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Me or We? The Effect of Team and Individual Sports Activity on Executive Functioning

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ME OR WE? THE EFFECT OF TEAM AND INDIVIDUAL SPORTS ACTIVITY ON EXECUTIVE FUNCTIONING

by

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Abstract

There is limited research examining the processes by which open and closed motor skill sports optimize Executive Functions (EFs). The aim of the present study was to examine the effects of motor sequencing and repetitive movement in individual and team sports and their influence on EFs. The study also investigated gender differences in EF abilities within a sporting context. We tested 40 University students (17 = Male, 23 = Female) aged 17-29 (*M* = 20.47, *SD* = 2.75) who were randomly assigned to a team and individual sports-oriented intervention focused on either repetitive or variable motor sequential movement. We predicted that individuals in the variable motor sequencing and team condition would yield the best EF performance.

Our results suggested a significant interaction effect of Gender x “Team/Individual” on EF measures, as females and males performed significantly different on a team compared to those in the individual conditions. For performance of intervention, we found an overall main effect of Team/Individual, such that participants in the Team conditions finished faster on the sports task than those in the Individual conditions. A significant main effect of Gender was also found, as males generally outperformed female participants. These findings have implications for optimizing sport and EF performance between genders.

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Table of Contents

Me or We? The Effect of Team and Individual Sports Activity on Executive Functioning

The physical benefits of sport on one's health, such as prevention from chronic diseases like obesity and hypertension, have long been documented (Tomporowski et al., 2015). Socrates and Aristotle postulated the possible association between physical and mental prowess, emphasizing the maintenance of physical health as equivalent to psychological health (LeUnes & Nation, 1996). More modern research has focused on whether participating in sports-oriented exercise not only optimizes physical wellbeing, but also psychological wellbeing. In the last two decades, evidence has emerged suggesting that physical activity in a structured, purposeful and planned manner (such as sports) can improve numerous components of physical fitness and psychological functioning (Tomporowski et al., 2015). One of these components is cognition.

Cognition is described as the "processes of knowing, including attending, remembering, and reasoning, as well as the content of the processes, such as concepts and memories" (Gerrig & Zimbardo, 2002, p. 280). The cognition-motor movement connection that is fundamental to goal-directed behavior, begins early in infancy and develops into adulthood. Researchers have suggested that motor development may act as a "control parameter" in further development, in that some motor capabilities may be necessary for the attainment of other developing functions such as cognitive ability (Piek et al., 2008). Bushnell and Boudreau (1993) substantiated this claim by demonstrating that object perception stemmed directly from haptic exploration in children. Piek et al. (2008) discussed a study which demonstrated that children who started walking earlier (10-13 months) displayed differences in comparison to those who started walking later (13-15 months) in affective relationships with their mother. This has led some, such as Leisman et al. (2016), to surmise that human species' bipedalism has enabled better movement, which in turn leads to enhanced brain development and thus, improved cognition. They argue that insufficient postural activity during childhood threatens natural exploratory growth, reducing the ability to learn, and therefore resulting in cognitive delays (Leisman et al., 2016). If infants receive inadequate levels of postural activity, then disruptions or delays in cortical and cerebellar maturation can result. Diamond (2000) suggests that when motor development is disturbed (i.e., insufficient postural movement), cognitive development is also often negatively impacted. Diamond (2000) found that the same holds true for the cerebellum, suggesting that the cerebellum may be integral to both cognitive and motor functioning. Hence, the cerebellum might act as the motor-cognitive bind that goal directed cognition and behavior is predicated on (Diamond, 2000). The goal-directed cognition and behavior especially influenced by experiences throughout one's development is referred to as Executive Function (Best, 2010).

Executive Functions

Executive Function (EF) is an umbrella term for a set of mental skills that develop across childhood and adolescence, which enables one to accomplish tasks or goals. These skills are regulated by the frontal lobe of the brain and assist in our ability to fulfill everyday tasks such as managing time, planning, concept formation or paying attention (Bhandari, 2015). Fundamental EFs include cognitive flexibility, inhibition (self-control, self-regulation), and working memory, whereas more complex EFs are problem solving, reasoning, and planning (Diamond & Lee, 2011).

Though there are many types of EFs that exists, there are certain EFs which are especially integral to both daily and sporting activities. One of them is *working memory*. Working memory, a fundamental EF (Diamond & Lee, 2011), is defined as retaining information and then mentally working with this information, being critical to making sense of something transpiring over time

(Diamond, 2012). Working memory requires that you keep in mind what occurred previously, and relate it to what is happening presently (Diamond, 2012). Working memory is therefore necessary for perceiving any linguistic information, as well as understanding cause and effect (Diamond, 2012), which is imperative in sporting and daily activities. Another fundamental EF that is central to daily and sporting activities is *cognitive flexibility* (Diamond & Lee, 2011). Cognitive flexibility is described as the ability to change perspectives on a situation, adjust your way of thinking about a problem (e.g., thinking outside the box to solve problem), and flexibility in adapting to erratic requirements (Diamond, 2012). Complex EFs, such as *problem solving* and *planning* (Diamond & Lee, 2011), are also key components in daily and sporting activities. Problem solving refers to the process of formulating a sequence of actions in order to attain a goal (Cohen, 1982). Planning is the premeditation of a course of action, so a plan is the embodiment of that course of action (Cohen, 1982). Working memory, cognitive flexibility, problem solving, and planning are the focal EFs of this study.

As research begun to focus on EF and its relationship with sports, results simultaneously started indicating a strong link between EF and sports performance (Ishihara et al., 2006). This is particularly true in team sports such as soccer or football, which require adaptation and anticipation to constantly changing environments (Verburgh et al., 2014). Evidence has suggested that neural circuitry within the prefrontal cortex (PFC) is critical to EF development (Best, 2010). In comparison to brain regions responsible for certain functions such as motor skills or language development, the PFC's maturational period lasts late into adolescence (Best, 2010). During this phase of PFC and EF development, myelination and synaptic pruning are driven by the experiences of the child. Therefore, the type of activities a child engages in are pivotal in determining the speed, strength and trajectory of both their PFC and EF development (Best, 2010).

Best (2010) suggested this may have to do with the complexity of a motor movement and its pairing from infancy with rudimentary EF processes. Best (2010) found that in early infancy and childhood development, sporadic spurts of organic motor movement provide the foundation for basic attentional processes. The creation of locomotive and exploratory connections, alongside the extended development of the PFC and the EF, might be another explanation as to why children's EF are sensitive to the effects of aerobic games (Best, 2010). Due to immaturity of both EF and a child's neural circuitry, certain experiences such as play and aerobic games (like sports) may consequently be a catalyst in positively shaping one's EF, by either accelerating development or temporarily improving functioning (Best, 2010). Findings suggest that exercise programs that contain aerobic games that demand EF skills such as decision making, goal-directed behavior and strategic behavior are advantageous to both physical health and EF development (Ishihara et al., 2006). Ishihara et al. (2006) indicate that these skills may transfer and facilitate improved inhibitory control and working memory, two fundamental EFs (Diamond & Lee, 2011).

