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An External Focus of Attention Enhances Isometric Wall Sit Endurance Time: A Quantitative and Qualitative Analysis of the Attentional Focus Effect

Russell Patrick Nolan

Southern Illinois University Carbondale, rnolan2@yahoo.com

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AN EXTERNAL FOCUS OF ATTENTION ENHANCES ISOMETRIC WALL SIT
ENDURANCE TIME: A QUANTITATIVE AND QUALITATIVE ANALYSIS OF THE
ATTENTIONAL FOCUS EFFECT

by

Russell P. Nolan

B.S., Louisiana State University, 2009

A Thesis

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

Department of Kinesiology
in the Graduate School
Southern Illinois University Carbondale
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THESIS APPROVAL

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Approved by:

Dr. Jared M. Porter, Chair

Dr. Philip M. Anton

Dr. Michael W. Olson

Graduate School
Southern Illinois University Carbondale
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AN ABSTRACT OF THE THESIS OF

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TITLE: An External Focus of Attention Enhances Isometric Wall Sit Endurance Time: A Quantitative and Qualitative Analysis of the Attentional Focus Effect

MAJOR PROFESSOR: Dr. Jared M. Porter

Recently, attentional focus studies involving force production have demonstrated that when participants focused externally motor units were recruited more efficiently and muscular communication was enhanced. When participants focused internally, however, increased “noise” was incorporated into the neuromuscular system resulting in energy waste. The present study explored the effects of an external or internal focus of attention in the isometric wall sit endurance test. Since motor unit recruitment is more efficient under an external focus, it was hypothesized that participants ($n = 23$) would have a higher endurance time when they focused externally (ex. I want you to focus on pretending like you are sitting in a chair through the duration of the trial) rather than internally (ex. I want you to focus on keeping your knee at 90 degrees through the duration of the trial). Results revealed when participants focused externally they had a significantly higher endurance time (68.41 ± 34.12 sec) than when they focused internally (60.22 ± 34.54 sec). Participants also adopted the correct attentional focus in a majority of the endurance trials (70% and 69% for the external and internal conditions, respectively). This was the first study to demonstrate the benefits of an external focus over an internal focus in an isometric wall sit endurance test. Future studies should use biomechanical analyses such as EMG and kinematic measures and perceived force measures such as RPE to explore the reasons why an external focus provided performance benefits.

DEDICATION

I dedicate this research project to Him who is worthy of our entire focus. May we fix our eyes on Him so that we will not grow weary and lose heart (Hebrews 12:3).

ACKNOWLEDGMENTS

I owe an immeasurable debt to my wonderful wife who sacrificed so much to allow us to be together for this last year, and to putting up with me as I many times chose working on this thesis over spending time with her. I love you, Hunnie.

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CHAPTER 1

LITERATURE REVIEW AND INTRODUCTION

Introduction

Focus of attention is a relatively new field of exploration in motor behavior research. This line of research has its foundation in the early theories of Kahneman's model of attention (Kahneman, 1973) and then later from Singer's explorations of his Five-Step Approach (Singer, 1988; Singer, Lidor, & Cauraugh, 1993). Realizing that this could enhance the way people learn and perform a motor skill, there arose a great need for researchers to investigate this topic more fully. However, the majority of initial support was from anecdotal and indirect evidence such as when researchers just simply asked highly skilled performers "what were you focusing on when you performed at your best?" (Singer et al., 1993). Thus there was some support for the notion that what a performer focuses on affects how they perform and learn a skill, yet more empirical data needed to be obtained to scientifically support this assumption. Starting in the late 1990s, Gabrielle Wulf and her colleagues (for a review see Wulf, 2007a and Wulf & Prinz, 2001) began to explore how a performer's attentional focus, what he or she "thinks" about when performing a motor skill, affects performance and learning of that motor skill. From these initial studies, a solid foundation of the attentional focus effect was laid that provided a strong launching point for many more studies to explore this effect. This in depth review will first define the important terms related to attentional focus such as attention, internal focus, and external focus. Next, this review will explore the theories that gave rise to the current field of attentional focus, and then evidence will be provided showing that an

external focus of attention is superior to an internal focus or no focus at all. Within this discussion, various factors that can influence the attentional focus effect will be described including what motor skills and populations this effect applies to. Then the current theories on why the effect is observed will be discussed. The review concludes with a discussion of the limitations and gaps in the current research, and directions for future research are offered.

Important terms

Attention in human performance relates to the characteristics associated with consciousness, awareness, and cognitive effort as they relate to the performance of skills (Magill, 2011). While sometimes difficult to answer, related questions could be ‘what aspects of the environment are you aware of?’ or ‘what aspects of the movement are you thinking of?’ or even ‘what is distracting you when performing the skill?’ As will be discussed later, attention can be influenced in many ways. Focus is a related term and can be thought of as the direction of one’s attention to the performance environment or to the activity (Magill, 2011). Important to this review is the difference between an internal focus and an external focus of attention. An internal focus of attention is when a performer focuses on movements of his or her own body while performing an action; an external focus is when a performer focuses on the effects of his or her movement on the environment (Wulf & Prinz, 2001). Many studies also include a control or no-focus condition where instructions only give the general action goal and cue no specific focus. Research robustly supports an attentional focus effect in which an external focus is superior to an internal focus or no focus at all (Wulf, 2007a). In golf putting, an external focus instruction would be to focus on swinging the putter like a pendulum when you

putt; an internal focus would be to focus on swinging your arms like a pendulum when you putt. In weight training an external focus would be to focus on lifting the weight during a biceps curl, and an internal focus would be to focus on the contraction of your biceps during the curl. The no-focus instruction in golf putting would be to perform the golf putting task to the best of your ability, and in weight lifting the no-focus condition would be to perform the lift to the best of your ability.

Background/History

The flexible central resource theory by Kahneman (1973) provided an initial foundation that led to more specific studies of attention. This theory states that humans have one central capacity for attention; however, that capacity can change depending on the situation, the abilities of the individual, or the task being performed. Then, the person can distribute or allocate attentional resources to various activities simultaneously. This allocation is influenced by two main factors. The first factor is called enduring dispositions. Enduring dispositions are considered distractions in the environment that involuntarily direct your attention away from the task. Magill (2011) provides the following examples of enduring dispositions: fans at a basketball game yelling to distract a player during a free throw, hearing unexpected noises like a sneeze, or hearing your name from across a room at a party. The second factor is called momentary intentions. Momentary intentions pertain to when a person purposefully directs his or her attention to something, or is given instructions or feedback from a practitioner that directs attention to an aspect of the task or environment. The study of these momentary intentions is most influential to the current discussion on attentional focus research. These momentary intentions relate to an external and internal focus as described above. Thus once the

importance of this aspect of attention was realized, the next question was on how to most effectively manipulate it.

From Kahneman's initial ideas on attention, Singer (Singer, 1988; Singer et al., 1993) began to theorize and test possible ways to take advantage of a performer's focus of attention. The initial concern that Singer raised was that most athletic programs stressed the importance of learning sport specific physical skills with little emphasis on the cognitive learning or performance strategies behind the entire process (Singer, 1988). Thus Singer questioned how to instruct performers in the most effective way possible to promote learning and increase performance. He cited the incredible ability of professionals like Larry Bird, Wayne Gretsky, and Ivan Lendl to concentrate, focus, and rapidly adapt to different situations and wondered if such capabilities are trainable. He proposed the Five-Step Approach as a method of instruction, or metastrategy, to combine the aspects of cognition and physical performance (Singer, 1988). Since the goal of motor skill learning is to progress a person's skill level towards that of an expert, the Five-Step approach proposed a way to encourage beginners to perform a skill as if it was 'automatic' like experts seem to do (Singer et al., 1993). One major problem with the Five-Step approach, however, is that it was based mainly on anecdotal and indirect research evidence.

Singer et al. (1993) designed an overhand ball toss experiment to compare the common techniques of an awareness strategy (directing attention to the way the person threw the ball or specific cues of movement or the environment), a non-awareness strategy (to focus on only one situational cue and to ignore one's own movement), and the Five-Step Approach (follow the steps of readying, imaging, focusing, executing, and

evaluating; the focusing aspect was the same as in the non-awareness strategy). These strategies were compared against a control group that received only information about the task. Singer and colleagues (1993) found each strategy improved performance and learning compared to the control condition, yet the non-awareness strategy and the Five-Step Approach showed superior performance versus the awareness strategy. The non-awareness part of the Five- Step Approach (focusing) can enhance performance, which empirically supported that the cognitive aspect does have an important effect on movement execution and learning. This study began to question the current trends in coaching and instructing; however, these results were only most applicable to self-paced tasks such as the one used in the study conducted by Singer (1993). While research in this area was still slim, the door for more specific attentional focus research had been opened.

External Versus Internal Focus

Based on Singer's initial observations, Wulf and colleagues began to explore this attentional focus issue further. They predicted instructions that direct learners conscious attention to the effect of their movement on the environment would be more beneficial than instructions that direct attention to the movements themselves. A two experiment study by Wulf, Höß, and Prinz (1998) was the first study to specifically test the differences between an internal and an external focus of attention. In experiment 1, they hypothesized that learning would be more beneficial on a ski simulator when participants focused externally (focus on the force exerted onto the wheels of the platform) rather than internally (focus on the force exerted by the feet). They compared these instructions to a control group that received no additional focus instructions. Interestingly (and similar to the experiments by Singer), this hypothesis was also based on anecdotal evidence

provided by a windsurfer who stated that focusing on the board (external) was more effective when performing a power-jibe than when focusing on the feet (internal). Results of experiment 1 showed those who focused externally rather than internally demonstrated greater performance during practice and retention, which implies greater learning. The internal focus group was significantly worse than the control group during practice but showed no differences during retention. Thus from one experiment, Wulf et al. (1998) provided evidence that focusing on the effects of the movement benefits performance, whereas focusing on the movement itself (the body) is no better, and possibly even worse, than receiving no additional instructions at all.

Wulf et al. (1998, Experiment 2) followed up on these results in a different task – balancing on a stabilometer. The stabilometer consisted of a horizontal platform that can deviate 15 degrees to either side with the goal being to remain in balance. The external instructions were to focus on keeping two markers on the platform at the tip of the feet horizontal. The internal instructions were to focus on keeping the feet horizontal. Thus, in this study the two attentional focus instructions were very similar and allowed the researchers to examine if even minor differences in the instructions would affect performance. Once again those who focused externally on the movement effect showed superior performance in retention, and thus greater learning, than those who focused on their body. There were no significant differences between the groups during practice. While these results could have significant influence to performers and instructors in a variety of sport contexts, the empirical evidence was limited to a controlled laboratory environment.

Recognizing the possible benefits of different focus instructions in sport settings, Wulf, Lauterbach, and Toole (1999) sought to apply the previous findings to novice golfers learning the pitch shot. Twenty-two participants with no prior experience in golf were randomly and equally divided into an external focus and an internal focus group. All participants received the same instructions regarding grip, stance, and posture with the only difference being the instruction on how to swing the club. The external group was instructed to focus on swinging the club in a pendulum like motion, and the internal group was instructed to focus on swinging the arms. Even though both groups became more accurate during practice, the external group was significantly more accurate than the internal group. This significant difference remained one day later during retention where no attentional instructions were given. One possible problem with the practice scores was the significant performance difference present during the first block of ten trials. Those who focused externally combined to have an accuracy score around thirteen, but the internal group combined to have a score around five. This could possibly be due to the fact that even though randomly assigned, the external group had a naturally higher skill level than the internal group. However, Maddox, Wulf, and Wright (1999) demonstrated the same results in performance and retention during the learning of the backhand stroke in tennis. These studies combined with Wulf et al. (1998) showed the relatively permanent learning benefit, and even a possible practice benefit, when instructions induce an external focus as opposed to an internal focus. Furthermore, Wulf et al. (1999) and Maddox et al. (1999) revealed that an external focus of attention is more advantageous than an internal focus in a real world setting. The results of these initial studies also appear to be in line with the findings of Singer et al. (1993) except for small differences

in the purpose of the attentional instructions. Wulf, McNevin, Fuchs, Ritter, and Toole (2000) noticed that the reason for Singer's focusing strategy in the Five Step approach is to prevent performers from focusing on their movements, but in Wulf et al. (1998) the instructions were given to direct the performer's attention specifically to either the effect of the movement or the movement itself. Thus the question arose as to whether it mattered if participants focused externally or just didn't focus internally. The control or no-focus condition in Wulf et al. (1998, Experiment 1) may provide some initial insight into this question. Since no specific focus instruction was given, participants in the control condition were free to focus on whatever they chose or perhaps not focus on anything at all. The control group's performance was not significantly different than the external group during practice, but was significantly worse (and equal to the internal group) than the external group during retention. It is not known what type of focus the control group utilized during the task, but whatever focus they used was not as beneficial as those participants explicitly directed to focus externally. It is possible that the important factor for focus of attention instructions is the explicit direction to focus externally on the effects of the movement (similar to Kahneman's momentary intentions) and not just preventing the learner from focusing internally.

