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# The Effect of Focus of Attention on Learning to Kick in Taekwondo

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The Effect of Focus of Attention on Learning to Kick in Novice Taekwondo Athletes

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## Abstract

Previous research has shown that focusing externally (outside the body) leads to better motor performance than focusing internally (within the body), yet many coaches and other instructors continue to use internal cues to teach. This is the first study to use electromyography (EMG) to assess the distance effect, to examine the benefit of a distal external focus of attention beyond a target, and to test the constrained action hypothesis in a stationary, dynamic task. People who did not have much experience in martial arts kicked a force bag while EMG was recorded using different verbally cued foci of attention. The differences in the force-accuracy measure (F-A) and cocontraction between conditions were not significant. Cocontraction and F-A were negatively correlated in the distal external focus condition, but positively correlated in the internal focus condition. These findings suggest that cocontraction may be beneficial in certain circumstances, but not in others.

## Introduction

When teaching an athlete a new skill, coaches must decide how to instruct their athlete. Should the athlete focus on the muscles performing the movement? Should the athlete focus on the end goal of the movement (like where to land in a long jump) or on the takeoff of the motion (like the beginning of a long jump)? The implications of these questions extend far beyond athletics – they have the potential to affect everyone's life. For example, someone who was paralyzed in a car crash might be interested in the best way to relearn to walk.

In fact, studies have already shown that attentional focus can positively affect motor learning in stroke patients (Durham et al., 2014). Children with developmental coordination disorders – such as those seen in attention deficit hyperactivity disorder (ADHD) – or other patient populations with impaired daily living skills also might want to know how to perform in sports or perform daily tasks as well as their peers. Previous studies suggest this is possible. For example, children with ADHD who were given external instructions were able to throw a bean bag more accurately than those given internal instructions. Furthermore, this effect was retained after two days with no instructions (Saemi, Porter, Wulf, Ghobti-Varzaneh, & Bakhtiari, 2013). In contrast to these findings, others have found that world-class acrobats show more active (less automatic) postural control when given external instructions on a balance task (Wulf, 2013) and juggling novices perform equally well given internal, external, or no instructions (Zentgraf & Munzert, 2009). So, is it better to focus outside the body (external focus) or inside the body (internal focus)?

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It has been well documented that, in general, external foci are more beneficial to learning than internal foci. For example, novices learning to throw darts tend to be more accurate when they focus on the dartboard (external) than when they focus on elbow angle (internal) (Lohse, Sherwood, & Healy, 2010). Despite these studies, however, many coaches still coach their athletes using internal foci. Track and Field Outdoor National Championship competitors reported that their coaches provided them with internal feedback 84.6% of the time (Porter, Wu, & Partridge, 2010). There is clearly a disconnect between the research and the application. That disconnect can be overcome with better understanding of how and whom attentional focus helps, which can be achieved with further research. Communicating that understanding to coaches, physical therapists, and other instructors may be a solution to this problem of instructors relying on internal cues.

The problem is further complicated by the fact that there are many possible external foci in the world. Returning to the dart-throwing example, the dartboard is not the only external focus. One could also choose to focus on the trajectory of the dart, the sounds in the room, or something else. Two lines of research have addressed this issue: one line asks how the relevance of the focus of attention affects performance, and the other line asks how the distance of focus of attention affects performance.

No clear effect of focusing on relevant compared to irrelevant stimuli has been found. The effect of focusing on a relevant stimulus seems to depend on many factors, such as the stimulus intensity, frequency, and duration (Escera, Corral, & Yago, 2002), and how stressed the performer is (Smith, 1990), among others.

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Several studies have shown that the more distal a person's focus is, the better performance the person tends to have. Participants throwing darts threw more accurately when they focused on the dartboard than when they focused on the flight of the dart (McKay & Wulf, 2012). Golfers were able to hit the ball closer to the hole when they focused on the flight of the ball after hitting it with the club, rather than focusing on the swing of their arms or the clubface (Bell & Hardy, 2009). Participants had better balance when they focused on markers farther away from their feet than when they focused on their feet (McNevin, Shea, & Wulf, 2003). Long jumpers jumped farther when they focused near a distant target rather than near themselves (Porter, Anton, & Wu, 2012).

One popular hypothesis to explain the benefit of external foci over internal foci is the constrained action hypothesis. According to the constrained action hypothesis, internal foci impose conscious control over muscles that would otherwise work efficiently and automatically. This conscious control is thought to increase muscular cocontraction (Wulf, 2013). If internal foci do prevent the muscles from working automatically, then external foci should increase muscle automaticity, and studies have supported this idea (Lohse, 2012; Wulf, McNevin, & Shea., 2001). Participants' reaction times decreased when using an external focus, providing evidence that their muscles were working automatically (Wulf et al., 2001). Similarly, an external focus also reduced pre-movement time in a force production task (Lohse, 2012), providing further evidence for muscle automaticity in external focus conditions.

One important extension of the constrained action hypothesis is the self-invoking trigger hypothesis. The self-invoking trigger hypothesis further explains the constrained

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action hypothesis by postulating that muscular cocontraction increases because attention near oneself facilitates access to the idea of the self, which imposes conscious control over what should be automatic functions, and leads to self-regulation (see Wulf, 2013 for a review). If focusing closer to oneself is more likely to facilitate access to the self, then more distal foci should allow for better discrimination between the self and the environment, thus not facilitating access to the self. This farther focus should result in less muscular cocontraction, and, therefore, lead to increased motor performance, due to the increased automaticity of muscle movement.

