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EFFECTS OF ATTENTIONAL FOCUS ON DYNAMIC WHOLE-BODY
MOVEMENTS AS A FUNCTION OF SKILL LEVEL

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EFFECTS OF ATTENTIONAL FOCUS ON DYNAMIC WHOLE-BODY
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By Charlend K Howard

We recommend acceptance of this thesis in partial fulfillment of the candidate's requirements for the degree of Master of Science in Human Performance (Applied Sports Science Emphasis).

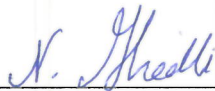
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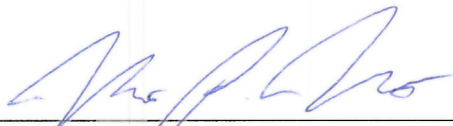
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ABSTRACT

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Focusing attention on an external cue (EF), as opposed to an internal focus of attention (IF), has been shown to improve reaction time (RT) for track and field athletes during a sprint start (Kovacs et al., 2018). The track sprint start is a rapid, discrete, whole body movement whereby athletes need to rely on a motor program that has all parameters specified before movement initiation. The purpose of this study was to address the question of whether improvements in a sprint start under an EF condition are dependent on the participants' skill level. Twelve collegiate track sprinters (age 20.8 ± 1.7), and twelve collegiate non-sprint athletes (age 20.1 ± 1.2) completed three testing sessions under EF, IF, and no focus instruction (NF) conditions. RT was recorded from the rear starting block. Muscle activation time (EMG) was recorded from the vastus lateralis muscles, and was used to determine pre-motor RT and motor RT. Mean RT was significantly shorter ($p < 0.001$) for sprinters (227.7 ms) compared with non-sprinters (273.8 ms). Mean RT for sprinters was significantly shorter ($p < 0.0001$) under the EF (212.11 ms) compared with the IF (234.21 ms) and NF conditions (236.87 ms). Similarly, mean premotor RT under the EF condition (157.75 ms) was significantly shorter ($p < 0.001$) compared with the IF (181.90 ms) and NF (173.60 ms) conditions. No differences in RT and pre-motor RT across conditions were found for non-sprint athletes ($p > 0.05$). Motor RT did not differ across the various focus of attention conditions ($p > 0.05$) or across experimental groups ($p > 0.05$). These results suggest that the beneficial effects of EF on dynamic whole-body movements are manifested at higher skill levels, and that adopting different types of attentional focus interferes with the efficiency of the movement planning processes. Improvement in RT likely originates at the level of central processes during movement preparation (pre-motor RT), and not at the level of peripheral processes associated with excitation-contraction coupling of the muscle fibers (motor RT).

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INTRODUCTION

Often within a sports training environment, coaches use verbal instructions to provide movement instruction and feedback to optimize performance (Porter, Crossley, Knopp, & Campbell, 2015). New strategies of applying verbal instructions to athletes to increase their competitive advantage are continually being sought out by coaches (Porter et. al., 2015). When delivering verbal instructions to athletes, an area of concern arises on how these instructions will direct the athletes' focus of attention.

Focus of attention is another factor, in addition to biomechanical and physiological factors, that can affect the efficiency of information processing involved in movement preparation and execution. Movement execution can be affected by the increased production speed of complex tasks that require a quick response to a stimulus and the coordination of multiple factors (Ille, Selin, DO, & Thon, 2013). An example of such a task is the track sprint start, wherein a person has to execute a whole-body movement that relies on a set of predetermined instructions sent to all the muscles involved in the action (motor program). Given that all the parameters related to such a movement need to be processed a-priori, any factor that interferes with these processes could potentially affect reaction time (RT). Focusing one's attention on specific aspects of movement execution has been shown to be an important factor than can improve reaction time during the start of a sprint race (Kovacs, Miles, & Baweja, 2018; Ille et. al., 2013).

Within the motor learning field, literature defines attentional focus as directing one's attention to specific characteristics in action-preparation activities (Wulf, McNevin, & Shea, 2001). Two distinct forms of attentional focus exist: external (EF) and internal (IF) focus of attention (Wulf, McNevin, & Shea, 2001). An IF requires the performer focusing on specific aspects of the movement of their own body, while an EF requires the performer to focus on the intended movement effect on the environment or implement. For instance, when looking at a track and field sprint start an EF would lead a performer to focus on pushing the blocks backward, while an IF would have the performer focus on extending their knees to get out of the blocks (Kovacs et al., 2018). In another example, using long jump, a performer may utilize EF by focusing on reaching a distant target or utilize IF by focusing on pushing with their legs and swinging their arms (Herbert & William, N/A). Literature from the field of motor learning has demonstrated that adopting an EF yields improved performance over adopting an IF (Wulf, 2013). Adopting an EF has shown improvement in performance in a variety of tasks such as dart throwing (Lohse, Sherwood, and Healy, 2013, 2010), dynamic balance task (Wulf, McNevin, & Shea, 2001), target shooting (Raisbeck & Diekfuss, 2017), jumping (Herbert and Williams; Wulf & Dufek, 2001; Wulf, Dufek, L & Pettigrew, Lozano, & Pettigrew, 2010), isokinetic elbow flexion (Marchant, Greig, and Scott, 2009), punching (Halperin, Chapman, Martin, & Abbis, 2017), sprinting (Porter & Sims, 2013; Porter et al., 2015; Ille et al., 2013), and golf shot performance (Wulf and Su, 2007).

These results are interpreted from the point of view of the constrained action hypothesis, which states that certain aspects of movement control emerge from automatic self-organized processes (Wulf, McNevin, & Shea, 2001). Adopting an IF would require

the participant to involve conscious effort during movement control that most likely disrupts or constrains these automatic processes, and in-turn leads to a decrease in task performance (Wulf, McNevin, & Shea, 2001). On the other hand, adopting an EF promotes this form of automaticity, which is associated with an increased efficiency of motor unit recruitment and movement production. In other words, a reduced neuromuscular activity and improved task performance has been observed under EF versus IF when performing the same task.

Additionally, different mean power frequency profiles were observed during continuous movements in a balancing task when utilizing an EF compared to IF. A higher mean power frequency is an indication of a more automatic, reflex-type mode of control that is based on finely tuned and faster movement responses. A higher frequency of responding is associated with an effective increase and integration of the degrees of freedom associated with performing a motor task and greater confluence between reflexive and voluntary control mechanisms. A lower mean frequency is associated with conscious interference of those automatic processes by adopting an IF resulting in a freezing or constraining of the degrees of freedom (Vance, Wulf, Tollner, McNevin & Mercer, 2004).

Reaction time (RT) is defined as the time between the presentation of a stimulus to the beginning of the response to it (Schmidt & Lee, 2011). Reaction time is affected by the number of stimuli presented, by the number of response choices, difficulty of the task, level of proficiency at that skill, and surrounding environment (Schmidt & Lee, 2011). The fewer the number of stimuli, task irrelevant cues, and number of possible associated responses, the shorter the RT. One of the best methods to measure information processing

speed is by utilizing (Jensen,2011). SRT is when there is only one possible response to the stimulus presented, giving the shortest amount of reaction time possible. An example of SRT is in the track and field sprint start. During a sprint start, participants are to leave the blocks as fast as possible upon hearing the starting gun (stimulus).

Information processing has three distinct stages, where information is perceived from the environment and then the central nervous system processes and prepares this information for an appropriate response to that stimulus. The three stages of information processing are stimulus identification, response selection, and response programming (Schmidt & Lee, 2011). Stimulus identification is when an environmental stimulus is detected and then recognized as part of an identifiable pattern by an individual. After knowing what has happened in the environment, an appropriate response to this stimulus must be made. This stage is known as response selection. Once the response is selected, the individual must translate this abstract idea into a set of muscular actions that will achieve the desired action known as response programming (Schmidt and Lee, 2011).

