Fall 2021

The Effect of Motivational General-Mastery Imagery on Reaction Time Performance and Heart Rate

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THE EFFECT OF MOTIVATIONAL GENERAL-MASTERY IMAGERY ON REACTION TIME PERFORMANCE AND HEART RATE

by

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(Under the Direction of Brandonn Harris)

ABSTRACT

Research suggests that imagery can reduce reaction time (Alikhani et al., 2001; Grouios, 1992; Hanshaw & Sukal, 2016; Iftikhar et al., 2018; Shanks & Cameron, 2000). Previous studies examining the imagery and reaction time relationship have almost exclusively focused on motor imagery. Additionally, a recent study by McNeil and colleagues (2019) concluded that imagery training improved decision time variables, but not overall reactive agility. Individuals may not be able to generate unpredictable stimuli during imagery. The purpose of this study was to examine the effects of motivational general-mastery (MG-M) imagery on reaction time and heart rate. Reaction time was measured using the Dynavision D2 visuomotor training device. It was hypothesized that the use of an MG-M imagery intervention will significantly increase reaction time and the number of hits during testing, and participants in the MG-M imagery group would have a lower heart rate range from beginning to end of test. A within-subjects and between-subjects pre-posttreatment design was implemented. Participants were 9 NCAA Division I student-athletes. The effectiveness of the imagery intervention on reaction time, number of hits, and heart rate range was assessed using nonparametric Wilcoxon-Signed rank tests and Mann-Whitney U tests. Results demonstrated that there was no statistically significant effect observed for reaction time, number of hits, or heart rate. Results suggest that MG-M imagery does not allow participants to react quicker to unpredictable stimuli, as participants could not generate unpredictable stimuli during imagery.

INDEX WORDS: Reaction time, Imagery, Motivational general-mastery, MG-M, Dynavision

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B.S., The College at Brockport, 2019

M.S., Georgia Southern University, 2021

A Thesis Submitted to the Graduate Faculty of Georgia Southern University in Partial

Fulfillment of the Requirements for the Degree

MASTER OF SCIENCE

WATERS COLLEGE OF HEALTH PROFESSIONS

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Electronic Version Approved:
December 2021

DEDICATION

For Mom, Dad, and Natalie. I love and miss you.

ACKNOWLEDGMENTS

This work was supported by the faculty members who served on my thesis committee.

First, I would like to thank my committee chair, Dr. Brandonn Harris for providing unconditional support and guidance throughout this process. You never discouraged me from pursuing my interests. As you know, this project's scope was much different in the beginning stages. The process from there to now was long, and difficult. This final paper would not have been possible without your support. I am forever grateful that you took a chance on me, and I was able to be one of your graduate students. Thank you, Brandonn!

Second, I would like to thank another faculty member who served on my committee, Dr. Megan Byrd. For you also never discouraged me from pursuing my interests and ideas. Thank you for listening to my questions and providing thoughtful answers.

Dr. Ryan, thank you for getting this project moving in the right direction. Dr. Rossi, thank you for hopping aboard.

Kelsey Kinnamon, I am forever grateful that you were there for me when I needed you most. You believed in me and taught me to believe in myself. You pushed me to the finish line. 2 years and it was all a pleasure. Thank you. We're just getting started.

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CHAPTER 1

INTRODUCTION

The ability to react following the processing and integration of relevant visual cues within a changing environment is a key determinant of successful sporting performance (Adam et al., 1992; Reid et al., 2019; Rosenbaum, 1980; Ward et al., 2002; Williams et al., 2004). Sport skills can be separated into two distinct categories: (1) reaction time (RT) based sport skills, and (2) non-reaction time-based sport skills (Wang, 2007). Reaction time-based sport skills are skills in which an athlete must respond to external stimuli. Reaction time is defined as the elapsed time between the presentation of a sensory stimulus and the subsequent behavioral response (Shelton & Kumar, 2010). In reaction time-based sports, athletes are unable to predetermine what actions they will perform in advance so they must rely on external stimuli when responding.

Reactive ability is especially important in open-skilled, dynamic sports including basketball, tennis, netball, or soccer, where athletes must react and adapt their bodies relative to changes in the environment (Araujo et al., 2006). Research examining football players competing at the National Collegiate Athletic Association (NCAA) Division 1 level found that the faster the reaction, the more likely a student-athlete is positioned to make a play and to prevent injury (Engeroff et al., 2019). The minimization of reaction time may also provide student-athletes with the needed edge to reach the next level of elite sports (Wylie et al., 2018).

Athletic performance in competitive sports is typically associated with conditions of stress produced by the physical, psychological, and environmental demands, and expectations and pressure to perform to a high standard (Gould et al., 1993). Under such circumstances, an athlete’s ability to quickly and accurately acquire relevant information reduces the time required to plan, further allowing more time for preparation and execution of motor behavior

(Savelsbergh et al., 2005; Shim et al., 2005). Athletes who have a greater ability to process visual information in their environment can acquire a greater amount of information in a shorter amount of time contributing to a competitive advantage over their competitors (Spiteri et al., 2013). The ability to process a greater amount of information also allows for the facilitation of decision-making ability and motor response time (Ando et al., 2001; Mori et al., 2002).

There is an increasing interest in visual training for athletes, that enhances the ability of athletes to see and integrate large volumes of information and react while playing on the field (Knudson & Kluka, 1997). In fact, 80% of all sports-related stimuli is suggested to be visually based (Haupt & Huber., 2008; Jerath et al., 2015). General visual ability with speed in visual processing is another critical factor as well for reaction time and injury prevention (Feldhacker et al., 2019), as "mean human reaction time to a visual stimulus amounts to approximately 250 milliseconds, with athletes showing lower values" (Mankowska et al., 2015, p. 6).

