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Two bodies of literature have addressed the question of how attentional focus relates to learning and performance of a motor task. The literature on direction of attention has found that focusing on the effects of one's movement, an external focus, rather than on one's bodily movements, an internal focus, leads to more effective and efficient movements and subsequently better performance on a variety of sport-related motor skills. The literature on the relevance of attention has determined that novices perform well when focused on aspects of the skill execution itself, but experience performance decrements when asked to focus on something extraneous. Experts show the opposite tendency in that they perform more poorly when focused on the skill execution than on a distractor. Both of these areas of research are well-established in their own right, but they are not purely independent because these different styles of focus overlap. A novice golfer who focuses on the swing of his arms while putting is predicted to do more poorly due to an internal focus, but the other body of literature predicts success due to a skill-relevant focus. Few have attempted to research the effects of *both* dimensions of focus simultaneously. Therefore, the purpose of this study was to identify whether the interaction of external and skill-focused attention could be more beneficial to skill acquisition and retention than either one separately. Participants learned to throw darts while receiving one type of attentional focus instruction: (1) internal, skill-relevant; (2) external, skill-relevant; (3) internal, extraneous; (4) external, extraneous. They returned

48 hours later to perform retention trials without any attentional instructions. Workload was assessed via a self-report survey for participants in each condition to assess whether any differences in subjective difficulty exist between the groups. Although all participants improved their throwing accuracy throughout the acquisition period, there were no performance differences seen between the conditions at acquisition or retention. There were also no differences in perceived workload between the conditions. These results were to be expected if workload does, in fact, mediate the effect of focus of attention on motor skill performance. With workload demands being similar across conditions, there exist no differences in performance between groups following different focus instructions. Further, the only reliable predictor of performance on the task was the participant's self-rating of expertise reported prior to participation. Future between-subjects research designs in motor learning should aim to balance participants across groups using self-ratings of skill level. Finally, the NASA-TLX should be used to measure workload in the typical methodology used in direction of attention literature and skill-relevance of focus literature, where performance differences have been observed, in order to determine whether differences in workload demands could be partially responsible for those performance differences.

EQUAL WORKLOAD DEMANDS MAY HINDER THE ABILITY OF FOCUS OF ATTENTION TO IMPACT MOTOR LEARNING

by

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APPROVAL PAGE

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CHAPTER I

INTRODUCTION

What is going through a performer's mind when he or she is performing a motor skill? In recent years, researchers have established that what we focus our attention on can have a significant effect on our performance during various motor tasks. In fact, simply directing an individual's attention to a particular component of the task or away from the task altogether can improve her performance. For example, a golfer performing a putt could be thinking about the arm movement, the imagined path of the ball, the putter's arc, or other external distractions. Although physical ability is an important aspect of performance, recent research has established that a performer's focus of attention (FoA) can also have a significant impact on performance. However, focus is not one-dimensional, and the various types of focus have been studied independently as each relates to performance.

Focus can be described in terms of width (broad, narrow), distance (proximal, distal), direction (internal, external), and relevance (skill-focused, extraneous). Width of focus describes the number of sources of information of which a person is keeping track. For example, an individual studying that does not hear their name being called is considered to have a narrow focus, however a quarterback who is simultaneously listening to his coach, noting the defensive lineup, remembering the play, and hearing the roar of the crowd is utilizing a broad focus. Another aspect of FoA is distance. Focusing on the basketball hoop is a more distal point of focus than focusing on the ball during a free throw.

Defined by Wulf, Höß, and Prinz (1998), an internal focus of attention directs attention towards a learner's own body movements; whereas, an external focus of attention directs attention to the effects of the performer's actions on the environment. Concentrating on one's own foot is an internal focus, while concentrating on the ground beneath the foot constitutes an external FoA. Lastly, focus during a motor task can be directed toward the task at hand (skill-relevant), like the swinging of the baseball bat, or away from the task, like on the announcer's words (extraneous). These dimensions of focus can be combined as well. For example, imagine a professional golfer standing over a critical putt. If the golfer focuses on the announcer's words, this is an example of a narrow, distal, external, and extraneous point of focus. If the golfer focuses on the hands gripping the putter, this is an example of a narrow, proximal, internal, and skill-focused FoA. These distinctions are important because each one has the potential to independently affect performance. Fortunately, researchers have already built a solid foundation of evidence regarding a few of these dimensions, two of which are most relevant to the current research: the *direction* of focus and the *relevance* of focus during a motor task.

One body of research on direction of attention, pioneered by Wulf in 1998, has repeatedly demonstrated that people perform better when they are instructed to focus on an external cue rather than a part of their body (an internal sensation). Early research examined the effects of giving different focus instructions to participants using a ski simulator (Wulf, Höß, & Prinz, 1998). One group was told to focus on the force exerted by their own feet on the platform, an internal focus, while a second group was told to focus on the force exerted onto the wheels of the platform, an external focus. A control group was not given any instructions. The external-focus group performed better than the other groups in both practice and retention implying greater learning. While the internal-focus and control groups did not differ at retention, the internal-focus group performed significantly *worse* than the control group during the acquisition trials. This finding, in part, led to the hypothesis that an external FoA will lead to better motor learning, while an internal focus will actually hinder it. Wulf and colleagues followed up this experiment using a stabilometer rather than a ski simulator and were able to replicate their findings. These findings led to the development of the Constrained Action Hypothesis (CAH; Wulf, McNevin, & Shea, 2001; Wulf, Shea, & Park, 2001). The hypothesis states that attempts to consciously control a motor movement by focusing internally interfere with typical motor control processes that otherwise occur automatically. Focusing on the effect of one's movement, like the golf club swinging, rather than the body movement itself, like the arms swinging, allows the motor system to carry out the movement more efficiently, resulting in more effective performance. These first tests of motor learning show that a novice learning a new motor skill will retain better performance after a delay when focused externally. Further, research has shown that changes in performance are evident immediately after receiving focus instructions. That is, participants can perform the same task with varying FoA instructions, and their performance will be best when focused externally (Lohse, Sherwood, & Healy, 2010; Porter, Nolan, Ostrowski, & Wulf, 2010; Wulf, Landers, Lewthwaite, & Töllner, 2009). Since then, researchers have been able to provide a large body of evidence supporting the CAH (see Wulf, 2013 for a review).

A similar hypothesis has been supported in another body of literature lead by Beilock regarding the skill-relevance of attention. This line of research considers how performance is affected by directing FoA toward the skill being performed or away from it. It also emphasizes that the automaticity of a motor skill comes with practice, so that only those with more expertise for a skill would have a motor “program.” Experts have been shown to perform more poorly when focused on the task itself (skill-relevant focus) than on some distractor (extraneous focus). Beilock and Carr (2001) hypothesize that explicit monitoring of a well-practiced skill would disrupt the automaticity of the motor program, but novices, who have yet to master the motor skill, still show a benefit when focused on the task itself, and perform worse when they are asked to focus additionally on a second task. This prediction of an interaction between expertise and relevance has been termed the Explicit Monitoring Hypothesis (EMH; Beilock & Carr, 2001). Tests of the EMH do not simply differ in the wording of focus instructions. Instead, a dual-task paradigm is used in which a participant engages in a motor skill while attending to a distractor. A primary example is when Beilock and colleagues asked experienced and novice soccer players to dribble through pylons while listening to a list of words for a specified word (Beilock, Carr, MacMahon, & Starkes, 2002). While novice soccer players’ performances were crippled by the addition of this second task, expert soccer players performed just as well with and without the secondary listening task. These results have been replicated many times, and research on this topic has centered on the applicability of this hypothesis to the causes of choking under pressure (see Beilock & Gray, 2007). The results from this line of research suggest that in order to most effectively teach a motor skill, a novice should focus on the skill itself, but as they develop automaticity for a movement, they should start to shift their focus outwardly in order to not interfere with their motor program.

While these two lines of research describe a similar phenomenon in which the FoA has an impact on successful performance of a motor skill, there has not been sufficient research regarding how these two dimensions of attention interact to affect performance. Failing to acknowledge the other well-researched dimensions of attention when designing a study could lead to confounded results. For example, Perkins-Ceccato, Passmore, and Lee (2003) conducted an experiment intended to evaluate whether an internal or external FoA would benefit golfers' pitching performance. Their instructions were either to focus on "the form of the golf swing," what they suggested to be internal focus instructions, or to focus on "hitting the ball as close as possible to the target," suggested external instructions. They found that low-skilled golfers benefitted most from the internal FoA, and skilled golfers from the external FoA condition. These findings appear to oppose Wulf's research that an external FoA is more beneficial across the board. However, their instructions differed on more than just the direction dimension of focus. Focusing on the form of the golf swing is not inherently internal or external. A focus on the arms, shoulders, or hips would constitute an internal focus, while a focus on the club's movement through the air would constitute an external focus. However, that instruction is inherently skill-focused. On the other hand, focusing on hitting the ball as close to the target as possible is more broad, distal, and less relevant to the motor task of swinging the club. Therefore, this study more accurately supports Beilock and Carr's EMH than it opposes Wulf's CAH. Additional studies further illustrate the importance of proper instructions for the specific dimension of attention being studied because their instructions vary in both relevance and direction (Schücker, Knopf, Strauss, & Hagemann, 2014; & Mohamadi, Kordi, & Ghotbi, 2012).