In fact, several studies have already shown that distal external foci lead to better performance than proximal external foci. For example, subjects who focused near (but not on) their feet in a balance task were less balanced compared to subjects who focused farther away from their feet (McNevin et al., 2003). Also, long jumpers who focused far outside their body jumped farther than those who focused internally or near their body (Porter et al., 2012). These results indicate that focusing near the body leads to the same access to the self as focusing within the body. These studies suggest that both internal and proximal external foci of attention decrease muscle movement automaticity, leading to a decrease in motor performance.

Other studies have not shown the same benefit of distal external foci over internal foci. In stroke patients, focusing internally before focusing externally accentuated the external focus benefits (Durham et al., 2014). The internal feedback may have made the external feedback easier to understand, so motor performance was increased. Similarly, volleyball players showed enhanced serve accuracy (compared to the internal focus group), even though the external instructions still referenced the body

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(for example, subjects were told to shift their weight towards the target before hitting the ball) (Wulf, McConnel, Gärtner, & Schwarz, 2002). These results may show an effect of instruction relevance. If subjects are given non-relevant external instructions, then their attention may be divided between the instructions and the task they are trying to perform, which may decrease their overall motor performance (Zentgraf & Munzert, 2009). In the study by Durham et al. (2014), the external instructions may have become more relevant after the internal instructions made the external instructions easier to understand, so the stroke patients were not dividing their attention between the task and the instructions. In a volleyball serve, the relevant motion is the movement of the body, so the increase in serve accuracy seen in the study by Wulf et al. (2002) may have occurred because the volleyball players were focusing only on the relevant aspect of the motion, and not dividing their attention between the task and instructions.

Some of the effect of relevance may be due to differences in subject skill level. As skill level increases, the relevant parts of a task change. A novice may need to focus internally at first just to understand the motion that he or she is trying to perform. An expert, however, should already understand the motion, and the goal of the movement becomes the relevant piece that the expert should focus on. Several examples in the research literature demonstrate that attentional focus may have varying effects depending on the participant's skill level. In a few studies, the external focus group had no learning benefit compared to the control group (Wulf, 2008; Zentgraf & Munzert, 2009). All of these studies used expert subjects. The subjects had performed thousands of repetitions of the desired task before the study, so the muscle automaticity could not be enhanced further than it already was (Wulf, 2013). In a balance task, participants in

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the control condition showed better balance than participants in the external focus condition. The subjects of this study were world-class acrobats, so the study suggests that allowing world-class athletes to use their “normal” focus leads to the best results (Wulf, 2008). For example, acrobats would focus on standing still while balancing (i.e., focusing on standing at the highest hierarchical level; focusing on the lower control mechanisms would impair performance). However, novices have not had the training to know how best to focus their attention or know which parts of the movement are relevant. Thus, it appears that distal external foci can only help motor learning to a certain point, after which it becomes redundant or detrimental. For more skilled subjects, the distal external focus becomes less beneficial as its relevance becomes less important. Distal external foci may also be less beneficial for novices learning a novel skill if it is harder for them to conceptualize the movement (Mckay & Wulf, 2012).

If distal foci become less beneficial after a certain point, it may make sense that people’s preferences for certain foci may affect their benefits. However, participants in a dart throwing study were more accurate when they adopted a distal external focus, despite their preference (although those who preferred a distal external focus showed greater benefit than those who preferred a proximal external focus). Furthermore, people in the same study generally preferred distal external foci to proximal external foci (Mckay & Wulf, 2012), indicating that a distal external focus may be more intuitively satisfying when learning a new motor skill. No studies, however, have examined the effect of focusing beyond the target, as the present study does.

The constrained action hypothesis explains the benefit of distal external foci of attention by postulating that internal foci act as a self-invoking trigger, facilitating access

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to the self and decreasing muscle automaticity. This seems to be true in novice and expert – but not world-class (Wulf, 2008) – athletes (Bell & Hardy, 2009; McKay & Wulf, 2012; Porter et al., 2012; Porter et al., 2010; Saemi et al., 2013; Wulf, 2013; Wulf et al., 2002), patient and healthy populations (Durham et al., 2014; Saemi et al., 2013; Wulf, 2013), regardless of preference (McKay & Wulf, 2012), and regardless of whether subjects were anxious (Bell & Hardy, 2009). All of these studies examined the effect of focus of attention in relatively static tasks (such as balance) or tasks with a clear target (such as dart throwing, bean bag tossing, or long jumping). However, it is unclear whether the effect generalizes to dynamic tasks that begin and end at the same position. Also, relatively few studies have analyzed muscle contraction as a function of focus of attention and no studies have analyzed muscle contraction as a function of distance of attentional focus.

The studies that have used electromyography (EMG) to analyze muscle activity have found varying results. Participants were able to perform a bicep curl more quickly when focusing externally compared to internally, but EMG activity did not differ significantly between conditions. However, the integrated EMG, which may be a more reliable measure since it takes EMG as a function of movement time, did show significantly more activation in the internal condition compared to the external condition (Vance, Wulf, Töllner, McNevin, & Mercer, 2004). When throwing free throws in basketball, participants had less activity and cocontraction in the throwing arm during the external condition compared to the internal condition (Zachry, Wulf, Mercer, & Bezodis, 2005). In a dart-throwing task, there was less activity in the triceps when subjects used an external focus compared to an internal focus, although cocontraction

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was not significantly different between conditions (Lohse et al., 2010). In a force production task, the antagonist muscle activation was greater in the internal condition than the external condition, and cocontraction was significantly higher in the internal focus condition than in the external focus condition (Lohse, Sherwood, & Healy, 2011). A key difference between the force production task and biceps curl task and the other tasks described here are that the force production task and biceps curl task were static tasks, whereas the others were dynamic tasks. Muscular cocontraction may be differentially beneficial depending on the movement type (i.e. static or dynamic). Alternatively, the results could simply be a consequence of the fact that EMG data are more reliable for static tasks than they are for dynamic tasks (Lohse et al., 2011).