The Dynavision D2 Visuomotor Training System (D2) has emerged as an assessment tool that is used to measure and enhance reaction time by training sensory and motor integration through the visual system (Dynavision International, 2020). The Dynavision D2 is used to assess visual scanning, peripheral vision awareness, visual attention, and visual-motor reaction times in several populations (Blackwell et al., 2020; Klavora et al., 1994; Klavora et al., 1995a; Klavora et al., 1995b). The Dynavision D2 is commonly used for upper-level sports training in preparation for elite competition (Dynavision, 2018). The device is designed to challenge users to expand their range of motion, improve visual scanning skills, quicken reaction times, and improve cognitive functions (Klavora & Warren, 1998; Vesia et al., 2008; Wells et al., 2014).

Based on a review of existing literature, the Dynavision has been utilized in various sport and exercise settings to train and assess visuomotor performance and has also shown utility as a reliable visuomotor reaction training tool, being able to improve visuomotor related abilities in participants from several different sports (Ong, 2020). The Dynavision has also been used for enhancing eye-hand coordination and visual performance of ball sports. Clark and colleagues (2012) implemented the Dynavision D2 device in a sports vision training program and found that it significantly increased the visual abilities and eye-hand coordination of Division I baseball athletes. Another study examined Dynavision D2 training of youth hockey players and determined that the training enhanced perceptual skills represented by improved visual and motor reaction times (Schwab & Memmert, 2012). Feldhacker and colleagues (2019) examined the efficacy of high-performance vision training and determined the effectiveness of the Dynavision D2 apparatus in comparison to traditional, non-machine vision training of collegiate softball players. Cross et al., (2013) found that Dynavision training successfully improved the visual motor skills of collegiate volleyball players over six weeks. However, no studies have explored the efficacy of implementing mental skills, such as imagery, with the use of the Dynavision D2 device.

Although researchers have noted the importance of identifying appropriate training methods for reactive task performance (Williams & Grant, 1999), there are limited examples of mental skills training techniques that enhance reaction time performance in existing literature. Improving reaction time performance has included cognitive training techniques such as imagining/visualizing as well as physical training methods such as resistance, stability, and plyometric power-building exercises (Harvey et al., 2011). The psychological technique, imagery, has been proposed to rehearse reactive tasks (MacIntyre & Moran, 2007; Paivio, 1985; Williams & Grant, 1999). Ungerlieder (1985) described the importance of imagery and visualization techniques for enhancing athlete performance, including reaction time, at the

Olympic level. Munzert (2009) described the specific role of imagery and mental representations on enhancing motor performance, including reaction time performance. A closer look to the literature on the use of imagery to improve reaction time, however, reveals several gaps and shortcomings.

For instance, Grouios (1992) conducted a study of 100 sport participants matched by their age, imagery ability, intelligence, kinesthesis, motivation, sex, skill level and speed of reaction to examine the effect of imagery on a choice reaction time task. It was found that imagery can significantly reduce reaction time because imagery directly influences the memory system and makes memory comparison and/or response selection processes more efficient. A recent study by Iftikhar et al. (2018) concluded that imagery can improve reaction time in elite sprinters. It is important to note that the authors utilized motor imagery (MI). The athletes in an imagery group improved more than the control group from pretest to posttest ($p < 0.05$), however, a select number of athletes in a physical practice group (no intervention) showed better results than the imagery group. Reaction time was measured on the starting blocks before a 30-meter race.

Another recent study observed findings that support imagery use for decision time variables associated with light-stimulus reactive agility performance, however, the findings also indicate that imagery training is not effective for all components of perceptual motor performance (McNeil et al., 2019). This study investigated the effects of imagery training on reactive agility and whether reacting to unpredictable stimuli could be improved using imagery. Imagery training improved stimulus-decision time and stimulus-foot performance but not overall reactive performance. Imagining the stimulus presenting enabled improved speed of reacting and provided an advantage to respond to the stimulus quicker, similar to perceptual-cognitive performance improvement from imagery rehearsal (Guillot et al., 2007; Jordet, 2005; Smeeton et al., 2013). The inconsistent results indicate that participants may not have been able to generate unpredictable stimuli during imagery (McNeil et al., 2019). It is possible that imagery rehearsal may not be an appropriate practice for improving reactive task performance because imagery involves the mental construction of a deliberate scenario (Paivio, 1985; Raisbeck et al., 2012). Generating an image of an unpredictable event may not be attainable because one cannot image a scenario with environmental unpredictability when the imager has conscious control over the image they create (Munroe et al., 2000; Spittle & Morris, 2007)

Despite the findings mentioned above, there are few, if any, rigorous studies that have been conducted with the primary purpose of investigating the effect of imagery on reaction time or response time. One study by Hanshaw and Sukal (2016) examined the effects of cognitive-specific (CS) mental imagery on the response times of trained martial artists. They utilized a within-subjects and between-subjects pre-post treatment design with a power sample of more than 200 participants. Results from the study revealed that CS imagery, and the combination of CS imagery and motivational self-talk significantly reduced the response times of trained martial artists.