There continues to be interest and exploration into the effects of extraneous focus and skill-focused attention on performance using a dual-task paradigm (e.g., Beilock & Gray, 2012; Diekfuss, Ward, & Raisbeck, 2016; Raisbeck & Diekfuss, 2015; Raisbeck, Regal, Diekfuss, Rhea, & Ward, 2015; Raisbeck, Suss, Diekfuss, Petushek, & Ward, 2015). Further, there is continuing research exploring how an internal and external focus effect performance through instruction-only manipulations. (e.g., Abdollahipour, Wulf, Psotta, & Palomo Nieto, 2015; Wulf, 2008). However, these are still only two studies that have purposefully integrated *both* the EMH and CAH hypotheses into a single study to better understand which theory (i.e., EMH, or CAH) best explains the effects of attention on performance (Castaneda & Gray, 2007; Russell, et al., 2014)

Castaneda and Gray (2007) designed a paradigm to disentangle the direction and skill-relevance dimensions of attentional focus with regards to the impact on performance. High and low-skilled baseball players completed a virtual batting task in each of four ways: a) external focus, skill-relevant; b) external, extraneous; c) internal, skill-relevant; and d) internal, extraneous. Regardless of condition, all participants listened to tones of high or low frequency while batting. For skill-relevant conditions, participants reported the location of their hands (internal) or the bat (external) upon hearing any tone. In the extraneous condition, participants were asked to report the frequency of the tone (high or low; internal), or to report the direction of flight of the virtual ball upon hearing the tone (external). As predicted according to the EMH, experts performed best when focused externally and extraneously, while novices performed best when focused on the skill, regardless of whether the FoA was internal or external. The researchers claimed these results supported the EMH more than the CAH. However, supporters of the CAH argue against the use of the dual-task paradigm because it increases the workload on the participant, which could differentially affect experts and novices (Russell, et al., 2014).

Russell et al. (2014) used the same experimental design as Casteneda and Gray (2007), but replaced the dual task paradigm with an instruction manipulation commonly used in the direction of attention literature. They conducted a within-subjects dart-throwing experiment with novice dart-throwers using their dominant hand. This time, the extraneous focus involved keeping a stable dominant hand while touching a curtain. This methodology was strategic, because it allowed the participant to focus internally (on their hand) or externally (on the curtain), but presumably did not increase the mental workload demands of the task. The other methodological strategy was to keep directions as similar in wording as possible. This was to ensure directions did not differ on other dimensions of focus like distance or width. This time, participants performed better when externally focused on the skill (dart flying toward target) rather than any other condition. These results support the notion that a skill-relevant FoA is important for novices, but also the notion that an external FoA promotes better performance overall.

The EMH explains that experts do not consciously think about the motor skill being performed, so they are able to complete a distractor task with ease. Indeed, relatively little mental effort is needed to complete a single task. However, novices generally perform more poorly when a secondary distractor task is introduced, because their attention is now focused on two tasks at once. It is possible that novice's poor performance in a dual-task condition is due to the fact that they are required to use more mental resources than the experts. For example, Diekfuss et al. (2016) determined that participants reported significantly less workload and demonstrated higher virtual target shooting performance during a dual-task that required an extraneous focus of attention compared to skill-focused attention. For this reason, researchers from the motor learning literature advocate using an extraneous (distraction) task that is comparable in presumed workload to the primary motor task (Russell, Porter, & Campbell, 2014; Wulf, 2013).

An important consideration in understanding this literature that has not yet been mentioned is to consider when performance is measured. Much of Wulf's work on direction of attention revolved around the concept of motor learning, meaning that, rather than testing performance, researchers often had participants practice a motor skill with a given set of instructions and then measured their performance at a later time to evaluate retention. In contrast, Beilock's work centers on performance in the moment rather than on learning. Both Casteneda and Gray (2007) and Russell et al. (2014) use a performance test rather than a motor learning test. Therefore, it is not yet known how the interaction of these focus dimensions impact motor learning. This is important because of insights it would provide for teaching novices how to focus while they learn a new motor task. The current study will aim to replicate and extend the study on motor performance by Russell et al. (2014) to determine the effects of the interaction between direction and relevance of focus on motor task learning. Further, the current study will expand upon the current research by addressing whether the results seen are mediated by a difference in participants' subjective mental workload, which may serve as a mechanism through which attentional focus affects the learning of a new motor skill.

Hypothesis 1: There will be a main effect of condition during acquisition blocks. Post-hoc tests will show the external, skill-relevant condition to have the best performance as compared to the other groups and will improve the most over the acquisition period.

Hypothesis 2: A main effect of condition will exist during the retention blocks. Post-hoc tests will show the external, skill-relevant condition to have the best performance as compared to the other groups.

Hypothesis 3: The effect of condition on acquisition performance will be mediated by perceived workload.

Hypothesis 4: The effect of condition on retention performance will be mediated by perceived workload.

CHAPTER II

REVIEW OF THE LITERATURE

Two primary bodies of literature address the question of how attentional focus affects performance and learning. Both bodies will be discussed to the extent that they tell us 1) how attentional focus affects performance and 2) how attentional focus affects learning of a new motor skill.

Direction of Attention Literature

Internal and external foci of attention fall under the dimension of *direction* of attention. There are two common paradigms for measuring the effectiveness of a particular direction of attention. Researchers looking at the immediate effects of a certain focus of attention (FoA) are measuring *performance*, whereas researchers looking at motor skill learning will measure *retention* after a delay. When measuring performance, researchers commonly use a within-subjects design in which the same participant attempts the motor task while using each type of FoA. This allows researchers to compare performance across the different FoA types without being concerned for differences between the groups. Studying retention is a bit more complex, however. To study how FoA affects how well an individual learns and retains a new motor skill, the participant must practice the new skill using only one type of FoA. Therefore, these experiments are almost always between-subject designs using novice participants.

Although experts could learn a new or different focus style, they would not be able to relearn the motor skill altogether to the extent that novices learn it. After a period of practice, the participant will return again to complete a retention task in which they are asked to complete the motor task once more without any further instruction. Tasks in which the result is easily measured are most commonly used in these studies, like dart throwing and putting, where the dart's or ball's final location can be measured from the target to get an average distance from the target rather than a simple hit-or-miss ratio. This design is simpler than measuring the impact point of a basketball when it misses the hoop, which would be impossible without a camera.

The experiments that launched the line of research regarding how direction of attention affects the learning and performance of a motor skill were conducted by Wulf and colleagues in the late 1990's (Wulf & WeigeIt, 1997; Wulf, Hob, & Prinz, 1998) and measured movement effectiveness. Researchers used a ski simulator and stabilometer, and participants were instructed to either focus on their feet (internal FoA) or the wheels (ski simulator) or platform (stabilometer) directly beneath their feet (external FoA). The control groups were given no instructions as they skied or balanced. After 2 days of practice, retention was measured on day 3. In both studies, participants' performance at retention excelled in the external focus condition above both internal and the control conditions, which did not differ. During acquisition, the internal-focus group actually lagged behind the control group. This experimental design used a learning paradigm, which shows that participants who learn a new skill using an external FoA will perform the motor skill more accurately during a delayed retention test than those being trained with internal focus instructions or no instructions.

Wulf has been a significant researcher on how direction of attention relates to performance and learning of a motor skill. In 2013, she wrote a review from which the organization of this literature review has been adapted. Wulf organizes the current research on attention into two primary categories, movement efficiency and movement effectiveness. Wulf credits Guthrie (1952) for characterizing skilled performance as requiring high levels of both of these categories. Movement effectiveness is related to the accuracy, consistency, and reliability of a movement. Movement efficiency refers to the ability to perform a movement fluidly and with relatively low effort. For example, a swing coach may define a successful golf swing by its form or effort required (efficiency) or by where the golf ball lands (effectiveness). These distinctions have been assumed to be related such that a more efficient movement may lead to a more accurate outcome, and if so suggests that the effect of attentional focus on motor performance is mediated by movement efficiency. However, this is not necessarily the case, and the current study focuses only movement effectiveness.

Movement Efficiency

Research on direction of attention has repeatedly demonstrated that an external FoA aids movement efficiency, or the degree to which movements are fluid and automatic and completed with relatively low effort. An efficient movement achieves the same outcome with less energy expended. Effort can be thought of as mental, as in the use of mental resources, or physical, as in energy expenditure. Kinematic changes have been studied with regard to direction of attentional focus by using cameras to analyze the differences in movements between participants who are focused on different aspects of the same task.

For example, An, Wulf, and Kim (2013) conducted a study that looked at kinematic changes in the golf swings of individuals who practiced using an external or internal FoA. The kinematic variables considered included X-factor stretch, which refers to the rotation of the shoulders relative to the pelvis during the golf swing, and angular velocities of the pelvis, wrist, and shoulders, all of which are greater in more experienced golfers. During the test period, novice participants who learned using an external FoA had a longer carry distance, greater X-factor stretch, and higher maximum angular velocities of the pelvis, shoulder, and wrist than the other participants, which the researchers determined to represent a more fluid movement. The internal focus and control groups performed similarly. These measurements were demonstrative of enhanced movement outcome and form, leading to a more effective "whole-body coordination pattern." However, it is important to note that although movement form is often assumed to be a result of body coordination patterns, this assumption is rarely empirically tested. Researchers have also made the jump to infer lower effort when kinematic data suggests greater fluidity. In a postural stability test, the external-focus group made smaller balance errors and responded to a secondary task faster and more frequently than the internal focus group, although it is hard to know whether the participants were able to follow the external focus instructions while completing the secondary task (Wulf, McNevin, & Shea, 2001). These results suggest that an external

FoA requires lower mental demands, reflected in greater ability to complete a secondary task while still performing better on the primary task. Further, a benefit for external attention is even seen in tests of movement preparation (Ille, Selin, Do, & Thon, 2013). In this study, sprinters instructed to focus externally had better reaction time and faster running times than the internal focus group. Other researchers have also found an association between external FoA and an improvement in speed and endurance (Fasoli, Trombly, Tickle-Degnen, & Verfaellie, 2002); Chen, Liu, Mayer-Kress, & Newell, 2005; Porter, Nolan, Ostrowski, & Wulf, 2010; Porter, Wu, Crossley, & Knopp, 2012), suggesting an improvement in movement efficiency.