Central and peripheral events of RT can be defined between premotor and motor RT. Premotor RT (central) is defined as the time elapsed between the presentation of a stimulus to the first change in electromyography signal at the level of the primary muscle of the movement (Kovacs et al., 2018). Motor RT (peripheral) is the time between the first change in electromyography signal and the time of force onset (Kovacs et al., 2018). Premotor RT reflects the time requirement associated with the three stages of information processing; stimulus identification, response selection, and response programming, while motor RT reflect the time requirement associated with mechanisms

of excitation contraction-coupling (Schmidt & Lee, 2011). In an SRT task, the first two stages of information processing have a low level of uncertainty. The stimulus and the associated response are known before hand, thus minimizing the processing time during the first two stages of information processing. Therefore, any changes in RT observed under different conditions for a SRT are likely originating in the response programming stage. Kovacs et al. (2018) utilized track and field blocks starts as an SRT task to isolate one response to a known stimulus, and showed that changes in premotor RT are likely occurring in the response programming stage of information processing.

The start of a short distance running race accounts for approximately 5% of total race time in the 100 m dash (Harland & Steele, 1997). The goal is to accelerate from the starting block in a horizontal linear direction as quickly as possible following the reaction to a gunshot, allowing athletes to reach maximum running velocity in the shortest amount of time. The focus of attention can be a factor that improves reaction time during a sprint start. In a study, Kovacs et al. (2018), involving 12 NCAA Division III sprinting athletes, adopting an EF improved reaction time compared to IF and NF conditions. They argued that the increase in RT under an IF is due to a less efficient process of response programming brought upon by artificially directing the athlete's attention to the action of a specific body part. This shift in focus presumably disrupts the processing of the movement output chunking for the specific task.

Movement output chunking is a strategy that reduces long strings of information into shorter more manageable pieces that are easier to remember. An example of chunking is when an individual memorizes a 10-digit phone number. Rather than memorizing a single sequence of numbers, the 10 digits are separated into three smaller

sequences. This 10-digit number is divided between the area code, middle three digits and the last four digits making the number easier and faster to recall from memory. This chunking pattern can be associated with muscular activation when performing a movement. Rather than activating each muscle of a movement in a series pattern, muscles that perform similar action on joints can be activated together breaking up the movement into smaller sequences. Overtime an individual can train to develop this movement output chunking pattern to improve their performance. It is hypothesized that IF creates conscious interference separating the chunks while simultaneously combining them into a long string of movements, while EF causes no interference with the movement output chunking pattern (Kovacs et. al, 2018; Ille et, al., 2013).

Ille and colleagues (2013) showed EF improved reaction time in track block starts in low level sprinters, while Kovacs and colleagues (2018) showed improved reaction time in Division three track and field sprinters. Kovacs and colleagues (2018) study had Division III NCAA track and field sprinters while Ille and colleagues study involved football and basketball players at regional and international levels. While both groups were of different skill level, both performed sprints as a regular part of practice and were familiar with sprint biomechanics. Another study by Porter and colleagues (2015), demonstrated an increase in sprint performance (time) under an EF focus condition for subjects with no formal training in sprint mechanics and who were not currently or formerly collegiate athletes. EF focus was shown to improve performance in sprint running (non-sprinters) and in the sprint start (sprinters). However, sprint starts, are highly complex and dynamic whole-body movements that require years of training and

coaching to perfect. And so, the effect of, adopting an to improve sprint start performance for participants with no formal training in the task requires further investigation.

The purpose of this study was to address the question of whether improvements in a sprint start under an EF condition are dependent on the participants proficiency level at that skill. It was hypothesized that participants with no experience coming out of a block start would not have significant reduction in reaction time under EF, while reaction time for the well-trained sprinters would be significantly affected by adopting an EF.

These findings have the potential to create a better understanding of the effect of skill level when looking into the constrained action hypothesis and the effect of attentional foci on reaction time throughout central processing.

METHODS

Participants

Twelve collegiate non-sprinters (six men and six women, age 20 ± 1.2) and twelve Division III collegiate track sprinters (four men and eight women, age 20 ± 1.7) volunteered. Sprinters were familiar with the task, while non-sprinters were unconditioned to the task, but both groups were naïve to the purpose of the study. Informed consent was obtained from participants before testing began. All forms and experimental methods were approved by the University of Wisconsin – La Crosse Institutional Review Board for the Protection of Human Subjects.

Apparatus

Sprints were conducted on a synthetic indoor track surface. Force data were acquired for the front and rear foot via two force plate sensors (FP3, Biometrics Ltd., Newport, UK) mounted to a standard track starting block. Electromyographic data were acquired through a Delsys TrignoTM (Natick, MA) wireless system from the left and right vastus lateralis (VL), as well as the left and right medial gastrocnemius (GM). These muscles have previously been identified as prime movers during a block sprint start (Coh, Peharec, Bacic, & Kampmiller, 2009). The force and EMG data were time synchronized through an A/D board (USB-6210, National Instruments, Austin, TX), sampled at 2000 Hz, and stored on a personal computer (Latitude E6530, Dell, Round Rock, TX) for further analysis. The start signal was produced by a gunshot sound clip (44,100 Hz; 16

100 Hz; 16 bits/sample), and played through external speakers (Labtec LCS-1030, Logitech, Newark, CA) placed behind the starting block. Data acquisition and processing was performed through a custom program (Matlab, Mathworks, Natick, MA)

Procedure

During the first session, baseline reaction time was recorded across fifteen trials. Baseline RT was collected by having subjects press a foot pedal, as fast as they can, with the forefoot of their right foot upon hearing an auditory signal (high pitched beep). Three separate sessions were used to collect data under three different focus conditions: no focus (NF), external focus (EF) and internal focus (IF). No additional instructions were given during the NF. Participants were instructed to “focus on pushing the blocks away” during the EF condition, and during the IF to “focus on extending your knees”. Test sessions were separated by a minimum of two days. Fifteen starts were performed during each session, with ~1-2 minutes of rest between each trial.

Delsys Tringo™ wireless surface EMG electrodes were placed on the erector spinae, right and left vastus lateralis and medial gastrocnemius. Before electrode placement, proper skin cleaning took place. Hair was removed first followed by cleansing of skin through light abrading to remove dead epithelial tissue, and then wiped with alcohol to remove excess oil. After skin preparation, electrodes were placed over the belly of the muscle, parallel to muscle fiber orientation, following placement guild lines from SENIAM.org. Vastus lateralis electrodes were placed 2/3 on the line between the anterior iliac spine and lateral side of the patella. Placement for the medial gastrocnemius electrode was on the most prominent bulge. Erector spinae electrode was placed one finger width medial from the line from the posterior spina iliac superior to the lowest

point of the lower rib, at the level of L2. After placement electrodes were secured using performance tape to prevent movement of electrode during the track sprint start.

To find quick/power (i.e. rear/front) foot participants, in the non-sprinter group, were asked to place both hands down on their sides against their hips. On a auditory “Go” signal participant were asked to slap their hands very quickly across their chest leaving the hands there. The hand that touched the chest first was determined to be the quick side, and the top hand was the power side. Foot placement in the blocks was determined by designating the quick foot and power foot. After designating the quick and power side, starting block placement was determined using shoe length of each participant. The power side would be placed 1.5 to 2 of the participants shoe size in distance from the starting line. The quick side would be placed 2.5 to 3 shoe size in distance from the starting line (Silvey,2018). The Division III track sprinters performed their routine warm-up before each testes session as they would before a competitive sprint event. The collegiate non-sprinters performed the same warm-up protocol before each test session (Table 1.).