EF and Sports

Aerobic games that incorporate specific sport components have also demonstrated benefits in childhood EF. Tomporowski et al. (2015) developed a cardiovascular fitness program for kindergarten children integrating a soccer-based coordinative exercise intervention, offering either low or moderate intensity exercise sessions twice a week for eight weeks. The intervention concentrated on soccer skills such as dribbling, passing and kicking that demand multi-limb sequencing and prompt decision making. A pre-post assessment of children's performance on the

Flanker Test demonstrated that regardless of intensity, the soccer-based intervention yielded faster responding and greater accuracy (Tomporowski et al., 2015). The Flanker Test is an EF assessment of attention, that has also been used to investigate the impact of cardiovascular fitness on EF performance in elderly populations (Kluding et al., 2011), demonstrating validity across ages. These findings indicate that irrespective of intensity, exercise demanding EFs and multi-limb sequencing lead to EF enhancements.

There has been much evidence to support the benefits of sport-oriented aerobic games on EFs (Ishihara et al., 2006; Budde et. al., 2008; Best, 2010; Tomporowski et al., 2015). However, the role complexity of a task plays in one receiving EF gains is not fully explored in the literature. One study that addresses task complexity and EF gains in sports examined adolescents in a soccer based program. The soccer based program had better performance on test of attention than children participating in a standard physical education (PE) class, with the PE class exercising for the same amount of time but without specific coordinative demands (Budde et al., 2008). The soccer based program involved a series of skilled bimanual coordination tasks, whereas exercise in a PE class usually involves only repetitive motor movement (Best, 2010). Bi-manual coordination is essential to our everyday living, responsible for many daily tasks such as eating, driving, and getting dressed. (Shetty et al., 2014). The findings by Budde et al. (2008) highlight the importance of task complexity in achieving benefits in EF, as the soccer based program cognitively outperformed the standard PE class.

As demonstrated by Budde et al. (2008), the complexity of a task greatly determines the positive outcomes in EF received. They suggest that the complex coordination permeated into the soccer program likely demanded “frontal-dependent cognitive processes”, also known as EFs, which rely on frontal circuitry (Budde et al., 2008). For the simpler, repetitive exercises that are not focused on bimanual or specific coordination, its seems the same cannot be said (Budde et al., 2008). This phenomenon has been supported by Ishihara et al. (2006)'s research on bimanual coordination tasks, where they used a soccer based intervention program similar to Budde et al. (2008). Performing complex motor movements, such as bi-manual coordination tasks, have demonstrated to be inherently cognitively engaging (Ishihara et al., 2006). Previous research has indicated that the more cognitively engaging an exercise is, the more we rely on top-down cognitive processes (Ishihara et al., 2006). High cognitively engaging exercises have been found to improve executive functioning in children and adolescents, compared to less cognitively engaging exercises (Ishihara et al., 2006). High cognitively engaging exercises demand strategic behavior, anticipation, decision making capabilities and superior reactivity, which all require top-down processing. In contrast, less cognitively engaging exercises such as circuit training or regular PE classes focus solely on bottom-up cognitive processes (Ishihara et al., 2006).

Team sports or coordinative exercises high in cognitive engagement have shown to have pronounced effects on children's EF (Ishihara et al., 2006). Ishihara et al. (2006) revealed that cognitively engaging exercises are most robustly associated with the EFs working memory and inhibitory control. Furthermore, their findings suggest that participating in highly cognitively engaging sport exercises only once a week may lead to enhanced EFs (Ishihara et al., 2006). The same cannot be said for less cognitively engaging exercises, as activities such as walking or running appear to not produce the same effect (Ishihara et al., 2006). Cognitive engagement in sports have displayed their paramountcy in EF enhancements. Still, it is possible that components of sports such as social interactions allow for sports to be more cognitively engaging, as social interactions may contribute to the level of cognitive engagement received from a task.

Sports group activities are not only socially and physically beneficial (Fraser-Thomas, 2005), but have also been shown to improve cognition (Ishihara et al., 2006; Di Russo et al., 2010). Many sports group activities require collaboration with teammates, anticipation of behaviors of teammates and opponents, discernment of strategies, and adaptation to constantly changing task demands (Best, 2010). Sports group activities, but more specifically, team sports such as basketball, hockey or football, contain many of the same cognitive demands (i.e., anticipation of behaviors, adapting to unstable environment) (Best, 2010). Analogous to these team sports, EF tasks place requirements on children's EF that demand formulating, monitoring, and modifying a cognitive plan to fulfil the task (Best, 2010). Therefore, we can conclude that team sports and EF tasks demand similar ways of thinking and similar cognitive skills, with the skills attained during these team sport activities transferrable to other EF tasks (Best, 2010).

A mechanism that possibly explains how participation in engaging aerobic group games can optimize EF is *contextual interference* (Best, 2010), which refers to the phenomenon when the components of a task are simple, predictable and repetitious, skill acquisition occurs more rapid. However, the retention and transference of those skills are heightened when aspects of the tasks are presented in a quasi-random and complex order (Best, 2010). Children's participation in team sports regularly involves this paradigm. For instance, a quarterback in American football may need to lob the ball to their receiver in one situation, while zipping it to them in another. The trajectory and type of pass needed at a given time cannot be predetermined and is rarely repeated. Instead, it is contingent on many factors that converge into one specific scenario (Best, 2010). Contextual interference effect is a learning experience in which functional interference during practice situations require multiple tasks to be learned, serendipitously enhancing skill acquisition (Magill & Hall, 1990). Although some postulate this potentially leads to negative transfer, others believe that under certain circumstances, contextual inference could instead result in positive transfer (Magill & Hall, 1990). Contextual interference depends on the activation of EFs, requiring a cognition-motor action plan to be formulated, supervised, and adjusted according to task demands (Brady, 2008). Hence, the contextual interference in team sports may produce more effortful and elaborative processing of relevant information, leading to greater learning (Best, 2010).

The practice with situations requiring processing of contextual interference has been demonstrated to positively transfer to other EF tasks, including the Tower of London (TOL) and Tower of Hanoi (TOH). The TOL is a modification of the TOH that provides more variety and different levels of complexity, originally designed to assess planning and problem-solving deficits in frontal lobe patients (Bull et al., 2004). Planning and problem solving are essential aspects of cognition, and are recognized as complex EFs (Diamond & Lee, 2011). In order to successfully complete the TOH and TOL, one must effectively identify and maintain goals. In addition, they must utilize a high level of programming, planning and understanding regarding the consequences of actions of operation required to solve this problem (Bull et al., 2004). The TOH and TOL require counter-intuitive moves because an individual must make moves in the opposite direction from the end-state goal in order to reach the desired end state (Bull et al., 2004).

As previously mentioned, acute exercise benefiting EF might be reflective of activation in specific brain regions (Budde et al., 2008). In particular, performance of the TOL task appears to rely on activation in the PFC, as brain images demonstrated that participation in the TOH and TOL tasks bilaterally activated frontal structures (Bull et al., 2004). A fMRI study revealed that more complex processing, such as problem solving and planning, demand more from EF-related circuity, as highlighted by greater frontal activation in the presence of contextual interference (Best, 2010). The counter-intuitive movement fundamental to both the TOH and TOL tasks elicit contextual interference, which results in positive transfer (Bull et al., 2004). The fMRI study demonstrated that in the presence of contextual interference, there was concentrated activity in the PFC, whereas in the absence of contextual interference, neural activity was dispersed between the parietal and cerebellar regions (Best, 2010). Acute exercise resulted in improvements in total move scores on the TOL task (Bull et al., 2004), defined as the total number of moves required to complete the assessment. The total move score is a validated measure of planning that is also indicative of one's problem solving capacities (Bull et al., 2004), with both planning and problem solving being recognized as complex EFs (Diamond & Lee, 2011). These findings suggest that activity of the PFC is perhaps the neural substrate underlying the association between acute sports exercise and EF enhancement (Bull et al., 2004).