Other researchers have used EMG to measure muscular activity during different tasks to demonstrate a benefit for external FoA on movement efficiency due to lowered high-frequency movement adjustments (McNevin, Shea, & Wulf, 2003); Wulf, Shea, & Park, 2001), lowered pre-movement times (Lohse, 2012), and other kinematic measures of automaticity (Vance, Wulf, Töllner, McNevin, & Mercer, 2004); Zachry, Wulf, Mercer, & Bezodis, 2005; Lohse, Sherwood, & Healy, 2010). Gradually, more research has come out regarding movement kinematics to test the different hypotheses about how an external FoA aids performance and learning. For example, asking rowers to focus on keeping the blade level versus their hands level resulted in greater technique improvements after seven weeks according to kinematic data (Parr, Button, MacMahon, & Farrow, 2009). Kinematic data is used to make inferences about whole body coordination, but a true test of movement coordination, a concept central to the CAH, has yet to be empirically tested.

The findings from these studies lead to the development of the Constrained Action Hypothesis (CAH), which states that an internal FoA leads to conscious control of a movement by interfering with quick, unconscious, reflexive motor system processes. An external FoA, however, may promote the self-organization of our motor system, or the coordination of muscle and nerve activation in order to optimize the motor movement to become more fluid while requiring less effort (Wulf, McNevin, & Shea, 2001; Wulf, Shea, & Park, 2001). The assumption is that better self-organization can lead to improved skill performance because effort not used to coordinate motor movements is freed up to be spent developing other aspects of performance. The above research on movement efficiency supports this hypothesis by providing evidence that movements are faster and more automatic when an individual is externally focused. Further support for the CAH is determined by evidence that skill-relevant aspects of an internal FoA that require self-monitoring are more detrimental to movement efficiency than more broad aspects that simply require observation. For example, researchers have shown (Schücker, Knopf, Strauss, Hagemann, 2014) that different types of internal focus differentially affect movement efficiency. They asked experienced runners to use a treadmill at a fixed speed of moderate intensity while they measured oxygen consumption. Participants were instructed to focus on internal aspects (either movement execution, breathing or the overall feeling of the body) or received no instructions. Those who focused on breathing and running movement experienced higher oxygen consumption than those who focused on a broad feeling within the body and those who received no instruction. They found a benefit to focusing more broadly on the overall feeling of the body rather than on the narrower, skill-relevant aspects of the task, breathing and leg movement. When only a broad sense of internal focus was maintained, the participant was able to avoid constraining the automaticity of their motor program. However, when asked to focus on skill-relevant aspects of the task, movement efficiency sunk.

Recent evidence has created a slightly less clear picture, however. Zentgraf and Munzert (2009) taught novices to juggle by focusing on the ball height (external) or their arms (internal). In this case, those in the control condition performed similarly to the externally-focused condition, while the internal focus group experienced worse performance. Wulf (2013) refuted these results stating that the instructions were not well-written and that participants actually successfully improved the aspect of the skill to which the directions were referring. Participants instructed to focus on ball height during juggling produced less variability in ball heights compared to those focused on their arms. Likewise, those told to focus on their arms had less variability in elbow displacement compared to those focused on the ball height. The results suggest that individuals will excel at the specific action they are instructed to focus on. Focusing on the balls themselves reduces variability in ball movement, but focusing on the arms reduces variability in arm movement. However, another recent study by Munzert, Maurer, and Reiser (2014) found similar kinematic outcomes when they measured the effects of switching from one focus direction to the other on both outcomes and kinematic measures in a golf putting task. They determined that individuals who first used an internal focus strategy and later switch to an external strategy experienced improved putting accuracy, though their movement kinematics remained similar. Those who used an external strategy first and then switched to an internal FoA actually experienced an improvement in movement kinematics but a decrement in performance. Lohse, Jones, Healy, and Sherwood (2014) also determined that an external FoA reduced variability in the outcome variable, while an internal FoA reduced variability in bodily movements. Based on these results, an internal FoA may aid movement efficiency more than an external FoA, meaning that movement efficiency is not related to movement effectiveness at all. If it is true that these two concepts are independent, it is possible that the types of instructions we would use for different performance situations would differ relative to which outcomes we are seeking: accuracy or fluidity. Therefore, it remains unclear if an external FoA is helpful in improving movement efficiency in addition to movement outcomes or effectiveness and if movement efficiency serves as a mediator to the effect of attentional focus on performance.

Movement Effectiveness

Although some recent has come out that contradicts the notion that movement efficiency is aided by external focus instructions, the bulk of earlier research has demonstrated that maintaining an external FoA generally leads to a more efficient movement, which supports the CAH. However, the majority of research on direction of attention measures motor learning or performance by measuring accuracy relative to a target. It is inferred through measuring the effect of an action how well the action was performed. A golf swing that looks beautiful but results in a miss or the golf ball flying out of bounds might be efficient in that it requires less physical and mental energy yet ineffective. A golf swing that is shaky and unattractive may still be effective if the goal of moving the golf ball closer to the target is accomplished. In this case, movement efficiency is less important to the success of a performer than is effectiveness.

Motor Learning

One of Wulf's first studies on attentional focus and motor skill learning considered movement effectiveness of a golf pitching task (Wulf, Lauterbach, & Toole, 1999). Novice participants practiced 80 pitch shots, while getting directions to attend to the arms during the swing (internal focus) or the club's swing (external focus). A day later they returned to perform 30 pitch shots without instruction. Those who learned this skill while focused externally performed most accurately on the retention task than those who focused internally.

In 2007, Wulf and Su conducted an additional experiment on FoA and golf pitch shot accuracy. This time, they analyzed both novice golfers and expert golfers. In the first experiment, novices completed a learning phase, being instructed to focus either externally or internally, or given no instructions at all. Although performance in the learning phase of the study did not differ significantly between the groups, as all groups improved similarly, the external FoA group excelled in the retention test, performing significantly better than both the control and internally-focused groups. It is important to note that in this learning paradigm, it is typical for participants to perform less accurately in the retention test than they did in the final phase of the acquisition test, so in this case, the external-focus group's performance dropped less than the other groups. The experts performed twenty pitch shots under each focus condition (internal, external, control) and again, the external condition resulted in better performance than both the internal and control conditions, which did not differ. In addition to showing the effectiveness of an external FoA on expert performance, this finding supports other studies showing the effectiveness of an external FoA on learning to hit golf pitch shots (Wulf, Lauterbach, & Toole, 1999) and has been replicated since (An, Wulf, & Kim, 2013). More experiments that studied movement (Al-Abood, Bennett, Hernandez, Ashford, & Davids, 2002) effectiveness during motor learning have been done with free throw shooting (Al-Abood et al., 2002), tennis serves (Wulf et al, 2002), volleyball (Wulf, McConnel, Gartner, & Schwartz, 2002), and force production (Lohse, 2012).

In addition to accuracy tasks like dart-throwing or putting, researchers have also shown that participants learn suprapostural tasks, like balance, best after practicing an external focus. Wulf and colleagues (2003) asked participants to balance a ball in a tube while standing on a stabilometer and focusing either on the ball inside or their own hands. After two days of practice in their assigned focus condition, participants who were focused on the ball (external FoA) performed best on the third day after receiving no additional instructions. These findings supported a previous research study done by Riley, Stroffregen, Grocki, and Turvey in 1999 on postural sway and the relevance of focus. In a stabilization task, participants were asked to touch a curtain with one hand. Participants who were told that they must minimize the movement of the curtain experienced less postural sway than those who were not told this touching task was important.

In support of an external FoA aiding motor learning, these effects have also been shown to generalize to novel situations (i.e. transfer tests) such as a new throwing distance (Wulf, Chiviacowsky, Schiller, & A'vila, 2010) or a different order of musical notes (Duke, Cash, & Allen, 2011). They have also been shown to be successful in tests under pressure (Bell & Hardy, 2009) or tests given with a distractor intended to prevent the participant from using their instructed focus at test (Totsika & Wulf, 2003; Wulf & McNevin, 2003).

Motor Performance

While many of Wulf's studies are focused on the benefits of an external FoA on motor learning, there is also evidence that an external FoA will aid performance immediately. For example, Wulf's 2002 study using tennis serves found a benefit of external FoA on the retention trials, but that group also performed best throughout the practice trials as compared to the other conditions. These studies are typically within-subject designs in which participants perform the same task using each of at least two (internal, external) or three (internal, external, control) focus conditions. In this case, the immediate benefits of an external FoA have been shown for tasks like badminton (Ahmadi, Kashef, Taghavi, & Borhani, 2012), dart-throwing (Lohse, Sherwood, & Healy, 2010), discus-throwing (Zarghami, 2012), free-throw shooting (Zachry, Wulf, Mercer, & Bezodis, 2005), gymnastics (Abdollahipour, Wulf, Psotta, Nieto, 2015), jump distance (Porter et al., 2010; Porter, Ostrowski, Nolan, & Wu, 2010; Porter, Anton, Wikoff, & Ostrowski, 2013) and height (Wulf, Zachry, Granados, & Dufek, 2007; Wulf & Dufek, 2009), keyboard playing (Duke, Cash, & Allen, 2011), and sprinting (Ille, Selin, Do, & Thon, 2013; Porter, Wu, Crossley, Knopp, & Campbell, 2015).

Aside from accuracy tasks like those listed above, an external FoA has also been effective at aiding better immediate balance on stability tasks (McNevin, & Wulf, 2002; Wulf, Mercer, McNevin & Guadagnoli, 2004). For example, Wulf and colleagues found that individuals with Parkinson's disease were better able to balance on a disk when instructed to focus on reducing the movements of the disk as opposed to focusing on their feet or without receiving instruction (Wulf, Landers, Lewthwaite, & Tollner, 2009). Additionally, a study by Porter, et al. (2010) found a benefit to an external focus of attention in an agility task in which participants completed 15 "L" run trials faster in the external focus instruction group as compared to the internal and control groups.