Table 1. Non-Sprinters warm-up protocol

400-meter Jog	Performed on Indoor Synthetic Track
High Knees	13 Meters
Butt Kickers	13 Meters
Walking Knee Hugs	13 Meters
Walking Quad Stretch w/ Overhead Reach	13 Meters
Body Weight Squat	6 Repetitions
Trunk Twist	6 Repetitions
Horizontal Trunk Twist	6 Repetitions
Glute Bridge	6 Repetitions

Participants in both groups were instructed to accelerate as fast as possible to a line placed 6 meters from the start line. This distance was chosen in order to give the participants a distance goal, while also minimizing fatigue that could occur from running longer distances (Majumdar & Robergs, 2011). Before the trials, participants were informed that they would receive the start commands “on your mark” and “set” before hearing the gunshot. The focus cues were given following the “on your mark” command, before the “set” command and gunshot. The first session always consisted of the NF condition, while the EF and IF conditions were completed utilizing a counterbalanced within-subject design.

Electromyography and Signal Processing

Data was collected and analyzed using custom developed computer programs (Matlab). The force signal was filtered using a second order low-pass zero phase-shift Butterworth filter with the cut-off frequency set at 15 Hz. Similarly, to obtain the linear envelope, the rectified EMG signal was filtered with a cut-off frequency of 35 Hz.

Premotor RT was determined as the time elapsed between the auditory signal and the detection of a 5% change relative to maximum in the EMG envelope. Motor RT was determined as the time elapsed between the occurrence of a 5% change relative to maximum in the EMG envelope and a 5% change from the maximum force applied against the block. The time elapsed between the auditory signal and the detection of a 5% change from the maximum force applied against the block was determined as the RT (Figure 1). Regardless of skill level or focus condition, the rear foot VL was the first muscle activated during the sprint start, premotor RT was determined as the time elapsed from the auditory start signal (gunshot) and the activation of the rear foot VL. Motor RT was determined as the time elapsed between the activation of the rear foot VL and the initiation of force production.

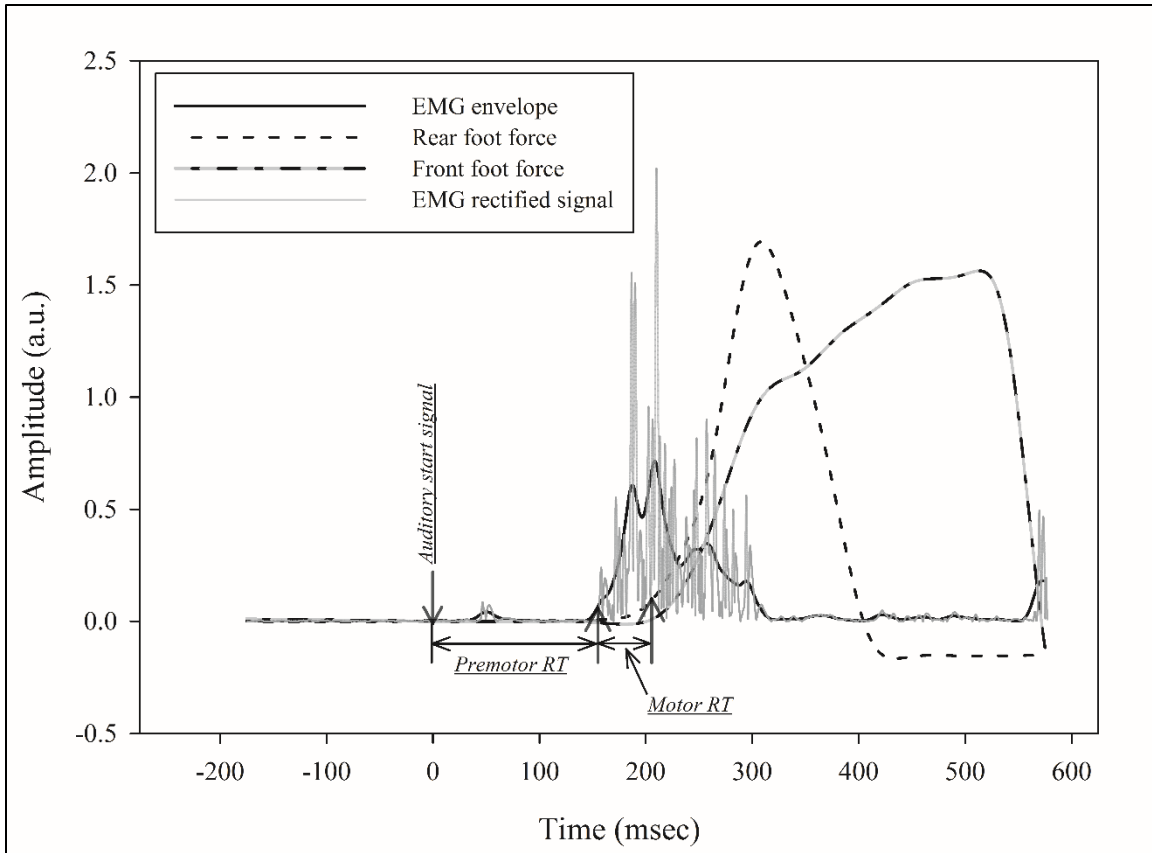


Figure1. Example of force and rectified EMG signals of vastus lateralis after filtering. Onset was determined as a 5% change in signal amplitude relative to the maximum value of each signal

RESULTS

Statistical Analysis

Standard deviation around the mean assumes normal distribution, making it strongly impacted by outliers and unlikely to detect outliers in small samples. Unlike standard deviation around the mean, absolute deviation around the median is insensitive to the presence of outliers, and immune to sample size (Leys, Leys, Klein, Bernard, & Licata, 2013). Therefore, in order to detect and eliminate outliers before further analysis, absolute deviation around the median was used. Analysis test was performed with statistical package for social science (SPSS v. 25).

Baseline RT for both groups was analyzed utilizing an independent t-Test. Baseline RT was used to assess any inherent differences between groups. A paired T-test was used to analyze baseline reaction time between groups.

A preliminary analysis, separating the total trials within each focus condition into three sets (trials 1-5, 6-10, and 11-15), was used to detect any potential changes in RT due to fatigue over the course of fifteen trials. A one-way ANOVA with repeated measures on sets failed to detect any significant differences, indicating no fatigue occurred over the course of the testing. Therefore, all fifteen trials were grouped together for further analyses. Timing variables were averaged across fifteen repetitions within one testing session and analyzed using a one-way ANOVA with repeated measures on focus

actor. The ANOVA was performed for each dependent variable followed by Bonferroni post-hoc comparisons. Criterion for significance level was set using an alpha level ($p < 0.05$). Data are presented as means and standard error of the means (SE) in the text, figures and table. To determine the difference between groups (sprinters and non-sprinters) timing variables were analyzed using a two-way ANOVA with repeated measures on focus factor with group as a between factor. Post hoc tests were completed using the Bonferroni post-hoc comparisons. Criterion for significance level was set using an alpha level ($p < 0.05$). Data are presented as means and standard error of the means (SE) in the text, figures and table.

Base Reaction Time

Mean baseline RT for sprinters ($M = 233.92$ ms, $SE = 35.69$) was found to not be significantly ($F_{(1,22)} = .075$, $p = .787$) different from non-sprinters ($M = 237.67$ ms, $SE = 31.29$).