Social Interaction via Team Sports

The adaptive and constantly changing nature of a task is essential to contextual interference improving EF. However, the significance of social interactions within EF tasks and team sports cannot be ignored. Recent research has examined this relationship, aiming to determine whether it is the social interaction or the adaptive nature of contextual interference that leads to EF improvement (Pesce et al., 2009). A 40-minute intervention was created consisting of team sport games (such as two-on-two basketball) and circuit training, both characterized as adaptive and anticipatory tasks (Pesce et al., 2009). Even though engagement in team sport games and circuit training optimized memory recall, only the team sport games augmented memory enhancement (Pesce et al., 2009). This suggests that team sports that are more mentally engaging enable better memory encoding (Pesce et al., 2009). Furthermore, the social component of contextual inference pervasive in team sports has shown to facilitate more intricate encoding in comparison to circuit training, leading to consequent memory benefits (Tomporowski et al., 2015). These results indicate that the social interactions embedded within contextual interference in team sports are important contributors to EF enhancement.

Other research corroborates the importance of social interactions on EF. A study was administered which also contained a circuit training and team sport intervention, with the sample's aerobic intensity once again controlled for (Best, 2010). Although the circuit training enabled more opportunities to acquire motor skills, the team sport condition provided more possibilities to apply those motor skills through competitive and strategic methods (Best, 2010). The researchers found that even though both aerobic conditions produced potential benefits in memory consolidation, only the team sport games elicited a specific EF activation that further optimized immediate recall (Best, 2010). They surmised that this specific EF activation likely stems from social interactions providing more opportunity to employ motor skills in a sequential and tactical manner (Best, 2010). These results, alongside Pesce et al.'s (2009) findings, underline the importance of social interactions in team sports on EFs, signifying that the complexity, adaptiveness, and controlled nature of a sports activity may determine its influence on EF. Despite all this, social interactions in team sports are still undeniably crucial to EF enrichment.

The significance of social interaction in EF enhancement has been consistent in both human and animal research. Stranahan et al. (2006) demonstrated that socially isolated rats do not gain the same benefits from exercise, as providing rats with social interaction elicited more neurogenesis in the hippocampus compared to rats individually freewheel running. These findings substantiate the importance of social interaction in boosting EF performance, for both non-human and human populations. The hippocampus is a region of the brain responsible for memory (Stranahan et al., 2006), with memory being fundamental to EFs. Their results emphasize the crucial role social interaction can play in enhancing EFs across species (Stranahan et al., 2006).

Team sport activities, such as those administered by Pesce et al. (2009), required that you adjust to unpredictable demands while collaborating with teammates strategically and coordinating complex motor movements. Furthermore, these activities are centered around being flexible in a novel and unpredictable situation (Best, 2010). Contrarily, repetitive individualized activities, such as circuit training, likely require less EF engagement, due to its predictably and consistency. One can therefore assume that the distinct demands imposed on EF by team sport activities may result in a more robust effect on EF than repetitive aerobic games (Best, 2010).

Open vs. Closed Motor Skill Sports

The difference in EF enhancements between team sports and repetitive aerobic games is analogous to the findings by Budde et al. (2008) and Pesce et al. (2009), in that both highlighted the importance of role complexity and social interactions in improving EF. This relationship might also exist between open and closed motor skill sports. Open motor skill sports require “open-skills”, in which continual adaptation is necessary due to a highly unstable environment (Di Russo et al., 2010). These sports are usually team based and focus on interdependent movements, such as rugby or lacrosse. Therefore, external forces determine when movement is necessary in persistently novel situations (Di Russo et al., 2010). Open motor skill sports correspond to most team sports, in that both demand cooperation with others in a flexible and adaptive manner in order to accomplish a goal. In contrast, closed motor skill sports occur in a predictable and stable environment, where the objective and method are clearly defined.

Swimming and golf are some examples of theses sports, because movement is usually repetitive and skills self-induced (Di Russo et al., 2010). Closed motor skill sports are tantamount to repetitive aerobic games, due to their repetitious, predictable and independent natures. From this, we can assume that open and closed motor skill sports would have different impacts on EFs parallel to team sports and repetitive aerobic games.

Recent literature has focused on the disentanglement of open and closed motor skill sports by attempting to determine what exact mechanisms lead to improvements in EFs. Wang et al. (2013) looked at the difference between open and closed motor skill sports on inhibitory control, a fundamental EF (Diamond & Lee, 2011). The open motor skill sport chosen was doubles tennis, as it demands superior locomotion and inhibition, fast reaction, bimanual coordination, and a high awareness of an unstable environment (Wang et al., 2013). Swimming was selected as the closed motor skill sport, because it is self-paced and less influenced by the environment (Wang et al., 2013). A sedentary control group was also included. They discovered that stop signal reaction times were significantly shorter for tennis players, in relation to both the swimmers and sedentary control group’s reaction times (Wang et al., 2013). These results suggest that the ability to impede prepotent responses was especially heightened by the open motor skill sport tennis, even though estimated aerobic levels were similar (Wang et al., 2013). They attribute this to the difference in cognitive and motor proficiencies gained from open and closed motor skill sports. Furthermore, athletes playing open motor skill sports potentially develop more flexibility in decision making, execution and visual attention; all of which are critical to EF (Wang et al., 2013). These findings strengthen the notion that similar to team sports, open motor skill sports involve motor sequencing in an unstable and unpredictable environment; whereas similar to repetitive aerobic games, closed motor skill sports demand repetitive movement in a stable and predictable context.

Though studies demonstrate that structured physical sporting activities induce EF enhancements such as increased reaction time or faster processing speed (Voss et al., 2009), the type of sport and the skills demanded of that sport may be the actual factors determining EF trajectory. Di Russo et al. (2010) examined disabled basketball (open motor skill sport) and swimming (closed motor skill sport) athlete adults, alongside healthy non-athlete adults (their control group). They predicted that basketball players should have an advantage over swimmers in the discrimination task. Thus, at the behavioral level, sports should improve simple reaction time skills in both disabled groups, and compensate for the impairment observed in comparison to the healthy control group (Di Russo et al., 2010).

They found that basketball players displayed higher control of inhibition and less switching costs between action inhibition and response (Di Russo et al., 2010), concluding that involvement in open motor skill sports facilitated and enhanced EF processes. This suggests that the basketball group had improved EFs due to the required adaptation and perpetually unstable environment challenging them. In comparison, swimming does not demand the same complex and flexible cognitive-motor coordination that open motor skill sports do. As a result, closed motor skills sports do not have an equal impact on EFs. Hence, participation in open motor skill sports enhances recovery of EFs in physically disabled patients, while optimizing EFs in healthy non-athletes, suggesting that open motor skill sports such as basketball can compensate for EF impairment.

The Present Study

To my knowledge, no research has tried to examine the process by which open and closed motor skill sports enhance EFs. The present study was designed to analyze the relationship between variable motor sequencing and repetitious movement in individual and team sports on EFs. The study focused on two fundamental EFs, working memory and cognitive flexibility, as well as two complex EFs, problem solving and planning (Diamond & Lee, 2011). The TOH and TOL are each assessments of problem solving and planning that also require working memory (Unterrainer & Owen, 2006), so both complex EFs served as supplementary working memory measures in our study. Gender differences in EF abilities have been well demonstrated (Seidman et al., 1997; Ryan et al., 2004; Fox & Neill, 2005; Upadhayay & Guragain, 2014), so another goal of ours was to investigate these differences specifically within a sporting context.