The purpose of the present study was to examine the role of the constrained action hypothesis and the distance effect for novices learning Taekwondo kicks and also to analyze the muscle contraction of the quadriceps and hamstrings as a function of attentional focus. If the constrained action and self-invoking trigger hypotheses apply to Taekwondo kicks, a distal external focus should be more beneficial to motor performance (specifically kicking force and accuracy in this study) than a proximal external focus, which, in turn, should be more beneficial than an internal focus. Furthermore, if the hypotheses hold, the internal condition should show more muscular cocontraction between the quadriceps and the hamstrings than the proximal external condition, which, in turn, should show more muscular cocontraction than the distal external condition.

## **Materials and Methods**

### **Participants**

Twenty healthy subjects were recruited for the study using a convenience sample from the University of Colorado at Boulder. Participants confirmed that they were healthy; they also confirmed that they had done less than 7 days of Taekwondo and less than 30 days of any other martial arts before participating in the study. Participants were compensated \$20 for their participation.

### **Design**

The study was a within-subjects design that consisted of two sessions that were conducted on two separate days within the same week. The independent variable was focus of attention (internal, proximal external, or distal external). The dependent variables were muscle activation of the quadriceps and hamstrings and a derived measure of force and accuracy (F-A). The bag used to measure F-A contained a force sensor in the center of the bag (see Appendix A). When participants hit the sensor directly (i.e. hit exactly in the center of the bag), the measure read higher than when participants hit the edge of the bag with an equal amount of force. The bag did not have a mechanism for accounting for the effect of accuracy on the reading. All procedures conformed to the University of Colorado – Boulder IRB requirements.

### **Materials**

Participants kicked a kicking bag that measured F-A during both sessions. On the second day of testing, EMG was used to measure the activity of participants'

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quadriceps and hamstrings. EMG data were collected using Biopac® MP100 hardware at a 2,000 Hz sampling rate and analyzed using Biopac AcqKnowledge software.

## **Procedures**

Subjects were asked to come in to the laboratory for two sessions. All participants were instructed to wear shorts and closed-toed shoes to both sessions. Upon arrival in the laboratory for the first session, the investigator explained the study to the subject. Subjects were provided with a written informed consent form. After reading the consent form, the investigator asked if the subject had any questions and answered them. If they agreed, subjects then signed the informed consent form and the form affirming they were healthy enough to participate in the study. Subjects also filled out a short questionnaire affirming that they had less than seven days of experience in Taekwondo and less than 30 days of experience in any other martial art.

Subjects were warmed up for five minutes (see Appendix B) prior to beginning the study. After the warm-up, subjects were provided with instructions on how to properly perform the kick, including a visual demonstration from the researcher and verbal instructions (see Appendix C). For example, a participant might be told to hold his leg parallel to the floor and extend his knee until the top of the foot hits the bag. Subjects were told to kick the bag, held at a distance and height of the length of their leg, as hard and accurately as they could. When the F-A readout from the bag was consistent (within 10% of the maximum F-A achieved) for at least 15 trials, the subjects were considered trained.

On the second day, participants performed the same kick they were trained on, with the bag held at the same distance and height, with EMG electrodes attached to the skin

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over their quadriceps and hamstrings and one electrode attached to the skin over the ilium. The surface of each subject's skin was shaved, if necessary, and the skin over his or her quadriceps and hamstring muscles was cleaned with an alcohol solution with a mild abrasive. Two electrodes were attached to the skin over the middle of the quadriceps and two electrodes were attached to the skin over the middle of the hamstrings. The EMG electrodes had a 1 cm diameter and were placed approximately 1 cm apart. One electrode was placed on the anterior portion of the ilium to ground the signal. Subjects were warmed up the same way as the first session. Subjects were randomly assigned to a condition order, with the restriction that each order had an approximately equal number of participants. Each subject participated in a control condition of five kicks (or more if a significant amount of time (i.e. a week or more) had passed between their first and second sessions) followed by three testing conditions of 15 kicks each for a total of 50 kicks. The F-A readout was covered, so participants did not have knowledge of results (KR), in accordance with findings by Wulf et al. (2002) that too much feedback makes participants dependent, causing them to focus too much on their own movements, leading to similar detriments to those seen with an internal focus. Furthermore, Sherwood, Lohse, & Healy (2014) showed that visual processing is not necessary to achieve the benefits of a distal external focus.

In each group, participants were provided with verbal instructions. All groups were told to kick the target as close to the center and with as much force as possible. In the distal external focus condition, participants were told to focus on the person holding the bag. In the proximal external focus condition, participants were told to focus on the target. In the internal focus condition, participants were told to focus on creating

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maximal muscular contraction to produce maximum force. Participants were purposely not directed to any particular muscle (if participants asked for clarification on the internal condition, they were told to squeeze the upper leg muscles) because results from Zachry et al. (2005) suggest that attentional focus is general and focusing on any one part of the body can spread to other areas, potentially constraining the entire motor system. Participants were asked to rate how well they focused on the instructions after each trial using a 1-5 scale (1 being not focused at all and 5 being completely focused). During each condition, the participant's muscular contractions of their quadriceps and hamstrings were measured via EMG (see Appendix D for sample data). Testing time was less than one hour per participant. Participants were given two minutes of rest between conditions.

### **Data Analysis**

The EMG measured the peaks and integrals of the quadriceps and hamstrings activations. The quadriceps activation integral was divided by the hamstrings activation integral to find the amount of cocontraction. The EMG was collected at a 2,000 Hz sampling rate and was rectified, then integrated using an average over 15 samples before being analyzed. The EMG measures were calculated from when the quadriceps and hamstrings first showed activation to when the EMG returned to baseline. There was an average of 15 good EMG trials for each condition and 1 unusable EMG trial for each condition. EMG measures (including cocontraction) and the focus ratings were correlated with the F-A using a Pearson correlation. The data were analyzed with a one-way ANOVA with repeated measures which included focus of attention (three levels).