To explore this issue, Wulf et al. (2000, Experiment 1) compared two types of an external focus in novices learning a forehand shot in tennis. One set of external focus instructions related to the antecedent of the action (focus on the trajectory of the ball coming towards the racket), while the other set of instructions related to the movement effect (focus on the anticipated trajectory of the ball hit). If it only mattered that participants not focus internally, then the groups should show similar learning scores;

however, if specifically focusing on the movement effect is critical, then the movement group should show superior learning scores (Wulf et al., 2000). In practice, both groups improved across trial blocks and there was no difference between groups. In retention, the movement effect group had significantly higher scores than the movement antecedent group. Interestingly, it took a day for the differences in the focus conditions to appear. A limitation of this study though is that neither a control group nor an internal focus group was included as a comparison. This study indicated that it is more advantageous for performers to specifically focus on the movement effect and not on the antecedent of the movement, with the latter instruction representing Singer's (1988) recommendation to just not focus internally. Through these studies (Maddox et al., 1999; Wulf et al., 1998; Wulf et al., 1999; Wulf et al., 2000), it was apparent that an external focus rather than an internal focus produced increased performance and learning in balance tasks, golf shots, and tennis strokes, yet no firm explanation for this effect existed up to this point in the experimentation lineage (Wulf, McNevin, & Shea, 2001).

Development of the Constrained Action Hypothesis

Many of the initial studies proposed that the different attentional focus instructions altered the way the nervous system controls the movement. Specifically, an internal focus encourages the performer to consciously notice and intervene in the control process, but an external focus allows for more automatic, subconscious control mechanisms (Wulf et al., 1998). This is in line with Singer's (Singer, 1988; Singer et al., 1993) observations of expert performance. Singer states it is obvious that experts in any sport know how to perform their skill at the top level, yet when asked what they were thinking about they simply state they weren't thinking about anything. This suggests the

experts made and planned each movement intuitively without any direct conscious awareness (Singer, 1988). Wulf et al. (2000) provided some anecdotal evidence of this phenomenon. They stated that humans are naturally more concerned with the effects their movements have on the environment. No new information is gathered by focusing on the body (i.e. internal focus) because humans already have a general idea on how the body moves. With no supporting scientific evidence, this assumption could progress no further. However, if it is true that focusing externally encourages more automatic control, it is possible that these movements would be controlled by quicker and more reflexive actions (Wulf, Shea, & Park, 2001). When performers focus internally, they may actively intervene in the control process which would disrupt these reflexive actions (Wulf, Shea et al., 2001).

Wulf, Shea et al. (2001) were able to test this prediction by measuring the frequency of responses while participants balanced on a stabilometer. The previous balance study by Wulf et al. (1998) provided evidence that focusing externally resulted in enhanced performance compared to focusing internally, but no analysis was conducted to explain why an external focus enhanced performance. In Wulf, Shea et al. (2001, Experiment 1) 17 inexperienced undergraduate students were instructed to balance on a stabilometer platform through eight 90-second trials. The stabilometer platform had a maximum possible deviation of 15 degrees to either side and had one orange marker placed 25 cm to either side of the sagittal midline. All participants placed the tip of each foot at an orange marker, and performed the trials under both the internal condition (focus on keeping the feet at the same height) and the external condition (focus on keeping the markers at the same height). Results from experiment 1 showed when participants

focused internally they had higher root mean square error (RMSE) than when focusing externally. This supports the results of Wulf et al. (1998), which suggested that balance performance is depressed when participants focus internally.

Wulf, Shea et al. (2001) then went one step further in experiment 2 to explain why the advantage exists. If focusing internally causes participants to actively intervene in automatic motor processes, then neural control differences between an internal and external focus should be present. The researchers analyzed the frequency characteristics of the balance performance and then computed mean power frequency based on the balance platform's movements. Mean power frequency analysis is able to detect subtle movement (and thus control) differences, and it relates to how quickly the motor control system is able to respond to changes. Previous research (Newell & Slifkin, 1998) has related higher frequency adjustments with more automatic movements and lower frequency adjustments with conscious or compromised movements. Therefore, Wulf, Shea et al. (2001) hypothesized that in the internal condition, response frequencies would be slower than those found in the external condition. Participants in experiment 2 who focused externally had significantly smaller RMSE values and higher response frequencies (mean power frequency) than those who focused internally. These results support the assumption that by focusing internally (on the body's movements) performers disrupt conscious and automatic control processes, thereby degrading balance performance. However, performance and learning are enhanced by an external focus, because it promotes automaticity and more fluid movements.

These results were supported by a study on attentional focus and postural sway by McNevin and Wulf (2002) and another study testing balance on a stabilometer by

McNevin, Shea, and Wulf (2003). Both studies used mean power frequency analysis to measure frequency of responding in the different focus conditions. Once again, the neuromuscular control system expressed more rapid movement adjustments when participants focused externally rather than internally. These results added further support to the explanation that an external focus allows for the nervous system to more naturally organize and produce more rapid adjustments in response to the environment, whereas an internal focus creates active intervention in the body's neural control which slows response time. This is especially important in dynamic balance which must be maintained by rapid and small movement adjustments to effectively respond to an unstable and changing surface (McNevin et al., 2003). McNevin et al. (2003) further stated that the active intervention in this automatic control process resulting from an internal focus would degrade motor control output (also see McNevin & Wulf, 2002). If an external focus truly does reduce conscious control and increase automaticity, then participants focusing externally should have more of their attentional capacity available to perform another task (Kahneman, 1973, Wulf, Shea et al., 2001). Conversely, an internal focus should utilize a greater amount of the attentional capacity, reducing the ability to simultaneously perform other tasks.

This is precisely what Wulf, McNevin et al. (2001) discovered in their attentional focus study which included a secondary probe reaction time task for participants attempting to balance on a stabilometer. The primary task, similar to Wulf et al. (1998), was to maintain balance. 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. The secondary task involved pressing a button held in the right hand when an

auditory stimulus was randomly presented. They predicted that those who focused externally would have better balance scores and faster reaction times than the internal group. No significant differences existed between the groups during practice, but on retention the external group had lower error balance scores and faster probe reaction times. This suggests that focusing externally encourages more automatic movements and that focusing internally “slows-down” neurological processes by utilizing a greater amount of attentional requirements. It appears that by focusing externally even novices can coordinate a movement automatically similar to experts (Wulf, Shea et al., 2001). The results of this study, combined with those from McNevin and Wulf (2002), McNevin et al. (2003), and Wulf, Shea et al. (2001), provided strong evidence for an external focus promoting more automatic movements and an internal focus depressing or constraining those automatic processes. From these results a solid theoretical foundation was created, and the constrained action hypothesis was proposed to explain these performance and learning differences.

The constrained action hypothesis provided a plausible explanation for the results from the previous studies that revealed the performance and learning advantages of an external focus over an internal focus. The constrained action hypothesis (Wulf, Shea et al., 2001) states when a performer focuses internally, conscious control processes are incorporated into the motor control system thereby constraining the more effective automatic control processes that are predicted in higher skilled individuals (Singer et al., 1993). Under an external focus, more automatic or unconscious control processes govern the movement leading to more effective performance and learning. While this hypothesis is the current paradigm for research, it is a very simple explanation that has produced

some very interesting results. Now that a hypothesis was in place, research could explore the limits of the predictions.

The Importance of the Constrained Action Hypothesis

Singer (1988) noted a deficiency on the part of instructors and coaches in understanding different learning strategies to teach their athletes how to perform. In other words, research needed to be completed that would inform coaches how to understand and incorporate the motor skill learning process into their coaching. Singer (1988) stated that “appropriate learning strategies enable talented athletes in any sport to acquire the skills necessary for accomplishment (p. 50).” The goal of these learning strategies is to facilitate skill acquisition of novices and quickly and efficiently increase their performance to that of an expert. The current model of Singer’s time emphasized learning technique and increasing performance with little thought on the best way to enhance these aspects cognitively. As mentioned previously, Singer proposed and tested his five step learning strategy to address this issue (Singer et al., 1993), but debate still continued. One area of continued debate was in the type of focus instructions to give to athletes. Due to the emphasis on outcome and technique goals, it seemed correct to focus the attention of athletes to their body and make them aware of their mechanics (Wulf et al., 2000). Research showed that ten years later this was still the prevalent assumption among coaches at the highest level (Porter, Wu, & Partridge, 2010), but this is in direct opposition to the recommendations of the extensive results of only a few years of attentional focus research (Wulf & Prinz, 2001). What the constrained action hypothesis provided was a testable hypothesis for attentional focus research, and after more than ten years it still remains the most predominant explanation for the attentional focus effect,

with evidence found in a variety of sport and performance contexts (Wulf, 2007a). Now coaches have valid support for giving instructions and feedback that induce an external focus, and as Singer (1988) mentioned, athletes can use this knowledge to learn a skill in one context and apply it to another context. Now that a proper history has been described, it is important to explore all the areas that attentional focus affects.

Current Understanding of the Attentional Focus Effect

There is only a small amount of research describing how most coaches tend to give instructions to athletes (Singer et al., 1993), yet there is some support that coaches use a majority of internal focus instructions (Porter, Wu et al., 2010; Wulf et al., 2000). If an external focus does enhance performance and learning, then a way to apply these findings is to know what factors affect these results. In better documenting the positive effects of an external focus, practitioners will be more inclined and better prepared to implement this into their teaching style thereby increasing the performance of their athletes or clients. As will be demonstrated, the benefits of an external focus permeate every motor skill and person characteristic that has been tested.

The Attentional Focus Effect and Skill Contexts

Object manipulation.

Balance.

The vast majority of research exploring the attentional focus effect has utilized tasks that require object manipulation (Porter, Ostrowski, Nolan, & Wu et al. 2010). This includes the earliest studies involving balance which were previously discussed. For this review, the studies requiring balance (McNevin et al. 2003; Wulf et al. 1998; Wulf, McNevin et al. 2001; Wulf, Shea et al. 2001) will be regarded as object manipulation

because the task does require the manipulation of an object (the stabilometer platform). In these previous balance studies the main task goal was to keep the platform in a horizontal position. Recently, a study by Wulf, Landers, Lewthwaite, and Töllner (2009) explored the effects of attentional focus in individuals with Parkinson disease. The task required the participants to stand while maintaining balance on a 33.02 cm semi inflated rubber disk. In this study 14 participants were instructed, in a counterbalanced order, to focus either externally (minimize movements of the disk), internally (minimize movements of the feet), or were given no focus (stand still). Results showed that postural sway, calculated from center of pressure data, was reduced when focusing externally compared to focusing internally or having no focus. The internal and no-focus conditions were not significantly different. This study extended the vast research supporting the benefits of an external focus over an internal or no focus, especially during a balance task. Most importantly, this study showed participants with a chronic motor impairment can benefit from instructions that direct their attention externally.

Golf.

Golf is another skill that has received a large amount of attention in the focus literature. Two studies that helped lay the foundation of this topic have also been discussed previously (Wulf, et al. 1999; Wulf et al. 2000), but other studies have been conducted further exploring this effect. Perkins-Ceccato, Passmore, and Lee (2003) conducted a golf study comparing the effects of an external or an internal focus of attention in a low skill and a high skill group. Participants were instructed to hit pitch shots from varying distances (10, 15, 20, and 25 meters) to an orange pylon. Focus instructions were counterbalanced across participants in both skill groups. The external

instructions were to “concentrate on hitting the ball as close to the target pylon as possible” and the internal instructions were to “concentrate on the form of the golf swing and to adjust the force of the swing depending on the distance of the shot.” Results showed that an external focus was more beneficial than an internal focus only in the high skill group, and the opposite was seen in the low skill group: performance was improved under an internal focus rather than an external focus. These results are in contrast to the previous findings of Wulf et al. (1999) which analyzed golf pitch shot performance and found that novice performance was significantly better when focusing externally and not internally. The contradiction between the Perkins-Ceccato et al. (2003) and Wulf et al. (1999) studies will be discussed in more detail later. Furthermore in Wulf et al. (1999), this advantage was maintained in retention trials implying an increased learning effect. No retention test was included in the Perkins-Ceccato et al. (2003) so no learning comparisons can be made.