A 2 (Team vs. Individual) x 2 (Repetitive Movement vs. Variable Motor Sequencing) factorial design was used. Our design contained 4 conditions: “Repetitive Movement x Individual”, “Repetitive Movement x Team”, “Variable Motor Sequencing x Individual”, and “Variable Motor Sequencing x Team”. Based on the literature (Budde et al., 2008; Pesce et al., 2009; Di Russo et al., 2010; Best, 2010; Wang et al., 2013; Tomporowski et al., 2015), we predicted that participants in the Variable Motor Sequencing conditions would outperform “Repetitive Movement” on all EF assessments, with the “Team” factor accentuating these results. In addition, the “Repetitive Movement x Individual” condition should show the weakest interactional effect of EF, with the “Variable Motor Sequencing x Team” condition having the strongest interaction. Thus, motor sequencing in a team oriented environment will have the biggest influence on EF performance.

Method

Participants

The sample comprised 40 university students (Male = 17, Female = 23) aged 17-29 (M = 20.47, SD = 2.75). There were 10 participants randomly assigned to each of the four experimental conditions. Twenty-one participants were recruited from the Sona Huron Psychology Participant pool. The remaining participants were peers and colleagues recruited and notified via electronic or verbal interactions with the researcher.

Procedure

Participants completed a sports' experience questionnaire, designed to get a thorough understanding of the sample's sporting background. These questions included years of experience in sports, level of competition, the type of sport(s) played, and how recently they were involved. The main rationale behind the questionnaire was to screen the sample for varsity athletes, in hopes of analyzing differences between Canadian university athletes and non-athletes. We were unable to garner enough varsity athletes; thus, this factor was omitted from analyses. Demographic questions were also featured on the questionnaire, such as gender and age. See Appendix I for questionnaire.

Pre-Intervention

A 2 (individual vs. team) x 2 (repetitive action vs. variable motor sequencing) factorial design was used that included a pretest-posttest design. Similar to Di Russo et al. (2010), the present study wanted to determine levels of cognition through tasks that assessed their working memory, cognitive flexibility, problem solving and planning; prior to and after testing. Hence, in the pre-test, each participant was administered the pretest Forward Digit Span Task (Woods et al., 2010), with two key measures of working memory (verbal memory and memory span) being assessed (Baddeley & Hitch, 2007). All assessments were electronically administered on a MacBook Air laptop. The Digit Span Task required participants to recall the numbers that they heard and saw appear on the screen. They were first given a practice run of four rounds that spanned three digits. The number span for the actual assessment reached up to 10 numbers, with a total of 15 rounds. Participants completion time and number of errors were recorded.

Participants were then presented the pretest cognitive flexibility assessment, Wisconsin Card Sorting Task (WCST) (Grant & Berg, 1985). The WCST is a test of “shift-set” (Grant & Berg, 1985) that demands that you adjust your choice accordingly to the “rule”. This rule is based on shape, color, or number of items (Quaney, 2009). After several correct choices are made, the rule is switched. They must then relearn which rule is applicable, requiring them to constantly maintain rules within their working memory (Quaney, 2009). Participants completion time and number of errors were monitored. There were 60 rounds in total.

The third pre-test assessment was the TOH, a measurement of planning and problem solving (Chang et al., 2011), also known as counter-intuitive moves (Welsh et al., 1999). The TOH consisted of three pegs and five disks located on the far-left peg. Each disk is larger than the other (5^{th} disk bigger than the 4^{th}, 4^{th} bigger than the 3^{rd}), with each resting on top of the other in ascending order. The goal is to move all the disks from the far-left peg to the far-right peg. You are only allowed to move one disk at a time, and cannot place a larger disk on top of a smaller disk (5^{th} disk cannot go on top of 4^{th} disk). Participants were instructed to never press reset and to make as few moves as possible. The total move scores, indicated by the number of moves needed; and the completion time were recorded.

Sports Intervention

For the study conditions, Repetitive Movement was defined as the factor that only required repetitive and consistent movement, where the objective and task were clear. In contrast, the Variable Motor Sequencing conditions required adaptiveness and flexibility to task demands within an unstable and unpredictable situation. In the Individual conditions, participants completed the target throwing task independently. The Team conditions incorporated a social and interactive component, as participants competed against others (who were confederates).

The study used a target throwing task, where participants were asked to hit the target 10 times, or hit the target as many times within five minutes. Participants used a standard ping pong ball covered in Velcro, alongside a target with a black strip of material running vertically down the middle of a white fabric board. This allowed for the ball to stick to the target. Each time the ball stuck to the target, this was scored as a “Hit”. Participants were required to stand 10 feet 7 inches from the target board. The target board measured 16 by 24 inches, with a black strip of material measuring 16 by 2 inches used as the target. The board was suspended in the air, standing 6 feet 1 inch from the ground. The ping pong balls covered with Velcro weighed 4.15 grams.

Repetitive Movement Conditions

In the Repetitive Movement x Individual condition, participants were required to utilize continuous and repetitious movement in order to complete the goal, while competing alone. Participants were told to sprint as fast as possible around the laboratory for a minute, which was timed by the experimenter. The one minute of running was included to help prevent physical activity arousal from being a confounding variable. Then, participants ran towards the target where they began the throwing task. They were responsible for retrieving the ball. Participants were assessed on how fast they reached the target of 10 “hits” or until five minutes was completed.

In the Repetitive Movement x Team condition, participants were also asked to run around the laboratory and then hit the target. However, this time each participant was paired with a confederate to face another team of confederates. This condition required the same continuous repetitive movement as the previous condition, except for now participants were in a competitive team environment, differentiating it from the Repetitive Movement x Individual condition. The confederate group was predominantly all-male throughout the experiments (in both the Repetitive Movement and Variable Motor Sequencing conditions), but occasionally there was one female and two male confederates (one male and female confederate facing the participant and the other male confederate). Confederates were in the laboratory pre-intervention (during pretest EF assessments) and during the intervention. None of the confederates were included in our sample, and were only fully debriefed after all experiments were completed.

All team members were to run around the laboratory for a minute simultaneously. After completion, participant ran towards the target to begin the target throwing task. One person on each team started with one ball. Participants were always last to throw, and their teammate had to meet the requirements (10 hits or five minutes) first before they could proceed. The person throwing the ball was responsible for retrieving the ball. The first team to finish “won” and completion times were measured.

Variable Motor Sequencing Conditions

In the Variable Motor Sequencing x Individual condition, participants were asked to follow instructions given by the experimenter, while additionally having the target component from the previous conditions incorporated. These instructions were central to the Variable Motor

Sequencing factor. Using elements of the “Up-Down Football Drill”, participants were instructed to move in whatever direction the experimenter pointed the football. When the ball was neutrally positioned (not in any particular direction), they were asked to maintain a continuous running motion or “chatter” their feet. If the instructor yelled “hit”, participants were to fall to the floor and quickly jump back up, then continue “chattering” their feet. If the instructor said “break”, participants were to jump, then once again continue “chattering”. The unpredictable nature and adaptability required of the “Up-Down Football Drill” mirrors the same motor sequencing demanded of open motor skill sports, just in an individualized setting. Hence, this condition is the “Variable Motor Sequencing x Individual condition”. After a minute of this drill (experimenter timed this), participants were told “go”, where they ran towards the target to begin throwing and were responsible for retrieving the ball. Participants were timed from when they started throwing until they meet their target requirement. They were also assessed on their inaccurate movements when following the Variable Motor Sequencing instructions.