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The Least Significant Difference Test was run if post-hoc tests were necessary. All results are reported as mean  $\pm$  standard error.

### Results

There was no significant difference in the self-reported focus ratings across conditions (Fig. 1). The results of an ANOVA did not show a significant effect,  $F(2,38) = 1.83$ ,  $p = .174$ ,  $\eta_p^2 = 0.088$ , although the ratings for the internal focus condition tended to be lower ( $M = 3.899 \pm 0.240$ ) than either the distal external focus ( $4.160 \pm 0.135$ ) or the proximal external focus ( $M = 4.205 \pm 0.136$ ) conditions.

F-A tended to be higher in the distal external focus condition ( $M = 43.482 \pm 3.294$ ) than either the proximal external focus ( $M = 38.716 \pm 3.024$ ) or internal focus ( $M = 38.699 \pm 3.935$ ) conditions (Fig. 2). The results of an ANOVA were marginally significant,  $F(2,38) = 2.45$ ,  $p = .099$ ,  $\eta_p^2 = 0.114$  for a two-tailed test. The results were significant using the directional hypothesis and one-tailed test. Focusing farther away produced a greater, though non-significant, F-A. Focusing on the target and focusing on the self (internally) produced approximately equal F-A.

There was no significant difference in cocontraction between conditions. Although the results of an ANOVA did not show a significant effect between conditions,  $F(2,38) < 1$ ,  $p = .428$ ,  $\eta_p^2 = 0.044$ , there was a trend toward lower cocontraction in the distal external focus condition ( $M = 1.669 \pm 0.285$ ) compared to the proximal external focus ( $M = 2.065 \pm 0.270$ ) and internal focus ( $M = 2.984 \pm 1.220$ ) conditions (Figs. 3, 4, and 5). Focusing farther away from one's body may reduce cocontraction, though the results are not clear in this regard.

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Correlations between the EMG measures and F-A were significantly different between conditions (Figs. 6 and 7). The results of an ANOVA revealed a significant effect of direction,  $F(2,36) = 3.98$ ,  $p = .027$ ,  $\eta_p^2 = 0.181$ , showing that cocontraction is significantly different between conditions. The correlation in the distal external focus condition was significantly different from the correlation in the internal focus condition ( $p = .011$ ), showing that cocontraction was negatively correlated with F-A in the distal external focus condition ( $M = -0.117 \pm 0.071$ ), although it is positively correlated with F-A in the internal focus condition ( $M = 0.143 \pm 0.061$ ). The correlation between cocontraction and F-A in the proximal external focus condition ( $M = -0.003 \pm 0.068$ ) was not significantly different from the other conditions (Fig. 7). Decreased cocontraction decreased F-A when subjects had an internal focus, but increased F-A when subjects had a distal external focus. Decreased cocontraction also increased F-A when subjects had a proximal external focus, though this condition was not significantly different from the others.

### Discussion

The goals of the experiment were to determine if the distance of focus of attention affects kicking F-A in novice Taekwondo athletes similarly to other motor performance tasks and to determine if muscular cocontraction could account for any observed benefits to distance of attention. It was hypothesized that more distal foci of attention would be correlated with higher F-A and lower levels of cocontraction.

Participants were able to focus equally well on all conditions, although the focus ratings in the internal focus condition tended to be slightly lower than in the other conditions. It is possible that F-A tended to be lower in the internal focus condition

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because participants were using more attentional resources thinking about the condition, which detracted from their overall performance.

Although there were no significant differences in F-A between conditions, F-A tended to be higher in the distal external focus condition, suggesting that focusing farther away from the body is associated with better results (in this case, increased F-A) than focusing on or near the body. These trends suggest that not only does focusing farther away from the body (near the target) increase performance, which is consistent with previous studies (Bell & Hardy, 2009; McKay & Wulf, 2012; McNevin et al., 2003, among others), but also that focusing beyond the target can show benefits compared to focusing on the target. This supports the constrained action and self-invoking trigger hypotheses in that focusing beyond the target minimizes the access to self (since the focus is very far away from the body) that may increase cocontraction and decrease efficiency.

Although there were no significant differences in the level of cocontraction between conditions, cocontraction tended to be lower in the distal external focus condition and higher in the internal focus condition. These results suggest that focusing on or near the body is correlated with increased cocontraction. Consistent with the constrained action and self-invoking trigger hypotheses, these results suggest that focusing on or near the body facilitates access to the self and causes the body to work less efficiently than it otherwise could. However, these results should be interpreted with caution, because increased cocontraction was seen to be beneficial when subjects adopted an internal focus.

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The correlations between cocontraction and F-A were significantly different between the distal external focus and internal focus conditions. Cocontraction was negatively correlated with F-A in the distal external focus condition, whereas it was positively correlated with F-A in the internal focus condition. These results suggest that cocontraction may have a differential effect on performance depending on the focus of attention. These data suggest that when focusing farther from the body, it is beneficial to motor performance to allow the muscles maximal efficiency (i.e. minimal cocontraction). This would allow the muscles to produce the maximum force. However, when focusing on the body, it may be beneficial to allow some cocontraction. Increased cocontraction could lead to increased steadiness, which, in this experiment, could lead to increased accuracy, which would produce a higher F-A. If increased cocontraction improves accuracy, and internal foci increase cocontraction, then perhaps the accuracy component of the outcome variable increased F-A scores in the internal focus condition. If accuracy was not included in the outcome variable, then the internal focus F-A scores may have been lower than was observed, leading to significance between the distal external focus and internal focus conditions.