Wulf et al. (2000, Experiment 2) also compared golf pitch shot performance in novices, but compared two different types of external focus: a technique-related effect (club movement) and a non-technique related effect (ball’s trajectory and target). This latter group is most similar to the external group in Perkins-Ceccato (2003). Wulf et al. (2000) found that the club-focused external group was more accurate than the target-focused external group in practice and in retention. Unique to this study is the proposal that “distance” of the external focus can have a significant impact on performance. In Wulf et al. (2000) “distance” relates to the location of where the participant is directed to focus. A near-focus instruction is focusing on the club head and a far-focus instruction is focusing on the ball trajectory and target. This study demonstrated that the “distance” of

an external focus is an important factor in the potency of the attentional focus effect and must be a consideration when interpreting attentional focus studies (McNevin et al., 2003; Wulf et al., 2000).

Wulf and Su (2007) demonstrated in a two experiment study that golf pitch shot accuracy (Experiment 1 and 2) and learning (Experiment 1) are superior under an external focus than an internal focus. Experiment 1 consisted of thirty undergraduate students with no or little experience playing golf. Participants were divided into either an external focus (pendulum like motion of the club), internal focus (swinging motion of the arms), or no-focus group. They found that in practice no significant differences in accuracy were observed even though the external group demonstrated greater performance scores; however, in retention the external group did have significantly greater scores than either the internal or no-focus group. The internal and no-focus groups were not significantly different. In experiment 2, six expert golfers were tested in each of the three conditions (same as in experiment 1) in a counterbalanced order. Greater performance scores occurred when experts focused externally rather than internally or had no focus, with the internal and no-focus scores showing no significant difference.

Bell and Hardy (2009) also conducted a pitch shot golf study using thirty-three skilled golfers. The golfers were equally divided into three focus groups: internal (focus on the motion of the arms during the swing and specifically maintain the hinge in the wrists through impact), proximal external (focus on the position of the club face through the swing, in particular, keeping the club face square through impact), and distal external (focus explicitly on the flight of the ball after it had left the club face and in particular the direction in which they intended to set the ball). They found that the golfers who focused

distally external had significantly greater accuracy scores than the golfers who focused proximally external and internally. The proximal external focus group also demonstrated significantly greater accuracy than the internal group. The specific differences between the external groups appear to conflict with previous data from Wulf et al. (2000), which showed that the proximal external focus produced greater golf pitch scores than the distal external focus. Bell and Hardy (2009) stated that this distance discrepancy may be explained by the different golfer skill levels, because they used experts whereas Wulf et al. (2000) used novices. Regardless, it is very clear from the studies reviewed above that performance and learning are significantly affected by what one focuses on when performing a pitch shot in golf. This data supports that instructions in golf should direct a performer's attention externally rather than internally or neutrally. Also, these studies provide evidence that the advantages of an external focus (distance) may depend on the performer's skill level.

Basketball.

Two studies have examined the attentional focus effect in shooting a free throw in basketball. The first study conducted by Al-Abood, Bennett, Hernandez, Ashford, and Davids (2002) involved participants instructed to focus on different cues when viewing a video of an expert model. The movement dynamics group (similar to an internal focus) was instructed to focus on the visual model's movement form, while the movement effect group (similar to an external focus) was instructed to focus on how the model scored a basket. The researchers compared free throw scores from before viewing the model and after viewing the model. Results showed that the movement effect group demonstrated a

significant improvement in performance from the pre to post test, while the movement dynamics group did not show any improvement.

This same outcome was demonstrated again in a study by Zachry, Wulf, Mercer, and Bezodis (2005). Fourteen university students, relatively experienced in basketball, participated in a within-participant design and performed 2 sets of 10 trials under the external and internal focus conditions. The external instructions were to concentrate on the center of the rear of the basketball hoop, and the internal instructions were to concentrate on the snapping motion of the wrist during the follow-through. An interesting addition to this study was that electromyography (EMG) data were recorded on the biceps brachii, triceps brachii, deltoid, and flexor carpi radialis of the shooting arm. Accuracy was also scored on a continuum between 0 to 5 with 0 at one end equaling a miss and a 5 at the other end equaling a made basket. Results showed that free throw accuracy was enhanced under external focus conditions compared to the internal conditions. Also, EMG activity was reduced in the biceps brachii and triceps brachii when participants focused externally. This suggests reduced 'noise' and more efficient neuromuscular control under the external focus condition (Zachry et al., 2005). Once again, the empirical data support that focusing externally is more advantageous than focusing internally during a basketball free throw.

Weight lifting.

A few studies have also explored the attentional focus effect during weight lifting activities. These studies are important because they were the first to directly explore the focus effect in tasks requiring force production. The first study in this context was by Vance, Wulf, Töllner, McNevin, and Mercer (2004) using a biceps curl task. In

experiment 1 of this study, 11 male participants lifted a bar weighted to 50% of their estimated maximal force as calculated on an isokinetic dynamometer. This was a within-participant design with a counterbalanced trial order between internal and external conditions. The internal instructions were to concentrate on the biceps muscles, and the external instructions were to concentrate on the curl bar. Angular velocity, EMG signal normalized to peak EMG magnitude during a maximal-effort isometric contraction, and mean power frequency scores based on fast Fourier transform on the raw EMG data were recorded and compared. In the external condition compared to the internal condition, the weight was lifted faster and EMG activity was reduced. Also, mean power frequency data showed that movements were more automatic when participants focused externally. Faster lifting velocity is in accord with the constrained action hypothesis where a more fluid motion prompted by an external focus would create smoother and more efficient movements which could increase lifting velocity (Vance et al., 2004). Also, the authors stated lower EMG activity supports less neuromuscular activity in the external versus internal condition to lift the same amount of weight. Experiment 2 furthered these results by controlling movement velocity with a metronome in the two focus conditions. The results of experiment 2 also demonstrated that movements were more economical and efficient in the external focus condition, meaning that only the minimally required neuromuscular input was utilized to perform the action.

The study by Vance et al. (2004) was replicated and extended by Marchant, Greig, and Scott (2009) to applying max force on an isokinetic dynamometer. By using the isokinetic dynamometer, lifting velocity could be controlled across participants and across focus conditions. EMG activity was recorded for the biceps brachii, as well as peak

net joint torque applied to the dynamometer. Marchant et al. (2009) found that EMG data were lower for the external focus trials compared to the internal focus trials, and that peak torque was higher under the external rather than the internal conditions. In other words, under an external focus, more muscular force was produced with less neuromuscular input. This is explained by more efficient muscular recruitment and coordination as predicted by the constrained action hypothesis (Vance et al., 2004). Under an internal focus, more erroneous neural input or ‘noise’ was present in the neuromuscular system which limited the production of peak force (Marchant et al., 2009).

Marchant, Grieg, Bullough, and Hitchen (in press) applied these results to three endurance type tasks. They stated that more efficient movement patterns and lower neural activity should prolong endurance in certain tasks. If motor units are recruited more economically then there should be more of a ‘reserve’ to continue the activity as fatigue arises. Three exercises were used to measure endurance: a modified version of the YMCA bench press test performed on a Smith machine, free weight bench press at 75% of the participant’s 1 repetition maximum (1RM), and free weight squat at 75% of the participant’s 1RM. The exercises also represented increasing complexity and difficulty. The YMCA bench press was the least complex and the free weight squat was the most complex. In each exercise, the participants performed under internal, external, and no-focus conditions but in a counterbalanced order. The internal instructions related to exerting force with either the arms (bench press tests) or the legs (squat test), and the external instructions related to exerting force against the barbell. In the YMCA bench press exercise, the external focus resulted in a significantly greater number of repetitions to failure than the internal focus. The no-focus or control condition was not significantly

different from either the external or internal scores. For the 75% 1RM bench press test, the external focus produced a significantly greater amount of repetitions to failure when compared to the internal and control conditions. The latter two conditions were not significantly different. The 75% squat test showed similar results with the external condition resulting in a greater amount of repetitions to failure when compared to the internal and control conditions. The internal and control conditions were not significantly different. Marchant et al. (in press) demonstrated that different attentional foci affect performance in an endurance test.

Marchant et al. (in press) also highlighted the fact that as task complexity increased, so too did the effect sizes which is in accord with previous research in balance tasks by Wulf, Töllner, and Shea (2007). These studies demonstrated that as task complexity increases so too does the size of the attentional focus effect. In tasks that are relatively easier and well learned, it is already more natural for automatic control processes to be used by the participant regardless of the focus instructions. As the task complexity increases, as in Marchant et al. (in press), the degrees of freedom increase thereby increasing the potential for error (Marchant et al., in press; Wulf, Töllner et al., 2007). Under the external focus, these variables are more automatically controlled increasing the efficiency of the movement and number of repetitions. Under the internal focus and control conditions, participants more actively intervened in the movement, consequently reducing efficiency. This reduced efficiency resulted in more erroneous neuromuscular control and decreased repetitions to failure.

Additional examples.

The effect has also been shown in a variety of other motor skills involving object manipulation. For example, Maddox et al. (1999) demonstrated the effect in learning a back hand stroke in tennis. In this study, beginning tennis players were instructed to either focus internally (the backswing and contact point) or externally (the target area and arc of the ball). These instructions actually both refer to an external focus (similar to Wulf et al., 2000), and thus a distance effect, but as Wulf and Prinz (2001) mention, the important part of the “internal” group is the focus on movement technique. The external group showed superior performance in a retention and transfer test. Wulf et al. (2000, Experiment 1) also explored the effect in tennis; however, in this experiment the authors only compared an antecedent group (focus on the ball coming from the ball machine) and an effect group (focus on the anticipated trajectory of the hit ball). The effect group showed superior performance than the antecedent group. Even though both of these studies are not necessarily a direct comparison between an external and internal focus, it is important for coaches and athletes to realize that a subtle difference in word choice can have a significant impact on performance and learning.

Wulf, McConnel, Gärtner, and Schwarz (2002) conducted a two experiment study exploring the attentional focus effect in volleyball and soccer. In this study, the external and internal focus manipulation was given as feedback and not as instructions, as had been done in previous attentional focus studies. In experiment 1, the authors examined novice and advance participants performing and learning the volleyball serve. Within each skill level, participants were divided into an internal and an external feedback group. The results showed that in both skill levels during practice, the external feedback group

was more accurate than the internal feedback group. The external group also had higher movement form scores as rated by experts. The performance advantage continued in retention where the external feedback group displayed higher learning scores than the internal group. Experiment 2 explored this feedback issue in 52 advanced soccer players. The task goal was to kick a soccer ball and hit a target with the participants divided into an internal feedback group or an external feedback group. Participants in each of these divisions were presented with the feedback after every trial (100%) or every third trial (33%). In practice, the external group was more accurate than the internal group. Internal 33% was more accurate than internal 100%, and both external frequencies were not significantly different. The trend continued in retention with the external group's scores more accurate than the internal group, internal 33% more accurate than internal 100%, and both external groups not significantly different.

Summary.

The studies reported above demonstrate that it is important for coaches, instructors, and athletes to understand the significant effect that instructions and feedback can have on performance and learning. Also important to realize is that this effect is not only seen in more simple and basic skills such as balance but in more complex skills requiring the control of multiple muscles and several degrees of freedom (Maddox et al., 1999). This has been specifically shown in some of the more popular sports of golf, basketball, soccer, and volleyball (Wulf, 2007a). The advantages of an external focus over an internal focus have been demonstrated in every sport context tested, thus it seems logical for instructions and feedback in any sport to direct the performer's attention to the environment or effects of the movement and not the body itself.

Whole body movements without object manipulation.

With such a large body of evidence supporting the advantage of an external focus in skills requiring object manipulation, accuracy, or balancing, researchers began questioning if this effect would also be observed in skills requiring maximal force production (Wulf, Zachry, Granados, & Dufek, 2007). Based on the evidence of performance measures seen from these studies and the constrained action hypothesis (Wulf, 2007a; Wulf & Prinz, 2001), an external focus allows for more efficient control of the neuromuscular system and greater coordination between various parts of the body (McNevin & Wulf, 2002; Vance et al., 2004; Zachry et al., 2005). Thus skills such as jumping and agility should also benefit because these skills require the correct timing and production of forces to optimally accomplish the task (Wulf, Zachry et al., 2007). If the nervous system erroneously fires muscles, then energy is likely wasted and motor control will be depressed, resulting in a less than optimal movement (Wulf, Zachry et al., 2007). To date only a few studies have been conducted on the effects of attentional focus on whole body movements without object manipulation.

Jumping.