Fatigue

There were no differences in rear foot RT for non-sprinters across groups of trials from beginning to end of testing session EF ($F_{(2,22)} = .029$, $p = .971$), IF ($F_{(2,22)} = .132$, $p = .877$), and under NF conditions ($F_{(2,22)} = 1.01$, $p = .379$). No differences in rear foot RT for sprinters across groups trial for NF ($F_{(2,22)} = .485$, $P > .05$), IF ($F_{(2,22)} = .135$, $p > .05$) and EF ($F_{(2,22)} = .343$, $p > .05$) were detected. Therefore, all trials within a focus condition were grouped together for further analysis.

Reaction Time

Mean RT for sprinters was found to be significantly shorter ($F_{(1,22)} = 1688.3741$, $p < .001$) for sprinters ($M = 227.21$ ms, $SE = 6.84$) when compared with non-sprinters ($M =$

273.8ms, SE = 6.84). No significant interaction was found between focus conditions and status (level of proficiency) ($F_{(2,44)} = 3.171$, $p = .052$), however focus did have a main effect on reaction time ($F_{(2,44)} = 5.91$, $p = .005$). Average reaction time under EF (M = 241.45ms, SE = 44.88) when both groups time were combined was significantly shorter than when compared to IF (M = 256.542, SE = 28.34) and NF (M = 254.333ms, SE = 32.50).

Reaction time for Rear foot was found to not be significantly different between focus conditions, ($p > .05$) for the non-sprinters group. However, rear foot RT was determined to be significantly different between focus conditions for the sprinting group ($F_{(1,22)} = 14.996$, $p < .0001$). The Post hoc tests showed mean rear foot reaction time was significantly shorter ($p < .0001$) under EF conditions (M = 212.11ms, SE = 8.45) than both IF (M = 234.21ms, SE = 5.76) and NF conditions (M = 236.87ms, SE = 8.82) with IF and NF conditions not being significantly different from each other ($p > .05$). RT results are shown in figure 2: RT across focus conditions for sprinters and non-sprinters.

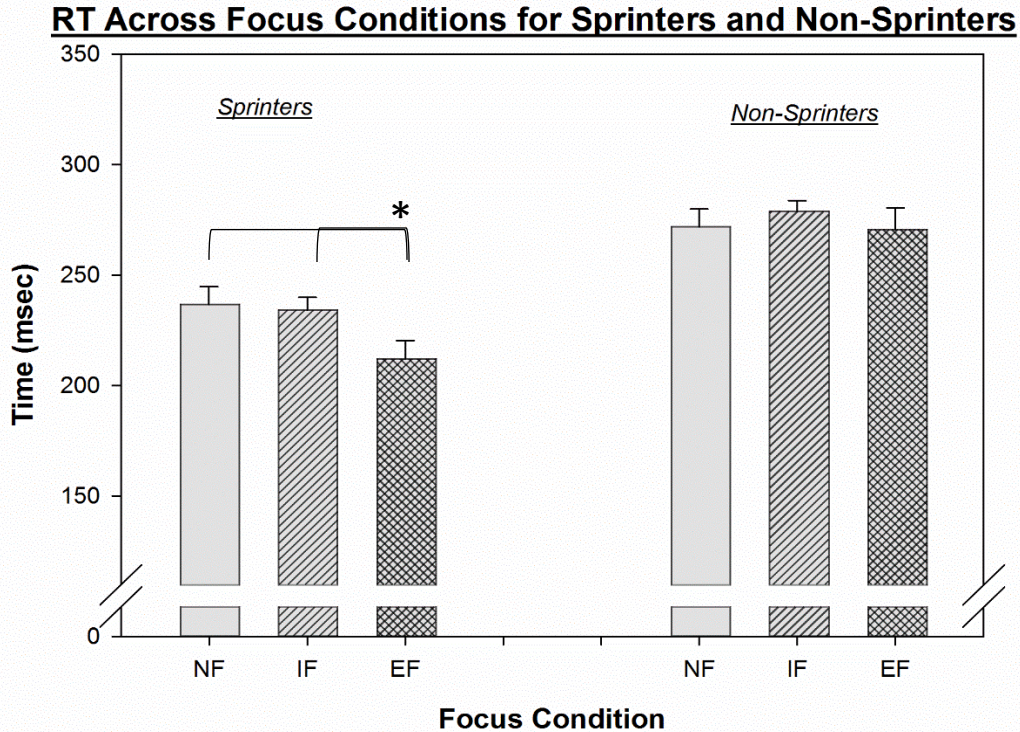


Figure 2. Reaction time recorded at the force plates across focus conditions for both groups.

* Significantly less than IF and NF ($p < 0.05$).

Pre-Motor Reaction Time

There was no significant main effect of focus condition on rear foot VL activation time ($F_{(2,44)} = 2.44$, $p = .099$) and no significant interaction was found between focus and group ($F_{(2,44)} = 1.37$, $p = .264$). Further analysis showed there was a significant group effect in the rear foot VL activation time ($F_{(1,22)} = 13.01$, $p = .002$). Mean pre-motor RT for the non-sprinter group was significantly slower, IF ($M = 248.88\text{ms}$, $SE = 21.707$), EF ($M = 247.74\text{ms}$, $SE = 24.61$), and NF conditions ($M = 310.20\text{ms}$, $SE = 29.04$) when compared the sprinter group EF (152.06 , $SE=24.61$), IF($M = 181.90\text{ms}$, $SE = 21.71$) and NF conditions ($M = 176.94\text{ms}$, $SE = 29.04$). Results are shown in figure 3: Pre-motor RT: sprinters vs. non-Sprinters.

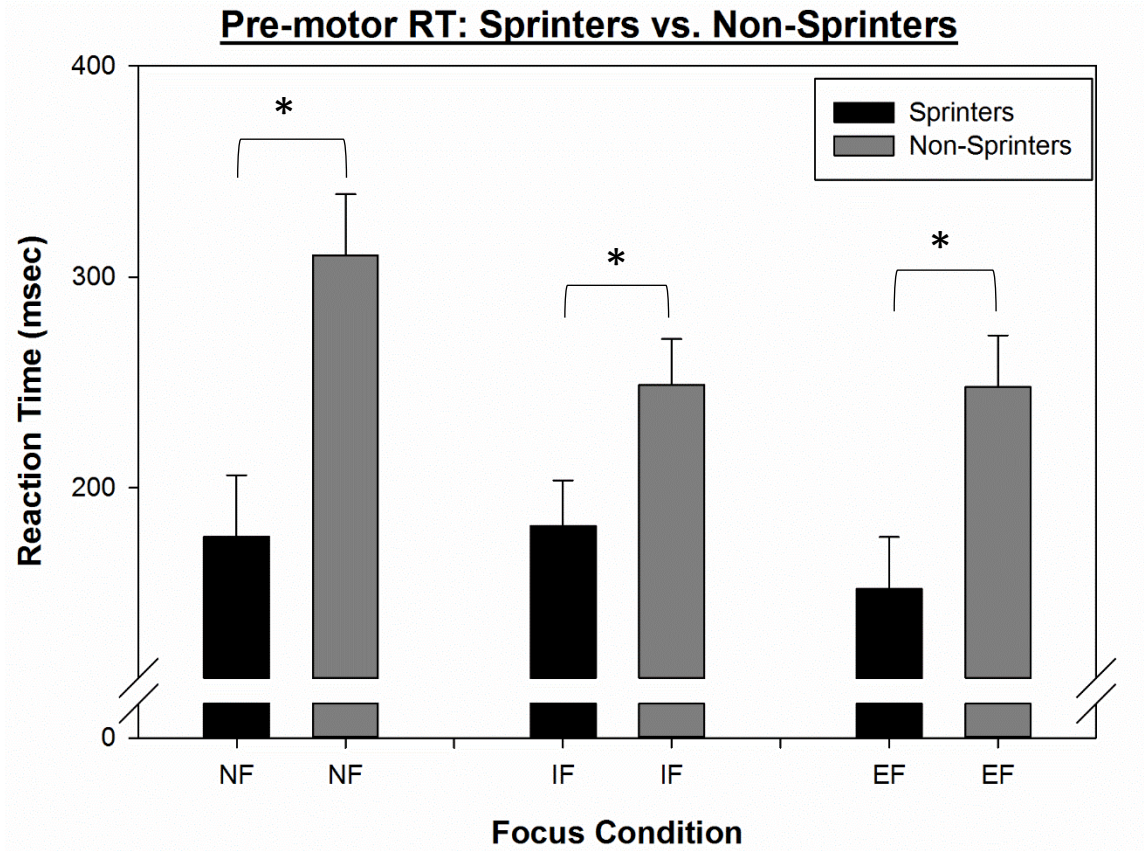


Figure 3. EMG activation time for vastus lateralis (premotor RT) across focus conditions for both groups.