The existing research on the relationship between imagery and reaction time has many inconsistencies relating to what type of imagery is utilized in an intervention, the length of imagery training, the population used to gather data, and what type of reaction time task is selected (simple, choice, complex). This is particularly important because of the relation between anxiety, reaction time, and performance. Several studies have examined the relationship between motor performance and anxiety, and motor performance and reaction time, observing correlational or causal relationships (Hainaut et al., 2006; Panayiotou & Vrana, 2004; Whelan, 2008). The relationship between anxiety, reaction time, and motor performance can be explained in various ways as anxiety can impair motor performance by means of attentional interference (Calvo et al., 1990), an attentional interpretation of the relationship between anxiety and motor performance (Mullen & Tattersall, 2005), and a psychobiological approach in which affect, cognition, and physiology are interconnected (Neiss, 1988). Ciucurel (2012) concluded that some athletes who experience anxiety have the tendency to obtain significantly better reaction times prior to competition, but that is associated with disorganization at the behavioral level, which subsequently leads to a decrease in motor performance. Ciucurel (2012) also found that some athletes who experience anxiety have an increase in response latency, which is associated with behavioral inhibition and the reduction of motor performance. The findings highlight the importance of how optimal and non-optimal areas of performance differ athlete to athlete.

Motivational general-mastery (MG-M) imagery was of interest in the present study as it has been shown useful for gaining or maintaining confidence, staying focused, modulating one’s activation, enhancing motivation, and regulating stress and arousal (Martin et al., 1999; Nordin & Cumming, 2008). Martin et al. (1999) conducted a literature review examining imagery used by athletes and proposed specific outcomes of MG-M imagery to be effective coping and mastery of challenging situations, including being mentally tough, confident, and focused. Nordin and Cumming (2008) tested the outcomes and confirmed the effectiveness of MG-M imagery for staying focused and gaining or maintaining confidence, while finding that MG-M and motivational general-arousal (MG-A) imagery were statistically indistinguishable for regulating stress and arousal and psyching up and calming down. MG-M imagery was utilized in this study because the reactive task (Mode B) on the Dynavision apparatus includes an additional cognitive load component, so participants needed to balance reacting as quickly as possible to rapidly moving stimuli and completing a cognitive task meant to induce stress.

Therefore, the purpose of this study was to examine the effect of MG-M imagery on reaction time performance and heart rate in Division I college student-athletes. More specifically, this study aimed to answer (a) what is the impact of MG-M imagery on reaction time, and (b) does MG-M imagery influence heart rate? NCAA Division I athletes are in a peak performance age range for minimal reaction times and determining appropriate training levels is critical for making reaction time improvement gains (Reid et al., 2019). The focus of this research was on athletes who compete in open skill sports, such as tennis, soccer, and football. Open skill sports can be defined as those in which players need to react to unpredictable, dynamically changing, and externally paced environment (Di Russo et al., 2010). Athletes from open skill sports can develop greater flexibility in visual attention, decision making, and action execution relative to athletes that compete in closed skill sports (Wang et al., 2013). Reaction time was measured using the Dynavision D2 apparatus.

In addition to investigating the effect of imagery on reaction time, it is also important to note the effect that imagery can have on physiological responses in athletes. Stimulating response information during imagery can result in measurable physiological changes (Lang, 1977, 1979). Lang (1977) proposed that emotional images are made up of different units of information, referred to as propositions. Each image contains stimulus propositions; information concerning external stimuli and the context in which the stimuli appear, and response propositions; or information describing physiological responses of an individual to the stimuli in that scene (e.g., heart rate). Response propositions are coded in the brain as motor output, and when activated in memory, an actual physiological response is evoked that can be measured through physiological recordings (Cumming et al., 2007).

Cumming and colleagues (2007) examined psychological states and physiological responses experienced during different types of motivational general imagery (MG-M). Findings in this study suggest that MG-M imagery enabled athletes to be confident and view anxiety symptoms as being under their control and facilitative to their performance. However, MG-M imagery did not lead to increased physiological activation or measurable heart rate changes. The authors suggest that by combining elements of both MG-A and MG-M imagery, athletes can experience elevated levels of anxiety intensity and associate those feelings as facilitative to their performance.

Three hypotheses were tested in the study. The first and second hypothesis concentrated on the MG-M intervention and its influence on an athlete's average reaction time and the average number of hits per reaction time test across trials. It was hypothesized that participants in the MG-M intervention group will have significantly lower reaction time scores from pretest to posttest compared to the comparison group. Also, it was hypothesized that participants who undergo the MG-M intervention will have a significantly higher average number of hits per Mode B from pretest to posttest compared to the comparison group. The third hypothesis focused on the experienced physiological response of a participant's heart rate when completing the reactive task and imagery. It was hypothesized that athletes in the MG-M intervention group will have a lower ΔHR from imagery to beginning and after of a Dynavision trial when compared to ΔHR of the comparison group from rest to the beginning and after of a Dynavision trial. It was expected that there would be a visible within-group difference in ΔHR in participants in the imagery intervention group between transitioning from rest to the Dynavision, compared to transitioning from imagery to the Dynavision.

CHAPTER 2

METHODS

Study Design

The study design was a within-subjects and between-subjects/pre-post treatment design. All participants arranged two separate visits for Mode B, reaction time testing. Participants were randomly assigned to an intervention group or comparison group using a randomized computer generator following their first visit to the lab. All participants, regardless of group, followed the same reaction time testing protocol in the first visit. The intervention group participated in a virtual, motivational-general mastery imagery training prior to returning to the lab for a second visit. During the second visit, participants in the intervention group followed a MG-M imagery script before completing Mode B reactive testing on the Dynavision D2 device. The comparison group did not participate in an imagery training and followed the protocol identical to the first visit. Comparisons were made within and between the two groups. Participants and research investigators were not blind to group allocation. Data was gathered following the intervention, incorporating these components for outcomes of reaction time scores and the average number of hits utilizing Mode B on the Dynavision apparatus.