Conflicting Results

Although the majority of studies addressing direction of attention have shown a benefit for those focused externally versus internally, a handful have demonstrated conflicting results. Perkins-Ceccato et al. (2003) found a benefit for an internal FoA for novices, but their instructions did not adhere to Wulf's standards. The external instructions to focus on hitting the ball close to the target were perhaps too broad and distant to enhance performance. Further, the internal instructions were to focus on the form of the golf swing, which could lead to an internal or external FoA depending on the participant's interpretation. The results of this study, then, do not accurately test the effects of direction of attention in the first place because the methods are confounded. Lawrence, Gottwald, Hardy, and Khan (2011) found similar benefits for an internal FoA when they instructed participants to focus on exerting equal pressure on the support surface (external) or equal force on their feet *and* keeping their arms out straight and level with their shoulders (internal) during a gymnastics routine. However, Wulf (2013) argued that the instructions were not consistently relevant to the performance of all the different actions in the routine. Further, the internal instructions contained more than one point of focus (arms and feet). Examples like these demonstrate a need to be careful about wording focus instructions in such a way that they do not blend together different dimensions of focus, especially when those other dimensions have been shown to have a significant impact on performance.

Moderators

While the direction of attention during performance or learning of a motor task has been shown to have a significant impact on outcome variables, many studies have introduced other variables that might moderate this relationship. These variables need to be considered in designing new studies on this topic so as to avoid confounding the new experiment and provide a more complete understanding of how the effects of an external FoA can be generalized.

Distance

For example, distance is a well-established variable that moderates the efficacy of an external FoA. Wulf et al. (2000) instructed novice golfers to focus externally on something proximal (the club) or distal (the ball trajectory). In this case, a proximal distance of external attention resulted in more effective learning than the distal external FoA. The authors explained that focusing too far from the movements being produced can reduce the perceived connection between the movement and the movement effect. However, more studies have shown a distant point of external focus to lead to better performance than a proximal external focus. Bell and Hardy (2009) studied expert golfers' pitch shots, after dividing participants into slightly different groups. Groups were instructed to focus on the motion of their arms (internal), the position of the clubface through the swing (proximal external), or the flight of the ball after it had left the club face (distal external). For these experts, a more distant point of external focus was more effective in aiding performance than a proximal external FoA. Both groups who were externally focused still performed significantly better than the group focused internally. In a balance task, participants demonstrated better learning when focused on a marker across the room as opposed to one on stabilometer platform itself (McNevin et al., 2003). In another case, subjects practiced throwing darts using both proximal external focus instructions and distal external focus instructions before revealing their preferred strategy. Afterward, they were randomly assigned to only one strategy at test. Among participants who preferred to focus proximally, those assigned to focus distally still performed better than those assigned to focus proximally (McKay & Wulf, 2012). McNevin et al. (2003) hypothesized that an external point of focus too close to the movements producing them could become entangled with an internal point of focus. For these reasons, it is critical to ensure that the points of focus being studied are similar in distance from the participant. Distant points of external focus would be likely to exaggerate the effects of an external FoA as compared to an internal FoA. A distal point of focus is said to trigger the whole action pattern (Wulf, 2007) because control is coming from a higher hierarchical level (Vallacher & Wegner, 1987), consistent with the CAH. Wulf and Prinz (2001) sum up this effect of distance by recommending to the performer that the external point of focus be as far away as possible while still being closely related to the action that produced it. For this reason, common points of external focus are the ball, dart, or other object as it leaves the body. For example, focusing on the dart flying toward the dartboard is a movement effect that is closely related to the movement of letting go of the dart, but is less distant than focusing on the dartboard.

Focus Preference

The study by McKay and Wulf in 2012 also addresses a concern that positive effects of an external FoA is due in part to individual preference. Perhaps more people simply prefer to focus externally (possibly due to the greater movement efficiency that accompanies it), so participant performance is in line with their expectations given the way they're being asked to focus. However, studies like Wulf and Su (2007) show that participants in an external FoA often outperform those in the control condition (Wulf, Hob, & Prinz, 1998; Wulf & McNevin, 2003; Wulf, Weigelt, Poulter, & McNevin, 2003; McNevin & Wulf, 2002; Landers, Wulf, Wallmann, & Guadagnoli, 2005; Wulf, Landersr, Lewthwaite, & Tollner, 2009; Marchant, Clough, & Crawshaw, 2007; Porter & Anton, 2011). This would indicate that, given the opportunity to choose their own attentional focus, participants do not naturally choose an external FoA, or the control conditions would perform more similarly to the external FoA conditions. Researchers then set out to establish if participants had a better preference after explicitly experiencing both internal and external attentional focus styles. Marchant, Clough, Crawshaw, and Levy (2009) had participants swap from one direction of attention to the other during practice and then gathered their self-reported preference before randomly assigning them to a performance test instructed to either perform internally or externally. Still, even those who preferred an internal focus performed better when instructed to focus externally at test. Finally, even for participants who were told that an internal focus was more effective, an external focus still resulted in more effective performance (Lohse & Sherwood, 2011).

Generalizability

Research has shown that the positive effects of an external FoA can be generalized to multiple groups of people and task types. For example, although researchers have primarily demonstrated the effects of an external FoA in novices, some have also shown a benefit of an external FoA in experts (Bell & Hardy, 2009; Stoate & Wulf, 2011; Wulf & Su, 2007). Further, researchers have shown this effect to generalize to multiple age groups including children (Chiviacowsky, Wulf, Lewthwaite, & Campos, 2012); Thorn, 2006; Wulf, Chiviacowsky, Schiller, & A‘vila, 2010) and older adults (Chiviacowsky, Wulf, & Wally, 2010). Task complexity, and sex have also been suggested as possible moderators of the direction of attention effect (Becker & Smith, 2013; Emanuel, Jarus, & Bart, 2008; Wulf, Tollner, & Shea, 2007). Becker and Smith (2013) asked adults and children to learn a simple or difficult balance task and complete a retention test. In this case, an external FoA was only helpful (i.e. resulted in faster completion times at test) for males performing the complex balance task. Since no differences were found in performance of the simple balance task, the researchers suggested that tasks used to test this effect must reach a certain complexity threshold. Even then, they suggest only males were affected, possible due to baseline differences that were unmeasured or differences in motivation. However, no other researchers have reported gender differences in performance based on attentional focus style

Another interesting variable to consider is the feedback given to the learner. Shea and Wulf (1999) demonstrated that concurrent feedback given to an individual during a balance task aided performance beyond an external focus alone. In fact, there was a main effect of feedback in which regardless of focus direction, participants receiving instant feedback were steadier than those who did not see feedback. Importantly the feedback interacted with the FoA in that the feedback group asked to focus externally performed better than the feedback group focusing internally. This means that in order to avoid confounding the results regarding direction of attention, feedback in general should be avoided, as it may serve more useful to the externally-focused participants than the internally-focused ones.

One study has also combined width of focus with direction of focus. Becker and Smith (2015) noted the abundance of internal focus cues given by strength coaches when working with athletes and examined whether a broad internal focus would promote better performance as compared to a narrow internal focus. However, performance among those who were told to use their legs, a broader FoA referring to the knees, ankles, feet, and calves, performed equally well as those told to extend their knees, a narrower FoA. In the end, those told to focus on jumping as far past the line as possible (external) performed the best of all the conditions. Further research on the interaction between width and direction of attention has yet to be done.

Mechanisms

Not long after a simple change in FoA was shown to cause a significant change in performance and motor learning did researchers start looking to determine the mechanisms to explain the effect. Although the CAH is the primary hypothesis for how FoA affects the motor system, it has also been suggested that the mental demands are lower while maintaining an external focus rather than an internal focus (Wulf, McNevin, & Shea, 2001), suggesting another mechanism that explains the connection between FoA and motor performance. These researchers used reaction times to an unrelated stimulus to measure attentional demands required under both internal and external focus conditions on a stabilometer. They found that participants in the external focus condition were able to respond to a stimulus more quickly than those in the internal focus condition, suggesting that the external condition was less demanding. However, different results have been found in subjective report of mental demands. Marchant, Clough, and Crawshaw (2007) conducted a dart-throwing study in which participants reported perceived mental demands required to follow instructions. The group given no focus instructions subsequently rated their experience as easier and less mentally demanding than participants in the internal or external conditions. Although the internal and external instructions were rated equally demanding, participants rated the external instructions as more successful than the internal instructions. Indeed, the external and control groups outperformed the internal group in dart throwing accuracy. The results on studies related to workload have shown mixed results. However, research on workload and attentional demands has been studied in more depth in the skill-focus literature, as compared to the literature on direction of attention, where there is evidence that workload demands mediate the relationship between expertise and focus style on performance of a motor skill (Diekfuss, et al., 2016). Currently, perceived workload is not considered to be part of the CAH, but if it does, in fact, mediate the relationship between FoA and performance, then it would be a worthwhile addition to the current understanding of the mechanisms through which attentional focus affects motor learning and performance.

Effect of Movement vs. External Distractor

One consideration relative to Wulf's findings with regards to external attention is whether an external focus on the effect of one's movement really aided performance over and above a simple lack of internal focus. For example, is it important that a person focuses on an effect of their movement (e.g. the swing of the golf club) or do they just need to avoid focusing internally (e.g. on the swing of their arms)? In one study, novices were taught a forehand tennis stroke and practiced hitting tennis balls toward a target across the court (Wulf et al., 2000). While everyone was focused externally, one group focused specifically on the effects of their movements (i.e. the ball flying away from their target after impact), while the other group focused on an external cue that was not the effect of their movement (i.e. on the ball flying toward them). The group instructed to focus on the effect of their movement on the ball flying away from them performed more accurately than the group instructed to focus on antecedents. This shows that an external FoA is not in and of itself critical to performance. What matters is the focus on the *effect* of an individual's movement, a point within their control. Another way to describe this effect would be that the external point of focus still has to be skill-relevant. An extraneous external distractor was not as successful as an external, skill-relevant point of focus in the novice participants.

Summary

In sum, well-designed studies analyzing the effects of direction of attention have consistently shown a benefit for an external FoA and only a handful of studied have ever shown null effects of FoA on performance. These beneficial effects have been established in motor learning as well as motor performance in both novices and experts, children and adults. Further, the effects are seen in both movement efficiency and movement effectiveness. Even when participants prefer an internal focus or expect it to help them, an external FoA typically proves more helpful to performance. In the few cases where conflicting results have been found, these results can presumably be explained by unideal methodology and wording in the instructions. However, these confounds relate to another well-studied dimension of attentional focus: skill-relevance.