Wulf, Zachry et al. (2007) first explored this issue in a two experiment study requiring participants to jump as high as possible using a Vertec instrument. In experiment 1, ten university students were instructed to jump as high as possible under control (no focus), internal (concentrate on the tips of the fingers reaching as high as you can), and external (concentrate on the rungs of the Vertec) focus conditions. When participants were in the external condition they jumped significantly higher than when they focused either internally or had no focus. The authors speculated that participants

produced greater vertical forces when focusing externally to reach a higher rung; however, Wulf, Zachry et al. (2007) stated that there is a possibility that the higher jump scores in the external condition were a result of body mechanics in the air and not force production. To explore this possibility Wulf, Zachry et al. (2007, Experiment 2) tested twelve university students, replicating the methods from experiment 1. Unique to this experiment, though, they used a force plate to measure vertical ground reaction forces and calculated center of mass changes. When participants focused externally, they reached a higher rung on the Vertec and their center of mass reached a greater maximum height compared to both the internal and control conditions. These results extend the findings from experiment 1, and further support the conclusion that an external focus of attention allows the body to produce greater forces compared to an internal focus. This advantage could be due to more efficient motor unit recruitment, muscular coordination, or both.

Based on the research from Wulf, Zachry et al. (2007), Porter, Ostrowski et al. (2010) investigated the application of the focus effect to a jump in the horizontal direction. In the Porter, Ostrowski et al. (2010) experiment, 120 university students with no formal jump training were randomly assigned to either the external focus group (focus on jumping as far past the start line as possible) or the internal focus group (focus on extending your knees as rapidly as possible). The results showed that the external focus group jumped significantly further than the internal focus group. These results not only expanded the generalizability of the benefits of an external focus in a variety of motor skills, but they also extended the findings of Wulf, Zachry et al. (2007) in tasks requiring maximum force production. Specifically, even though no performance production measures were recorded, it seems likely that the advantages of an external focus were a

result of greater force production due to more efficient muscle recruitment and coordination.

Agility.

Porter, Nolan, Ostrowski, and Wulf (2010) sought to extend these findings to an agility task requiring locomotion, changing directions, acceleration, and deceleration. The general instructions in this experiment were to run through the course as quickly as possible with maximum effort. This complex task requires efficient coordination of muscles to accelerate, decelerate, and change directions, as well as the ability to produce maximum forces across time (power). Specifically, the external focus instructions were to focus on running towards the cones and pushing off the ground as forcefully as possible when turning, and the internal focus instructions were to focus on moving your legs as rapidly as possible and planting your foot as firmly as possible when turning. Twenty students participated in the study and performed trials under each condition with the control (no-focus instruction) condition performed first and the internal and external conditions counterbalanced. Movement time was significantly lower (faster) when participants focused externally rather than internally or had no focus. The internal and no-focus conditions were not significantly different. These results extended the benefits of an external focus to a complex task requiring body transport across multiple seconds, coordinating forces, and changing directions. No performance production measures were recorded, but these results lend further support to the explanation that the benefits are a result of greater force production and more efficient muscular coordination.

Also interesting in the Porter, Nolan et al. (2010) study was the inclusion of a written manipulation check that analyzed what participants focused on when performing

the agility task, and if participants adopted the correct focus for that condition. Responses in each condition were grouped into three broad categories: external, internal, or other. Responses were then further sub categorized based on what the participant specifically focused on. In the broad control category, responses were subcategorized into either time (responses such as “going as fast as possible” or “performing faster than the previous run”), mixed (aspects of both an internal and an external focus such as “moving my feet quickly and staying close to the cones”), or blank if the participants left the response blank. The results of the manipulation check revealed that participants adopted the intended focus most of the time, and that when participants are not given any specific focus they tend to focus on a variety of cues that are not specifically internal or external in nature.

Summary.

These previous studies extend the generalizability of the benefits of an external focus to those skills that do not require object manipulation but rather the production of maximal forces to propel the body through space. These studies also provide interesting insights to the biomechanical processes that are occurring to bring about these performance differences (Porter, Nolan et al., 2010). In addition, the vertical jump, horizontal jump, and agility “L” test are common evaluative methods in a variety of sport contexts (Porter, Nolan et al., 2010; Porter, Ostrowski et al., 2010), thus the importance for test administrators to use consistent instructions is highlighted.

Performance and learning.

Previous research has shown that while both are important, performance variables and learning variables are very different and not highly correlated (Schmidt & Lee, 2005).

Even certain factors like feedback, practice variability, and contextual interference can produce drastically different results in both a performance (practice) and a learning (retention or transfer) context (Magill, 2011). Thus it is important for researchers and coaches to understand how focus of attention affects performance in both a practice and a learning environment where direct coaching is removed or reduced (Wulf & Prinz, 2001). The advantages of an external focus are consistently demonstrated in both immediate effects upon performance and long term effects in learning (Wulf, 2007a).

A major methodological context in which both immediate and long term effects have been observed is with the use of within and between-participant designs. Several studies have used a within-participant design to control for certain performer variables and to see relatively immediate performance effects of different attentional foci (McNevin & Wulf, 2002; Marchant et al., in press; Marchant et al., 2009; Porter, Nolan et al., 2010; Vance et al., 2004; Wulf & Su, 2007, Experiment 2; Wulf, Zachry et al., 2007; Zachry et al., 2005). In all of these studies the group that focused externally, rather than internally or had no focus, demonstrated significantly greater performance scores. While these findings are quite robust, Wulf and Su (2007) mention that these effects can only be interpreted as immediate and possibly temporary. Only a design that utilizes multiple groups with practice over time and either a retention or transfer test can determine the relative permanence of this effect. Regardless, these studies strongly support instructions that direct attention externally provide immediate benefits during motor skill execution.

Fortunately, several studies have utilized a between participant design with a retention test to explore the lasting effects of different attentional foci (Maddox et al., 1999; Wulf et al., 1998; Wulf, Shea et al., 2001; Wulf et al., 2002; Zentgraf & Munzert,

2009). These studies are important because learning differences between the internal and external focus conditions can be assessed since each variable is applied to only one group during a practice period, then after a period of no practice, the groups' performances are reassessed without any focus instructions. These studies demonstrate that focusing externally during practice promotes greater learning in retention than focusing internally.

Totsika and Wulf (2003) conducted an important study extending these findings to a variety of transfer tests. They state that the previous attention studies only used retention tests, but by implementing a transfer test, the application to more real world situations would be greatly enhanced. The question addressed here was whether or not the advantages of an external focus practiced in one context persist into related novel skills in different environments. This study (Totsika & Wulf, 2003) consisted of 22 university students divided equally into an internal focus group or an external focus group. In practice, all participants operated a Pedalo device for 20, seven meter trials. The external focus group had a significantly faster movement time during practice. All participants then performed in three different transfer environments without any focus instructions: riding forward with speed pressure (perform as fast as you can), riding backwards as fast as you can, and riding forward while counting backwards. The first condition demonstrated the effect in a situation with increased stress (time pressure). The second condition demonstrated the effect in a novel variation of the skill. The third condition measured the permanence of the effect between the external and internal focus conditions. The authors stated that there could be a possibility that even though no focus instructions were given in the previous attentional focus learning designs, participants could potentially still use their instructed focus from practice. If this were true, then the learning

advantages might only be a further representation of immediate performance effects. The secondary counting task would prevent the participants from utilizing their practiced attentional focus. In all three transfer tests, the external group continued to show faster movement times than the internal group, adding further support that an external focus enhanced learning compared to an internal focus.

External focus distance effect.

It is interesting to note that in some studies, the external focus group scores did not significantly differ from the internal during the practice trials (McNevin et al., 2003; Wulf & Su, 2007, Experiment 1; Wulf, Shea et al., 2001; Wulf, McNevin et al., 2001). McNevin et al. (2003) noticed that across the previous attentional focus studies, the distance between the action and its remote effect differed and this might affect the appearance of performance differences in the external and internal focus effects. For example, in Wulf et al. (1998, Experiment 2) the internal group was told to focus on keeping the feet horizontal, and the external group was told to keep the markers horizontal. The distance of these foci are considered very close because the tip of each foot touched one of the markers. In Wulf et al. (1998, Experiment 2), no group differences were seen in practice, but one day later in retention, those who focused externally had significantly smaller error scores. Conversely, in Wulf et al. (1999), the distance between the instructions (the swinging motion of the arms versus the weight and motion of the clubhead) is greater and performance differences were seen immediately during practice. Based on these two studies, McNevin et al. (2003) hypothesized that a greater distance between the body and the effect of the movement would increase the magnitude and time of appearance of the attentional focus effect.

McNevin et al. (2003) conducted a stabilometer balance task where participants were divided into four focus groups. Three external focus groups were instructed to focus on keeping the markers horizontal but each differed in marker location. A near group had markers directly in front of the toes, a far inside and far outside group had markers approximately equal distance away from the toes (23 cm and 26 cm, respectively). The internal focus group was instructed to focus on keeping the feet horizontal. No significant differences between the groups were revealed during practice, but the far inside group did maintain higher scores across the two practice days. In the retention test, the two far external groups, which were not significantly different from each other, were significantly better than either the near external or internal group. This study showed that increasing the distance of the external focus can enhance the learning effect. The authors explained these results using the constrained action hypothesis and stated that the internal and near focuses constrained the motor system which was revealed by depressed mean power frequency scores. As the object of the focus (what the performer is instructed to focus on) nears the body, or actually is the body, the performer's motor control system attempts to more actively intervene in the movement reducing automaticity and performance.

Wulf et al. (2000, Experiment 2) compared two different external focus distances. Both external foci related to the effect of the movement, which has been shown to be more effective than an internal or a non-effect related focus (Wulf et al., 2000, Experiment 1). Participants were instructed to focus on either the club head (near) or ball's trajectory and target (far). In practice, the club head group showed superior scores compared to the target/trajectory group, and these differences were also observed one day later during retention. Thus it appears that there is some limit to how far the external

focus can be directed and still see a benefit. The near group's instructions may have been more beneficial because they were more closely related to the correct swing technique (Wulf et al., 2000). Participants instructed to focus on the ball's trajectory and target could have produced the same outcome with a variety of possibly incorrect swing techniques, which would harm performance and learning (Wulf et al., 2000).

Interestingly, in a group of skilled golfers, Bell and Hardy (2009) found that the far external group (focus on the flight of the ball) had greater accuracy scores than the near external group (focus on the club face). It is possible that the beginners in Wulf et al. (2000) needed the more technique-related instructions to perform well, whereas the more advanced golfers, who would already have the swing automated, benefited from a more distal focus (Bell & Hardy, 2009). A more-technique related external focus likely could have promoted conscious intervention into the swing mechanics in the more skilled golfers which depressed performance (see Wulf & Su, 2007 as well as the skill related discussion to follow).

To date, few other studies have investigated the distance effect of different attentional focus instructions. These results lead to an interesting question that has not been fully explored: how far is too far or how abstract is too abstract for external focus instructions? By definition an external focus is one that directs the performer's attention to the effects of his or her movements on the environment (Wulf, 2007a), but even within that definition there is great variability. Wulf et al. (2000) mentioned possibly using metaphors which could help direct attention externally. Also, how should researchers classify time-related focus responses? The manipulation check by Porter, Nolan et al. (2010) revealed that some participants focused on time related issues such as "I focused

on going as fast as possible” or “performing faster than the previous run.” These responses do not necessarily relate to the body and its movements, but they do not necessarily relate to the effect of the movement on the environment. Clearly more research needs to be conducted furthering the knowledge and benefits of various types of external focus.

The Attentional Focus Effect and Performer Characteristics

Now that a variety of contexts of the attentional focus effect have been demonstrated, it is important to explore various performer characteristics that can influence the attentional focus effect. The research in this regard is less robust compared to the research in environmental and motor skill contexts; however, enough research has been conducted that allows for valid conclusions to be made describing the attentional focus effect in various performer skill levels and performers with motor impairments.

Skill level.

A limited amount of research has been conducted specifically exploring the effects that skill level has upon the attentional focus effect. Parts of this issue were mentioned in the previous sections on golf and the distance effect, but here it will be discussed more fully. The first empirical study exploring this relationship was a golf related study conducted by Perkins-Ceccato et al. (2003). They hypothesized that an internal focus of attention would be detrimental in experts because the internal focus would “revert the athlete to a mode of control associated with less skill [decreased automaticity]” (p. 594). This is effectively the same explanation predicted by the constrained action hypothesis which states that an internal focus of attention decreases motor control automaticity in any motor skill regardless of skill level; however, Perkins-

Ceccato et al. (2003) predicted novices practicing with an internal focus would be as good if not better than novices practicing with an external focus. The researchers found that the low skill group had superior accuracy scores when given an internal focus rather than an external focus. The experts showed greater accuracy in the external condition rather than in the internal condition. In fact the two skill conditions were not significantly different when both were focusing internally. From these results it appears that the attentional focus effect is significantly affected by the performers skill level; however, the authors disregard the results of Maddox et al. (1999) and Wulf et al. (1999) which both showed, in tennis and golf respectively, that an external focus produced better scores in novices than an internal focus.