It is not difficult to think of situations in which it would make sense that cocontraction would be differentially beneficial to motor performance. In tasks where accuracy is important, increased cocontraction would be beneficial in order to improve steadiness. For example, a surgeon would want a high level of cocontraction in order to prevent his or her tool from slipping in a patient. A patient with an incomplete spinal cord injury would need a high level of cocontraction to maintain stability while relearning to walk. However, if a task requires speed, cocontraction would be a detriment, making it

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more difficult for the person to move his or her limbs efficiently. For example, in Taekwondo it is necessary to kick quickly to hit the opponent, so decreased cocontraction would be beneficial to allow the muscles maximal movement and efficiency, while increased cocontraction may cause the athlete to be too slow to hit the opponent.

The results presented above should be interpreted with caution. As mentioned previously, only marginal significance was found when using a two-tailed test between attentional focus condition and F-A, in contrast to many other studies (Bell and Hardy, 2009; Lohse, 2012; McKay & Wulf, 2012; McNevin et al., 2003; Saemi et al., 2013; Wulf et al., 2001, among others). If this study were to be repeated with a larger sample size and, thus, increased power, it is possible that significance would be found.

Furthermore, the outcome variable of the experiment was not simply force, but rather a combination of force and accuracy. It is possible that force is significantly greater when using a distal external focus, while accuracy may be enhanced with a different focus or reduced with a distal external focus. Since cocontraction was positively correlated with F-A in the internal focus condition (and not in the other conditions), it may be that focusing internally increases accuracy, while decreasing force. Future studies should account for the variability due to force and accuracy separately. One way to find the variability due to accuracy would be to repeat the study using an accelerometer in addition to the force bag and EMG. Acceleration should be proportional to force, so any variability not accounted for by acceleration should be accounted for by accuracy.

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Another limitation of this study is that it used EMG to measure a dynamic task. It is more difficult to get an accurate EMG reading for dynamic tasks than it is for static tasks (Lohse et al., 2011). It is possible that the vibration of the skin over the quadriceps and hamstrings when the foot made contact with the bag made the EMG reading unreliable. Interference from other sources in the room, such as cell phones, may have also produced noise in the EMG, making the results less interpretable. Another study should address a similar task to the one done in this study using either a static task or a more reliable method for measuring muscle activation in dynamic tasks.

Although the findings do not support previous literature, the trends give good reason to believe that, given a larger sample size, accounting for force and accuracy separately, the difference in F-A in the distal external focus would be significantly greater than the other foci of attention. Furthermore, though the results were not significant, these data seem to support the constrained action hypothesis, at least in part, because there was a trend toward lower cocontraction in the distal external focus condition and higher cocontraction in the internal focus condition. However, the positive correlation between cocontraction and F-A in the internal focus condition contradicts the constrained hypothesis, because the hypothesis says that more cocontraction should be correlated with decreased performance. In this experiment, increased cocontraction was correlated with increased performance in the internal focus condition. The study should be repeated using an accelerometer to address the accuracy confound, a different measure of muscle activation that is more reliable for dynamic tasks, and a larger sample size.

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Many coaches still instruct their athletes using internal focus cues (Porter et al., 2010), despite the growing body of literature that shows a benefit to motor learning when using a distal external focus of attention. This research provides more evidence for the benefit and mechanism of that benefit of external focus cues, which, if this and the information in other studies is utilized, could help improve novice athletes to an expert level more quickly and more efficiently.

In studies by Estevan, Alvarez, Falco, Molina-García, & Castillo (2011) and Falco et al. (2009), kicking distance did not affect kicking execution time for medalist Taekwondo athletes, whereas distance did have an effect on non-medalist Taekwondo athletes. These results suggest that novices and experts are using different mechanisms or foci to execute the action. The focus of attention research can help reduce the gap between novices and experts. The instruction of novice Taekwondo athletes can be improved (i.e. more external focus instructions can be provided) to help non-medalist athletes reach the same level of performance as medalist athletes.

Patient populations with motor control deficits also benefit from this research. Relearning to walk is a motor skill that must be learned just like any sports skill. Because walking requires stability, this study suggests that there may be some benefit to internal focus cues when learning to walk, because the increased cocontraction would increase stability in the legs. This is consistent with the findings by Durham et al. (2014), who found that having stroke patients focus internally before they focused externally improved results. It is possible that, in addition to making the external foci easier to understand, the internal foci also improved stability throughout the study through increased cocontraction.

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In conclusion, the results of this study were not consistent with results found in much of the previous research. However, the trends, though not significant, still tended to show benefits to motor performance in the distal external focus condition compared to the internal focus condition. Future studies should use larger sample sizes to increase power and should use an accelerometer (or other method) to address the accuracy confound. Future studies should also use a static task that is otherwise similar to the one used in this study or use a more reliable method to measure muscle activation in the dynamic task. If coaches refer to the growing body of research on focus of attention, then their athletes will be able to improve more quickly and efficiently. Physical therapists and other medical staff will also be better able to help patients who have motor deficits by understanding the varying benefits of focus of attention and cocontraction to motor learning.

