control conditions. The internal and control conditions were again not significantly different. These results clearly demonstrate that focus of attention significantly affects performance outcomes for muscular endurance weightlifting tasks (Marchant et al., 2011).

It is interesting to note that the control condition in the simplest of the tasks (i.e., YMCA Smith machine bench press), was not significantly different from the external condition, but the external condition was significantly better than the internal condition. This highlights the fact that as task complexity increases, so too does the magnitude of the focus of attention effect. The participants were all experienced and consistent lifters. When they were instructed to perform a relatively easy and experienced movement “to the best of their ability” on the Smith machine it is likely that a more natural and automated control process controlled their movements thus allowing them to perform the movement efficiently. As task complexity and difficulty increases so to does the degrees of freedom which can potentially increase opportunities for error (Marchant et al., 2011). As the tasks became increasingly more complex during the 75% 1RM for both free weight bench press and back squat, participants apparently more actively intervened in the motor control process when they directed their attention internally, thus degrading movement efficiency. This degradation of movement efficiency resulted in decreased repetitions to failure while the external focus conditions effectively produced a higher number of repetitions to failure.

To determine if the benefits of externally focusing would apply to an isometric endurance task, Lohse and Sherwood (2011) designed a study in which participants performed a standard wall sit to failure. Each participant completed an internal trial and one of two external trials; an associative or dissociative focus of attention in a counterbalanced order. As part of the experimental design, participants had reflective anatomical markers placed on the knee at the lateral condyle of the femur, and on the hip at the greater trochanter of the femur on each leg. Two parallel markers were also placed on two pylons 1.5 meters in front of the participants during trials. During the internal trial participants were instructed “to mentally focus on the position of your thighs, trying to keep them parallel to the floor to minimize any movement up and down.” For those who completed the external-associative trial they were instructed “to mentally focus on drawing imaginary lines between the markers from your knee to your hip, trying to keep the lines parallel to the floor to minimize any movement up and down.” For those who completed the external-dissociative trial they were instructed “to mentally focus on the drawing imaginary lines between the pylons in front of you, trying to keep the lines parallel to the floor to minimize any movement up and down.” (Lohse & Sherwood 2011). As expected, when participants focused externally they were able to hold the wall sit for a significantly longer time than when they internally focused regardless of whether they adopted an external-associative or external-dissociative focus. There was no significant difference between an external-associative and an external-dissociative focus conditions.

In both of the previous studies (Lohse & Sherwood 2011; Marchant et al., 2011) where participants performed submaximal muscular contractions, they had significantly better outcomes when they focused externally relative to focusing internally. Both research teams concluded that this suggests the participants muscular systems were working more efficiently when they were

focusing externally opposed to when they were directing their attention internally. If sub-maximal concentric and isometric contractions are performed more efficiently when externally focusing opposed to internally focusing does this mean that one's cardiovascular system is also working more efficiently when the individual is externally focusing? Presently, no study has investigated the effects of focus of attention on heart rate while performing muscular contractions.

According to Wilmore, Costill, and Kenney (2008), the cardiovascular system's role in the body is to carry nutrients to the working muscles and carry the by-products produced by those working muscles away to be recycled or discarded. Due to the cardiovascular system's synergistic relationship with the working muscles, heart rate has a linear relationship with exercise intensity (i.e., the greater the exercise workload the greater the heart rate). This is due to the fact that when the workload of the working muscles increases, so too do the nutrient requirements needed to power the muscles, as well as the by-products produced from the cellular reactions taking place. The cardiovascular system responds to these needs by increasing heart rate accordingly (Wilmore et al., 2008). If during an external focus of attention, the body's motor control system is working more efficiently; (i.e., the working muscles use less nutrients and produce fewer by-products), then it should be expected that the cardiovascular system will respond accordingly with a relatively lower heart rate compared to trials completed while adopting an internal focus of attention.

The aim of the present study was to measure the effects of focus of attention on heart rate and performance while performing a fatiguing standard wall sit. It was hypothesized that heart rate would be lower during the external trials compared to the internal and control trials. In addition, it was also predicted that the performance outcomes (i.e., time to muscular fatigue)

would be greater during the external trials compared to the internal and control trials. It was also hypothesized that heart rate would be higher in the internal trials compared to the control trials and that the performance outcomes would be lower during the internal trials compared to the control trials.