Skill-Focus Literature: Focus Relevance

While the FoA literature has established a benefit for an external FoA, other researchers were conducting similar research with a different question. Instead of asking, “How does our focus affect our performance?,” researchers were asking, “Why do individuals choke under pressure?” This literature is relevant to the extent that it address a different dimension of attentional focus effects on performance. However, the research from this field is usually concerned with how attention shifts under pressure, relating to episodes of choking. Beilock (2007) describes choking as subpar performance outcomes given a person’s skill level. For example, a professional basketball player missing free throws when they usually demonstrate a high free throw percentage in practices and other games. Hill and colleagues (Hill, Hanton, Matthews, & Fleming (2010) add that a drop in performance must be accompanied by a person's perception that the situation is demanding and that his or her cognitive resources are insufficient to meet those demands (i.e. a high pressure situation). Wulf (Wulf, 2013; Lewthwaite & Wulf, 2010) addressed choking under pressure as well, tacking on a concept to her CAH. She suggests that an internal focus triggers self-evaluative processes that result in an excess of self-regulation during a time when automatic performance is most critical, leading to "micro-choking episodes."

Attentional Theories

Attentional theories have been used to explain how one's FoA can lead to a breakdown in performance, especially during instances of high perceived pressure to perform well. These theories address what the athlete is thinking about and focusing on during a choke. The first attentional theory for discussion here is Processing Efficiency Theory (PET), developed by Eysenck and Calvo in 1992. PET states that the thoughts associated with an athlete's high-pressure situation utilize a portion of her working memory capacity alongside any thoughts required for skill execution. Essentially, these thoughts increase the demands on her working memory system from those of a single-task condition to those of a dual-task condition, leading to processing inefficiency. If too much of the working memory is overloaded, the athlete will need to sacrifice mental resources dedicated to performing the task and experience a drop in performance. However, this theory does not describe where the athlete's attention is directed during the presumably poor skill execution (i.e. the choke). Further, the theory fails to describe how these choking episodes take place in experts.

The second attentional theory, as previously described, is Beilock and Carr's EMH, which that experts become self-conscious in high-pressure situations and attempt to deal with it by thinking explicitly about the task. Fitts and Posner (1967) demonstrated that experts in a task have developed that skill to the point of automaticity, characterized by the lack of conscious processing during task execution. They do not require the use of their working memory to complete the task, but rather their procedural, implicit memory system. The EMH states Masters (1992) used the notion of "reinvestment" of conscious processing to refer to this tendency to shift one's focus away from the automatic and implicit to the deliberate and explicit. Explicit focus includes rule-based thoughts (e.g. "keep the arm straight, rotate the shoulders") and involve consciously monitoring how the skill execution feels. Ironically, this coping strategy is commonly encouraged by coaches who say, "just focus on the stroke," or "make sure you follow-through on this shot." By calling attention to the imminent task, athletes will focus on the parts of their movements they usually do not think about and process their actions through their working memory, just as a beginner would. Novice performers are able to maintain performance under highly self-conscious and self-focusing conditions because this systematic, rule-based thinking is natural and necessary when one is first learning a task (Masters, 1992; Beilock, Carr, MacMahon, & Starkes, 2002).

This hypothesis is generally tested using dual-task methodology. To demonstrate these dual-task methods, it is useful to expand upon a study mentioned earlier by Beilock, Carr, MacMahon, and Starkes in 2002. These researchers conducted two studies with golfers and soccer players to illustrate this difference in how experts and novices respond to skill-focused attention. In experiment 1, participants in the skill-focused condition were asked to monitor the swing of the golf club head and call out when it came to a complete stop after follow-through. In the dual-task condition, participants were asked to respond to a specific pitch while hearing tones of varying pitch. In experiment 2, participants were asked to respond to which side of their foot was in contact with the ball at the time a tone was sounded. Participants in the dual task condition were instructed to respond to a target word while listening to a series of words over a speaker. Novices in both studies performed better in the skill-focused condition than in the dual task condition. In contrast, the participants who had a well-learned skill performed better when completing the unrelated task as opposed to the skill-monitoring task. Novices presumably chose to focus on their skill execution in addition to the distractor task, which overloaded their working memory and resulted in a breakdown of performance. According to the EMH, experts were not naturally thinking about task execution. Therefore, when asked to perform an unrelated task, their performance was less affected; they were only paying attention to the counting and the performance was occurring automatically. However, when asked to monitor their performance, they had to think about the skill that is normally automatized by reinvesting their attention, which resulted in a decrease in performance. Similarly, when the soccer experts were asked to switch from dribbling with their dominant foot to their non-dominant foot, their performance was no longer automatic, so they performed just like the novices, excelling in the skill-focus condition and struggling in the dual task condition. The novices, not being accustomed to dribbling with either foot, did not change their performance patterns when asked to switch feet, they continued to excel in the skill-focus condition and struggle in the dual task condition. The results of the prior experiment demonstrate that self-focus does not simply serve a distraction role in athletic performance, which provides support for the EMH over the PET.

In sum, dual task paradigms show that expert skill execution is automatic because distracting experts by asking them to focus extraneously does not break down their performance. Although novice performance is not affected by tasks that require a skill-relevant focus, expert performance is. According to the EMH, experts who are asked to focus on skill execution are forced to reinvest their attention into a motor skill that is already automatic. The act of breaking down what was an unconscious task into a conscious one results in a performance decrement. Experts who reinvest their attention in the task at hand in response to heightened stress are then susceptible to episodes of choking.

Dispositional Reinvestment

An important concept in the EMH is that performers who normally focus elsewhere during motor performance reinvest their attention into the motor skill execution. It follows that individuals who have a tendency to focus on her skill execution in times of heightened arousal or stress may be more susceptible to choking behavior. Masters, Polman, and Hammond (1993) dubbed this tendency ‘dispositional reinvestment’ and developed a measure to evaluate a person’s propensity to reinvest.

Indeed, the researchers found a negative correlation between Reinvestment Scale scores and performance under pressure among participants in a golf-putting task. They concluded that individuals that scored high in reinvestment were more prone to choking under pressure. Soccer players who scored high in dispositional reinvestment also reported greater somatic anxiety and lower confidence after a heightened pressure manipulation and subdequently acknowledged worse performance in a wall volleying task than those who scored low on the reinvestment scale (Chell et al., 2003). Reinvestment scores have also correlated with poorer performance after a high pressure manipulation in peg-board motor tasks, putting tasks, and arithmetic tasks (Kinrade, Jackson, & Ashford, 2010). In a test on surgical efficiency, low reinvestors were able to speed up their performance to meet the demands of a time limit, while high reinvestors performed at the same speed both before and after the pressure manipulation, even though both groups experienced an equal increase in state anxiety (Malhotra, et al., 2012). Jackson, Ashford, and Norsworthy (2006) conducted two experiments with field hockey and soccer players to investigate this effect further. They found that experienced players who were also high reinvestors tended to perform worse under high-pressure conditions than their low investor peers both when left alone and when given a distraction task (e.g. counting backwards). This tells us that experienced players who are naturally high reinvestors are especially likely to choke under intense pressure. However, the high and low reinvestors performed very similarly when given a self-focus task. This somewhat surprising finding suggests that the skill-focused task, though the most detrimental to performance, was not moderated by reinvestment.

Dispositional reinvestment has also been hypothesized to affect experts more than novices. Poolton, Maxwell, and Masters (2004) found that individuals who have high explicit knowledge regarding how to perform a skill may be more likely to reinvest their attention to that knowledge in times of high stress. They used structural equation modeling to demonstrate a directional association starting at the accumulation of explicit knowledge leading to a higher reinvestment score ending in performance under pressure. Furthermore, all participants improved slightly when given a distraction task. It is important to reiterate that although reinvestment seems to be detrimental to experts, most novices who maintain focus on skill execution can benefit from the attention to their movements when attempting to improve at a task.

Working Memory

According to attentional theories of choking, working memory overload leads to inefficient processing of information necessary to perform a skill at optimal levels. It naturally follows that individuals who have a larger working memory capacity may be more resistant to choking behavior caused by an "overfilled" working memory. However, in 2005, Beilock and Carr demonstrated that it was actually the individuals with high working memory who choked under pressure, while those low in working memory performed equally well in high- and low-pressure situations. The researchers explained that individuals with a high working memory capacity (WMC) generally outperform their peers. Therefore, when high amounts of pressure consume the working memory capacity usually relied upon to succeed, their advantage disappears. Gimmig, Huguet, Caverni, and Cury (2006) extend these findings and make a strong claim that *only* individuals high in working memory experience will choke in high-demand tasks. They tested the WMC of 67 undergraduates and found that those high in working memory expected to perform better in the tasks of fluid reasoning. They then manipulated pressure by explaining to one group that the test was intended to be diagnostic the person's analytic reasoning skills. The high WMC participants in the high-pressure condition performed significantly worse than those in the low-pressure condition, while the low WMC participants did not experience this performance decrement. In addition, the high WMC individuals reported higher state anxiety in the high-pressure condition than their low WMC counterparts did. Additional research has been able to replicate these findings showing that high WMC individuals were more likely to choke under pressure (Beilock, Kulp, Holt, & Carr, 2004; Kane & Engle, 2000; Smeding, Darnon, & Van Yperen, 2015). Further research could shed some light on the generalizability of these findings in other experimental designs and could help us predict a person's vulnerability to choking.

Summary

Instances of choking under pressure have led to a substantial amount of literature attempting to model what individuals are focused on during a choke. The performance decreases following certain focus conditions are presumed to mimic those experienced during a choke. Therefore, experts focus on something skill-relevant during a high pressure situation may experience a drop in performance, or a choke. Likewise, novices who are focused on a secondary task in addition to the primary task will also show decreased performance. Further, individuals who have a high working memory and are high in dispositional reinvestment may be more likely to experience a drop in performance in a high pressure situation. However, even without a pressure manipulation, the relevance of focus dimension itself is sufficient to impact the effectiveness of an individual's movement. For this reason, researchers can potentially measure this focus dimension in combination with other focus dimensions in order to evaluate how they might interact to affect performance and retention.