A majority of studies support that novices benefit more from an external focus than an internal focus. In Wulf et al. (1999), twenty two university students with no prior golf experience practiced hitting a golf chip shot. The group instructed to focus externally was significantly more accurate than those instructed to focus internally during practice and retention. In Maddox et al. (1999), low skill tennis players who focused externally, rather than internally, demonstrated superior performance when learning a backhand tennis stroke. Wulf and Su (2007, Experiment 1) tested 30 novice undergraduate students in practicing and learning a golf pitch shot similar to Wulf et al. (1999). The accuracy scores of the external and internal focus groups did not significantly differ from each other during practice even though the external group did demonstrate, on average, greater scores across the practice interval. In retention, the external group demonstrated significantly greater accuracy scores than the internal group. The practice scores replicate the findings found in other studies (McNevin et al., 2003; Wulf, Shea et al., 2001; Wulf,

McNevin et al., 2001) where differences were not observed during practice but appeared during testing.

As was discussed in the distance effect section, the similarity of scores found in Wulf and Su (2007, Experiment 1) during practice could be due to the fact that the external instructions (focus on the club swing) were relatively close in distance to the internal instruction (focus on the arm swing). Also, in the Perkins-Ceccato et al. (2003) study, the internal instructions (concentrate on the form of the golf swing) were more external-technique related than internal, meaning that a distance effect between the instructions was compared similar to Wulf et al. (2000). Based from Wulf et al. (2000), it would be no surprise that the technique-based instruction provided a greater performance benefit in novices than more distant-effect related instructions. These results suggest novices benefit more from an external focus of attention than an internal focus of attention.

In experts, who already perform the skill automatically, it could be assumed that they should actually not benefit from any type of focus instructions. Singer et al. (1993) mentioned that experts don't think about anything when they are performing at their best, thus it would seem that experts should most benefit from the no-focus condition. Wulf and Su (2007, Experiment 2) was the first study to compare external, internal, and no-focus conditions in an expert population. They found that accuracy was greatest when experts focused externally, with the internal and no-focus conditions not significantly different. The authors state that the optimal external focus might vary with skill level based on a hierarchy. As the skill becomes more learned and automatic, it is more advantageous to focus on progressively higher order effects. Based on the previous

studies, focusing on the golf club would be a lower order effect, and focusing on the ball trajectory or target would be a higher order effect. This explanation is supported by the fact that novices performed better with lower order effects (Wulf et al., 2000) and experts performed better with higher order effects (Perkins-Ceccato et al., 2003).

Wulf and Su (2007) explained that the advantage of an external focus is that it promotes more efficient biomechanical processes to effectively achieve the task goal. It still is not yet fully understood why in experts, the no-focus condition would be similar to the internal condition. One possible explanation was found in the manipulation check utilized by Porter, Nolan et al. (2010). They found when performers were not given any specific focus instructions, the performers frequently switched their focus of attention trial to trial or didn't focus on anything. Even though these performers were considered untrained (not novices however), their erratic search behavior coincides with the initial stages of the Fitts and Posner (1967) and Gentile (1972, 2000) stages of learning models. It is possible experts in the no-focus condition might continuously be switching their focus, thereby depressing their performance. Further studies should investigate this prediction in experts.

This trend does not appear to apply to experts in the highest caliber of skill level. Wulf (2008) analyzed balance performance in 12 world class acrobats from Cirque du Soleil. Participants were required to balance on an inflated rubber disk. The control (no focus) group was instructed to stand still. The external group was instructed to focus on minimizing movements of the disk, and the internal group was instructed to focus on minimizing movements of their feet. Wulf (2008) argued that in this population who have truly mastered and automated their skill, no benefit would be seen with an external focus.

Postural sway did not significantly differ between the three focus conditions, but frequency of responding (mean power frequency) was greater when the performers were provided no focus-directing instructions and were simply told to stand still. The external and internal conditions were not different. Mean power frequency relates to how quickly the motor system responds to changes, thus the performers were quicker and more automatic when they were given no focus instructions. Apparently at this level of skill, the no-focus condition represented the highest order of focus (Wulf & Su, 2007). By focusing either externally or internally, the motor control system was directed to lower order focus mechanisms relative to their skill level, and more conscious control was encouraged. Only in the no-focus condition was the motor control system truly automatic and free to operate.

These results continue to support the large body of research demonstrating the advantages of an external focus. Even at the highest level of performance, where the external instructions did not provide a benefit, the instructions that are given can significantly affect performance. Perhaps when performers attend to any lower order focus compared to their skill level, performance will be depressed, and this could even be an explanation of why performance is often decreased in high pressure or ‘choking’ situations (Wulf, 2008). At all skill levels, however, optimal instructions are those that direct the performer’s attention to higher order effects relative to their skill level, and the optimal instructions for the majority of motor skill performers will be external in nature (Wulf, 2007a). In those who have truly mastered their skill (Wulf, 2008), the highest order focus is simply no focus at all. More research should explore the different “orders”

of focus and how either an external focus, internal focus, or no focus affect performers across the skill level continuum.

Age.

No studies have directly explored how age relates to the attentional focus effect. The only studies involving older populations have focused on the effects of attentional focus in individuals with certain neuromotor impairments such as Parkinson disease (Wulf et al., 2009) and “chemo-brain” (Porter & Anton, 2011). Porter and Anton (2011) tested a sample of older adults who had undergone chemotherapy for cancer treatment. These participants showed signs of difficulty performing motor skills associated with “chemo-brain.” The participants performed nine, 30-second trials on a photoelectric rotary-pursuit tracking device under three different focus conditions. The external focus instructions directed participants to focus on moving the stylus handle at the same speed as the rotating light. The internal focus instructions directed the participants to focus on moving their hand at the same speed as the light, and the control condition instructions simply asked participants to track the rotating light. The results revealed when participants focused externally their tracking time on target was significantly greater than when they focused either internally or had no focus. These studies (Porter & Anton, 2011; Wulf et al., 2009) demonstrated that participants with chronic motor impairments can benefit from instructions that direct their attention externally, but more research needs to be conducted in age specific populations.

Underlying Mechanisms of the Attentional Focus Effect

Attentional focus research has taken an interesting path to exploring the underlying mechanisms of the attentional focus differences. Other than the initial, more

theory-generating studies (McNevin & Wulf, 2002; Wulf, McNevin et al., 2001), most studies have involved only outcome-based measures that show the beneficial effects of an external focus (Vance et al., 2004; Wulf, 2007a). From the previous studies that have been reviewed, it is clear that the effective allocation of attention is a powerful factor in motor skill performance. The proposal of the constrained action hypothesis gave researchers an initial explanation for the effect, but researchers still did not fully understand what was causing observed performance differences. More recent studies have used performance production measures to investigate what contributes to the benefits of an external focus of attention (Vance et al., 2004). Thus researchers are just now starting to re-explore more theory driven studies of the attentional focus effect. The following discussion outlines the main analyses that have been conducted to help explain why performance outcome differences exist.

Mean power frequency.

The first line of research conducted in support of the constrained action hypothesis was in balance tasks measuring mean power frequency (McNevin & Wulf, 2002; Wulf, McNevin et al., 2001). In these studies, mean power frequency analysis on the postural sway data does not represent a true performance production measure; however, it does provide a valuable insight to postural control and thus is included in this section's discussion. Also for these balance studies, mean power frequency analysis related to the frequency of postural adjustments, with a higher value relating to motor control processes that are performed more automatically. The study by McNevin and Wulf (2002) provided an interesting insight into this type of analysis. In their balance study, participants were instructed to stand still while conducting a super postural task

(lightly touch a sheet and minimize its movements) under external, internal, and no-focus conditions. The measure of postural sway revealed no significant difference between the external or internal condition; however, the mean power frequency analysis revealed when participants focused externally, their posture was maintained with more rapid movement adjustments. When participants focused internally, their posture was maintained with slower and less responsive movement adjustments. Faster responses equate to enhanced balance because afferent and efferent neurological pathways are in greater communication if need arises for the individual to adapt to a changing environment (McNevin & Wulf, 2002). When responses are slower under an internal focus, supported by the lower mean power frequency score, the individual cannot adapt to the changing environment as quickly. Even though no differences were seen by the postural sway measurement, clear motor control differences resulted from different attentional foci. These differences in the balance control mechanism can have major effects in the real world where environmental variability can be even greater. The mean power frequency production characteristics are in accord with the constrained action hypothesis. Since an external focus “frees up” the motor control system, faster and more reflexive responses relating to more automatic control are expected, but an internal focus, which “constrains” the motor control system via conscious intervention, should be reflected by slower and less reflexive movement adjustments (Wulf, McNevin et al., 2001). These results have been replicated by McNevin et al. (2003), Wulf, McNevin et al. (2001), and Wulf, Shea et al. (2001).

Electromyography and force production.

Realizing that the mean power frequency values still did not measure the exact source of control, Vance et al. (2004) sought to measure the neuromuscular system directly by using electromyography (EMG) analysis. In their study, participants performed a biceps curl with a weight equal to 50% of their 1RM under an internal and an external focus. The EMG sensors on the biceps and triceps muscles revealed the contraction patterns and activity of both agonist and antagonist muscles involved in the lift. According to McNevin and Wulf (2002) and the constrained action hypothesis, an external focus allows for greater communication and automaticity within the neuromuscular system. Based on these observations, Vance et al. (2004) predicted that when participants focused externally, greater communication and automaticity would be revealed by more economical motor unit recruitment and less neuromuscular activity to lift the same amount of weight.

Vance et al. (2004) found when participants focused externally they had lower EMG values in both the biceps and triceps muscles during the initial repetitions. The difference in the initial repetitions implies that when focusing externally instead of internally, less neuromuscular activity was utilized to lift the same amount of weight. This implies a greater economy in muscle fiber recruitment because the same force output was produced with less neuromuscular (energy) input. Also, the lower EMG values in both the biceps and triceps muscles in the external focus trials suggest more efficient communication between muscle groups (McNevin & Wulf, 2002). EMG data only represents economy of energy in performing the lift, so mean power frequency was used by Vance et al. (2004) to analyze the order of motor unit recruitment. Mean power

frequency values of the EMG signal were initially lower when participants focused externally, which specifically demonstrates that fewer motor units were recruited to lift the same amount of weight. An internal focus resulted in an increase in energy waste with more motor units being recruited than were needed to lift the weight. These results further support the constrained action hypothesis and show when participants focus externally, the efficiency of motor unit recruitment in the same muscle (intramuscular) and coordination between different muscles (intermuscular) are enhanced. These results have been replicated and expanded into a real world applied environment demonstrating a robust and consistent neuromuscular advantage when using an external focus (Marchant et al., 2009; Zachry et al., 2005).

Kinematic analysis and conclusions.

Only one study has used kinematic analysis to describe the differences in the biomechanics under different attentional foci. Zentgraf and Munzert (2009) analyzed the wrist, elbow, and shoulder movements of 61 novice jugglers. They found that one's focus of attention significantly affects the movement pattern of a motor skill. A previous study (Wulf et al., 2002) used experts to analyze correct movement form, but Zentgraf and Munzert (2009) published the first study to provide biomechanical evidence that the performer's focus of attention can significantly impact movements and muscular control across the body. The kinematic analysis, combined with the mean power frequency and EMG studies, demonstrated that different types of attentional focus induce different motor control methods. Specifically, an external focus promotes more efficient neuromuscular recruitment and more effective movement patterns to accomplish the action goal. These types of analyses also provide possible explanations for the differences

seen in the more recent outcome based studies such as in jumping (Wulf, Zachry et al., 2007; Porter, Ostrowski et al., 2010), agility (Porter, Nolan et al., 2010), and endurance weight lifting (Marchant et al., in press). Only further research utilizing production characteristics in these contexts will be able to more fully answer this question.

Limitations and future considerations

Since the advent of the field of attentional focus research in the late 1990s, Gabrielle Wulf and others have consistently demonstrated that an individual's focus of attention can significantly affect the performance and learning of a motor skill. This research has shown that focusing externally (on the environment or outcome of the movement) is more beneficial than focusing internally (on the movement of the body itself) or even having no focus at all. Studies conducted over more than a decade have shown this beneficial effect in a variety of skill contexts and in specific performer populations. Significant strides in research have been made during this period, but many gaps still remain.