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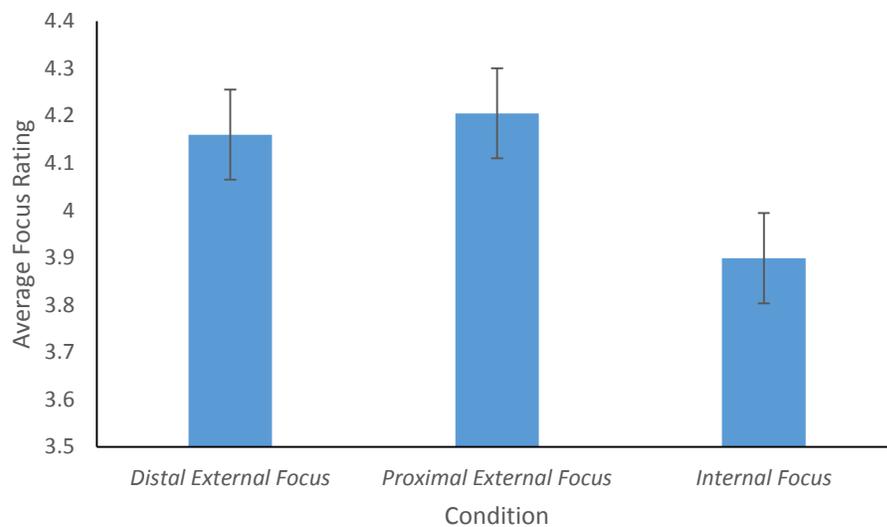
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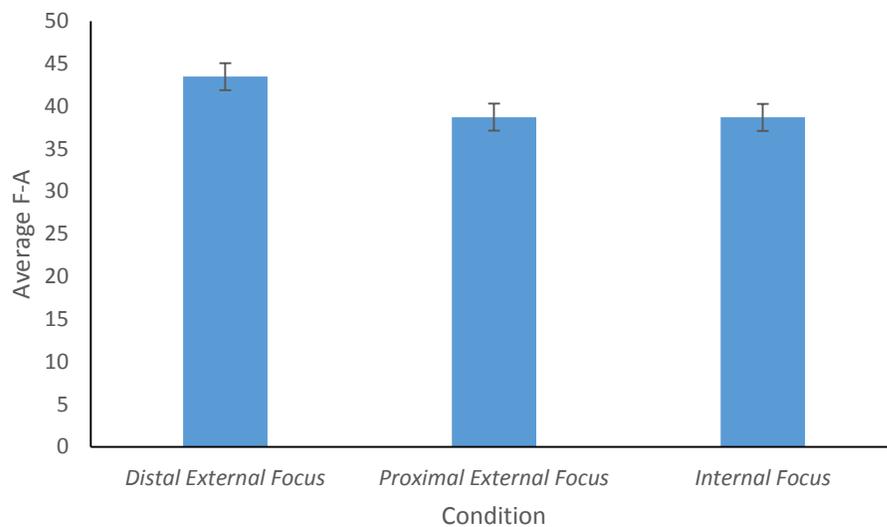
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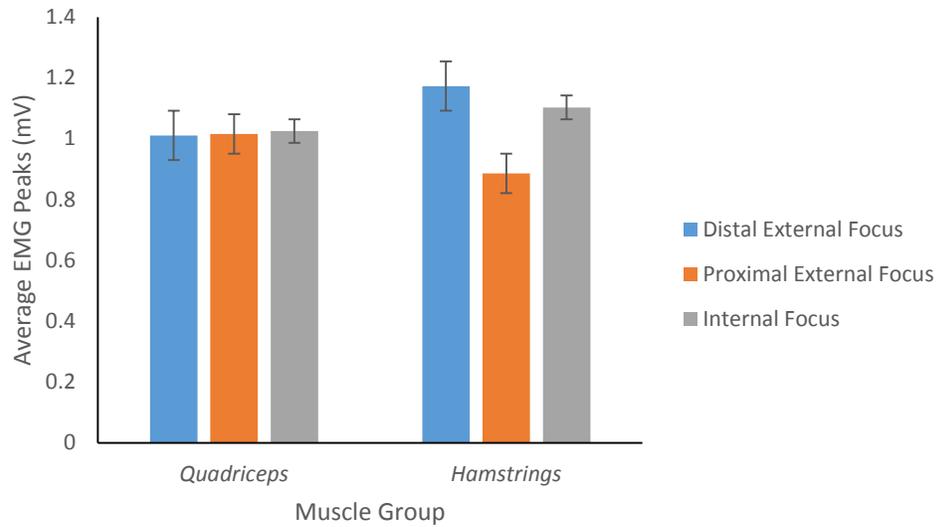
*Figure 1: Average focus rating  $\pm$  standard error for each condition (distal external focus, proximal external focus, and internal focus).*

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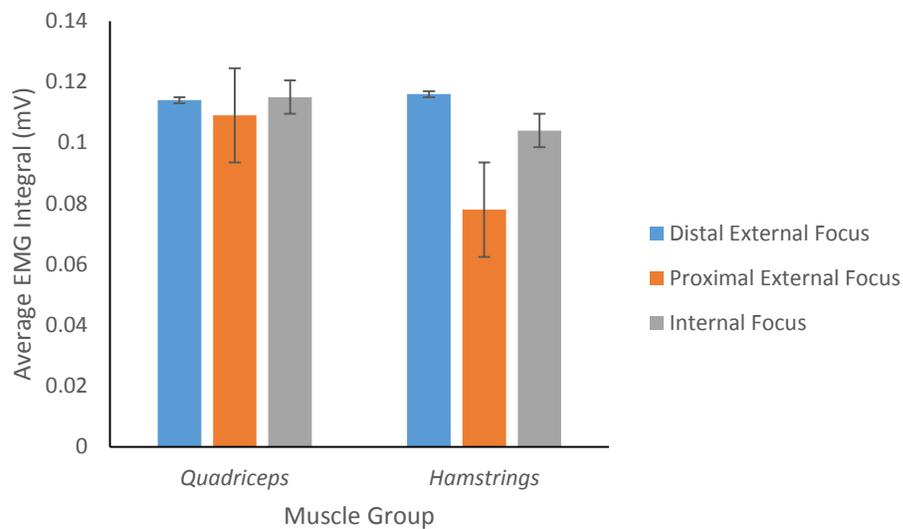
*Figure 2: The average F-A  $\pm$  standard error for each condition (distal external focus, proximal external focus, and internal focus).*