Merging the Fields

There have been two major attempts to combine what we know about the benefits of an external FoA on motor learning and performance and the benefits of a skill-relevant focus to novices. Wulf and Lewthwaite (2010) acknowledge the application of attentional focus as an explanation for choking under pressure and amended their CAH to address this. After finding that participants given feedback that their performance exceeds false norms were more successful in learning a new motor skill, Wulf and Lewthwaite (2010) suggested that internal focus cues trigger self-evaluative and self-regulatory thoughts. These thoughts relating to one's self-schema lead to conscious control of movements as well as competition for mental resources, referred to ask the self-invoking trigger hypothesis (SITH). In Wulf's 2013 review, she describes that micro-choking episodes are due to internal cues activating the self-schema. McKay, Wulf, Lewthwaite, and Nordin (2015) tested this hypothesis and found that participants asked to self-reflect on their performance between blocks showed poorer performance and learning of motor skills. On the other hand, Jauregui (2015) conducted a similar experiment but was unable to replicate the findings. Still, this hypothesis reflects another possible explanation as to why novices may perform more poorly when asked to focus internally. In fact, the SITH relates closely to the reinvestment explanation used by Masters (1992) credited for how experts are triggered to explicitly monitor their performance (EMH), resulting in performance degradation. In both lines of research, degraded performance due to the use of the “wrong” style of attentional focus is due to a breakdown in the automaticity of a motor skill execution.

Currently the two lines of research on choking under pressure and direction of attention on motor learning have been studied independently, however there are enough similarities to look at them together. Skill-relevant attention is hypothesized to affect performance similar to an internal direction of. Both EMH and CAH consider the way FoA can alter what are normally automatic motor processes. However, when it comes to novice performance, these two hypotheses conflict.

Nonetheless, researchers have conducted only a couple of studies that actively attempted to use what we know from both these strong bodies of literature to form a more complete hypothesis for how FoA affects performance and learning. The first of these studies was conducted by Castaneda and Gray in 2007. Because both researchers examine skill-focus, a dual-task paradigm was used to compare direction and skill-relevance of attention. Results show that novices in both of the skill-relevant conditions (internal and external) performed better than those in either of the extraneous focus conditions. However, it has been noted that any task performed under dual-task conditions may require more mental resources and generally increase the demands of the task (Casteneda & Gray, 2007; Russell et al., 2014). The increased demands may affect novices and experts differently. In fact, a new study shows the relationship between skill level and performance is mediated by workload (Diekfuss, et al., 2016). Another study with the same goals of comparing the EMH and CAH was conducted by Russell, et al. (2014), but they used the typical methodology from the direction of attention literature that Wulf would support. Instead of the dual task paradigm, they used an extraneous task that was presumed to be similar in workload to the primary dart throwing task, and the attentional focus instructions differed by only a few words. In this case, they found that novices threw darts more accurately when their focus was external and skill-relevant. However, this study was within-subjects and focused on immediate performance. Typically, Wulf and colleagues use a learning paradigm wherein subjects practice a new skill under certain focus instructions and return later for a retention test with no instructions. The purpose of this study adapts the methodology of the Russell et al. (2014) study under a learning paradigm rather than a performance one. Using a between-subjects design to extend their findings to determine whether an external, skill-relevant FoA will aid retention as well as immediate performance. Further, subjective workload demands will be assessed in order to determine any perceived differences amongst these four distinct conditions: external skill-focus, internal skill-focus, external extraneous focus, and internal extraneous focus.

CHAPTER III

OUTLINE OF PROCEDURES

Participants

Eighty undergraduates recruited from kinesiology courses at the University of North Carolina, Greensboro participated in this experiment (*M* age = 22.5, s = 4.92 years). Participants were all novice dart throwers who fit the criterion of having thrown darts on fewer than five occasions (Radlo, Steinberg, Singer, Barba, & Melnikov, 2002); Marchant, Clough, & Crawshaw, 2007). This was verified on the demographics questionnaire. Further, all participants ranked their dart-throwing experience on a Likert scale of 1 (no prior experience throwing darts) to 10 (a large amount of prior experience) and the average experience was reported to be # (s = 1.56). Before participation in the study, all volunteers signed an informed consent, which was approved by the University's Institutional Review Board along with all of the experimental procedures.

Instrumentation

Subject demographics and prior experience in dart throwing was assessed by self-report. The primary measure of performance used was the linear distance from the tip of the dart as it rests on the dartboard to the center of the dartboard. The dartboard was a competition-grade bristle dartboard hung at regulation height (1.73 m from the ground). Participants stood at regulation throwing distance (2.37 m from the dartboard), as defined by the British Dart Organization. Participants used regulation-grade 22-g steel-tipped darts for all throws. Distance from the center in millimeters was measured using a tape measure.

Workload was assessed in each condition in order to determine whether performance differences found between focus groups were mediated by workload differences. The National Aeronautics and Space Administration-Task Load Index (NASA-TLX; Hart & Straveland, 1988) is a self-reporting tool developed by the Human Performance Group at NASA Ames Research Center and has been shown to have good reliability and structural validity (Xiao, et al., 2005). It is used to measure task load via a series of six sliding-scale questions (between 0 and 20) asking the participant to rate difficulty and stress level during the task (e.g. “How hard did you have to work to accomplish your level of performance?”). Each question is used as a subscale measuring the following: mental demand, physical demand, temporal demand, performance, effort, and frustration. The average rating on all subscales offers a measure of overall perceived workload. This scale has been used by a number of other studies regarding participant performance (Prinzel, Pope, & Freeman, 2001; DiDomenico & Nussbaum, 2008; Recarte, Perez, Conchillo, & Nunes, 2008; Schmutz, Heinz, Métrailler, & Opwis, 2009).

Procedure

Participants were randomly assigned to one of four experimental conditions: skill-focus internal, skill-focus external, extraneous internal, or extraneous external. The primary experiment was completed by the participant with their dominant arm. Prior to the start of the experiment, all participants were told that their overall goal for each trial was to throw the dart as close to the center of the dartboard as possible and that darts will be scored by their distance from the center, not the points on each section of the board. The instructions used were adapted from Russell et al. (2014), which required the participant to place his or her non-throwing hand on a curtain near the dartboard. This task was used to instruct extraneous foci of attention, while not interfering with performance on the primary task.

During their first visit, participants completed the demographics form. They were informed about the primary and secondary tasks and instructed to approach the line marking 1.73m from the dartboard. Prior to the specific instructions, all participants, regardless of condition, were told to make contact between their non-throwing hand and a curtain hanging next to their throwing location. They were all told, "Today, you will be throwing a number of darts while following a specific set of instructions. When throwing the dart we ask that you always try to be as accurate as possible and aim for the center of the bulls-eye. Please listen carefully to all instructions and do your best to follow them as closely as you can." Each participant was given four familiarization trials before any specific attentional instructions were given. Participants then performed 5 blocks of 10 throws under their assigned condition. In previous research, participant performance during acquisition reaches a plateau after about 20 throws (Lohse, Sherwood, & Healy, 2010; Marchant, Clough, & Crawshaw, 2007). However, because this study is focused on the learning process (including acquisition and retention), more trials were used to maximize the learning effect. Participants paused after each throw to allow the experimenter to measure their result. No feedback was given by the experimenter at any time. After every 10 throws, participants completed a compliance check in which the researcher asked the participant what he or she was focused on for the last 10 throws and recorded the response. Regardless of how the participant responded, he or she was always reread the instructions before proceeding to the next block. The same condition-specific instructions used in the study by Russell et al. (2014) were used in the current study. During the external skill-focus condition, participants were instructed to “focus on the flight of the dart to the dartboard.” In the internal skill-focus condition, participants were asked to “focus on the motion of your throwing arm.” In the external extraneous condition, participants were instructed to “focus on minimizing the movement of the curtain.” Finally, in the internal extraneous condition participants were instructed to “focus on minimizing the movement of your non-throwing hand.” Immediately upon completion of the acquisition trials, participants completed the NASA-TLX.

Participants returned 48 hours after completion of the learning period to complete the retention task. As in Wulf and Su (2007), participants performed 10 trials without instructions. The retention task consisted of two blocks of 10 trials, both without instructions. The curtain was hung up for the first retention block, but removed for the second retention block. After each retention block, participants completed the NASA-TLX.

Data Collection and Analyses

Participant performance was measured in millimeters from the center of the dartboard. Perceived workload was measured using the total average score from the six subscales of the NASA-TLX. Corrected statistics are reported using a Greenhouse-Geisser adjustment if sphericity violations were violated.

Hypothesis 1 was tested using a 4 (condition) by 5 (acquisition trial block) ANOVA. If a main effect of condition was present, Bonferroni post-hoc tests were done to assess which conditions are different from one another.

Hypothesis 2 was tested using two one-way ANOVAs to test for significant differences between conditions for retention block 1 and retention block 2. Additionally, a 4 (condition) by 2 (Acquisition Block 5, Retention Block 1) ANOVA was conducted to determine if differences existed between retention performance relative to performance at the end of the acquisition phase. If any main effects were present, Bonferroni post-hoc tests were done to assess which conditions are different from one another.

Hypotheses 3 and 4 were only examined if Hypotheses 1 and 2 were supported and there were significant differences in TLX subscale scores between the groups, as determined by a separate 6 (TLX subscale) x 4 (condition) MANOVA conducted for each time point the NASA-TLX was completed: at the end of the acquisition phase, after the first retention block, and after the second retention block. To test for mediation, regression analyses were conducted to determine whether some of the variance in the relationship between FoA and performance (retention) is explained by perceived workload (NASA-TLX scores).