* Significantly less than Non-Sprinter group ($p < 0.05$).

Motor Reaction Time

There was no significant main effect of focus condition on motor RT ($F_{(2,44)} = .008$, $p = .992$) and no significant interaction was found between focus and grouping factor ($F_{(2,44)} = .974$, $p = .386$). Also, the analysis showed no significant difference between groups ($F_{(1,22)} = .14$, $p = .712$). Results are shown in figure 4: Motor RT: sprinters vs. non-sprinters.

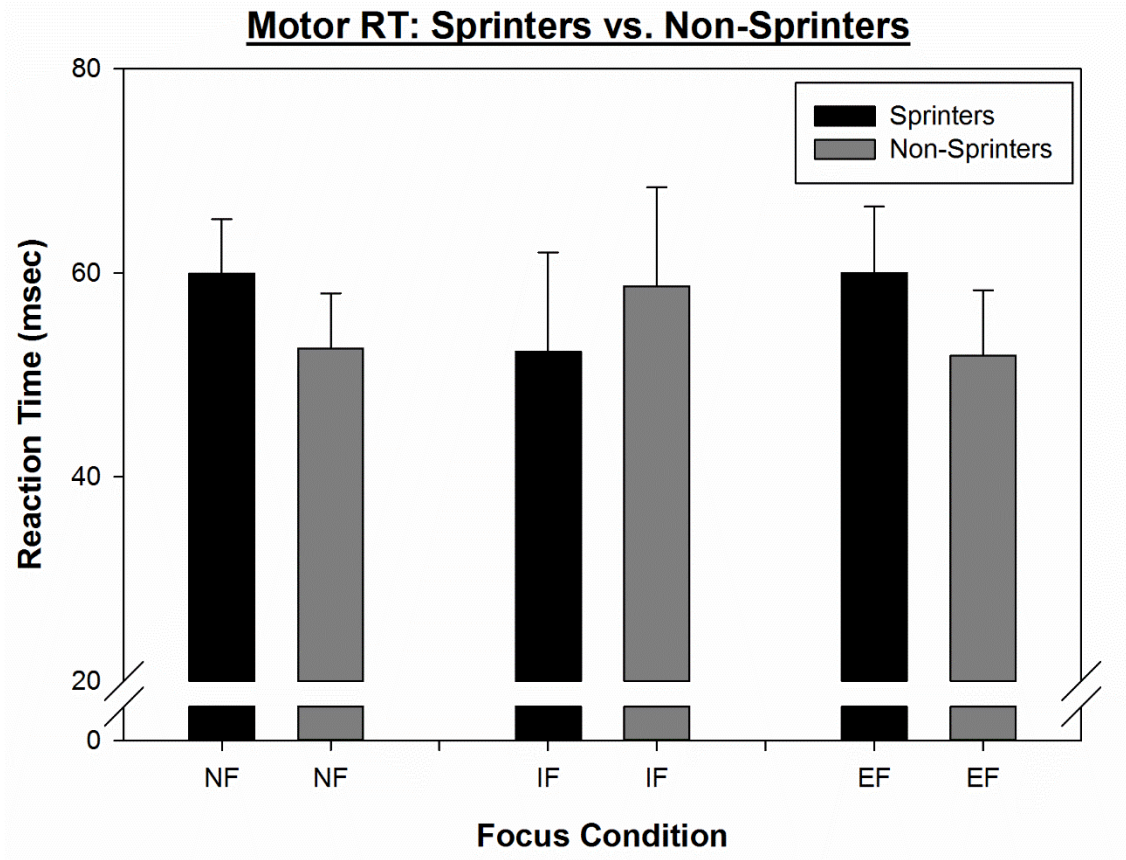


Figure 4. EMG activation time for vastus lateralis (premotor RT) across focus conditions for both groups.

Table 2. Mean RT (ms) for each attentional focus condition between groups (SE in parentheses).

	EF	IF	NF
Sprinters			
Premotor RT (VL EMG)	152.06 (24.61)*	181.90 (21.71)*	176.94 (29.04)*
Motor RT	60.04 (6.45)	52.32 (9.71)	59.93 (5.45)
RT	212.11 (8.45)†	234.21 (5.76)	236.87 (8.82)
Non-Sprinters			
Premotor RT (VL EMG)	247.74 (24.61)	248.88 (21.71)	310.20 (29.04)
Motor RT	51.93 (6.45)	58.74 (9.71)	52.60 (5.45)
RT	270.79 (9.86)	278.88 (4.91)	271.80 (8.02)

* Significantly different from non-sprinter group ($p < 0.05$).

† Significantly shorter than IF and NF condition ($p < 0.05$).

DISCUSSION

The purpose of this study was to address the question whether improved RT in a sprint start under an EF condition are dependent on the participants' skill level. Reaction time was observed to not be significantly different between the three focus conditions in the non-athlete group, while reaction time was significantly shorter under the EF condition when compared to the other focus conditions in the athlete group.

According to the constrained action hypothesis, focusing internally hinders performance through conscious interference with automatic self-organizing processes of a movement, while adopting an EF promotes the automatic responses of the motor system. Previous research has shown that attentional focus affects the information processing of the central nervous system by decreasing pre-motor reaction time (movement preparation) when adopting an EF (Kovacs et. al., (2018)). While adopting EF improves pre-motor reaction, the level of proficiency at that skill might determine if the subject benefits from adopting an EF. If the level of proficiency at that skill influences reaction time under EF, reaction time in the athlete group would be significantly different from the other conditions while, there would be no significant difference between focus conditions in the non-athlete group. The results of this study support the idea that level of proficiency of a skill has an influential factor over an individual benefiting from adopting an EF. In a RT task, the movement is split up between pre-motor and motor RT. Pre-motor RT is associated with central processing (central processing), while motor RT is

related to peripheral mechanisms (excitation-contraction coupling). A previous study by Kovacs et al. (2018), demonstrated that when adopting an EF, during a track sprint start, reaction time is significantly shorter when compared to IF and NF conditions. The time elapsed between the auditory start signal (stimulus) and the attenuation of muscle activation, assessed by EMG, was shorter under EF conditions, while the time elapsed between attenuation of muscle to force onset was the same across all conditions. Faster time between the auditory start signal and muscle attenuation shows a reduction in time requirement to prepare for the movement. Kovacs et al., (2018) was able to show the effects of attentional focus originating in the central processing: pre-motor segment of reaction time rather than the peripheral processing: motor RT segment.