The Variable Motor Sequencing x Team condition had participants teamed up with a confederate, competing against another squad of confederates. The “Up-Down Football Drill” was also implemented in this condition. However, only one of the team members (a confederate on each team) were to follow the exact Variable Motor Sequencing instructions of the experimenter. Therefore, the confederate was the person directly following the instructions of the experimenter. The other teammate (participant or confederate) had to observe their partner, then move in the opposite direction or complete the opposite movement (i.e., If instructor said “break”, one teammate should jump, while the other should drop to the floor). The task demanded interdependent sequential movement among teammates; thus, this is the “Variable Motor Sequencing x Team condition”. The participant was always located behind the confederate, who was located in front of the instructor. After one minute (experimenter timed this), they were told to "go". This was when the participant and confederates ran to their targets, and were required to hit the target 10 times or until they reached five minutes. Participants were always last to throw, and their teammate had to meet the requirements first before they could proceed. Participants were timed from when they began throwing, until the fulfilment of all targets, or until their time was up. The person throwing was responsible for retrieving the ball. Inaccurate movements when following the Variable Motor Sequencing instructions were scored.

Post-Intervention

After completion of the sports intervention, the post-test Forward Digit Span Task was administered. Both the Forward and Backward Digit Span Task have displayed solid retest reliability (.70 & .71 over a three-week period, respectively) (Müller et al., 2012), so the threat of practice effects was not salient. Completion time and amount of errors were recorded.

Next, participants were given Part A and Part B of the Trail Making Test (TMT). The TMT is the post-test cognitive flexibility assessment (Arbuthnott & Frank, 2000), that demonstrates reliable construct validity and is correlative to WCST in measuring cognitive flexibility (Sánchez-Cubillo et al., 2009), yet still different. This method was espoused to minimize practice effects. Using the mousepad and the arrow, in the TMT-A one must connect 25 encircled numbers that are randomly dispersed on the screen (Kopp et al., 2015). The procedure is the same on TMT-B, however now letters are included and must be connected in alternating order (i.e., 1-A-2…6-F-7-G) (Kopp et al., 2015). TMT-B demands mostly working memory and task-switching ability, whereas TMT-A requires visuospatial and visuoperceptual skills (Sánchez-Cubillo et al., 2009). Participants were measured on completion time.

The final cognitive assessment was the TOL originally adapted from the TOH to enable more difficulty and great complexity levels (Welsh et al., 2001). Both the TOL and TOH are considered higher-order planning tasks (Welsh et al., 1999) because of the planning and problem solving they demand. Similar to the TOH, the TOL has three pegs. However, each peg is shorter than the other, with the far left one being the tallest. The tallest peg is located on the far left and the shortest peg on the far right. The tallest one can occupy three balls, while the middle peg can occupy two, and the shortest peg one ball. The balls are placed in a particular position, and the objective is to arrange the balls in the desired position (indicated by an image above the pegs) within a certain number of moves. Participants were first given one practice round. There was a total of 10 rounds for the actual assessment, with participants given a score at the end based on speed and accuracy. Participants were instructed to complete each round and never press reset, even if they exceeded the number of moves allowed. Completion times were measured, then participants were debriefed and given full disclosure on the purpose of the study.

Results

The aim of the current study was to determine if the different conditions of our intervention would result in distinct EF enhancements. As the study utilized two different EF assessments during pre-intervention and post-intervention for cognitive flexibility (WCST and TMT), and for problem solving and planning (TOH and TOL), we were unable to measure change in EF due to the intervention for our sample. In order to make more objective observations, we decided to break the analysis down into three sections: a correlation of the EF measures for reliability and validity purposes, EF measures by condition, and Target Throwing Task performance by condition.

EF Measures Correlation

A Pearson bivariate correlation coefficient was conducted between all EF assessments. The results suggested high validity and reliability between each EF measure, as many of the tasks were significantly correlated, especially between EF assessments designed to assess the same function (such as TMT time and WCST time assessing for cognitive flexibility). Furthermore, we found significant correlations between the different subcomponents of each EF measure (such as Pre-Digit Errors and Pre-Digit Time). From this, we could justify choosing only one subcomponent from each EF assessment to include as dependent variables in our analysis of EF measures. This analysis will be further discussed. (See Table 1 for correlation chart.)

EF Measures

2 x 2 x 2 MANOVA

A 2 (Repetitive Movement vs. Variable Motor Sequencing) x 2 (Team vs. Individual) x 2 (Male vs. Female) multivariate analysis of variance (MANOVA) was ran to analyze the relationship between EF measures. WCST Errors, TOH Moves, TMT Time, TOL Score and Digit Span Error Difference were defined as the dependent measures. Overall, there was a significant main effect of "Individual vs. Team" found on the dependent measures, Wilks' λ = .665, F (2, 27) = 2.83, p = .035. Overall, a marginal significant main effect was found for Gender on dependent measures, Wilks' λ = .720, F (2, 27) = 2.17, p = .086. No other significant effects or interactions were found in the overall analysis.

Pre-Test Intervention

WCST Errors reported a significant main effect for Gender, F (1, 32) = 6.17 p = .018, partial η^2 = .162, with males (M = 11.74, SD = 1.64) performing significantly better than females (M = 16.99, SD = 1.34). A marginally significant Gender x "Team vs. Individual" interaction was found, F (1, 32) = 2.93, $p = .097$, partial $\eta^2 = .084$. Males in the Team conditions (*M* = 10.08, *SD* = 2) reported significantly lower errors on the WCST than males in the Individual conditions (*M* = 13.4, *SD* = 2.6). However, the results were reversed for females, as females in the Team conditions (*M* = 18.96, *SD* = 2.0) reported significantly more errors on the WCST than females in the Individual conditions (*M* = 15.04, *SD* = 1.77). (See Figure 1.) No effects or interactions were found for TOH moves.

Post-Test Intervention

For TMT Time, we found a significant "Repetitive Movement vs. Variable Motor Sequencing" x Gender interaction, F (1, 32) = 4.97, $p = .033$, partial $\eta^2 = .134$. Males in the Repetitive Movement conditions (*M* = 123.92, *SD* = 14.43) completed the task faster than males in the Variable Motor Sequencing conditions (*M* = 163.63, *SD* = 10.82), whereas females in the Repetitive Movement conditions (*M* = 162.45, *SD* = 11.86) finished the task slower than females in the Variable Motor Sequencing conditions (*M* = 148.43, *SD* = 10.7). (See Figure 2.) For all other post-test intervention EF measures, no significant effects or interactions were revealed.

Pre-Post Difference in EF

For Digit Span Score Difference, a significant main effect was reported for "Individual vs. Team", F (1, 32) = 6.82, $p = .014$, partial $\eta^2 = .176$, with those in the Individual conditions (*M* = -.80, *SD* = .26) generally making less errors after the intervention than those in the Team conditions (*M* = .125, *SD* = .24). A significant main effect was also reported for the factor "Repetitive Movement vs. Variable Motor Sequencing", F (1, 32) = 4.89, $p = .034$, partial $\eta^2 = .133$, as participants in the Repetitive Movement conditions (*M* = -.73, *SD* = .26) generally made less errors after the intervention than those in the Variable Motor Sequencing conditions (*M* = .054, *SD* = .24). No other significant effects or interactions were found.