One such gap is the lack of other theories explaining this effect. While the constrained action hypothesis has been supported through a plethora of experiments, this hypothesis is actually quite general and does not explain, nor do researchers understand, what is happening internally to cause the attentional focus effect. Up to this point, the discussion of previous research has only focused on attentional focus studies utilizing the paradigm developed by Wulf and colleagues (Wulf, 2007a; Wulf & Prinz, 2001). This view specifically centers on the performance and learning effects of different attentional foci that are induced by either instructions or feedback. Not only is this type of research the overwhelming majority of published studies, and thus has the most support, it is also

the theory that is most applicable to the real world performance environment (Porter, Nolan et al., 2010). Other studies (Perkins-Ceccatto et al., 2003; Zentgraf & Munzert, 2009) have mentioned another possible explanation and experimental methodology for the attentional focus effect. The alternate explanation promoted by Beilock, Berenthal, McCoy, and Carr (2004) and Gray (2004) describes the motor control and attentional demands of well learned and novel skills. However, these studies explore the specific level of control automaticity in different skill levels using a dual task methodology that involves responding to auditory stimuli. This methodology is very different and less applicable than that used by Wulf and others mentioned in this review (Porter, Nolan, et al., 2010). Due to different terminologies and methodologies, at the present time it is not advisable for researchers to compare the results of these two lines of research.

Another major limitation to the method of the attentional focus studies is the fact that researchers cannot be guaranteed that the performers are focusing on what they are supposed to be focusing on (Wulf, 2007b). More elaborate focus check mechanisms need to be implemented in future studies similar to what others have attempted to do previously (Perkins-Ceccatto et al., 2003). An effective open ended manipulation check was implemented by Porter, Nolan et al. (2010) that showed performers executing an agility task predominantly focused on where the instructions cued them to focus.

Additionally, this study revealed the wide variety within the categories of internal focus, external focus, or not cuing a focus. Thus another major limitation is the exact definition of an external focus. One example from Porter, Nolan et al. (2010) is how to classify a performer who mentioned he or she focused on time related actions such as “going as quick as possible” or “improving my time.” Porter, Nolan et al. (2010) classified these as

an “other” focus, but according to Wulf et al. (2000) these “time” responses could be an “anticipated effect” of the movement and thus an external focus. Continuing to implement an open-ended manipulation check will help to analyze the specific thoughts the participants have when performing a skill. Finally, researchers need to do a better job of disseminating this information into applied settings (Williams & Ford, 2009). The results from these studies contradict some current assumptions on feedback (Wulf & Prinz, 2001), and go against the common coaching trend that predominantly uses internal focus instructions and feedback (Porter, Wu et al., 2010; Singer et al. 1993; Wulf et al., 2000). Such robust findings need to be implemented by coaches to further the knowledge and the impact of this effect.

These limitations and gaps prompt the need for further research in a variety of directions. First, more biomechanical-type analyses need to be conducted to better understand what changes are taking place to produce higher quality movements. McNevin and Wulf (2002) suggested this research idea, but only a few studies (Marchant, et al., 2009; Vance et al, 2004; Zentgraf & Munzert, 2009) have explored this consideration in almost a decade. Conducting studies with motion analysis cameras would allow for researchers to determine if there are actual biomechanical changes that lend to the external focus advantage. Also, continuing to use performance production measures such as EMG give researchers better insight into the neuromuscular control system during a task and will help explain differences between different focus cues.

A wider variety of skills need to be tested to increase the application of the attentional focus effect into the real world setting. Only a few studies have explored the focus effect in those skills requiring specific force production such as in weight lifting

(Marchant et al., 2009; Vance et al., 2004). These studies revealed that an external focus enhances the coordination between muscles and increases the energy efficiency of the neuromuscular system. This explanation has been applied to skills requiring a single maximum generation of force such as jumping (Porter, Ostrowski et al., 2010; Wulf, Zachry et al., 2007) or in skills relating more to the generation of variable forces over relatively short periods of time such as agility (Porter, Nolan et al., 2010). That explanation has not been fully implemented into an endurance setting where force generation is applied across relatively long time spans. If neuromuscular control is more efficient with an external focus, then advantages in endurance tasks should also be seen when participants focus externally. More efficient muscular control would reduce energy waste suggesting that more energy ‘reserve’ would be available to prolong the endurance time. Only recently have studies examined endurance type tasks using the attentional focus paradigm (Marchant et al., in press; Marchant, 2011), thus more research should be conducted exploring this area

The Present Study

Recent research has demonstrated the significant effects that different attentional focus cues can have on the performance of motor skills. As outlined previously, it is advantageous to focus externally when hitting shots in tennis, volleyball, and golf; shooting basketball free throws; lifting weights; and balancing on various types of surfaces. These same benefits have not only been shown in common athletic motor skills but in common tests that evaluate and predict motor skill performance (YMCA bench press test - Marchant et al., in press; agility “L” run - Porter, Nolan et al., 2010; standing long jump - Porter, Ostrowski et al., 2010; vertical jump – Wulf, Zachry et al., 2007).

These studies demonstrated that instructions given when administering a test could have a major influence on performance. Coaches and test administrators must be consistent in the instructions they give, and also know the most effective instructions to give in specific situations (Porter, Ostrowski et al., 2010). While much of the research has supported the external focus advantages in whole body power tasks (Porter, Nolan et al. 2010; Porter, Ostrowski et al. 2010; Vance et al., 2004), few studies have looked at the effects in prolonged endurance type tasks (for a review see Marchant, 2011; Marchant et al., in press; Schucker, Hagemann, Strauss, & Volker, 2009).

Although few studies have specifically explored the endurance issue, certain assumptions can be proposed based on the constrained action hypothesis (Wulf, Shea et al., 2001). This hypothesis states that an internal focus increases conscious control in a movement and “constrains” or decreases automaticity in motor control processes, while an external focus increases unconscious control leading to greater automaticity and greater efficiency in a movement. Vance et al. (2004) demonstrated that when a performer focuses externally, motor unit recruitment is also more efficient. Results from Vance et al. (2004) showed when participants focused externally they had lower EMG activity and consequently less neuromuscular activity while performing a biceps curl task at a set percentage of their one repetition maximum. This reduced neuromuscular activity implies that movements in the external condition compared to the internal condition were produced with less energy to lift the same amount of weight. Also, muscle unit recruitment was more efficient because fewer motor units were initially recruited in the external condition compared to the internal condition. Since the Vance et al. (2004) findings were published, other studies have supported that focusing externally results in

more efficient muscular recruitment (Marchant et al., 2009; Zachry et al., 2005).

If an external focus does produce more efficient movements and muscle unit recruitment, then increased performance on prolonged sub maximal endurance tasks can be expected (Marchant et al., in press). If an external focus allows for the motor control system to more effectively select only the minimally required muscle units for a given movement, then more motor units should be left over as ‘reserve’ as the movement continues across time (Vance et al., 2004). Since an internal focus promotes a “superfluous response strategy” (Vance et al., 2004, p. 456), indicating that motor units were recruited more indiscriminately, then an internal focus should hinder the total endurance of certain movements. Marchant et al. (in press) is one of the only studies that specifically explored this issue. In this experiment, the researchers tested attentional focus effects in three endurance type tasks: a modified version of the YMCA bench press test on a Smith Machine, free weight bench press test, and free weight squat test. They found in all three tests, an external focus resulted in greater repetitions to failure than the internal focus conditions. Schucker et al. (2009) also displayed the advantages of an external focus in cardiovascular performance. When participants focused externally, they had significantly greater running economy (lower oxygen consumption) than when they focused internally. Since the type of instructions can significantly alter performance, it is important for researchers to determine what type of instructions are best for different types of testing protocols.

The purpose of the present study was to further explore how differences in attentional focus affect performance in a sub-maximal endurance test. The results can have major implications for all endurance type activities where maintaining force for an

extended period of time is paramount. This could apply in sports such as rowing, skiing, long distance running, and weight lifting. Also, many activities of daily living (ADLs) require the continuous application of sub-maximal forces for an extended period of time. These activities include walking, sitting, and balancing while standing still. In some of these contexts it has been shown that focusing externally benefits these skills (McNevin & Wulf, 2002; Wulf, Shea et al., 2001), but the present study specifically utilized a muscular endurance setting. This study also has application into the rehabilitation or general exercise environment where consistent and valid pre and post testing is important. Also, the results can change the way instructions are given during the exercise session to change the neuromuscular control system for potential training benefits (Marchant et al., 2009).

The isometric wall sit test is a common test used for evaluating endurance because it can be administered almost anywhere and is not complex (Tomchuk, 2011). Participants were required to hold an isometric contraction as long as possible in a 90 degree sitting position (the test is also called the “ghost” chair test). This study was unique because no attentional focus endurance experiment has measured this effect in an isometric test. The velocity of contraction is an important variable to control (Vance et al., 2004), and the static nature of an isometric contraction may influence neuromuscular efficiency differently than that seen in previous dynamic contractions (Marchant et al., 2009). Based on the constrained action hypothesis and evidence of increased neuromuscular efficiency, it was predicted when participants focused externally, they would maintain the contraction and hold the wall sit position for a significantly longer time than when focusing internally.

CHAPTER 2

METHOD

Participants

A total of 32 undergraduate Kinesiology students were recruited for participation in this study. Nine of these participants were excluded from the data analysis due to not completing the test or not providing valid data. Two participants did not return on the second day of testing so their first day scores were removed from the sample. Seven other participants were removed due to invalid participant scores. These scores were invalid because the participant slipped during the trial, or the time keepers disagreed on the participant's trial time. If a trial was invalid on one day then the entire participant's data were removed from the sample. The final analysis included 23 total participants (16 males, 7 females, age: 21 ± 2 years, body mass: 81 ± 19 kg, height: 177 ± 10 cm). Participants were naïve to the purpose of the study. Participants were instructed to not consume alcohol or participate in any resistance or cardiovascular training 24 hours prior to the testing times. There were no exclusion criteria based on training status. All participants read and signed an informed consent before participating. The university's Human Subjects 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 wall sit test is a common and feasible test to measure static leg endurance, and the instructions used for this test were borrowed from Tomchuk (2011). Participants were required to hold the correct position for as long as possible. The

correct wall sit position was feet flat and shoulder width apart, knees at 90 degrees, shoulders against the wall, and arms hanging straight down (see Figure 2.1). For this experiment, maximal time to fatigue was defined as the time span from the initiation of the task to when any of these positions were not able to be maintained. All participants performed the task while wearing athletic shorts and socks. Participants were instructed to be silent and to look straight ahead through the duration of the trial. A within-participant design was used with each participant performing one trial under both the external and the internal conditions. Conditions were counterbalanced across participants, and each trial was separated by 48 hours. This was to control for order effects and to ensure adequate recovery by eliminating the presence of fatigue on the second trial (American College of Sports Medicine, 2010).



Figure 2.1. The correct wall sit position.

Two experimenters were present for timing each participant. Standard sport stopwatches that made no sounds when starting or stopping were used to record the wall sit times. Both stopwatches were started when the lead experimenter gave the “start”

command. Experimenters were 180 degrees opposite each other and on either side of the participant throughout the trial. Each experimenter independently recorded the end time based on the maximal fatigue criteria. Then both scores were recorded in a computer and stored for later analysis. A manual goniometer was used to confirm the participant's knee was at a 90 degree angle at the start of each trial. The center of the goniometer was placed at the lateral femoral epicondyle with the 'arms' pointing to the lateral malleolus of the tibia and the greater trochanter of the femur. A standard meter stick was also used to record the distance of each participant's foot from the wall. This measurement was taken from the back of the left heel to the wall and was recorded so that on trial two, the participant's foot was in the same position as on trial one.

The same experimenter explained the instructions to each participant. The general instructions given to each participant were to "maintain the correct wall sit position for as long as possible." The external instructions were "I want you to focus on pretending like you are sitting in a chair through the duration of the trial." The internal instructions were "I want you to focus on keeping your knee at 90 degrees through the duration of the trial." Based on the 30 second limitations of working memory (Magill, 2011), a verbal cue was given by the lead experimenter every 15 seconds to remind the participants of the correct focus. The external cue was "keep sitting in chair" and the internal cue was "maintain knee angle." After the trial, participants wrote a response to the following question regarding their focus of attention: "on the previous trial what did you focus on?" Written responses were recorded by the lead researcher into the computer and stored for the qualitative analysis.