CHAPTER 2

METHOD

Participants

A total of 48 undergraduate kinesiology students were recruited for participation in this study. Four of these participants were excluded from the data analysis because they did not complete all of the required testing. These four participants did not return on either the second or third day of testing so their first day scores were removed from the sample. Additional participants were removed from the data set if they were identified as outliers. Participants were naive to the purpose of the study. There was no exclusion criteria based on training status. The only inclusion criteria for participation in the study was that individuals had to have the physical ability to hold a standard wall sit. All participants read and signed an informed consent before participating. The University's Human Subject Committee approved all forms and methods.

Apparatus and Task

All data collection took place in the same room that contained two blank walls directly opposite each other. The standard wall sit is a common test to measure static leg endurance, and the instructions used for this test were adopted from Tomchuk (2011). During each trial, participants held the correct position for as long as possible "until failure." The proper position of the wall sit included participants feet flat on the floor and shoulder width apart, knees at a 90 degree angle with the shoulders against the wall, and arms hanging straight down (see Figure 1).



FIGURE 1 Wall Sit. Proper wall position while wearing socks on a carpeted floor with feet flat, knees at 90 degrees, and arms hanging down.

For this experiment failure was defined as a 5 degree deviation from the 90 degree knee angle. All participants performed the experiment in athletic shorts and socks without shoes on. The task was completed on a carpeted floor. Participants were instructed to look straight ahead throughout the duration of the trial. A within-participant design was used with each participant participating in all three experimental conditions; internal, external, and control. Each trial was separated by at least 48 hours. This was to ensure adequate recovery time by eliminating the

presence of fatigue on the second and third trial (American College of Sports Medicine, 2010). Conditions were counterbalanced across participants to control for potential order effects.

The same experimenter gave all instructions and collected all data from each participant. A Polar (Polar Electro company, Finland) heart rate monitor (model number: RS400) was used to collect both the time until failure and heart rate data simultaneously. Before each trial began the participant would place the heart rate monitor strap securely to their chest and the experimenter would confirm the monitor was receiving a proper pulse. The time began during each trial once the instructions were given and the participant assumed the proper wall sit position. Time until failure performance scores were manually recorded then transferred to a computer and stored for later analysis. Heart rate data was stored on the heart rate monitor until it could be downloaded onto a computer at the end of the day and stored for later analysis. Before the start of each trial a goniometer was used to ensure the participant's knee was at a 90 degree angle. The center of the goniometer was pressed against the lateral femoral epicondyle with the "arms" pointing to the lateral malleolus of the tibia and the greater trochanter of the femur. This was measured before each trial during a brief 5-10 second familiarization period.

Following the familiarization period, the experimenter gave the following general instructions to each participant that once they began the trial they were to "maintain the correct wall sit position for as long as possible." When participants were in the internal condition they were provided the following instructions: "I want you to focus on keeping your knee at the 90 degree angle throughout the duration of the trial." The external instructions were "I want you to focus on pretending like you are sitting in a chair throughout the duration of the trial." The control instructions were "I want you to perform the wall sit to the best of your ability for as long as possible."

Procedures

On the first visit to the motor behavior lab each participant was asked to sit down and sign an informed consent. The participant was then asked to securely strap the heart rate monitor across their chest in a private room. Upon their return the participant would remove their shoes and follow the experimenter into a second smaller room to ensure privacy during data collection. At this time the experimenter demonstrated and verbally described the correct wall sit position as well as the test termination criteria. Then the participant performed a 5-10 second familiarization trial while the experimenter measured the knee angle to ensure it was at 90 degrees. The participant then stood up without moving their foot positioning. While standing in this position, the experimenter gave the participant the proper focus instructions for that trial. When the participant was ready, he or she then squatted down and the experimenter began the stopwatch the moment they were in the proper position. A verbal cue was given every 15 seconds during the trial to remind the participant of the correct focus. Procedures on day two and day three were exactly the same except a different set of focus instructions were prescribed.