Performance on the Target Throwing Task

2 x 2 x 2 MANOVA

A 2 (Repetitive Movement vs. Variable Motor Sequencing) x 2 (Team vs. Individual) x 2 (Male vs. Female) multivariate analysis of variance (MANOVA) was conducted to determine the effects of these variables on within task performance of the intervention. Number of "Hits" and Time to Complete task were used to assess within task performance, and were defined as the two dependent variables. Overall, there was a significant main effect of gender found on the dependent measures, Wilks' $\lambda = .733$, $F(2, 31) = 5.63$, $p = .008$. A significant main effect was also found for the Team vs. Individual condition, Wilks' $\lambda = .813$, $F(2, 31) = 3.58$, $p = .04$. No other significant effects or interactions were found in the overall analysis.

For the first dependent measure, Number of "Hits", there were no significant main effects or interactions found. For Time to Complete, we found a significant main effect for Gender, $F(1, 32) = 11.63$ $p = .002$, partial $\eta^2 = .267$, with males (M = 211.02, SD = 15.05) finishing significantly faster than females (M = 277.22, SD = 12.26). There was also a significant main effect for "Team vs. Individual", $F(1, 32) = 6.69$, $p = .014$, partial $\eta^2 = .173$, with participants in the Team conditions (M = 219, SD = 13) reporting significantly faster times than those in the Individual conditions (M = 269.25, SD = 14.42). A significant Gender x "Team vs. Individual" interaction was found, $F(1, 32) = 4.50$, $p = .042$, partial $\eta^2 = .123$, as males (M = 165.29, SD =18.39) and females (M = 272.71, SD = 18.39) in the Team conditions performed significantly faster than males (M = 256.75, SD = 23.83) and females (M = 281.75, SD = 16.24) in the Individual conditions. (See Figure 3.) No other significant main effects or interactions were reported.

Discussion

Our objective was to analyze the effects of variable motor sequencing and repetitious movement on EF enhancements. The study also examined differences regarding the influence of individual and team sports on EF performance. In addition to this, we wanted to investigate if gender differences in EF performance existed within a sports-oriented situation. The study utilized two distinct EF assessments for cognitive flexibility, and for problem solving and planning during pre-intervention and post-intervention, so we were unable to concretely confirm our hypothesis. Despite this, we still came across a wealth of interesting findings that can guide future directions.

The results of this study show that participants in the Team conditions completed the intervention faster than those in the Individual conditions. This indicates that being on a team improved one's sporting performance. These results might also be indicative of social influence's role in benefitting sports performance. The impact of social influence on sports has been examined since the dawn of sports psychology. Triplett (1898) analyzed the performance of cyclists in the presence of other opponents in comparison to when they competed alone. His results revealed that the bodily presence of another opponent improved the completion times of cyclists (Triplett, 1898), and could possibly be attributed to a social facilitation effect. Social facilitation refers to potential improvements in performance from the mere bodily presence of another (Zajonc, 1965). Zajonc (1965) describes two paradigms constituting social facilitation, audience effects and co-action effects. Co-action effects, delineated as influences on a person's behavior engaged in the same activity (Zajonc, 1965), is the type of social facilitation that could account for Triplett's (1898) results and possibly explain our findings. Akin to our results, Triplett (1898) found that youth winding a fishing reel worked faster in pairs than when working alone (as cited in Gill & Williams, 2008, pp.207), further supporting the notion of co-action effects enhancing sports performance. These results allude to the potential social facilitation and more specifically, the co-action effects participating in team sports have in improving sporting performance.

Triplett (1898) suggested his findings were due to the principle of dynamogeny, stating that the presence of others arouses competitive drive, releases energy, and increases speed of performance (as cited in Gill & Williams, 2008, pp.207). Though the concept of dynamogeny might help explain our present findings, it is does not sufficiently describe the impact of our Team conditions in optimizing sports performance. In the Individual conditions, participants were essentially competing against themselves, as their task was to complete the intervention as quickly as possible. However, in the Team conditions, participants were working in pairs while also competing against another team. Hence, the Team conditions had the presence of another competitor and a co-action component. Future extensions should analyze whether it was the presence of other competitors, merely being on a team, or the combination of both that possibly led to the significant difference in sports performance for our Team conditions. To better examine this relationship, a 2 (Team vs. Individual) x 2 (no competition vs. competition) factorial design could be espoused, with teammates competing against another team, alongside another condition of teammates who compete alone. This would help concretely distinguish the impact of social facilitation on team sports, by determining whether competitive drive via opponents, or simply being on a team are most salient in improving sports performance.

Aside from the MANOVA of EF measures, our analyses revealed few significant results between the Variable Motor Sequencing and Repetitive Movement conditions, suggesting that the type of motor movement does not affect EF, as measured in this study. However, important inferences can still be made from the results. Ishihara et al. (2006) found that cognitively engaging exercises (i.e., the Variable Motor Sequencing instructions) are strongly associated with the EFs working memory and inhibitory control. So, although the Repetitive Movement conditions reported better scores on Digit Span error difference, it is possible that working memory, inhibitory control and cognitive flexibility were enhanced in the Variable Motor Sequencing conditions. These potential improvements in working memory and inhibitory control are revealed by participants' TMT completion time, represented in Figure 2. Figure 2 highlights the relationship Variable Motor Sequencing has in enhancing participants' TMT completion time (cognitive flexibility assessment), and the role gender plays in determining these differences. Future research should more explicitly examine the relationship between other measures of EF and motor movement type.

Males in the Repetitive Movement conditions demonstrated the best TMT completion times, whereas females reported significantly faster TMT times when in the Variable Motor Sequencing conditions. These results underline possible gender discrepancies in susceptibility to EF enrichments depending on the motor mechanics rooted within the sport (i.e., Variable Motor Sequencing/Repetitive Movement). Females in our sample might have gained more from the Variable Motor Sequencing intervention because their EFs possibly respond differently to this condition in comparisons to males, whose EFs actually might have been negatively influenced. Thus, gender differences in EF responsiveness might potentially explain why females reported faster TMT completion times in the Variable Motor Sequencing conditions.

In order to better examine this relationship, future research should first and foremost ensure that concrete pre and post EF assessments are included that mitigate practice effects and enable causality. Another step would be having a sample that is gender balanced, in order to make more substantiated gender difference implications. Controlling for levels of aerobic activity should also be considered for future research to ensure equivalency in physical exertion between conditions. Furthermore, we would extend the duration of the intervention to a minimum of 10 minutes, as this has previously proven effective (Budde et al., 2008). Budde et al. (2008) demonstrated that a 10-minute stint of team sports-oriented exercise while controlling for aerobic activity led to EF improvements; so, developing at least a 10 minute sports-oriented intervention while monitoring heart rates should certainly be considered for future research.

A main effect of gender was revealed for performance on the EF measure, WCST. Regardless of condition, females reported significantly more errors on the WCST than males, conflicting with previous literature regarding these gender and sex differences. Seidman et al. (1997) found that male schizophrenics were significantly more impaired on WCST performance than females, contradicting our results. These findings have also been demonstrated in psychologically healthy populations. In both healthy and non-healthy participants, Fox and Neill (2005) found a highly significant correlation between gender and EF performance, with females consistently outperforming males on the Intra-Extra Dimensional Set Shift task (IED). Similar to the WCST, the IED is a hormone-sensitive task conducive to the benefits of Oestregon, as Oestrogen may improve attention and rule acquisition (Fox & Neill, 2005). More recent research has emerged that also supports this argument, looking specifically at the impact of hormones on EF performance. Adult males and adult females pre-ovulatory were found to have similar levels of EF. However, females post-ovulatory (high in Oestregon) potentially received EF gains, as they reported enhanced WCST performance (Upadhayay & Guragain, 2014).