Participants

Nine participants (7 males, 2 females) were originally recruited to participate in the study. Participants were eligible Division I, male and female student-athletes at a university located in the southeastern region of the United States. Participants had a mean age of 19.9 years (SD = 0.93). All were actively participating in their sport, regardless if their sport was in season or out of season. Participants were from the following sports, soccer (*n*=3), tennis (n=5), and football (n=1). Participants averaged 11.56 years (*SD* = 2.40) of involvement in their sport. Participants class status based on eligibility included freshman (*n*=4), sophomores (n=2), and seniors (n=3). None of the participants reported previously receiving imagery training or using imagery with a mental-skills professional. All participants provided informed consent prior to participation in the study. Demographic information can be found in Table 1.

Table 1.

Participant Demographic Information

Participant	Age	Class status based on eligibility	Sport	Years of experience in sport
1	19	Freshman	Tennis	7
2	19	Freshman	Tennis	12
3	20	Sophomore	Soccer	10
4	19	Freshman	Soccer	11
5	19	Freshman	Soccer	13
6	21	Senior	Football	14
7	21	Senior	Tennis	15
8	21	Senior	Tennis	12
9	20	Sophomore	Tennis	10

Instrumentation

Demographic information

The participants were requested to provide information regarding their name, age, gender, sport, athlete’s class status based on eligibility, and prior experience competing in sport. The demographic questionnaire included questions that pertained to exclusion criteria. The exclusion criteria for participation included: (a) any head injury in the last six months (e.g.., concussion), (b) use of nicotine or tobacco products, (c) any vision problems not correctable without prescription lenses (glasses and/or contact lenses), (d) have previously utilized imagery/guided imagery with a mental-skills professional, (e) currently academically and athletically eligible.

Reaction time

Reaction time was assessed using the Dynavision™ D2 Visuomotor Training Device (D2; Dynavision International LLC, West Chester, OH). The Dynavision D2 is a light-training reaction device that is used to train sensory motor integration through the stimulation of the visual system (Wells et al., 2013; Wells et al., 2014). The Dynavision D2 consists of a board (4 ft. x 4 ft.) that can be raised or lowered relative to the height of the participant. The board contains 64 target buttons that are arranged into five concentric circles that can be illuminated to serve as a stimulus for the participant. The board also contains an LCD display screen located above the innermost ring of the target buttons. The LCD screen is utilized to place a cognitive stressor on the participant during testing trials and provide a five second visual countdown to signal the beginning of testing.

The assessment utilized on the Dynavision light board is Mode B. Participants reacted to a visual stimulus with both hands, as it changed positions on the board. Participants were also tasked with verbally reciting a five-digit number that is presented on the LCD screen of the apparatus simultaneously to reacting to as many lights as possible. The five-digit number was presented a total of 11 times throughout the 60 second test and remained on the screen for 0.75 seconds each time. Additionally, the visual stimulus remained illuminated for only one second before changing location on the board. For a trial to be deemed successful, participants had to verbally recite all 11 of the five-digit numbers correctly. Intraclass correlation coefficients of 0.73 and 0.72 were found for the number of hits and average reaction time respectively in Mode B testing (Wells et al., 2014). A similar reliability value of 0.82 for the number of hits in Mode B was also found (Wells et al., 2013). Klavora et al. (1995) reported an ICC of 0.92 for Mode B testing for trials two through five.

Improvements in reaction time performance on the Dynavision D2 device have been attributed to learning effects (Klavora et al., 1994; 1995). Familiarization trials were included in the testing protocol to eliminate learning effects (Wells et al., 2014). For example, in the CRT assessment only one familiarization trial is necessary because no significant differences were found between consecutive trials for both visual and motor RT. This indicated that a learning curve was not present in the task, possibly facilitated by the simplicity of the task compared to other modes (Wells et al., 2013). Significant differences were observed between trials one through three for both Mode A and Mode B tasks, indicating a significant learning effect was present (Klavora et al., 1994; Wells et al., 2014). Three familiarization trials are needed for Mode B before a reliable baseline can be established (Wells et al., 2014). This is consistent with previous literature from Klavora et al. (1994) who recognized a learning curve through three trials while utilizing Mode B testing.

Despite the learning curve present in Dynavision tasks, significant time effects have been observed for all reaction time tasks. Results suggest that continuous training with the Dynavision D2 results in a training effect that leads to increased performance on the task. However, increases in performance in Mode B testing have previously stagnated beyond a fourth trial. This is likely due to the complexity of the task interfering with any associated training curve.

Heart rate

A (Polar F1) heart rate monitor was used to measure heart rate. Heart rate was measured every 10 seconds during the two-minute washout period between Dynavision trials. The washout period was implemented to accurately assess ΔHR between rest and immediately before and after the Dynavision trial, and ΔHR between imagery and immediately before and after the Dynavision trial. Heart rate was also measured immediately before and after a successful Dynavision trial. Before and after heart rate measures were used to compute change in ΔHR for each trial. Thus, three ΔHR measures were obtained per lab visit and averaged for a value representing average ΔHR across an entire lab visit. For participants in the imagery intervention group, heart rate measurements during the second visit only, were obtained every 10 seconds during the imagery script as well as the initial one-minute rest period. For example, these participants had one minute of rest during which a heart rate measurement was collected every 10 seconds, followed by the one-minute imagery script in which heart rate was measured every 10 seconds. Measurements of heart rate were recorded during rest periods to ensure participants returned to their resting heart rate levels after completing a Dynavision trial, and to accurately assess ΔHR from rest to beginning the next Dynavision trial. Also, heart rate recorded during rest ensured that participants in the imagery intervention group returned to resting heart rate levels before imagery. On average, it took about 30 seconds for each participant to return to steady resting heart rate levels after completing a Dynavision trial. Heart rate was measured on a beat-to-beat basis. The dimension for heart rate as a variable was assessed in beats per minute.