Reaction was proven to be shorter in Division three track athletes who had a higher level of proficiency for that skill, while results for the non-athlete group yielded different conclusions. RT was not significantly different between the three focus conditions indicating the non-athlete group were not able to reduce their movement preparation time by adopting an EF. This might be related to the subject's inexperience of the skill subjecting them to stay in the cognitive stage of motor learning. There are three stages to learning a motor skill; Cognitive, Associative, and Automaticity. The first stage, cognitive, is when there is an effortful and conscious regulation of the movement. The second stage, associative, is when there is more focus on the task and less on the movement itself. The final stage, automaticity, is when the mind is relaxed, and the skill is executed automatically by the body's natural self-organizing processes (Haff and Triplett, 2015). Past literature has shown adopting an EF improves performance by promoting the automaticity stage, however this is inhibited if the subject has a low level

of proficiency in that skill in which adopting any focus inhibits these automatic processes by providing conscious effort during movement.

The track sprint start is a complex dynamic sequential whole body movement involving many muscles. The time to prepare and initiate these muscles is increased when compared to a less complex SRT task. This can be seen when learning a novel complex task where the elements of each sequence are processed independently. With practice, the individual elements of a sequence can be organized and chunked together forming bigger, but fewer elements, allowing each chunk to be processed as a single unit decreasing the amount of processing time required for movement planning. This pattern leads to a more rapid, smooth and coordinated movement execution. Presumably the non-sprinter group did not chunk the individual elements of the track sprint start, but processed each element individually, due to their inexperience with the task. This may be related to no significant difference between RT across focus conditions due to no conscious interference disrupting the movement sequence and chunking pattern. The sprinter group had several years of experience performing the sprint start; it is assumed they have developed a chunking pattern that allowed them to be proficient with the task. RT under IF and NF was significantly greater than EF which might be related to these conditions causing a disruption to the regular chunking pattern, causing a greater number of chunks to be formed. An increase in the number of chunks formed causes an individual to process a greater number of motor chunks, thus increasing movement planning time (Kovacs et al., 2018; Klapp and Jagacinsky, 2011).

Another area to consider when trying to explain why reaction time under EF was faster for sprinters when compared to non-sprinters, is the warmup. When comparing

within the groups, warmups were the same regardless of condition for every session for sprinters and non-sprinters which would not influence either groups RT. However, when comparing between the groups, each group had their own warmup which could have the potential to explain why reaction time under EF was faster for sprinters versus non-sprinters. The same concern can be raised when looking at gender differences between groups. When comparing RT's within each group, the task was the same for every individual in each group across focus conditions where gender would have little influence on RT within groups. When comparing between groups gender could have the potential to influence RT due to a greater number of women in the non-sprinter group and a fewer number of men in the sprinter group. More research needs to be conducted to understand the full effects of warmup and gender on SRT in a dynamic whole-body movement.

Practical Applications

Porter and Sims (2015) stated that verbal instructions are commonly used by coaches to deliver information to athletes in testing and training conditions. Most verbal instructions from track and field coaches promote an internal focus 84.6% of the time and 69.2% of athletes adopt an internal focus during competition. One way a coach could improve performance is by basing their verbal instructions off the individual's skill level and also has them promote an EF.

Proficiency of skill level can be determined by periodic testing of an individual, while verbal instructions should have the individual focus on the movement effect on the environment. When coaching athletes with a high level of proficiency at a skill, such as a track sprint start, verbal cues that promote an EF will promote the automatic processes and decreasing pre-motor RT time. When coaching an individual new to the task,

adopting any type of attentional focus shows no benefit to sprint start performance. While this study shows level of proficiency having an influence on attentional focus, no study compares the effects of attentional focus on an individual whose proficiency level progresses over time. It would be interesting to see if there is a transition between each focus conditions during a task as the proficiency level increases within an individual.

Conclusions

The pattern of results from this experiment provide evidence that an EF is better than IF for motor performance, during a dynamic whole-body movement. The results also provide evidence that the level of proficiency at a skill does have influence over the effects of attentional focus.

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APPENDIX A
INFORMED CONSENT

Informed Consent

Attentional Focus and Reaction Time during track start.

I, _____, volunteer to participate in a research study being conducted at the University of Wisconsin - La Crosse.

Purpose and Procedure:

- The purpose of this study is to investigate reaction time and muscle activity (as measured by EMG) during a typical Track & Field start.
- My participation in this study will involve three sessions. Each session will last approximately one hour.
- The exercise to be tested will be a typical Track & Field start, out of the blocks.
- During each session I will perform a simple reaction time test first, where I will have to depress a pedal as quick as I can when an auditory signal is presented.
- Following this first test, I will perform 15 repetitions of a typical track start. This requires me to settle in the appropriate position, and upon the presentation of an auditory signal, start running as fast as I can for a short distance (approximately 20 meters).
- During all sessions I will have adhesive electrodes placed on my leg muscles in order to record muscle activity.
- Research assistants will be conducting the research under the direction of Dr. Attila J. Kovacs, an Assistant Professor in the Department of Exercise Science.

Location: Field house indoor track in Mitchell Hall, and the UW-L stadium track.

Potential Risks/Discomforts:

- The risks in this experiment are minimal, but muscle fatigue and soreness may be experienced
- Minor skin irritation from placement of the EMG electrodes is possible
- The risk for serious or life-threatening complications, for healthy individuals like me, is near zero.

Potential Benefits:

- I, and other athletes, may benefit by gaining knowledge and in-depth analysis about our own technique used during a track start.

Rights & Confidentiality:

- My participation is voluntary
- I can withdraw from the study at any time, for any reason, without penalty of any kind.
- The results of this study may be published in the scientific literature or presented at professional meetings using group data only.
- All information will be kept confidential through the use of numeric codes
- My data will not be linked with personally identifiable information.

Compensation: No compensation will be given for this study.

I have read the information provided on this consent form. I have been informed of the purpose of the test, the procedures, and the expectations of myself as well as the testers, and the potential risks and benefits that may be associated with volunteering for this study. I have asked any and all questions that have concerned me and received clear answers so as to fully understand all aspects of the study.

Contact Information: In case of any problems or questions that may arise concerning the study, subjects may contact the primary investigator, Attila Kovacs. He can be reached by his office phone (608-785-8786), email (akovacs@uwlax.edu), or at his personal office in room 223A Cartwright. Questions regarding the protection of human subjects may be addressed to irb@uwlax.edu.

Signature of Subject

Date

Signature of Investigator

Date

APPENDIX B
REVIEW OF LITERATURE

REVIEW OF LITERATURE

Introduction

All coaches seek to improve the performance of their athletes. One potential way an athlete can improve his or her performance is to shift their attentional focus to produce a more efficient motor program. The purpose of this literature review is to examine the effects of external focus (EF) and internal focus (IF) of attention on information processing with special emphasis on the response programming stage. Use of electromyography devices (EMG) to measure muscle activation, as well as track and field starting blocks across various levels of athletes will also be discussed.

Information Processing

Human information processing is a three-step method in the central nervous system (CNS) modeled after serial processing in a computer. Information processing is broken down into three major stages: stimulus identification, response selection, and response programming. These stages occur between stimulus presentation and the initiation of the response (Schmidt and Lee, 2011). The stimulus must be recognized as part of an identifiable pattern. This identifiable pattern is processed on multiple levels until it can be associated with a past memory. After the pattern has been associated with a past memory, a response is selected to accommodate the change in the environment. Following these two stages is response programming, the final step before the production of a response.

The individual must organize the abstract idea into muscular actions that

will achieve the desired outcome. This translation requires a motor program to be retrieved from memory, prepared for activation, and relevant portions of the motor system to be initiated for movement. Information processing can be studied in multiple ways, but most common is the chronometric approach which considers the duration of these various processes (Schmidt and Lee, 2011).