CHAPTER IV

RESULTS

Eighty-two individuals participated in the study. Of those, three reported throwing darts more than five times, three missed the dartboard and surrounding foam more than 10% of the time (resulting in additional trials), and one individual had an acquisition average greater than three standard deviations above the overall average; for these reasons, these seven participants were excluded from all data analyses. Four individuals did not return for the second visit. Therefore, 75 individuals were included for data analysis for acquisition trials, and 71 were included for data analysis regarding retention trials (see Tables 1 & 2 for descriptive data).

Table 1. Participant Demographics and Acquisition Phase Data.

Condition		**Age**		**Self-Rating**		**Acquisition Trials**	
	N	Mean	SD	Mean	SD	Mean	SD
External-Skill	18	23.44	6.64	3.00	1.50	9.44	2.82
External-Extraneous	20	21.70	3.50	2.35	1.50	9.75	2.71
Internal-Skill	17	21.35	3.57	3.35	1.73	9.28	2.62
Internal-Extraneous	20	22.50	5.40	3.60	1.35	9.37	2.53
Total	75	22.25	4.92	3.07	1.56	9.47	2.62

Note: Participants (n=75) were randomly assigned to groups and, after exclusions, resulted in the following distribution of participants in each of the four conditions with the corresponding averages and standard deviations for age, self-rating of dart-throwing expertise, and acquisition performance (distance from the center of the dartboard).

Table 2. The Distribution of the 71 Eligible Participants for the Analyses Involving Retention Trials.

Condition	N	**Retention Trials** Mean	SD
External-Skill	18	9.78	2.77
External-Extraneous	19	9.91	3.14
Internal-Skill	15	9.53	4.21
Internal-Extraneous	19	9.10	2.61
Total	71	9.58	3.13

For the 75 individuals included in acquisition analyses, the average age was 22.25 years (s = 4.92 years), and the ages between the groups did not significantly differ, $F(3,71) = 0.63$, $p = .60$. The average self-reported skill level was 3.07 out of 10 points (s = 1.56 points), showing that participants generally believed themselves to have low dart-throwing skill. However, there was a nearly significant difference between the groups in terms of their self-rated expertise on a scale of 1-10, $F(3,71) = 2.523$ $p = .06$ (see Table 1).

Performance Compared Over Time and Across Conditions

<u>Hypothesis 1</u>

The main effect for condition was not significant, F(3,71) = 0.11, $p = .95$. There was a main effect of trial block, $F(3.57,253.61) = 6.18$, $p < .001$, partial $\eta^2 = .08$. To follow-up this significant main effect, post-hoc analyses were conducted with a Bonferonni adjustment. These tests determined there were significant differences in performance from the first block to the fourth block, t(74) = 3.93, $p = .002$ and from the first to the fifth trial block, t(74) = 4.20, $p = .001$ (see Figure 1). There was no significant interaction between acquisition block and condition, $F(3.57,253.61) = 0.83$, $p = .61$.

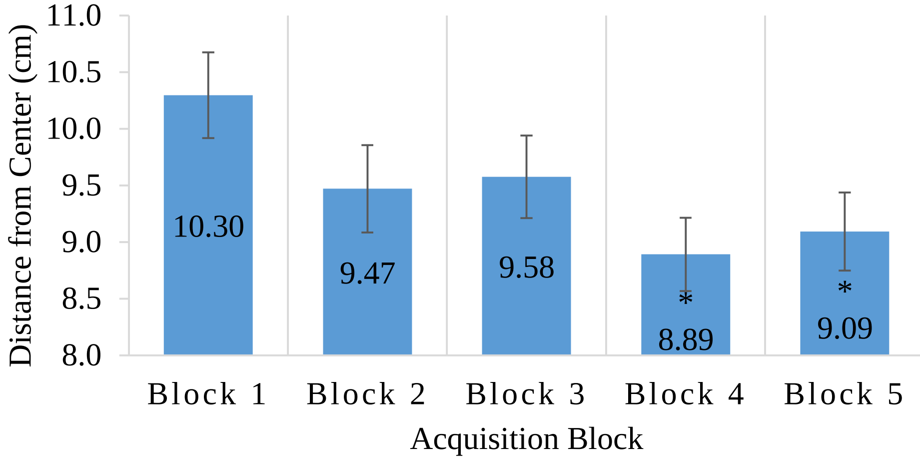

Figure 1. Overall Acquisition Performance throughout the Five Blocks of Ten Throws Each. An asterisk (*) represents a relationship to Block 1 that is significant at the .01 level.

Hypothesis 2

See Table 2 for number of participants per condition during retention blocks. The difference in performance in retention block 1 as a function of condition was not significant, $F(3,67) = 0.21$, $p = .89$. The same analysis was conducted for retention block 2, after the curtain was removed, and was also not significant, $F(3,67) = 0.18$, $p = .91$. Both these analyses were repeated while controlling for 5th acquisition block performance, but did not produce any substantive change in the results.

There was a significant main effect of block from acquisition block 5 to retention block 1, $F(3,67) = 8.77$, $p = .004$, partial $\eta^2 = .12$ (see Figure 2). This main effect indicates that all participants performed worse at the first retention test than they did at the end of their learning period. There was no significant main effect of condition, $F(3,67) = 0.17$, $p = .92$. The interaction between condition and block was not significant,

$F(3,67) = 0.82$, $p = .49$, meaning that there was no difference between the groups in the amount of performance degradation over the delay.

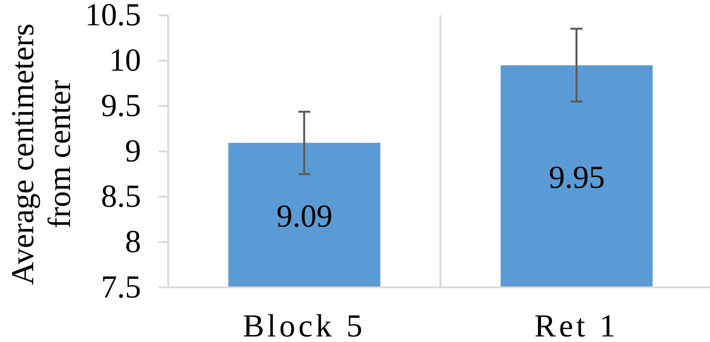

Figure 2. Change in Performance from the End of the Acquisition Period to the Retention Period. Participants showed a significant decrease in performance after a 48-hour delay.

Hypothesis 3 and 4

TLX subscale scores did not differ between the groups, $F(18,187.16) = 1.04$, $p = .42$, demonstrating that participants rated the conditions as equally demanding (see Table 3 for subscale comparisons). Because there were no significant differences in TLX subscale scores between the groups, mediation analyses were not conducted.

Table 3. TLX Subscale Comparisons between Conditions.

Subscale	**F (3,71)**	***p***
Mental Demand	0.84	.48
Physical Demand	1.16	.33
Temporal Demand	1.08	.36
Performance Success	1.24	.30
Effort	0.16	.92
Frustration	2.20	.10

Note: In all ratings, participants considered each condition equally demanding regardless of condition.

Repeated Analyses Using Self-Rating as a Covariate

With the included sample (n = 75), average acquisition distances were significantly and negatively correlated with self-reported expertise, $r = -.37$, $p < .001$ (see Figure 3). For this reason, previously-reported analyses were also conducted using self-reported expertise as a covariate. However, analyses with the covariate did not result in any substantive change in the results.

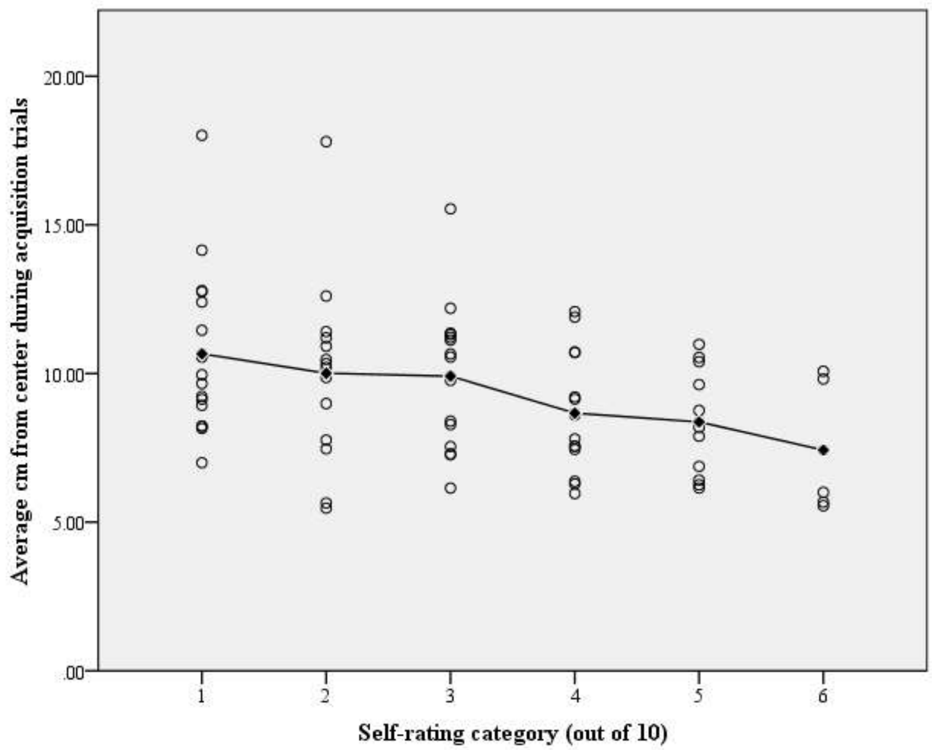

Figure 3. Self-Rating and Acquisition Performance. The relationship between subject self-rating and average acquisition performance as measured by distance from the center of the dartboard in centimeters, r = -.37, p < .001.

CHAPTER V

DISCUSSION

The purpose of this study was to identify whether a combination of external and skill-focused attention could be more beneficial to skill acquisition and retention than any other combination of direction and relevance of attention and whether the difference in performance between the conditions is mediated by differences in workload, as measured by NASA-TLX scores. This discussion will cover each hypothesis as well as the two primary findings.