Imagery ability

The Motivational Imagery Ability Measure for Sport (MIAMS) was employed as a measure of motivational general imagery ability (Gregg & Hall, 2006). Participants were asked to create images of eight situations in sport. Four of the images represented motivational general-mastery imagery and four represented motivational general-arousal imagery. After participants imaged the scenes, they rated the imagery on two scales. The ratings were made on a 7-point Likert-type scale, anchored at 1 (*difficulty forming the image* or *no emotional experience*), and 7 (*easily formed image* or *a very strong emotional experience*). The resulting items on both the emotional and ease scales for both MG-M & MG-A imagery were used to form subscales. The MIAMS has been shown to have acceptable psychometric properties and an accurate assessment of motivational general imagery abilities (Gregg & Hall, 2006).

Post-imagery manipulation check

Participants who were assigned to the imagery intervention group concluded the experiment with a post-imagery manipulation check following their last successful Dynavision trial. Items used in the manipulation check are based on those utilized in previous imagery research (Williams et al., 2010; Williams & Cumming; 2012). The first five items and subsequent responses from participants were made on a 7-point Likert-type scale. The first two items ask participants to rate the ease that they were able to form the image and how strong were the emotions that they experienced during imagery. Ratings are made from 1 (very hard/no emotion) to 7 (very easy/strong emotion). The next two items ask participants how accurately the imagery script reflected the thoughts and feelings associated with the Dynavision task, and the extent to which participants imaged the scenario precisely as they were trained. Responses for both items range from 1 (not at all) to 7 (exactly). The fifth item asks participants how meaningful the imagery script was to them, with responses ranging from 1 (not at all) to 7 (completely). The final item included in the manipulation check asks participants "Did you use any other mental techniques during the trials?" (Hanshaw & Sukal, 2016; Theodorakis et al., 2000).

A post-imagery manipulation check was used to reveal statistically significant differences between participants' ability to generate the imagery scripts and the emotions that they experience while imaging. An individual's imagery ability has been found to impact the effectiveness of imagery interventions in terms of improving performance (Hall et al., 1992). Imagery training in this study emphasizes personally meaningful stimulus propositions and consequent response propositions that are included in the imagery script (Lang, 1979). It has been suggested that personally meaningful stimulus propositions are sufficient to evoke similar emotional responses between participants (Williams & Cumming, 2012). Furthermore, the post-imagery manipulation check was implemented to ensure that any within and between group differences in the main statistical analysis are likely due to the manipulation of participants' situation appraisal following the imagery scripts rather than variables such as ease of imaging, emotional experience, extent imaged as described, meaningfulness of imagery, and the extent to which imagery realistically reflected participant responses.

Procedure

Development of Protocol and Pilot Testing of Imagery Script

The initial protocol in this study was pilot tested to ensure all procedures allowed for accurate data collection by the researcher and comfortability for participants. Specifically, initial testing with use of the Dynavision (Mode B), collecting heart rate data, and the imagery training were included in the pilot testing phase. One change to the protocol was made after pilot testing. Firstly, only one minute of rest was allotted between Dynavision trials to participants in the experimental group during their second visit to the lab, the visit in which the imagery script was provided. This change was implemented because it allowed for an accurate comparison between resting heart rate data for comparison group participants (two minutes) and experimental group participants (one minute rest, one minute imagery).

One imagery script was developed for the purpose of this study. The imagery script was initially pilot-tested with two student-athletes that met all of inclusion criteria. The script was developed based on a motivational general-mastery script used in a previous study (Cumming et al., 2007). Material included in the script was also based on recommendations from bioinformational theory (Lang et al., 1980). The script did contain response propositions (e.g., heart beating fast, tight muscles). The scene described in the imagery script portrayed the participant feeling confident, being focused, and in control of the situation while experiencing a rising heart rate and possible cognitive load while using the Dynavision. Revisions were made to the script after receiving recommendations from the pilot participants. Revisions included aspects specific to the Mode B testing. One revision included the addition of information relating to mistakes, or a participant missing lights during Mode B testing (e.g., mistakes will not hinder your performance). This recommendation was relevant given that none of the participants completed

Mode B testing without missing lights. Another revision included information regarding attentional focus. Specifically, this new information highlighted the importance of attentional focus shifting from the light stimuli as it changed location in any the four quadrants of the Dynavision, and processing in addition to reciting the five-digit numbers on the LCD screen located in the center of the board (e.g., “your attention will shift from the screen to the four quadrants, yet you will remain calm”).

General Procedure

Eligible participants provided informed consent and were then asked to complete a demographic questionnaire on Qualtrics. The demographic questionnaire was completed prior to any testing. The questionnaire included questions regarding exclusion criteria to ensure participants could continue their participation in the study. Participants signed up for individual blocks of time (45 minutes) to report to the Sport Psychology Lab located in a university building on two separate occasions, with at least 48 hours between each visit.

During each visit, participants completed three consecutive visuomotor trials with a cognitive load protocol. If a participant did not correctly recite all 11 five-digit numbers during the Mode B trial, the trial was deemed unsuccessful, and the participant was required to retest and complete a fourth trial successfully. Participants were allowed four trial attempts per lab visit. Data was not evaluated from unsuccessful trials and was only gathered from a lab visit in which participants successfully completed three trials.