Experimental Procedures

When the participant entered the room he or she was asked to sit and sign an informed consent. The participant performed a five minute walking warm up and then sat and rested for two minutes while the wall sit instructions were explained. At this time the lead experimenter demonstrated and verbally described the correct wall sit position and the test termination criteria. The participant's height, weight, and age were also recorded during this time. At the end of two minutes, the participant performed a brief (less than five seconds) familiarization trial to experience the correct form and for the researcher to measure the participant's foot to wall distance. The goniometer was used to place the knee at 90 degrees, and then the foot distance measurement was recorded. The participant then sat and rested for 30 seconds to remove any possible fatigue from the familiarization trial. At this time, the lead experimenter gave the participant the correct focus instruction. The experimenter then instructed the participant to place his or her left heel at the correct distance from the wall and while still standing, lean back against the wall. When the participant was ready, he or she was instructed to sit down into the correct wall sit position. The knee angle was measured again to ensure 90 degrees, and then both stopwatches were started at the lead experimenters "start" command. Every 15 seconds the verbal cue was given, and this continued until the participant could not maintain the correct wall sit position. Then the participant answered the written question to complete that trial. Participants were not informed of their wall sit time or provided any performance related feedback. Procedures on the second day were exactly the same as day one except a different set of focus instructions was given.

Data analysis

Times from both experimenters were recorded in Microsoft Excel and then averaged to obtain a final outcome score. An intraclass correlation (ICCR) was performed to determine the reliability of the outcome scores from the two independent experimenters. Outcome scores of the two trials for each participant were analyzed in a univariant repeated measures analysis of variance (ANOVA) using the Statistical Package for the Social Sciences (SPSS) version 16. A univariant ANOVA was also conducted for the outcome scores of the two trials for each day to analyze for a potential day effect. A p-value of 0.05 was used to determine significance for the condition and day effects. For qualitative analysis, two researchers independently categorized the written responses as either internal, external, or mixed similar to the categories used in Porter, Nolan et al. (2010). An interobserver agreement (IOA) calculation was used to find a percentage of agreement the two researchers had in coding the written responses (Thomas, Nelson, & Silverman, 2005).

CHAPTER 3

RESULTS

Endurance times

From the univariant repeated measures ANOVA, a significant main effect was observed for focus of attention condition, $F(1,22) = 4.983, p < .05, \eta^2 = 0.185$. Figure 3.1 shows that participants had a significantly higher endurance hold time when they focused externally (68.41 ± 34.12 sec) rather than when they focused internally (60.22 ± 34.54 sec). There was no main effect for day, $F(1,22) = 0.530, p > .05$ with average hold times for all trials on day one (65.78 ± 36.83 sec) not significantly different from average hold times for all trials on day two (62.86 ± 32.10 sec) (see Figure 3.2). ICCR analysis revealed that the two independent endurance time scores were reliable for each trial ($r = 0.99$). See appendices A and B for the ANOVA output for the condition and day effects.

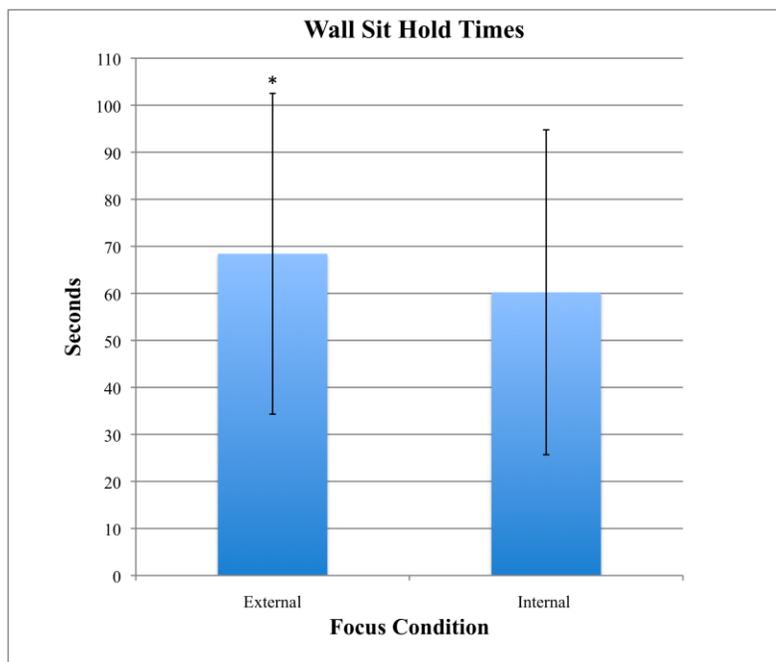


Figure 3.1. Wall sit hold times for the external and internal focus conditions.

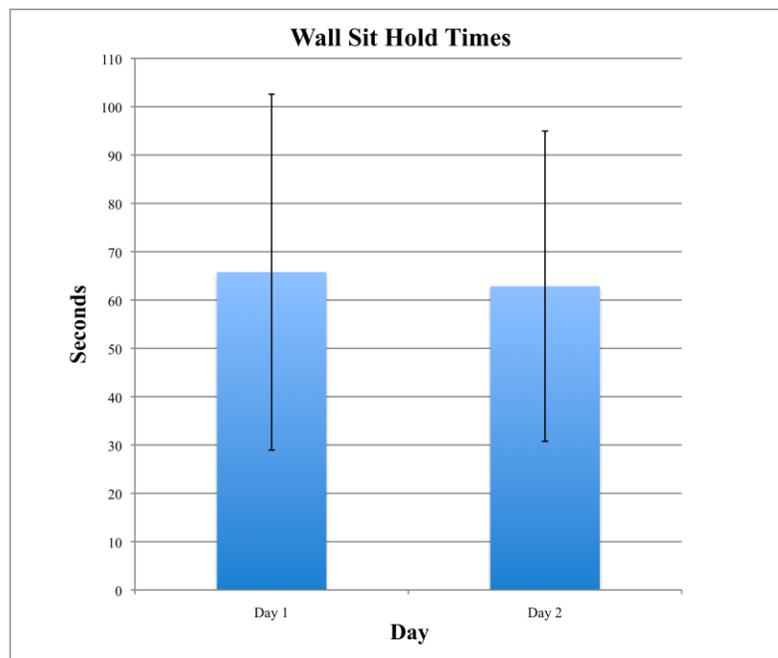


Figure 3.2. Wall sit hold times for days 1 and 2.

Manipulation check

Two experimenters analyzed and coded the written manipulation check answers. The answers were categorized as either external, internal or mixed. For example, the majority of externally labeled responses were “sitting in a chair.” This type of response was clearly external regardless of the actual focus condition. Other participants clearly described a focus that was internal and related to the body. These responses included “isolating my quads,” “hold my foot 17.5 [inches] from the wall,” and “keeping my knee at 90 degrees.” Five total participants reported a mixed focus which included elements of both an external and an internal focus. Examples of these were “a chair underneath me holding me up and holding weight with my feet instead of my thighs” or “sitting in a chair and contracting leg muscles.” Due to the similarity of many responses within each broad category, it was not necessary or appropriate to subcategorize responses similar to the Porter, Nolan et al., (2010) study.

The interobserver agreement (IOA) score between the two independent raters was 85% indicating high reliability between the answer classifications. See appendix C for a complete listing of the participant responses and the classifications provided by both raters. The raters disagreed on vague responses such as “maintaining the angle,” “I was focusing on slipping,” and “I tried to focus on sitting up straight and not dropping my arms.” The lead rater classified these responses as external, external, and mixed, respectively. The first two responses are external because they relate to the effect of the movement, or specifically in this case, the effect or possible result of maintaining the correct wall sit position. The third example was mixed because it included both an external and an internal focus. Posture (“sitting up straight”) is an external focus since no specific body part is cued, and it relates to the intended outcome of the movement (Marchant et al., 2009; Wulf et al., 2000). Focus was also on the body (arms) thus an internal component was present. According to the lead researcher’s classifications, analysis (see Table 3.1) revealed that when instructed to focus externally, participants adopted an external focus 70% of the time, an internal focus 17% of the time, and a mixed focus 13% of the time. When instructed to focus internally, participants adopted an internal focus 69% of the time, an external focus 22% of the time, and a mixed focus 9% of the time.

Table 3.1

Lead raters response classifications

External Condition			
23 total			
	<u>External</u>	<u>Internal</u>	<u>Mixed</u>
Responses	16	4	3
Percentage	70%	17%	13%
Internal Condition			
23 total			
	<u>External</u>	<u>Internal</u>	<u>Mixed</u>
Responses	5	16	2
Percentage	22%	69%	9%

CHAPTER 4

DISCUSSION

The purpose of this study was to test the relationship between endurance time and two different attentional focus strategies. It was hypothesized when participants focused externally (maintaining the chair position) they would be able to hold the isometric wall sit position for a longer time than when they focused internally (maintaining the knee angle at 90 degrees). The results support the hypothesis and show that participants can maintain the wall sit position for a longer time when focusing externally than when focusing internally. Also, the manipulation check indicated that participants adopted the correct focus 70% of the time during the external trials, and 69% of the time during the internal trials. These results, along with those of Porter, Nolan et al. (2010), give researchers confidence that participants will adopt the correct focus implemented by the experimental conditions (Wulf, 2007b). This study adds to the sparse attentional focus literature that demonstrates an external focus enhances muscular endurance (Marchant et al., in press), and it extends the generalizability of the attentional focus effect to tests that are used to evaluate motor skill performance (Porter, Ostrowski et al., 2010). This study is unique because it is the first to measure the attentional focus effect specifically in an isometric endurance contraction that requires no movement.

The constrained action hypothesis provides a plausible explanation for the present findings (Wulf, Shea et al., 2001). According to this hypothesis, when a performer focuses internally (on the body and its movements) the neuromuscular control system is “constrained” by conscious control intervention. This reduces automaticity and results in

slower and more inefficient movements. An external focus however, “frees” the motor control system and results in more automatic movements. These automatic movements are equated with more fluid and efficient muscular recruitment that can respond faster and more appropriately to the environment or task demands. Marchant et al. (2009) and Vance et al. (2004) have demonstrated these performance advantages at the neuromuscular level using EMG sensors and mean power frequency analyses. In these studies, it was shown that when performers focused externally, motor units were recruited more efficiently and less neural input was required to lift the same relative amount of weight. When participants focused internally, more muscle fibers were recruited than was necessary to accomplish the lift which resulted in energy waste and increased “noise” in the EMG data (Vance et al., 2004). It seems reasonable to conclude that in the present study, where regulating energy input is paramount to prolonging the wall sit time, that the more efficient muscular recruitment induced by an external focus would be more beneficial than an internal focus. More research in an endurance context is needed to validate this possibility.

Also, there is evidence that in response to fatigue, the neuromuscular system reorganizes input to different muscles to maintain the action (Bonnard, Sirin, Oddsson, & Thortensson, 1994; Côté, Mathieu, Levin, & Feldman, 2002). In the Bonnard et al. (1994) study, participants were required to hop on one foot for as long as possible. Using EMG data collected from the vastus lateralis, rectus femoris, gastrocnemius, and soleus, the researchers found that participants’ neuromuscular system compensated for fatigue at the ankle joint with two different strategies: several altered neuromuscular control at the ankle while others altered neuromuscular control at the knee. Even though the Bonnard et

al. (1994) study involved dynamic repeated contractions to fatigue, those results further support the assumption that changes in neuromuscular activation in response to fatigue may possibly be different in both focus conditions utilized in the present study. This possible change in neuromuscular activation may explain the observed differences in endurance times. Also, slight alterations in foot and ankle muscle activation might be present in maintaining the wall sit position as fatigue becomes evident. Instructions for the current test involved keeping the feet flat, but participants still could have applied force in different places on the foot through the duration of the trial. This would potentially change the rate at which muscles of the upper and lower leg are fatigued by changing the muscles that are primarily bearing the weight at that time. Slightly different kinematic control patterns may provide another insight into the performance differences (Zentgraf & Munzert, 2009). While major dynamic movements are constrained in the isometric wall sit, medial to lateral knee movements, or shaking, were possible and present in some individuals. Increased knee movements may be a result of erroneous neural input creating energy waste and decreased endurance time. Further analysis using EMG and kinematic measures would support or refute these possible explanations.