CHAPTER 3

RESULTS

Heart Rate

Data were analyzed using the Statistical Package for the Social Sciences (SPSS) Version 19. A univariant repeated measures analysis of variance (ANOVA) was conducted to test if the three experimental conditions differed in their heart rate during the study. The ANOVA indicated that there was a significant main effect, $F(2,82) = 8.805, p < .05$. Post-hoc analysis of the focus of attention main effect indicated that the heart rate of participants in the internal condition ($M = 117.51$ beats per minute (bpm), $SD = 14.19$) was significantly higher than both the external ($M = 114.17$ bpm, $SD = 13.19$) and control ($M = 115.40$ bpm, $SD = 16.85$) conditions. The heart rates of the external and control condition were not significantly different. The average heart rates for each condition are displayed in Figure 2.

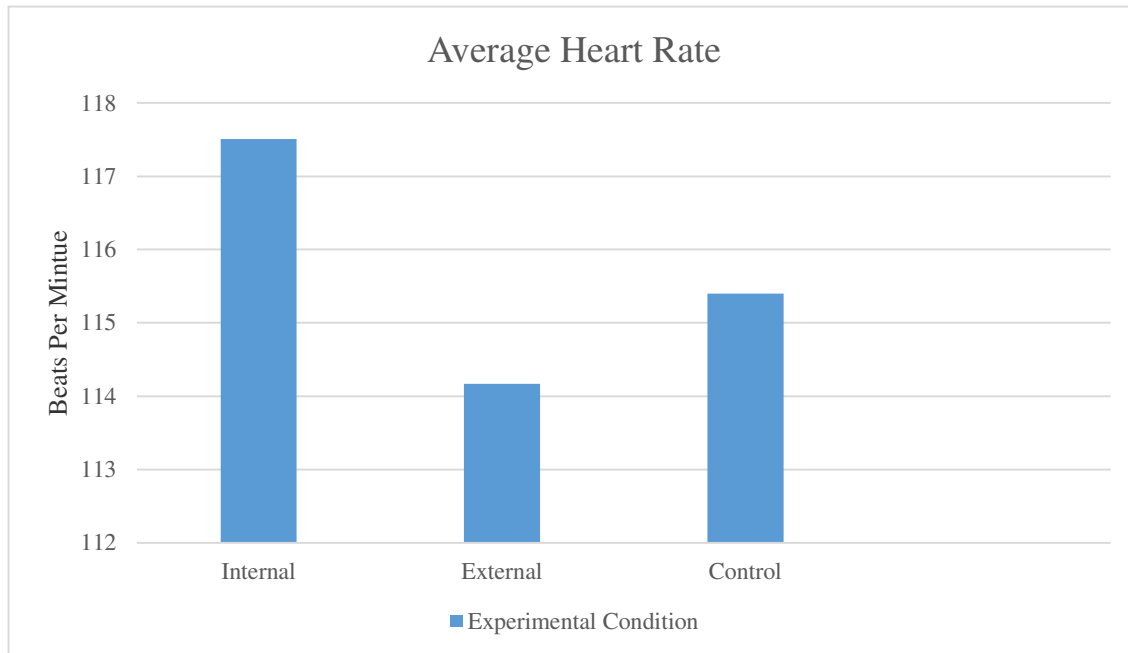


FIGURE 2 Heart Rate. Heart rates for the internal, external, and control conditions.

Endurance Times

The time until failure data were also analyzed using SPSS Version 19. Similar to the heart rate data discussed above, a univariate repeated measures ANOVA was used to test if significant differences existed between the three experimental conditions. The results of this test revealed that there was a significant main effect, $F(2,84) = 8.145$, $p < .05$. Post-hoc testing indicated that the external condition ($M = 107.01$ s, $SD = 46.35$) had a significantly higher time until failure compared to the internal condition ($M = 95.25$ s, $SD = 38.19$) and a marginally significant ($p = 0.06$) higher time until failure compared to the control condition ($M = 102.17$ s, $SD = 43.04$).

Additionally, the control condition had a significantly higher time until failure compared to the internal condition. The average times until failure for each condition are displayed below in Figure 3.