The current study differs from past literature comparing the CAH to the EMH in a few important ways. The first is that Casteneda and Gray (2007) utilized a dual task paradigm in which the workload demands experienced by the experts and novices presumably differed between the conditions. Past literature has shown that workload demands as measured by the NASA-TLX do differ between subjects in a dual task virtual shooting experiment (Diekfuss et al., 2016). Considering that different workload demands may differentially affect novices and experts, Russell, Porter, and Campbell (2014) identified this as a limitation of the Castaneda and Gray study and used a study design that was intended to balance workload between conditions. However, these researchers did not measure workload demands to determine whether their study design was successful. Russell et al. (2014) also used a within-subjects design that participants completed in a single visit. The present study used a between-subjects design and recruited participants using a stricter criterion to ensure only truly inexperienced dart-throwers participated. These participants threw 50 darts under a single condition as compared to 120 darts divided among the four conditions in the earlier study and also returned for a retention test 48 hours later. Finally, workload demands were measured in the current study but not in either of the aforementioned studies.

The first hypothesis proposed a main effect of condition would exist over the course of the acquisition period such that participants in the external, skill-relevant condition would score more accurately than those in any of the other conditions. Although all participants were successful in learning the motor skill, as evidenced by a significant main effect of trial block, this hypothesis was not supported because there was no significant interaction between the groups over the trial blocks, suggesting that each condition improved an equal amount over the five blocks. This finding conflicts with prior research by Russell et al. (2014) that found that participants performed best after receiving the external, skill-relevant instructions compared to any of the other four conditions. That study, however, used a within-subjects design whereas the current study was between subjects. Further, the current study measured workload demands, which were shown to be rated comparably between the four conditions. This lack of a significant difference between conditions during acquisition performance is consistent with the hypothesis that differences in workload demands would mediate the effects of focus of attention on performance. Therefore, a lack of workload demand differences would lead to equivalent performance between focus conditions. The second hypothesis was that the external, skill-relevant focus group would perform the best during the first and second retention blocks. This hypothesis was also not supported. Each condition performed equally well during the retention blocks. Further, there was a significant main effect of block from acquisition block 5 to retention block 1, suggesting that there was no difference in the skill retained over the delay as each condition experienced an equal degradation in performance at the first retention block as compared to the final acquisition block.

The third and fourth hypotheses suggested that any difference seen in performance would be mediated by perceived workload. No differences in performance were seen between the conditions at any of the acquisition or retention blocks. Therefore, mediation analyses were not conducted because there were no differences between groups to explain using workload scores. However, there was also no evidence against these hypotheses. If workload differed between the groups and performance did not, then the hypothesis would be unsupported. However, in this study, there were no differences in any of the NASA-TLX subscale scores between conditions, demonstrating that participants in each condition rated the workload demands to be about the same. This finding is not surprising, given the aims of the methodology were to minimize demand differences between groups. The methods were adopted from Russell et al. (2014) in an attempt to use conditions that combined two dimensions of focus into four equally-demanding conditions. Criticisms of past dual-task literature on the skill-relevance of focus during performance of a motor task included the idea that a dual-task condition could be more demanding than a single-task condition, and that those demands would differentially affect novices and experts. Indeed, the NASA-TLX subscale averages seen in a dual-task study that also measured workload were higher (about a 12 out of 20) than the ratings seen in this study (about 8 out of 20), suggesting that the dual-task design is perceived to be more demanding (Diekfuss, Ward, & Raisbeck, 2016). Therefore, since the workload demands did not differ between the groups in this study, the chosen methodology was successful, and the lack of workload differences could explain the lack of performance differences as well. These results do not provide evidence for or against the third and fourth hypotheses.

The first major finding of this research is that when workload demands are controlled for, there are also no differences in performance due to different focus styles. The means of each group do not match the patterns seen in Russell, et al.'s (2014) work, suggesting that the lack of significant differences would not be resolved by increasing the statistical power in this study. By ruling out this explanation, it seems more likely that the equal workload demands were partially responsible for the lack of any focus-related performance differences. However, this explanation alone does not explain how Russell et al. (2014) were able to find significant differences using these same conditions. There would have to be another explanation for why this study was not able to replicate the pattern in which the external, skill-focused condition performed the best of the four conditions. This explanation may lie in the methodological differences between the current study and the previous study by Russell et al. (2014).

One of the few variations in methods that exist between these studies is that Russell et al. (2014) used a within-subjects design while this study used a between-subjects design. The use of a within-subjects design ensured that subjects could not differ between the groups in their initial dart-throwing ability whereas a between-subject design is vulnerable to these differences. Even though this study utilized a relatively stringent inclusion criterion such that recruits must have thrown darts on fewer than five occasions in the past, participants varied in their self-ratings of skill level from a 1 to a 6 out of 10. However, the self-ratings of these participants did not differ enough to reach statistical significance when compared across conditions, and including the self-rating variable as a covariate in the analyses did not substantially affect the results. Although controlling for self-rating did not reveal any group performance differences, meaning these differences do not explain the lack of significant differences between the conditions, the fact that self-rating was correlated with actual performance has other implications.

In particular, the second major finding of this research study was that self-rating was the only variable that successfully predicted an individual's performance even though participants had equally low experience (<5 instances of dart-throwing) with the task. This inclusion criterion was based on previous between-subjects dart-throwing studies (Radlo, Steinberg, Singer, Barba, & Melnikov, 2002; Marchant, Clough, & Crawshaw, 2007) in order to assure that only true novices would participate in this learning study. As a result, the participants in this study did seem less talented initially than those in the Russell et al. (2014) study, with the average of the participants' first three throws being 11.24 cm from the center compared to their participants' 9 cm. Therefore, one can assume that even though all participants had extremely low experience with dart throwing, individuals must have had other reasons to rate themselves higher than a 1 or 2 out of 10. Perhaps some participants had had success with other throwing tasks in the past, leading them to have greater self-efficacy for the novel task of dart throwing and greater subsequent performance. In fact, self-efficacy has been shown to correlate with motor performance (Moritz, et al., 2000; Feltz, 2007), so individuals with high self-efficacy may be novices to the dart-specific task but not to throwing accurately. If self-rating successfully predicts performance on the task, then performance on the task could also predict initial self-efficacy. This is important because those who initially consider themselves to have a higher skill level for a task might be technically novices to the specific motor skill but behave more like experts because they are experienced with similar tasks. In the past, dual-task studies have used a median split to divide their sample into novices and experts based on initial task performance. Participants who perform well at baseline, then, are considered part of the experienced or expert group and have been shown to choke under different circumstances than the more poorly-performing novice group (Hill, 2010). The correlation found in this study further validates the median split method because it appears that this split does not just divide people of different skill level but also divides people of different *perceptions* of their skill level. People who believe themselves to have a skill beyond that of a novice, even with the same amount of experience as a novice, will likely behave more like an experienced participant than a beginner participant.

To conclude, workload performance did not differ between the conditions and therefore could not have mediated differences in performance in this particular study. Because these performance differences did not exist either, it is possible that had workload differed between groups, performance would have followed accordingly. However, future research is needed to determine if this is the case. For now, it remains unclear whether workload demands mediate the relationship between focus styles and performance of a motor skill. Although task demands and focus styles did not predict any changes in dart throwing accuracy, self-rating of expertise prior to participation did predict performance, providing support for the median-split method of defining groups in order to study novice vs experienced differences in performance.

Future Directions

The primary hypothesis that focus of attention would impact immediate performance of a motor skill was not supported. The results of this study offer some interesting future directions to researchers in order to clarify why the expected effects were not seen in these unique experimental conditions. First, because of the significant correlation found between self-rating and performance, additional between-subjects studies on focus of attention and performance might be well-advised to balance novice participants between conditions based on their self-rating of expertise or expected performance, as they are reliable estimators of their ability to learn a skill. In fact, this simple question about expected performance could reflect other relevant variables between the groups like self-efficacy, competitiveness, and motivation.

Next, to truly investigate whether performance differences between focus styles are mediated by workload, it is imperative that workload differs between the groups. If workload demands are primarily responsible for mediating the effects of focus of attention on performance differences, these differences will not appear without workload differences and therefore cannot be statistically assessed. This study found no significant differences in overall perceived workload or any subscale scores between any of the conditions. Future research using dual-task methodology could include the NASA-TLX as in this study in order to determine whether those conditions do differ on that level as presumed. Prior literature by Diekfuss and Raisbeck (2016) has already shown that workload as measured by the NASA-TLX mediated performance differences between skill-focused and extraneous-focused conditions in a dual-task shooting study. Further research could use the same NASA-TLX during methods used commonly by Wulf and colleagues in the direction of attention literature. Further, an attempt to replicate the findings of Casteneda and Gray (2007) while measuring workload demands would provide insight into whether workload serves as a mediator for the observed performance differences. However, research that is not attempting to look at mediators of the effects of attentional focus could benefit from using the methodology from this study in order to control for workload demands between conditions.

Conclusion

The methods used in this study appear to have equalized the workload demands between conditions. There were also no performance differences between the conditions. This pattern is consistent with the hypothesis that workload demands mediate the effects of attentional focus strategies on motor skill performance. Therefore, because workload demands were not significantly different between conditions, there were subsequently no changes in performance between focus conditions. In the future, the NASA-TLX should be used to measure workload in the typical methodology used in direction of attention literature and skill-relevance of focus literature, where performance differences have been observed, in order to determine whether differences in workload demands could be partially responsible for those performance differences. Although focus style did not predict performance, initial self-rating of performance did. This relationship justifies the act of distributing participants between conditions based on their initial self-rating in order to control for differences in actual and perceived skill level rather than experience alone. Further, this relationship provides support for the common strategy of defining groups of novices and experts through the use of a median split of the entire sample. The assumption is that individuals who perform well initially are presumed to have had higher self-efficacy based on previous experiences with similar tasks. These individuals may be novices to the specific motor task, but could be treated as experienced individuals in terms of a broader motor ability.

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