The results of the current study also highlight the possible cognitive and affective impact of the attentional focus effect. One such area is in perceived exertion (for a review see Hampson, Gibson, Lambert, & Noakes, 2001; Robertson & Noble, 1997). According to this view, one of the major contributors to fatigue is the performer's subjective perception of work. Robertson and Noble (1997, p. 407) defined perceived exertion as "subjective intensity of effort, strain, discomfort, and/or fatigue that is experienced during exercise," and how a performer perceives his or her effort can significantly affect the

onset of fatigue (West, Smith, Lambert, Noakes, & Gibson, 2005). Jones and Hunter (1983) showed that for any given constant load, the perception of applied force at the time of maximal endurance is similar regardless of the participant. In the current study, which used a within-participant design, internal and external performance times were compared in the same participant. Since it is assumed body weight did not change significantly from trial one to trial two, then the weight held (body weight) remained constant. According to Jones and Hunter (1983), it is predicted in the current study the same participant would rate his or her perceived exertion in both trials as being equal at the point of maximum fatigue. If this is true and perception of fatigue plays a major role in actual fatigue, then perhaps the participant's attentional focus affects perceived effort ratings at the onset of the endurance trial. An external focus compared to an internal focus may also slow the increase in these detrimental feelings and prolong endurance time. Future studies that analyze different afferent cues and their effect on ratings of perceived exertion are necessary to explore this assertion (Hampson et al., 2001).

Another related psychological component is explored in the attentional association and dissociation literature. According to a topical review by Lind, Welch, and Ekkekakis (2009), this line of research analyzes differences in *how* participants focus on the perceptions of fatigue. Associative techniques direct performers attention to bodily sensations while dissociative techniques direct attention towards the environment and distract attention away from the bodily sensations. These definitions appear similar to the internal and external definitions employed by Wulf and her colleagues (Wulf, 2007a) but different methodologies and terms restrict any direct comparisons (Marchant, 2011). Interestingly, several studies have demonstrated that dissociative strategies result in lower

perceived effort ratings than associative strategies (Johnson & Siegel, 1992; Stanley, Pargman, & Tenenbaum, 2007). Combined with the results from the perceived effort studies mentioned previously, the association and dissociation literature support the assumption that attentional focus strategies in the wall sit test may have a major effect on cognition as well as physical performance. A major problem with the associative and dissociative literature is conflicting data and various different operational definitions that exist (Lind et al., 2009). Perhaps exploring the similarities of the association and dissociation literature with the recent attentional focus findings by Wulf and others (Wulf, 2007a) may provide useful insights and advantages to both lines of investigation.

Certain limitations must be acknowledged in the present study, and these limitations lead to future research directions. A major limitation in the present study is that only one trial was performed for each condition. The only previous attentional focus endurance study (Marchant et al., in press) also had participants perform only one trial in each focus condition. This method was appropriate in the present study since the major purpose was to test the attentional focus effect in the isometric wall sit test. Tomchuk (2011) stated that only one trial of the test is performed, so only testing each participant with one trial in each condition most accurately replicates this muscular endurance assessment. Only using one trial in each condition could be problematic for validity of the results because a variety of factors such as food intake and prior activities could affect one trial and not affect or not be present for the next trial. Instructing participants to refrain from alcohol consumption and resistance and cardiovascular training 24 hours prior to each testing session should have improved the quality of the trials completed in the current study. Utilizing a within-participant design also helped control for participant

variability since the same participant was used in both conditions. The results of the present study revealed a significant difference between the two focus conditions with no observed day effect. This provides confidence that even with the possible limitation of using only one trial per condition, an external focus increased endurance performance over an internal focus.

Another limitation to the present study is that no control condition was used. The purpose of the present study was to test how different attentional focus instructions affect endurance time in the isometric wall sit so trials under a “neutral” focus were not required. Also, previous studies have compared only an external and an internal attentional focus using a withinparticipant design and found advantages for an external focus (Vance et al., 2004; Zachry et al., 2005). Without a control condition, no conclusion can be made regarding if an external focus improved wall sit endurance or if an internal focus decreased wall sit endurance. Marchant et al. (in press) included a control condition in their endurance study. They found that in the YMCA bench press endurance test, the external and control conditions were not significantly different from each other, yet only the external condition was significantly greater than the internal condition. In the two more complex tests (free weight bench press and squat) the external condition was significantly greater than the internal and control conditions with the latter two not significantly different from each other. From the results by Marchant et al. (in press) and others (Porter, Nolan et al., 2010; Wulf, Zachry et al., 2007) it is hypothesized that an external focus would result in greater endurance times than a no-focus control condition during the wall sit test. Additional research is needed to assess this prediction.

A final limitation to the present study is that certain bodily movements could not

be completely restricted. The wall sit test requires participants maintain a 90 degree angle at the knee, but as the trial progressed slight bodily adjustments could have occurred. These adjustments could be the feet moving slightly, medial and lateral knee movements, and up and down movements of the body against the wall. The current study restricts most bodily movements by using an isometric contraction, but an isometric test using an isokinetic dynamometer would allow for greater restraints to be imposed on the participants' movements and for greater consistency of applied force trial to trial within the same participant.

The present study also revealed a possible weakness to the current definition of an internal and external focus of attention. Highlighted by this study is the difficulty in classifying some focus responses measured during a manipulation check. Knowing what focus the participant uses is vital to understanding performance responses and creating recommendations for instructors and coaches (Porter, Nolan et al., 2010; Porter, Wu et al., 2010). The original definition of an external focus described by Wulf and Prinz (2001) related to performers focusing on the effects of their movements on the environment (the implement or apparatus), whereas an internal focus directed performers to focus on the movements themselves. Marchant et al. (2009) further elaborated on this definition by stating that an external focus is directed toward an outcome of the movement being produced such as a goal, target, or intended effect, while an internal focus directs a performers attention toward the body during the movement. A common factor in all the operational definitions up to this point involves some obvious form of movement of either the body or an implement, however, questions remain regarding the current movement based attentional focus definitions apply to skills that require no overt

movement to execute the task.

Wulf et al. (2000) proposed that in a skill without object manipulation, a metaphor could be used that directs the performer to the movement effect which would give a mental image of the movement goal. This type of external focus would also distract the performer from the movements of his or her body (Wulf et al., 2000; Wulf et al., 2002). In the current study visualizing sitting in a chair is an externally focused metaphor describing the outcome of the activity. Focusing on keeping the knee at 90 degrees clearly cues the performer internally to the body itself. The lack of a clear attentional focus definition arose when the researchers attempted to classify the participant responses. The majority of responses fit clearly into the categories of external, internal, or mixed supported by the IOA score of 85%. Disagreement arose for the responses that related to posture or included no direct reference to the body. One response was “keeping my posture and looking straight ahead.” From this response it cannot be determined if the focus on “posture” relates to the performer’s body (internal) or the intended outcome of the wall sit (external). A few responses were “maintain the angle”. Once again, a focus on the “angle” could be specifically on the body (internal) or an image of the outcome of the wall sit (external). The lead researcher classified these responses as external based on the thought of what would be cued if these exact instructions were given to new participants in the wall sit. Since no specific body part is cued then an external image of the intended outcome becomes the focus (Marchant et al., 2009; Wulf et al., 2000). Furthermore, it is not known how a “mixed” focus affects the performance outcome. Wulf et al. (2002) stated that a beneficial effect is seen as long as the induced focus is predominantly external, but it cannot be determined if the current

“mixed” responses classify as predominantly external or not. More research using a manipulation check, and analyzing skill performance specifically based on the participant’s focus responses, will help answer these questions and create more accurate definitions of an internal and external focus.

In future studies, researchers should test at different percentages of maximal voluntary contractions to increase the application of the focus effect to different weight lifting and endurance settings. It is also important for researchers to understand how an internal or external focus of attention affects neuromuscular adaptations during training. Marchant et al. (2009) mentioned instructions that induce an internal focus may actually promote greater neuromuscular adaptation in a training or rehabilitative environment by purposefully increasing neuromuscular activity thereby increasing energy use and muscular overload. This study raises the question if in endurance training settings it is better to increase the stress and fatigue on the muscles in a shorter amount of time via an internal focus or prolong the stress and fatigue via an external focus. Implementing an endurance training protocol with a pre and post testing would help determine if training with one type of focus of attention affects the rate or amount of neuromuscular adaptations.

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 advantages of an external focus of attention in an isometric wall sit test and adds to the growing evidence that an external focus enhances muscular endurance (Marchant et al., in press). 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 rowing, cross country skiing, and certain strong man weight lifting events. The present study proposes that different attentional focus instructions may be a major factor in cognition and sensory perceptions of fatigue while performing an endurance task. Future studies should continue to utilize the present design to limit movement variables and analyze the reasons why an external focus provides these advantages.

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APPENDICES

APPENDIX A

ANOVA Output for Condition Effect

Tests of Within-Subject Effects

Source	condition	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power
condition	Linear	772.563	1	772.563	4.983	0.036	0.185	4.983	0.569
Error(condition)	Linear	3410.62	22	155.028					

APPENDIX B

ANOVA Output for Day Effect

Tests of Within-Subject Effects

Source	day	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power
day	Linear	98.36	1	98.36	0.53	0.474	0.024	0.53	0.107
Error(day)	Linear	4084	22	185.674					

APPENDIX C

List of External Focus Responses

Participant	Lead Rater's Classification	2nd Rater's Classification	Disagree	Responses
2	E	E		I tried to focus on me sitting in the chair and to distract myself from what I was actually doing
3	E	E		Sitting in a chair
5	E	E		Sitting on a chair
6	E	I	x	I was focusing on slipping
8	E	E		Sitting in a chair
9	E	E		Act like sitting in a chair
10	I	I		Sitting on a chair, isolating my quads, and not sliding my feet
11	M	M		a chair underneath me holding me up and holding weight with my feet instead of my thighs
13	E	E		Hold my position as steady as possible and not even thinking about the trial itself
14	E	E		I focused my attention on everything but my legs, my main train of thought was "sitting in a chair"
15	M	M		I was focusing on feeling as if I was sitting in a chair and more focused on my glutes and lower back
16	M	M		Sitting in a chair and contracting leg muscles
17	E	E		Sitting in a chair
18	E	I	x	Keeping my posture and looking straight ahead
19	E	E		Focus on sitting in a chair
22	E	E		The chair in front of me and sitting on it
23	E	E		Holding as long as I could and like I was sitting in a chair
25	I	I		Hold my foot at 17.5 from the wall
26	I	I		My quads burning up and looking forward
27	E	E		I was focusing on trying to keep the correct posture as if I was sitting in a chair
28	I	I		Not moving my shoulders away from the wall
30	E	E		Sitting in a chair and not shaking
32	E	E		Sitting in a chair

APPENDIX D

List of Internal Focus Responses

Participant	Lead Rater's Classification	Second Rater's Classification	Disagree	Responses
2	M	I	x	I tried to focus on sitting up straight and not dropping my arms. I think that focusing on other things helps you last longer.
3	I	I		My knees
5	I	I		Maintain knee angle
6	I	I		Pain in my knees
8	E	I	x	Maintaining the angle of 90 degrees
9	I	I		breathing, and knee angle
10	I	I		Quads, keeping 90 degree angle, keeping my knees at 90 degree angle
11	E	E		a spot on a tile in front of me
13	I	I		Throughout the trial my mind was focusing on my knees and hamstring muscle.
14	M	I	x	I focused on maintaining the angle and I felt less pressure on my knee
15	I	I		I was thinking about the angle of my left knee and focusing on the position of my left foot
16	E	I	x	Maintain the angle
17	I	I		Knee angle
18	I	I		Maintain the knee angle
19	I	I		On trying to keep my knees at 90 degrees
22	I	I		Keeping my knee at 90 degree
23	E	E		To stay in the wall sit position for as long as I could
25	I	I		Holding foot placement
26	I	I		Keeping knees at 90 degrees
27	I	I		I was focusing on trying to keep my knee at 90 degrees without breaking
28	E	I	x	Keeping my 90 degree angle
30	I	I		Maintaining knee angle
32	I	I		Maintaining a 90 degree angle at the knee

VITA

Graduate School
Southern Illinois University Carbondale

Russell P. Nolan

Date of Birth: April 7, 1987

92-B Highlander Drive, Carbondale, Illinois 62903
Rnolan2@yahoo.com

Louisiana State University
Bachelor of Science, Kinesiology, May 2009

Special Honors and Awards:

Southern Illinois University Graduate Student Achievement Award for 2011

Thesis Title:

An external focus of attention enhances isometric wall sit endurance time: A quantitative and qualitative analysis of the attentional focus effect.

Major Professor: Dr. Jared M. Porter

Publications:

Porter, J. M., **Nolan, R. P.**, Ostrowski, E. J., & Wulf, G. (2010). Directing attention externally enhances agility performance: A qualitative and quantitative analysis of the efficacy of using verbal instructions to focus attention. *Frontiers in Psychology, 1*, 1-7.

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