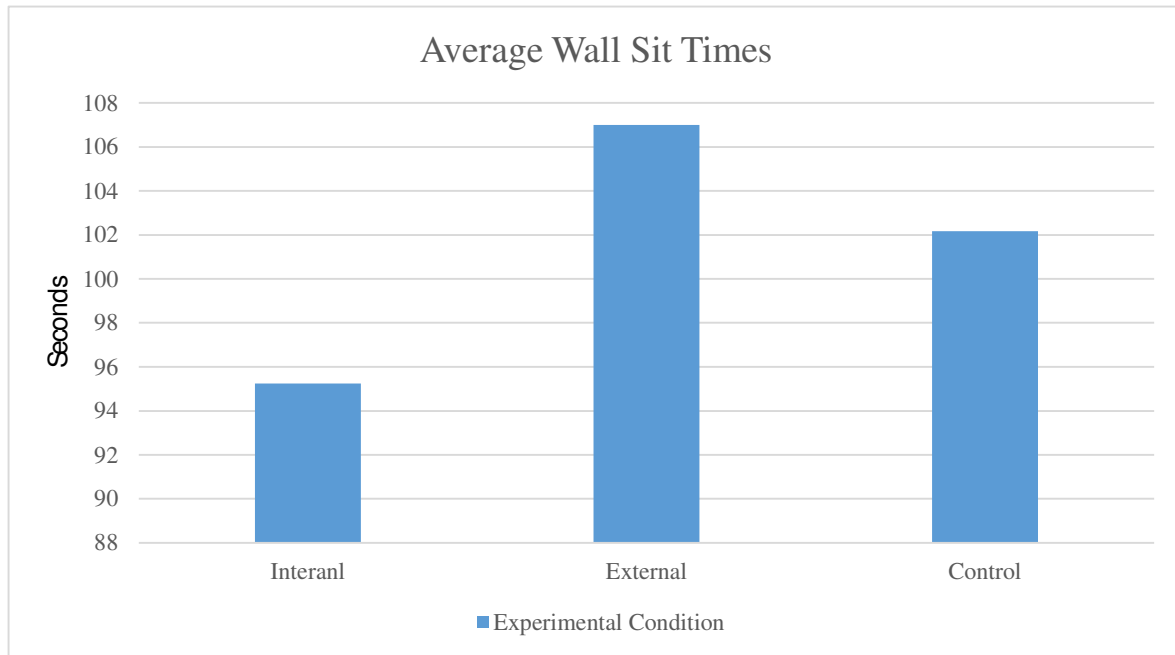


FIGURE 3 Wall Sit. Wall sit times for the internal, external, and control conditions.

CHAPTER 4

DISCUSSION

The purpose of this study was twofold. First, the relationship between endurance time and three different attentional focus strategies was examined. Second, the relationship between heart rate and these three attentional focus strategies was investigated. It was hypothesized when participants focused externally (i.e., maintaining the chair position) they would be able to hold the wall sit position for a longer time than when they focused internally (i.e., maintaining the knee angle at 90 degrees) or had the freedom to choose their focus (i.e., control condition). In addition, it was also predicted when participants focused externally that their heart rates would be lower than when they focused internally or had the freedom to choose their focus. It was also hypothesized that heart rate would be higher in the internal trials compared to the control trials and that the wall sit time would be lower during the internal trials compared to trials completed in the control condition.

As predicted, when participants focused externally their heart rates were lower than when they focused internally; however, contrary to the above mentioned hypothesis, there was no significant difference in heart rates between the external and control conditions. In addition, the internal group had a higher heart rate compared to the control group.

Also as predicted, when participants focused externally, their wall sit times were higher than when they internally focused or had the freedom to choose their focus. In addition, the internal group held the wall sit for a shorter amount of time compared to the control condition. These results add to the growing body of focus of attention literature that demonstrates an

external focus enhances muscular endurance (Lohse & Sherwood 2011; Marchant et al., 2011). It is also the first study which investigated the relationship between heart rate during muscular contractions until failure while altering the participants' focus of attention.

The findings of this study are partially in accordance with the constrained action hypothesis (Wulf et al., 2001). According to this hypothesis, when an individual focuses internally while performing a motor task, the neuromuscular system is “constrained” by conscious control intervention. This reduces automatic control processes within the motor control system, and as a result decreases movement efficiency. By contrast, an external focus induces a more liberated motor control system and results in more automatic movements. These automatic movements are associated with more fluid and efficient muscular recruitment, which respond in a more appropriate and faster manner to the environment or task demands. It has been previously demonstrated by Zachary et al. (2005) and Lohse, Sherwood, and Healy, (2010) that during an external focus, participants EMG activity decreased while the accuracy of their movements simultaneously increased. During the free-throw task used in the Zachary et al. (2005) study, participants EMG activity increased in both the biceps and triceps brachii during an internal focus (i.e., wrist flexion) and decreased during an external focus (i.e., basketball hoop). Performance scores were also significantly better in the external group. This suggest that EMG activity increased and spread to other muscle groups when participants were instructed to focus internally, creating more “noise” throughout the entire motor control system and likely contributed to the decrease in performance. Thus, it seems reasonable to conclude that in the present study the same mechanisms occurred producing a more efficient muscular recruitment when participants adopted an external focus. This more efficient muscular recruitment would explain why participants held their wall sit longer when they focused their attention externally.