We would expect from previous literature (Seidman et al. 1997; Fox & Neill, 2005; Upadhayay & Guragain, 2014) for females in our sample to have had a biological advantage over males in WCST. Conversely, we found the opposite, with females ostensibly not displaying a hormonal advantage over males in WCST performance. The results of the present study, like those of Fox and Neill (2005), and Upadhayay and Guragain (2014), are correlational rather than causal. Future research should examine more causal reasons as to why these sex and gender differences exist, hopefully determining direction and causation of the relationship. Future research should also consider testing participants in a real-world sports setting, as this may produce more authentic results in EF enhancements congruent to those gained from live competition.

We found significant findings from our analyses that suggest clear gender differences in EF and sports performance. However, these differences were magnified by the “Team vs. Individual” factor. Figure 1 depicts how being on a team improves WCST performance in males, but the opposite holds true for females, in that they generally perform better on the WCST when in the Individual conditions. Another significant interaction was found for intervention completion time between genders and the “Team vs. Individual” factor, with both males and females on teams outperforming those in the Individual conditions. Despite social facilitation potentially improving both genders completion times, Figure 3 illustrates that males performed exceptionally faster, and these results were accentuated by males on teams. Together, Figure 1 and Figure 3 allude to the potential gender differences that exist in susceptibility to social facilitation, as team sports may have distinct impacts on males and females. Differences in “self-construal” and its influence on one’s predisposition to social facilitation effects might help to explain why males performed significantly better than females when on teams.

Self-construals refer to schemas of the self, consisting of motivations, expectancies and self-cognitions that drive our behavior (Mosley & Harrison, 2012). Cross and Madson (1997) theorized that females are more inclined towards interdependent self-construals, whereas males are more prone to independent self-construals. An interdependent self-construal is a self-representation that emphasizes group relationships and relational harmony (Mosley & Harrison, 2012). An independent self-construal is more self-focused, concentrating on uniqueness, self-definition, and self-autonomy (Mosley & Harrison, 2012). The differences in self-construals mirror the potential difference in social facilitation experienced by our participants, in that females might perceive teams as an opportunity for relationships, while males might see teams as a platform to display their talents (Mosley & Harrison, 2012). Thus, the interaction observed in our results may be due to a magnification of social facilitation effects in distinct directions for each gender respectively.

As previously stated, the confederates were generally an all-male group, which could have had distinct gender impacts on sports performance. Gender stereotypes in sports and their potential negative influence on female performance could have been compounded by an all-male confederate group. Female participants may have been intimidated by being the only female competing with a group of males, potentially hindering their performance on teams compared to men. This is especially true when considering the sports stereotypes that pervasively regard males as “athletes”, and females as “female athletes”. In fact, it was only until the 1970s, when exercise and sports psychology became more academically recognized, that the concept of “athlete” empirically referred to both males and females (Gill & Williams, 2008). This denotes the systemic and institutionalized stereotypes of females that permeate sports, and their part in potentially shaping female sports performance.

The self-fulfilling prophecies that stem from gender stereotypes in sports (Siekanska et al., 2013) could have also factored into our findings. Central to self-fulfilling prophecies in sports is the Pygmalion effect, which describes how our expectations of others can shape their performance, whether negatively or positively (Martinek, 1981). Compared to females, the Pygmalion effect could have had more positive performance benefits for males in our study, as self-construal differences might cause females to be more relational with confederates, while drive males to be more performance oriented. Therefore, gender differences in expectations (via self-fulfilling prophecy) and self-construals might be facilitative in male sports performance, yet debilitative for female sports performance.

The facilitating and debilitating nature of the Pygmalion effect in sports was exhibited by Siekanska et al. (2013), where they analyzed gender differences in perception of coach-athlete interactions. They found that compared to males, females were much more focused on building relationships and spending time with other teammates (echoing interdependent self-construals) (Siekanska et al., 2013). On the other hand, males focused more on factors such as control and error correction because they pertained specifically to peaking performance (echoing independent self-construals) (Siekanska et al., 2013).Where females displayed more need for emotion-directed actions and a strong belief in their coach, males placed more value on performance and technique feedback (Siekanska et al., 2013), further illustrating how gender differences in self-construals and self-fulfilling prophecies might result in distinct performance outcomes. The fact that the present study employed mostly all male confederates could have amplified these gender differences in social influences, as females in our team conditions might have perceived the intervention more relationally, whereas males might have become even more focused on optimizing performance. Future research should examine more in-depth the impact of confederate’s gender on influencing sports performance.

Our findings can help explain female disadvantages in performance stemming from influences of social facilitation within team sports. These findings can also help elucidate why male-dominated professions, such as professional sports, lack females (Mosley & Harrison, 2012). If males are perceived as better public performers, then occupations demanding constant public evaluation and assessment (i.e., professional team sports) might be subsequently more readily offered to males (Mosley & Harrison, 2012), leaving females at an inherent disadvantage in both performance and opportunities to perform.

To further investigate gender differences between individual and team sports, a possible future study would include a 2 (male vs. female) x 2 (swimming vs. hockey) factorial design that examines athletes immediately after live competition. Swimming would be selected because it is a closed motor skill sport (Di Russo et al., 2010; Wang et al., 2013) that is individualized, whereas hockey would be chosen as the open motor skill sport (Di Russo et al., 2010) requiring teammates. The sample would be assessed for baseline EF prior to competition, then measured again after competition. To more soundly establish difference between Gender and "Individual vs. Team", future research could espouse a 2 (male vs. female) x 2 (singles vs doubles) factorial design looking specifically at one sport (i.e., tennis, badminton) that is playable in teams or individually. This would control for EF differences stemming from sport type.

The present study has brought to light the distinctive nature of EF and sports, with the findings having important implications on optimizing sport and EF performance. Our research demonstrates that gender, mechanics of a sport, and whether that sport is played collaboratively or individually, are all factors that dictate the benefits experienced in EF and sports performance. Our findings lead us to conclude that a gender difference may exists in EF responsiveness to certain sporting mechanics, as females are potentially better suited to reap the EF benefits coinciding with the Variable Motor Sequencing instructions. As a result, males in our Variable Motor Sequencing conditions did not receive the same EF improvements, with their performance actually faltering compared to the Repetitive Movement conditions.

We can also conclude that overall, team sports participation might increase both sporting and EF performance. The social interaction and contextual interference ubiquitous in team sports might have heightened EF and sports performance in our participants. However, this enhancement is apparently not equal across genders, with male participants performing drastically better when on teams. Our results indicate that females and males perform differently in team and individual settings. From this, we can conclude that gender differences in sports and EF performance appear to intensify with team participation, suggesting that self-construals play a pivotal role in the direction of social facilitation effects experienced in sports. These differences may not only account for athletic performance, but also may contribute to performance in other aspects of life (i.e., school, careers). Replicating and extending the present study would provide invaluable insight into potential gender and team differences for many facets of sports, exercise, health and developmental psychology.