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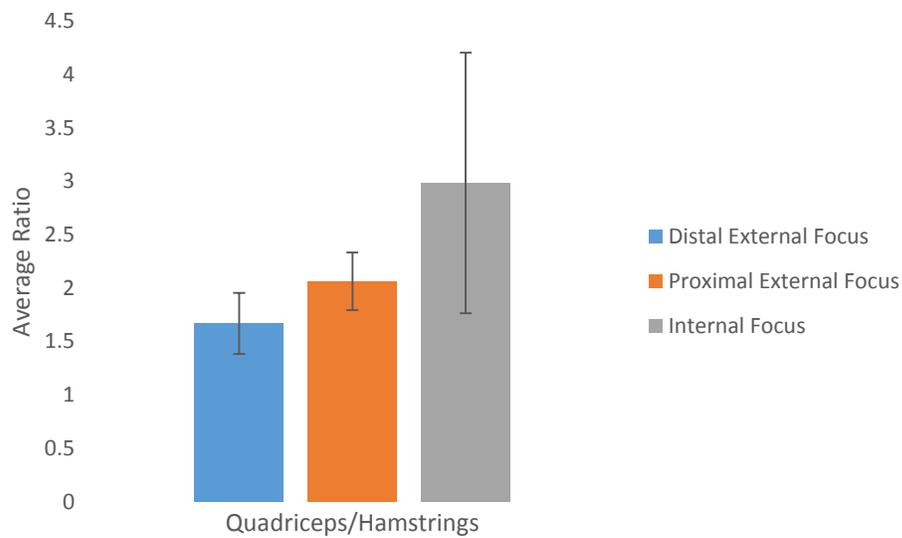
*Figure 3: The average peaks  $\pm$  standard error of the EMG (mV) for the quadriceps and hamstrings in each condition (distal external focus, proximal external focus, and internal focus).*

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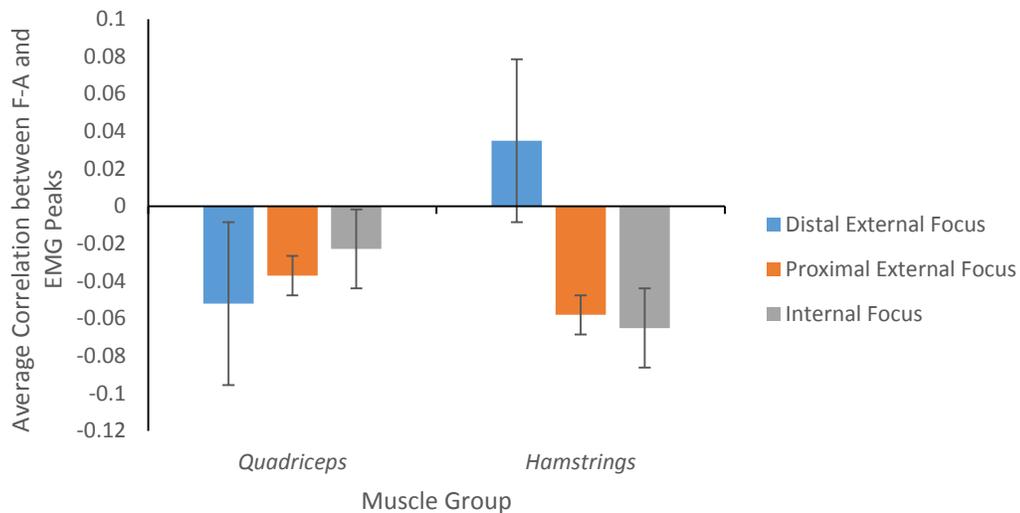
*Figure 4: The average integrals  $\pm$  standard error of the EMG (mV) for the quadriceps and hamstrings in each condition (distal external focus, proximal external focus, and internal focus).*

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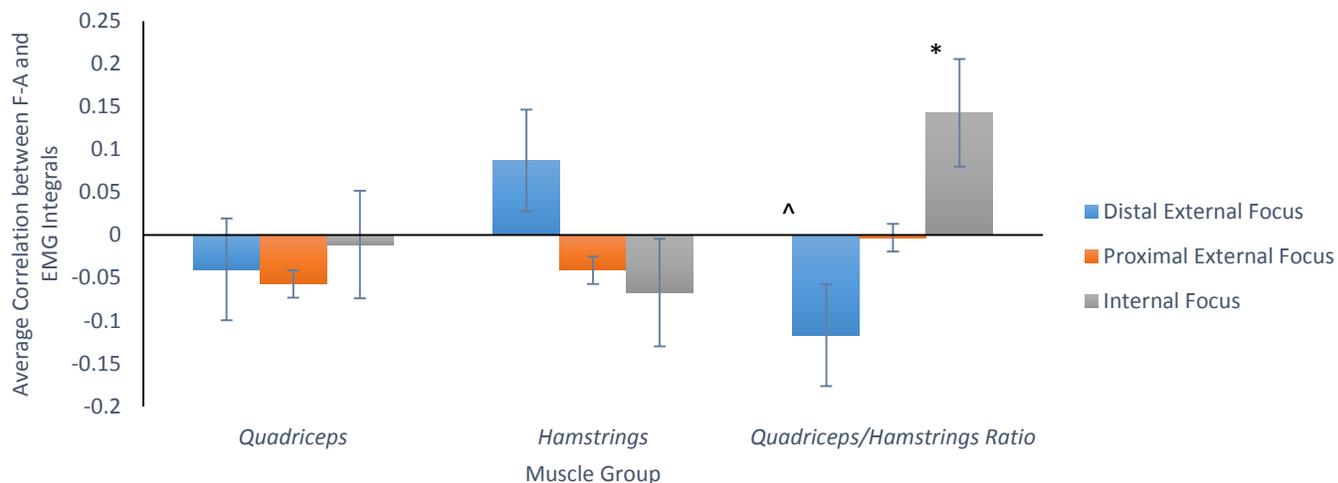
*Figure 5: The average ratios  $\pm$  standard error of the quadriceps integral to the hamstrings integral for each condition (distal external focus, proximal external focus, and internal focus).*