The less efficient muscular recruitment during the internal and control trials likely contributed to the participants fatiguing faster, resulting in them holding the wall sit for shorter times than during the external trials.

There is also evidence by Bonnard, Sirin, Oddsson, and Thortensson, (1994) that in response to fatigue, the neuromuscular system reorganizes input to different muscles in an attempt to maintain and stabilize the action. In that study, participants hopped on one foot for as long as possible. EMG data was collected from the vastus lateralis, rectus femoris, gastrocnemius, and soleus. The results showed that participants' neuromuscular system compensated for fatigue in two ways: 1) several participants altered neuromuscular control at the ankle, 2) while others altered neuromuscular control at the knee. While the present study involved static muscular contractions to failure, the Bonnard et al. (1994) study's results support the supposition that changes in neuromuscular activation in response to fatigue were possibly different in the three conditions utilized in the present study. If this were the case, it could explain the differences in endurance times between the conditions. While participants were instructed to keep their back flat against the wall with their feet flat on the ground, it is also possible that participants slightly shifted a percentage of their weight from foot to foot and to different areas of each foot and thus redistributed their weight throughout the duration of the present study during each trial in response to the fatiguing task. These slight weight distribution shifts which seemed to occur more often than not towards the end of the trial as participants were struggling to maintain the wall sit for as long as possible, could potentially change which muscles were predominately being used and fatigue them differently and at dissimilar rates. These slightly different kinematic control patterns have the potential of affecting performance differences (Zentgraf & Munzert, 2009), and were likely affected by what the participant was

focusing on during each respective trial. Further analysis using EMG, kinematic, or kinetic measures could support or refute these possible explanations.

Investigating heart rate differences between focus of attention conditions was the principal reason for conducting the present study. During an isometric muscle contraction heart rate (HR) and blood pressure (BP) increase accordingly to meet the increasing needs of the working cells within muscle tissue (Gladwell & Coote, 2002). This is because the longer an isometric contraction is held, the higher the oxygen and energy needs are for the working muscle as well as the increased needs of by-product waste removal to maintain homeostasis. This process occurs during all isometric contractions. Which consequently raises an important question relative to the results of the present study; that is, what caused the observed differences in HR between the conditions in the present study?

One possible answer to this question is based on the mechanics of HR contractions. The stimulus responsible for the increase in HR during muscular contractions is thought to be a combined result of central motor command, and the muscle afferent mechanoreceptors and metaboreceptors (sometimes referred to as chemoreceptors) (Thornton et al. 2001; Kaufman & Rybicki, 1987). The theory of central motor command states that the signal to contract muscle fibers also stimulates cardiovascular centers simultaneously and has been well documented by Thornton et al., (2001). Afferent mechanoreceptors are termed as such due to their stimulation during musculoskeletal mechanical work including stretch, contraction, and pressure and respond abruptly when muscles contract. Afferent metaboreceptors are stimulated by chemical products of contraction such as potassium, bradykinin, and inorganic phosphate. It was concluded by Gladwell and Coote (2002) that both groups of afferents include receptors that are polymodal, thus responding to both mechanical and chemical stimuli. Since these processes represent a

feedback system which communicates via electrical and chemical messengers within and throughout the entire body, it seems likely that what one focuses on while performing a motor skill would have an impact on the communication system.