Each participant was initially tested using the Dynavision D2 lightboard for average reaction time and average number of hits while completing a reactive task with additional cognitive load. The protocol utilized with the Dvnavision D2 in this study incorporated additional cognitive load to mirror real and live game play scenarios experienced by athletes on the court or field. In previous research, cognitive load has been defined as “a multidimensional construct representing the load that performing a particular task imposes on the learner’s cognitive system” (Paas et al., 1994, p.420). All participants were instructed not to consume caffeine at least five hours prior to testing, alcohol within 24 hours of testing, and pre-workout supplement 24 hours before testing. This information was verbally confirmed prior to each visit, and again at the conclusion of the experimental protocol.

Upon arrival to the lab for both Visit 1 and Visit 2, all participants completed a screening for: (a) Covid-19 related symptoms, (b) non-contact temperature scan, (c) caffeine in the last five hours, (d) if any use of alcohol occurred within 24 hours of testing, (e) pre-workout supplement use within the last 24 hours. Participants who did not pass all the required criteria were asked to reschedule their lab visit. Participants were randomly assigned to one of two conditions (imagery/experimental or no imagery/comparison) after completing testing with the Dynavision.

Comparison Group

Visit 1. Upon arriving at the Sport Psychology Lab for the first visit, participants in the comparison group completed the pre-screening questionnaire and were instructed to fit a heart rate monitor to themselves to wear for the remainder of the visit. Detailed verbal instructions on both the testing protocol and how to complete the Mode B assessment from a standardized script were given to participants. Before each of the trials, participants were instructed to take an athletic stance, consisting of flexed knees, low center of gravity and upright posture. The Dynavision was raised or lowered to the height of the participant so that the LCD display was at approximately eye level, and the target buttons in the outermost ring were within hands reach.

Following verbal instruction, each participant completed three practice trials of 30 seconds to familiarize with the task and apparatus. No data was collected during the familiarization trials.

Participants engaged in deep breathing and relaxation for two minutes prior to their first trial in which heart rate data was collected every 10 seconds. This two-minute period was used to establish baseline heart rates and allow for heart rate changes during the Dynavision task to be more clearly observed. Following the familiarization trials and two-minute resting period, participants completed three trials of Mode B testing in which baseline data was collected. Heart rate measures were collected immediately before and after a trial with the Dynavision. Reaction time scores and the number of hits per trial were averaged using the data from the three trials. At the end of each trial, participants were given two full minutes to recover for heart rate to return to baseline level before starting the next trial. All participants completed three successful trials of Mode B testing during their first visit. Following completion of the three trials, participants in the comparison group were asked to complete the Motivational Imagery Ability Measure for Sport (Gregg & Hall, 2006). Participants assigned to the comparison condition did not engage in any imagery training. The procedure of the first visit is outlined below in Table 2.

Table 2.

Procedure of Protocol – Visit 1 – Comparison Group

Trial/Resting Period	Time in seconds
Familiarization Trial 1	30
Familiarization Trial 2	30
Familiarization Trial 3	30
Rest	120
Mode B Trial - Dynavision	60
Rest	120
Mode B Trial - Dynavision	60
Rest	120
Mode B Trial - Dynavision	60

Visit 2. Upon returning for their second visit, participants in the comparison group completed the pre-screening questionnaire and fit a heart rate monitor to themselves. The protocol for visit one and two for participants in the comparison group was identical except the absence of familiarization trials. Participants completed three successful Mode B trials on the Dyanvision. Each Dynavision trial was followed by a two-minute resting period where heart rate was measured every 10 seconds. Heart rate was measured identically to the first visit. The participants could look at their scores if they chose. Finally, upon completion of the final Dynavision trial, participants were shown their reaction time scores across the two separate lab visits and debriefed.

Experimental Group

Visit 1. The procedure for visit one was identical for participants assigned to the experimental group and comparison group. Upon arriving to the Sport Psychology Laboratory, participants in the experimental group fit a heart rate monitor to themselves to wear for the remainder of the visit. Participants were provided detailed verbal instructions on both the testing protocol and how to complete the Mode B assessment from the standardized script. Congruent with the protocol used in visit one for the comparison group, the Dynavision was raised or lowered to the height of the participant so that the LCD display was approximately eye level, and the target buttons in the outermost ring on the apparatus were within the participant's reach. Participants completed three familiarization trials, each 30 seconds long, where no data was collected.

Participants were asked to relax themselves and breathe deeply for two minutes to establish baselines heart rates before beginning their first trial using the Dynavision. Following the two-minute baseline period, participants completed their first trial of Mode B testing. Heart rate was measured immediately before task initiation, and immediately after task completion. At the end of each trial, participants rested for two full minutes before beginning their next trials. Heart rate was measured every 10 seconds during the resting period. Participants had to complete three successful trials of Mode B testing on the Dynavision during this lab visit. Analogous to the comparison group for the first visit, reaction time scores and the average number of this per trial will were averaged using the scores collected form the three successful trials. Upon completion of all trials for visit one, participants in the experimental condition scheduled a virtual imagery training.

Virtual Imagery Training. In the experimental condition, participants took part in a virtual imagery training using Zoom before returning for their second visit to the lab. The researcher initiated the imagery training by providing participants a definition of imagery:

> "Imagery is an experience that mimics real experience. We can be aware of "seeing" an image, feeling movements as an image, or experiencing an image of smell, tastes or sounds without experiencing the real thing. Sometimes people find that it helps to close their eyes. It differs from dreams in that we are awake and conscious when we form an image." (White & Hardy, 1998, p. 389)

Participants were then instructed to complete the Motivational Imagery Ability Measure for Sport (MIAMS). The MIAMS assessment was administered virtually. The researcher read aloud the eight scenarios that are included in the MIAMS to the participant. After the participant imaged each scenario, the researcher prompted the participant to rate the imagery on the two scales included in the MIAMS. Participants verbally reported their response directly to the researcher, and responses were noted on the MIAMS.