Reaction Time

Reaction time (RT) is a measure of the time from the arrival of a suddenly presented stimulus, to the beginning of the response to it (Schmidt and Lee, 2011). When only one appropriate response for a given stimulus is available, it is termed simple-RT (SRT). When two or more stimulus-response (S-R) alternatives are available it is termed choice-RT (CRT). As the number of S-R alternatives increase, the time required to respond increases due to an increased amount of information needing to be processed (Schmidt and Lee, 2011). The end result is an increase in RT during CRT, compared to SRT tasks.

This SRT paradigm can be further broken down into smaller intervals based in relation to muscular activity during a RT task. After a warning signal, but before the stimulus is presented, there is a fore period. During this period, no movement, EMG is mostly quiet meaning little muscle activation is detected. Following the stimulus presentation, there is an interval of time before a change in the EMG signal is detected. Before the muscles can be activated for a response, the stimulus must be identified, a response must be selected and then programmed to activate the appropriate muscles in order to achieve the desired movement (Schmidt and Lee, 2011). The delay in muscle activation is due to the information being processed during this premotor-RT stage. Once

the motor program is selected, the activation pattern of the muscles is sent from the primary motor cortex down the descending pathways to the muscles in the form of electrical impulses. The period elapsed between the first detected change in EMG of the muscle until the detection of force output is termed motor-RT, and represents the time needed for excitation contraction coupling of the muscle to occur (Schmidt and Lee, 2011). Therefore, RT is the sum of premotor-RT and motor-RT. Finally, from the detection of force initiation or movement output, to the completion of the movement is designated as movement time (MT). Together, RT and MT make up the total response time (Schmidt and Lee, 2011).

External vs. Internal Focus

An EF requires the performer to focus on the effects of performance, while an IF requires the performer to focus on their body during the movement (Wulf, McNevin, and Shea, 2001; Wulf, 2013; Schmidt and Lee, 2011). Various studies over the years have shown increased proof of enhanced performance from adopting EF. Wulf, McNevin, and Shea (2001) demonstrated that while adopting an EF there is a greater push of automaticity of a movement by greater mean power frequency (MPF) by using a stabilometer under both conditions. For this experiment subjects were asked to balance on a stabilometer by keeping the platform in a horizontal position for as long as possible. Subjects were randomly assigned to two focus groups; internal and external focus conditions. The external focus group were instructed to focus their attention on the markers attached to the platform, while the internal focus group were instructed to focus on their feet. The EF condition resulted in participants making more frequent and smaller amplitude adjustments (0.329 ± 0.011 MPF) relative to the internal focus condition

(0.268 ± 0.011 MPF). Higher frequency responding is associated with increased degrees of freedom resulting from an effective integration while performing a motor task and greater confluence between reflexive and voluntary control mechanisms. IF restricts these automatic control processes, constraining the degrees of freedom and consequently decreasing the rate and effectiveness of the system. Wulf, McNevin, and Shea used these results to propose the base of the “*constrained-action hypothesis*” which states that when a performer utilizes an IF to consciously control their movements, he or she may constrain their automatic control processes that would normally contribute to the regulation of the movement. However, when adopting an EF a person allows their motor system to self-organize more naturally.

Efficiency

A movement pattern that is completed with the same outcome, but uses less energy is considered more efficient (Wulf, 2013). Higher efficiency is valued when fatigue is the limiting factor to performance outcome.

An EF led to significantly reduced surface electromyography (EMG) while producing greater movement velocity during bicep curls and isometric plantar flexion test (Vance, Wulf, Tollner, McNevin, and Mercer, 2004). The results from this experiment showed decreased surface EMG in the antagonist muscle. IF lead to ineffective neuromuscular coordination by increasing motor unit recruitment resulting in increased error. Adopting an EF also showed an increase in efficiency during motor unit recruitment. Similar results are seen in an elbow flexion isokinetic test where subjects were instructed to focus on the crank bar (EF) or focus on their elbow flexors(IF) throughout the test. The participants produced significantly greater peak joint torque

during the external focus condition, ($101.10 \pm 2.42\%$ MVC), compared to the internal focus condition ($95.33 \pm 2.08\%$ MVC). The results also showed lower peak EMG activity when focusing externally compared to internally ($134.43 \pm 16.83\%$ MVC; $155.23 \pm 22.54\%$ MVC) (Merchant, Greig, and Scott, 2009).

More evidence on efficiency can be used when looking at EMG activity in dart throwing. Lohse, Sherwood, and Healy (2010) had dart throwers focus on the movement of their arm (IF) or the movement of the dart (EF). Results showed less IEMG activity in the triceps during external focus conditions, $F(1,10)=5.54$, $n^2_p=.35$, $p=.040$. This same pattern was also seen in the antagonist muscle, biceps, during external focus conditions, $F(1,10)=1.84$, $n^2_p=.14$, $p=.200$. An index of co-contraction was calculated by taking the ratio of IEMG of the agonist divided by the antagonist, where no difference in contraction ratios were found in either focus condition. The difference between agonists and antagonist was found to be non-significant, however, iEMG being lower during EF shows improved movement economy and reduced muscle stiffness because less activity (energy) is required (Lohse, Sherwood, and Healy, 2010).

Effectiveness

A movement that can be performed consistently, reliably, and with greater accuracy is considered to be effective (Wulf, 2013). Lohse, Sherwood, and Healy(2011) examined if an IF or EF effected the subject's ability to produce a specific amount of force. Participants were instructed to perform an isometric plantarflexion task focusing on either their soleus or tibialis anterior. Results showed EF resulted in less error in force production (9.11 ± 1.38 N) compared to an IF (10.01 ± 1.69 N). The IF condition showed

more activation of the antagonist rather than the agonist when compared to EF condition (Lohse, Sherwood, and Healy, 2011).

Focus of attention has also been shown to influence golf shot accuracy. Wulf and Su (2007) used novice and expert golfers to test the effects of IF and EF on golf shot accuracy. IF showed no change in accuracy, but both novice and expert golfers had an increase in accuracy while focusing externally. Diekfuss and Raisbeck (2017), looked at attentional focus and its effect on division one NCAA golfers. Results showed an increase in performance in practice and competition settings within athletes when focusing externally.

Focus of attention has even been shown to influence punching velocity and impact forces (Halperin, Chapman, Martin, and Abiss, 2017). Expert and intermediate level kickboxers and boxers were used to test EF and IF conditions on their punching velocity and impact forces. The results showed significantly less normalized impact forces during IF when compared to EF and significantly higher normalized impact forces during EF focus when compared to the control condition. Regarding punching velocity, EF condition showed faster delivery of punches to the apparatus when compared to IF and control condition.

Quality of Instruction

When delivering instruction, one way an instructor can deliver his or her messages is through verbal commands. Instructing athletes during tasks to adopt an EF will benefit performance, but the quality of instruction also has an effect (Polsgrove, Parry, and Brown, 2016). In particular, providing short, concise, verbal cues has been established to improve skilled performance (Raisbeck and Diekfuss, 2017). Raisbeck

and Diefuss performed a study looking at how the number of verbal attentional focus cues would affect acquisition and learning of a target-shooting task. Sixty-eight healthy participants were instructed to shoot a Glock 17 with their non-dominant hand, therefore making the task a novel task. Participants were assigned to one of four groups: IF with one verbal cue, IF with three verbal cues, EF with one verbal cue, and EF with three verbal cues. The cue for IF were “focus on keeping your hand steady” or “focus on keeping your hand, wrist, and arm steady”. The cues for EF were “focus on keeping the gun steady” or “focus on keeping the gun, gun barrel, and gun stock steady”. Subjects focusing on a single verbal cue showed higher scores of immediate retention, compared with subjects receiving three verbal cues. Regarding EF vs. IF, EF participants had higher scores during delayed retention under EF when compared with IF condition. These results agree with sport pedagogy literature suggesting that subjects should focus on one single verbal cue to block out any other distractions (Raisebeck and Diefuss, 2017). In an applied setting, it is recommended that instructions given to participants should be a clear and concise singular command.