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*Figure 6: The average correlations  $\pm$  standard error between F-A and EMG peaks of the quadriceps and hamstrings in each condition (distal external focus, proximal external focus, internal focus).*

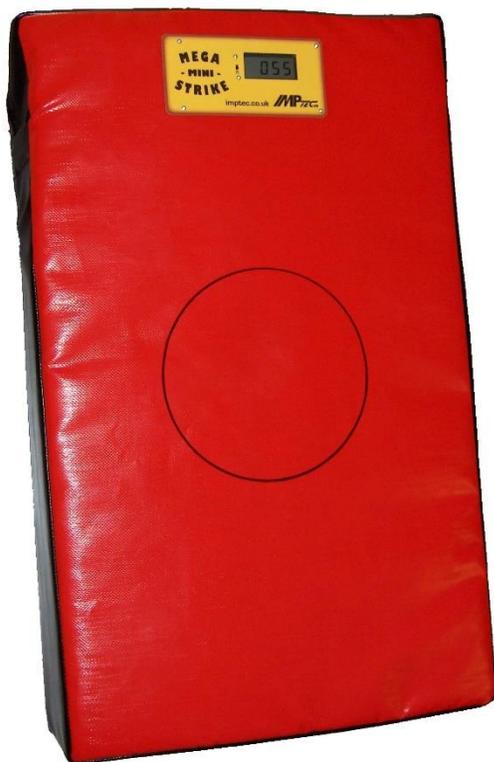
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*Figure 7: The average correlations  $\pm$  standard error between F-A and EMG integrals of the quadriceps and hamstrings in each condition (distal external focus, proximal external focus, and internal focus) and the average ratios  $\pm$  standard error of the quadriceps integral to the hamstrings integral in each condition. \* indicates significance at  $\alpha = .05$  compared to the distal external focus condition. ^ indicates significance at  $\alpha = .05$  compared to the internal focus condition.*

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## Appendix A: Force Bag



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## Appendix B: Warm- up

*Table 1: The warm-ups that participants performed before kicking each session. Warm-ups were conducted in the order listed in the table. All exercises were done in place.*

<b>Exercise</b>	<b>Amount</b>
Jog	1 min
Heel to butt	1 min
High knees	1 min
Jog	1 min
Straight leg lifting	10 reps each leg
In to out circles	5 reps each leg
Out to in circles	5 reps each leg

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## Appendix C: How to Perform a Taekwondo Kick



*Figure 8: A diagram of how to perform a kick in Taekwondo. Participants did not see this diagram, but rather saw the experimenter demonstrate the same progression using the front leg. Participants were instructed to execute the third and fourth positions and were told that they may put their foot down after the fourth position.*

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## Appendix D: Sample EMG Data

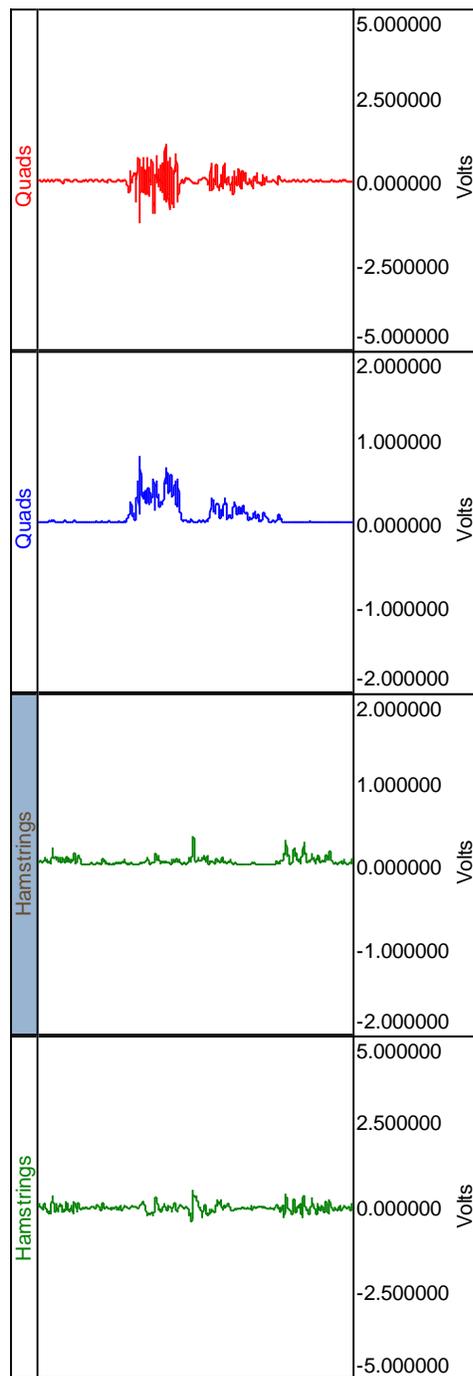


Figure 9: Sample EMG data. The top and bottom panels show the raw EMG data for the quadriceps and hamstrings, respectively. The middle two panels show the rectified EMG for the quadriceps and hamstrings (top and bottom, respectively).