After completing the MIAMS, participants completed a series of exercises to make them more aware of stimulus and response propositions that are present in the guided imagery script. This procedure is described by Lang et al., (1980) and it involves drawing the participants' attention towards specific stimulus details related to the imagery scene as well as encouraging them to experience relevant physiological and emotional responses during their imagery. After stimulus and response proposition training, participants were instructed by the researcher to image the guided imagery script that was to be used in their second and final lab visit with the Dynavision. Participants followed the guided imagery script three times for further practice before the training concluded. Participants were instructed to use the imagery script before each of the trials on their second lab visit. Before concluding the virtual imagery training, participants scheduled their second and final lab visit. Their second lab visit had to be within fourteen days of both the virtual imagery training and their first visit to the lab.

Visit 2. Upon returning for their second visit, experimental group participants completed the pre-screening questionnaire and fit a heart rate monitor to themselves to wear for the remainder of the visit. Participants were instructed to breathe deeply and relax themselves for one minute once the heart rate monitor was fitted to establish baseline heart rates and allow for heart rate changes to be more observable during guided imagery. Following the one minute of rest, participants were prompted with the one-minute guided imagery script before using the Dynavision.

Participants in the experimental condition were prompted to image the guided imagery script practiced in the virtual imagery training prior to each trial on the Dynavision. Participants in this group had one minute of rest, followed by a one-minute guided imagery script in between each Dynavision trial. Heart rate was measured every 10 seconds during the guided imagery script and rest period. Again, heart rate was measured every 10 seconds during rest to ensure that participants could return to their baseline heart rate levels after completing a Dynavision trial, and prior to following the imagery script. Upon completion of the imagery script, participants began Mode B testing with the Dynavision. The process of guided imagery preceding the completion of a Mode B trial was repeated for three successful trials. The procedure of visit two for participants in the experimental group is outlined in Table 3.

Table 3.

Procedure of Protocol – Visit 2 – Experimental Group

Trial/Resting Period	Time in seconds
Rest	60
Guided Imagery	60
Mode B Trial - Dynavision	60
Rest	60
Guided Imagery	60
Mode B Trial - Dynavision	60
Rest	60
Guided Imagery	60
Mode B Trial - Dynavision	60

After the last trial, participants completed the post-imagery manipulation check (Williams et al, 2010; Williams and Cumming, 2012). The post-imagery manipulation check consisted of six items. Responses for five out of the six items included on the measure were made on a 7-point Likert-type scale. Finally, upon completion of the post-imagery manipulation check, participants were shown their reaction time scores across the two separate lab visits and debriefed.

Data Analysis

This is a within-subjects and between-subjects/pre-post treatment design. The independent variables for this study include group (imagery training and comparison group) and time of testing visit (pre intervention or post intervention). The comparisons will be made to the comparison group and between the intervention. The dependent variables are average reaction time outcomes of the individual tests on the Dynavision, the average number of hits per Mode B with the Dynavision D2 apparatus, average HR while utilizing the Dynavision. Reaction time scores for both the first and second visit will be calculated by averaging reaction time scores of the participants' three successful Mode B trials. The number of hits per trial will be calculated by subtracting the number of unsuccessful hits from the successful hits (Number of hits = successful hits – errors). This is to account for accuracy of the hits while participants utilize the Dynavision and avoid participants randomly striking the board as quickly as possible to achieve successful hits. Scores achieved in the first visit by participants across all dependent variables will be used to establish baseline data.

Statistical Analysis

Statistical analyses were calculated using IBM SPSS Statistics 27 software (SPSS Inc, Chicago, IL). The statistical analysis initially proposed was a 2 (group) x 2 (time) model repeated measures analysis of covariance (ANCOVA) to compare scores of participants in the imagery intervention group to participants in the comparison group. Imagery ability was the covariate. A separate ANCOVA was going to be run to compare the effectiveness of the imagery intervention on each of the three dependent variables (RT, average number of hits, HR) whilst controlling for imagery ability.

Assumptions associated with analysis of covariance were tested and violated. This was expected due to a small sample size ($n = 9$) that was obtained in this study. Nonparametric tests including Wilcoxon signed-rank tests and Mann-Whitney U tests were run on each dependent variable to ascertain within- and between-group differences. Difference scores were calculated for participant scores on the MIAMS and the post imagery manipulation checks.

CHAPTER 3

RESULTS

Preliminary Analyses.

Data Screening.

Prior to the main statistical analysis, the data were screened for missing scores, outliers, and accuracy of data entry. The data did not contain any missing scores, inaccurate data, or univariate outliers. Before the analyses of covariance were conducted, assumptions associated with analysis of covariance were tested. Assumptions included normality, linearity, homogeneity of variance, and homogeneity of regression slopes. A Levene's test of homogeneity of variance was conducted to assess the variances between the experimental and comparison group were equal on the pretest and posttest. Results indicated that the variances were homogeneous for the pretest or posttest, indicating the assumption of equal variances was violated. Furthermore, bivariate scatterplots for the pretest and posttest for each group did not indicate a linear relationship between the variables. Based on the scatterplots, the assumption of linearity was violated. Based on the results of the tests for assumptions, the analyses of covariance were deemed inappropriate to run. Also, the sample size recommendation for normal distributions was violated.