Electromyography

“Electromyography is the study of muscle function through the inquiry of the electrical signal the muscles emanate” (Basmajian and De Luca, 1985). EMG recording provides investigators with the means to measure the timing of muscle activation, force/EMG signal relationship, frequency, amplitude, and fatigue index etc. (De Luca, 1997).

Before appreciating and understanding EMG, one must grasp the structural and functional physiology of a striated muscle. A striated muscle is deemed excitable due to

the plasma membrane of the muscle fibers and neurons ability to exhibit voltage charges in response to stimulation.

When a muscle cell is unstimulated, there are more negative ions in the inside of the plasma membrane than on the outside. With more negative ions on the inside, the plasma membrane becomes polarized. Upon stimulation, ion gates on the plasma membrane open allowing cations and anions to switch places. Cations flow into the membrane while anions flow outside the membrane (Basmajian and De Luca, 1985). This process of anions and cations changing places is called depolarization. To return to equilibrium (polarization) the cell must repolarize by opening gates on the cell membrane to let cations out and anions back in (Basmajian and De Luca, 1985). While stimulated the quick change in voltage from negative to positive is known as an action potential.

Once depolarization happens, an impulse travel down a neuron towards the neuromuscular junction (NMJ) where the impulse is transferred from nerve to muscle cell. After crossing the NMJ depolarization of the postsynaptic muscle fiber takes places (Basmajian and De Luca, 1985). Depolarization is coupled with movement of ions generating electromagnetic field in area of muscle fibers that are stimulated. Voltage during this excursion is known as an action potential (Basmajian and De Luca, 1985). “The individual muscle fiber action potential represents the contribution that each active muscle fiber makes to the signal detected at the electrode site” (Basmajian and De Luca, 1985) The EMG signal can be affected by anatomical and physiological properties of the muscle, the control scheme of peripheral nervous system, as well as the characteristics of the instrumentation being used (Basmajian and De Luca, 1985).

Fibers never contract individually in normal conditions, but as an entire group as stated by the All or non-Principle (Basmajian and De Luca, 1985). A group of muscle fibers are innervated by a motor neuron's terminal branches. A motor neuron can innervate multiple muscle fibers, but a muscle fiber can only be innervated by one motor neuron. A motor neuron that innervates muscle fibers through terminal branches is labeled a motor unit. When an electrical impulse travel down a descending pathway and stimulates all the muscle fibers to contract at once, labeling the motor unit the functional unit of a striated muscle (Basmajian and De Luca, 1985).

Electrodes

EMG is detected through electrodes that measure the electrical current generated from contractions in a muscle (Luca, 1997). Two forms of electrodes exist: inserted or wire, and surface electrodes. Wire electrodes are inserted into the muscle tissue while surface electrodes are placed over the skin of the muscle being measured (Luca, 1997).

Surface electrodes are non-invasive and have become increasingly popular due to this characteristic, but have a limitation in only being able to detect superficial muscles. In order to measure deeper muscles an invasive approach must be taken using inserted: wire or needle electrodes. Proper skin preparation is required for accurate surface readings of electrodes (Luca, 1997). During application, hair must be removed first followed by cleansing of skin through light abrading to remove dead epithelial tissue, and then wiped with alcohol to remove excess oil. Proper skin preparation reduces electrical impedance, enhancing signal quality.

After proper skin preparation, the electrode must be placed over the desired muscle. Anatomical landmarks should be used to find proper placement of the EMG.

Guidelines do exist on placement of electrodes (e.g SENIAM.org); however, no singular method exists. Electrode should be placed over the belly of the muscle. Improper placement leads to erroneous signal detection due to poor signal detection, muscle cross talk, and other factors that may contaminate the signal (Basmajian and De Luca, 1985; Luca, 1997).

Electrodes can have two different configurations. In a monopolar configuration, there is only one detection surface along with a reference, or ground electrode located in an environment which is electrically quiet (Luca, 1997). The drawback of this configuration is that the electrode will detect all electrical signals near the detection site. This electrical noise includes signals radiating from power cords, outlets and other electrical devices (Luca, 1997).

This limitation can be overcome through a bipolar configuration. This configuration comprises of two detection surfaces to identify two potentials in the muscle tissue with respect to a reference electrode (Luca, 1997). The two signals are then propelled to a differential amplifier which amplifies the difference of the two signals. This eliminates any common components in the two signals. Signals originating from the muscle of interest will be different at each detection surface due to the localized electrochemical events occurring in contracting muscle fibers (Basmajian and De Luca, 1985). The result is a higher quality signal with less noise.

Track and Field Sprint Starts

Starting blocks are required in 100 m dash up to the 400 m dash events in track and field according to the National Collegiate Athletic Association (NCAA). The start of a sprint event is defined as the time elapsed between the start signal and the movement of

both feet clearing the blocks. The start of a sprint is a crucial skill for sprinters to learn to maximize their performance over the race distance (Porter et al., 2015). Tellez and Doolittle(1984) reported starting blocks accounting for approximately 5 % of total 100 m race time demonstrating how a well-executed sprint start can contribute more to a race than merely clearance times. The sprinter starts in a stationary position and must move as fast as possible in a linear asymmetrical action (Mero, Kuitunen, Harland, Kyrolainen and Komi, 2006: Tellex and Doolittle, 1984: Porter and sims, 2013: porter, WU, Crossley, Knopp, and Campbell, 2015). Reaction time in a sprint start is measured as the time elapsed from the onset of the start signal to the first measurable change in force at the blocks. Any force measured before the start signal is deemed a false start and inconclusive. Movement time is the time elapsed between the first measurable force input into the block to the first strike of the sprinter foot on the ground. Response time is considered the time from the start signal to the first foot strike (Majumdar and Robergs, 2017).

A successful sprint start requires the sprinter to develop large horizontal forces from pushing off the block while keeping knee drive low during the first step (Harland and Steele, 1997). Thrust angle during block phase should be as low as possible, 32 to 42 degrees, keeping force production mainly in the horizontal plane (Harland and Steele, 1997). The goal for a sprinter is to generate as much horizontal force as possible from both feet during a sprint start. Higher peak force at a faster rate is generated in the rear block compared to the front block in skilled sprinters. Even though the higher peak force is generated in the rear block (rear limb), the duration of the front limb is twice as long as the rear limb creating a higher overall impulse. Higher impulse is created by higher

average force output which is seen in higher skilled sprinters than less skilled sprinters (Harland and Steele, 1997).

Conclusion

The benefits of EF seem to reach across a variety of skills. Evidence consistently supports the outcome benefits provided from an EF. However, there is no empirical evidence so far if the outcome benefits provided from an EF are influenced by the level of proficiency of a skill. Because EF has been shown by Kovacs et al (2018) to influence central processing of reaction time, differences in reaction time between EF compared to IF and NF conditions would be apparent in a subject with a high level of proficiency at a skill. On the other hand, subjects with no affiliation of the task would show no significant differences between the three focus conditions. During an SRT test, the stimulus is known by the individual, and there is only one appropriate response to be selected with regards to that stimulus. Thus, any changes between reaction time can be hypothesized to be influenced by the subject's proficiency level of that skill reducing reaction time at the central processing level or by having no effect between any focus conditions.

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