One possible explanation for the results of the present study is central motor control theory. As defined by Wilmore, Costill, and Kenney (2008), central motor control theory “involves parallel activation of both the motor and the cardiovascular control centers of the brain. Activation of central command rapidly increases HR and blood pressure. In addition to central command, the cardiovascular responses to exercise are modified by mechanoreceptors, chemoreceptors, and baroreceptors” (p.173). According to this theory, it can be assumed that the initial stimulation to increase HR of participants when they began the wall sit during each trial was largely activated by the participants’ mental preparation for the approaching task. During the seconds leading up to each trial every participant was given a set of instructions regarding what to focus on as they performed the upcoming wall sit. The results showed that when individuals focused their attention internally their HRs were higher compared to when they focused externally or had the freedom to choose their focus. One possible explanation for this is that the excess “noise” within the motor control system as predicted by the constrained action hypothesis (Wulf, 2001) during an internal focus could have a spreading effect across central motor control and thus contribute to an elevated HR at the onset of the exercise. Since the HR of the external and control trials were not significantly different, it would seem that specifically adopting an internal focus of attention stimulated the increase in HR. It would be interesting to specifically analyze and compare the initial HR’s of participants in this and future studies. This could help support or refute this explanation.

Central command theory could also explain another interesting result that occurred across trials of all the participants. Although these data are not reported in the present paper, when looking at the graphed HR changes throughout each trail, a similar and consistent phenomenon occurred. For each participant, HR sharply dropped within the first 10-15 seconds then steadily and linearly increased until the completion of the trial. This result can be explained by central command theory. According to central command theory both blood pressure and HR rapidly increase at the onset of exercise by the simultaneous stimulation of both the motor and cardiovascular control centers in the brain (Wilmore et al., 2008). It seems that after this initial rapid increase in HR occurred at the onset of each wall sit, this stimulation progressively dissipated allowing the HR of participants to decline and match the required load necessary to perform the task at hand. The explanation for the gradual linear increase in HR thereafter is discussed in the following paragraphs.

Another possible explanation for the results of the present study are the mechanisms of both the mechanoreceptors and metaboreceptors which represent an electrical and chemical feedback system which are continually communicating with the cardiovascular control centers in relation to changing demands placed on working muscles. These receptors are located throughout the entire body including but not limited to the blood vessel walls and muscle cell membranes of skeletal and cardiac muscle (Wilmore et al., 2008). The mechanoreceptors of the legs and heart were immediately stimulated once participants assumed the wall sit position in the present study due to the contraction and stretching of muscle fibers being utilized. The metaboreceptors conversely would have been stimulated at a slower and more gradual rate due to the chemical reactions occurring and building up as the duration of the wall sit continued. It is also important to note that both types of receptors have the ability to respond to both mechanical and chemical

stimuli (Gladwell & Coote, 2002). Because the mechanoreceptors are intimately intertwined within the cellular membranes of muscle fibers and ligaments, it seems feasible that these receptors could also be affected by an increase in electrical and neural “noise” created by an internal focus of attention during a wall sit. As was shown by Zarchay et al. (2005), EMG activity increased not only in the working muscle during an internal focus of attention, but elevated EMG readings seemed to spread to antagonist muscle groups as well. It seems likely that a similar phenomenon is occurred in the present study, which would explain why HR was lower during the external and control conditions compared to the internal condition. This increase in noise within the motor control system could also spread and negatively affect the functioning of mechanoreceptors in and around both the skeletal and cardiac muscles being utilized. If so, it would contribute to this proposed explanation. It seems less likely that focus of attention would affect the functioning and stimulation of the metaboreceptors since they are primarily stimulated by increases in blood chemicals; however, since these receptors have the ability to be polymodal and are also located in and around the cell membranes of muscle tissues, they may very well be affected by increased electrical “noise” within the motor control system in a similar way as proposed for the mechanoreceptors. If so, then an internal focus of attention would likely also negatively effect the functioning of these receptors as well, potentially disrupting or degrading the standard flow of communication they send to the cardiovascular control centers. Further research examining mechanoreceptor and metaboreceptor function and focus of attention is needed to support or dispute this explanation.