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Appendix I

Sporting Background Questionnaire

General Information

Age____

Gender
_____ Male
_____Female

Year
_____ Freshmen
_____ Sophomore
_____ Junior
_____ Senior
_____ Graduate student

Sports Background

1. List the sport(s) you enjoy playing or play frequently:

---

2. List the sport(s) you have played competitively: (write "0" if none)

---

3. If the answer to question # 2 is more than one sport, list one that you think you are best at:

---

4. How long did you play this sport competitively?
_____ less than a year ago
_____ 2-3 years ago
_____ 4-6 years ago
_____ 7-10 years ago
_____ 11 or more years

5. How recently did you play this sport competitively?
_____ less than a year ago
_____ 2-3 years ago
_____ 4-6 years ago
_____ 7-10 years ago
_____ 11 or more years

6. Which sport do you think is the most physically challenging?

---

7. Which sport do you think is the most psychologically challenging?

Appendix II

Table 1

Table of Correlations for Main Variables

		1	2	3	4	5	6	7	8	9	10	11
1	**Pre-Dig Error**	**--**										
2	**Pre-Dig Time**	.54**	--									
3	**WCST Errors**	.01	.19	--								
4	**WCST Time**	.05	.13	.35*	--							
5	**TOH Moves**	-.1	-.15	.25	.11	--						
6	**TOH Time**	-.22	-.28	.18	.28	.72**	--					
7	**Post-Dig Error**	.18	.06	-.25	-.11	-.13	-.2	--				
8	**Post-Dig Time**	.25	.61**	.02	.02	-.21	-.28	.42**	--			
9	**TMT Time**	-.09	-.14	.29	.50**	.29	.57**	-.23	-.38*	--		
10	**TOL Time**	-.26	-.34*	-.02	.38*	.15	.53**	-.04	-.19	.45**	--	
11	**TOL Score**	.26	.35*	-.04	-.11	-.09	-.33*	.19	.28	-.28	-.70**	--

Note: *p < .05, ** p <.01, two tailed. N = 40

Figure 1. Means of WCST Error Score grouped by Individual x Team, and by Gender. Error bars represent standard deviation of mean.

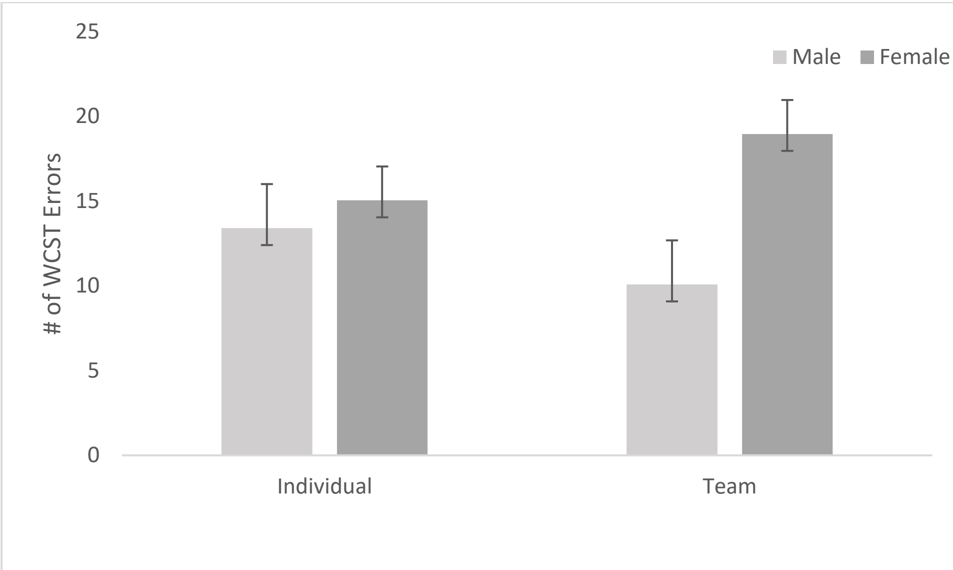


Figure 2. Means of TMT Completion Time grouped by Repetitive Movement x Variable Motor Sequencing, and by Gender. Error bars represent standard deviation of mean.

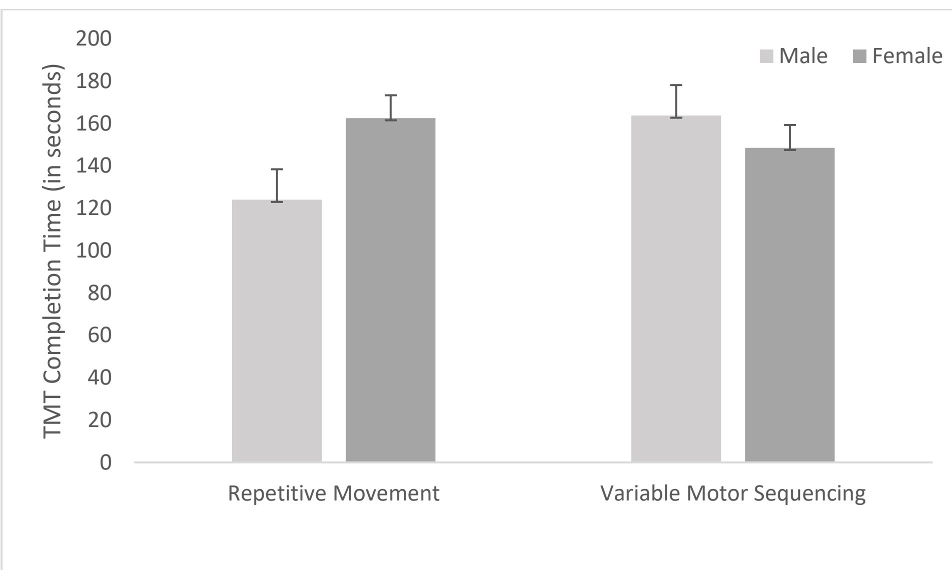
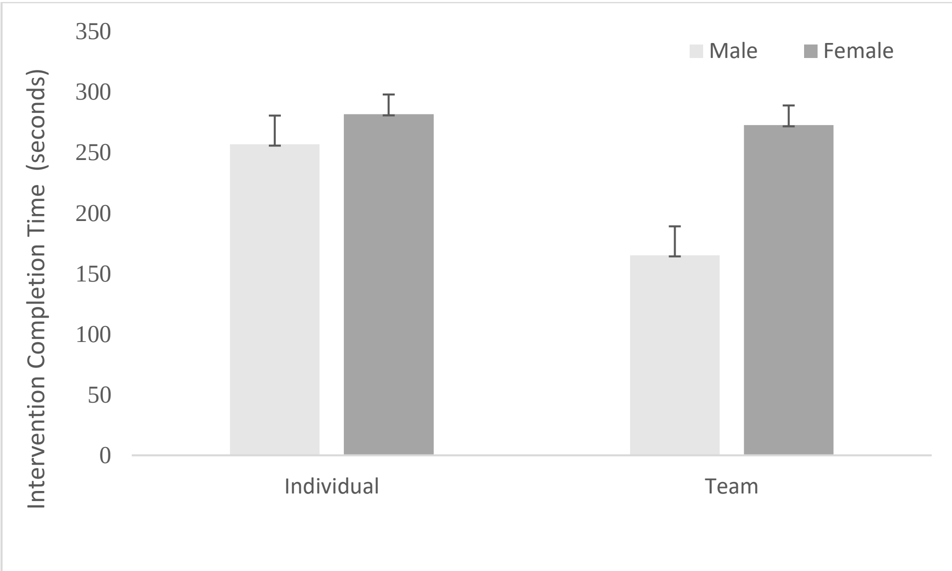


Figure 3. Means of Intervention Task Completion Time grouped by Individual x Team, and by Gender. Error bars represent standard deviation of mean.



Curriculum Vitae

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