Regardless of whether the mechano- and metaboreceptor functioning was impaired during an internal focus of attention as previously proposed, another possible explanation for the increase in HR during an internal focus of attention exists. Assuming the metaboreceptors were

functioning optimally and unaffected by the increased “noise” in the motor control system during the internal trials of the present study, these receptors would hypothetically still be receiving more stimulation to increase HR as participants held this focus. As thoroughly explained and continually demonstrated by the constrained action hypothesis, muscular movements and contractions during an internal focus of attention are less efficient compared to control and external foci of attention (Wulf, 2013). It seems likely that this inefficiency during an internal focus of attention requires more energy metabolism and thus creates more chemical by-products in the blood. As a result, this increase of chemical by-products within the blood would be recognized by the metaboreceptors and thus stimulate an increase in HR in an attempt to remove the waste. More intravenous research examining the blood levels of chemical by-products as a result of exercise metabolism and how they are affected by focus of attention are needed to fully test this possibility.

A final thought on this topic is that the heart itself is a muscle and thus may be subject to the functional and electrical disadvantages of adopting an internal focus of attention. While it is composed of cardiac muscle and all studies thus far examining focus of attention effects have investigated skeletal muscle, it seems possible that the spreading of the unintended internal “noise” of the motor control system during an internal focus of attention could also spread to and affect the heart directly. Furthermore, an abundance of research conducted and analyzed by McCraty, Atkinson, Tomasino, and Bradley (2009) has concluded that the heart and brain intimately communicate and thus affect the functioning of one another dependent upon a combination of physiological and psychological variables at any given time. The researchers concluded that the state and functioning of the heart has just as much of an impact on cognitive processes occurring in the brain as vice versa. This is important to consider when analyzing the

results of the present study because this complex communication feedback system between the heart and brain is largely governed by electrical signals. Future research should examine this topic in more depth and see if there is increased EMG activity in and around the heart while internally focusing on other body parts as demonstrated by Zachary et al. (2005) in skeletal muscles.

Certain limitations must be acknowledged in the present study. A major limitation is that only one trial was performed for each condition. This method was used in a similar study by Nolan (2009) and thus was replicated in the present study. Only using one trial in each condition could be problematic for validity and reliability of the results because there are a variety of factors such as prior physical activities or food intake that could affect one trial and not influence or not be present for another. Utilizing a within-participant design helped to control for participant variation since the same participants were used in all three conditions. The results of the present study revealed there were differences between the three conditions and there was no day effect. This provides confidence that even with the possible limitation of only using one trial per condition, the results are valid.

Another limitation to the present study is that certain bodily movements could not be completely restricted. The wall sit test requires participants to maintain a 90 degree angle with their knees with feet flat on the floor and back against the wall, but slight bodily adjustments throughout each trial could have occurred. Slight adjustments of the arms, feet, and back against the wall could have been made by participants throughout each trial. A more accurate isometric test would be to use an isokinetic dynamometer which would allow for greater consistency of applied force between trials within the same participant.

CHAPTER 5

CONCLUSION

The purpose of this study was to test the relationship between endurance time and three different attentional focus strategies. Furthermore, the relationship between heart rate and these three attentional focus strategies were investigated as well. The results demonstrated that adopting an external focus of attention resulted in superior motor performance compared to trials completed in the internal and control conditions. Additionally, the results of the present experiment demonstrated that instructing participants to focus their attention internally resulted in a faster fatigue time compared to trials completed in the control condition, suggesting that directing attention internally had a depressing effect on motor performance. HR results showed that the external and control conditions were not significantly different. However, the HR of the external and control conditions were significantly lower compared to the internal condition, suggesting that directing attention internally had a stimulating effect on HR.

The performance outcomes of this study add additional support to the well documented phenomenon of the constrained action hypothesis whereby adopting an external focus of attention during motor skills elicits a more automatic and efficient movement pattern (Wulf et al., 2001). The HR differences between trials can likewise be explained by the constrained action hypothesis whereby adopting an internal focus of attention during motor skills creates internal “noise” within the motor control system. It seems reasonable to conclude this increased “noise” within the motor control system affected the stimuli for increasing HR; central motor command, and the muscle afferent mechanoreceptors and metaboreceptors.

Whenever possible instructors, coaches, and test administrators should give skill instructions that direct a performer's attention externally towards the environment and away from the body. This study is the first to demonstrate the cardiovascular advantage in adopting an external focus of attention and adds to the growing evidence that an external focus enhances muscular endurance (Marchant et al., 2011). These results can be applied to the performance of skills that require the application of sub maximal forces for an extended period of time such as bicycling, swimming, or rowing. Future studies should continue to investigate and analyze the effect of focus of attention on heart rate differences during more dynamic movements.

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