In lieu of using ANCOVAs to measure within- and between- group differences, while controlling for imagery ability, nonparametric tests including two Wilcoxon signed-rank test (within) and two Mann-Whitney U test (between) were run on each dependent variable. Overall, six Wilcoxon signed-rank tests and six Mann-Whitney U tests were run in the statistical analysis.

Motivational Imagery Ability.

Difference scores between participants were calculated for imagery ability using the nonparametric Mann-Whitney U test. Means and standard deviations for MG-M and MG-A subscales gathered on the MIAMS are reported in Table 4. The ease subscale for MG-A imagery was the only subscale found with significant differences between the comparison group and the experimental group. Imagery ability on the MG-A ease subscale was found to be statistically significantly higher in participants in the comparison group than the experimental group, U = 1.50, z = -2.215, p = 0.027.

Table 4.

Imagery scale means (± SD) with p values

Scale	Mean ± SD	Sig. ($p < 0.05$)
MG-M		
Emotion	5.00 ± 1.19	0.283
Ease	5.67 ± 0.71	0.592
MG-A		
Emotion	5.11 ± 1.36	0.345
Ease	5.44 ± 0.88	0.027*

$p < 0.05$

Descriptive statistics were calculated on the data resulting from items of the post imagery manipulation checks. The means and standard deviations for these items are reported in Table 5. All participants in the experimental group reported not using any other mental techniques other than imagery during the trials.

Table 5.

Means and Standard Deviations for Post Imagery Manipulation Check Items

	MG-M imagery	
Item	Mean	Standard Deviation
Ease of seeing	5.00	0.00
Level of emotion	4.00	1.63
Realism	6.00	0.82
Imagery accuracy	5.50	0.58
Perceived meaning	4.75	1.50

Main Analyses.

Reaction Time.

Nine participants were recruited to examine the effect of an imagery intervention on reaction time, measured via Mode B on the Dynavision D2. A visual representation of participant's reaction times beginning with trial one through six are included in Table 6.

Table 6.

Reaction times in seconds – Mode B – Trials (1-6)

Participant	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6
Comparison Group						
1	0.64	0.66	0.65	0.68	0.65	0.63
2	0.71	0.72	0.73	0.69	0.68	0.65
4	0.67	0.66	0.61	0.65	0.66	0.63
6	0.66	0.67	0.63	0.60	0.64	0.61
9	0.62	0.67	0.61	0.61	0.62	0.62
Experimental Group						
3	0.65	0.66	0.62	0.65	0.58	0.56
5	0.77	0.76	0.76	0.76	0.77	0.76
7	0.57	0.58	0.58	0.60	0.61	0.61
8	0.60	0.60	0.60	0.60	0.58	0.59

A Wilcoxon signed-rank test determined that there was no statistically significant effect on reaction time (*Mdn* = 0.0050 sec) from pre (*Mdn* = 0.6200 sec) to post intervention (*Mdn* = 0.6050 sec) in the experimental group, $z = -.535$, $p = 0.593$. Another Wilcoxon signed-rank test determined that there was no statistically significant effect on reaction time in the comparison group (*Mdn* = 0.0050 sec) from pre (*Mdn* = 0.6200 sec) to post intervention (*Mdn* = 0.6050 sec), $z = -1.60$, $p = 0.109$.

Two independent-samples Mann-Whitney U tests were run to determine if there were differences in reaction time scores between the experimental and comparison groups across both visits (pre- and post-intervention). Mean ranks are reported instead of medians due to the dissimilar distributions in the data. Reaction time scores achieved pre-intervention by the comparison group (mean rank = 5.80) and experimental group (mean rank = 4.00) were not statistically significantly different, $U = 6.00$, $z = -1.00$, $p = 0.413$, using an exact sampling distribution for *U* (Dineen & Blakesley, 1973). Reaction time scores achieved post-intervention for the comparison group (mean rank = 6.00) and experimental group (mean rank = 3.75) were not statistically significantly different, $U = 5.00$, z = -1.24, $p = 0.286$, using an exact sampling distribution (Dineen & Blakesley, 1973).

Average number of hits.

A Wilcoxon signed-rank test was run to determine within-group differences of the average number of hits for the experimental group. There was no statistically significant median increase in the average number of hits (*Mdn* = 6.50 hits) when participants completed Mode B testing without imagery (*Mdn* = 71.50 hits) compared to using imagery (*Mdn* = 78.00 hits), $z = 1.47$, $p = 0.14$. Due to a positive skew of results in the comparison group, an exact sign test was conducted to determine within-group differences. There was no statistically significant median increase in the average number of hits during Mode B testing (*Mdn* = 6.00 hits) from visit one (*Mdn* = 75.00 hits) to visit two (*Mdn* = 80.00 hits), $p = 0.06$.

Similar to the analysis of reaction time, two independent-samples Mann-Whitney U tests were run to determine if there were differences in the average number of hits between the comparison and experimental groups across two time points (pre-post intervention). Exact sampling distribution values for *U* were used (Dineen & Blakesley, 1973). The distributions of the average number of hits between both groups, pre intervention, were not similar. Thus, mean ranks are reported instead of medians. The average number of hits, pre intervention, for the comparison group (mean rank = 5.70) and the experimental group (mean rank = 4.13) were not statistically significantly different, $U = 6.50$, $z = -0.86$, $p = 0.413$. Distributions of the average number of hits between both groups, post intervention, were not similar as assessed by visual inspection. The average number of this post intervention were also not statistically significant different when comparing between-group differences of the comparison group (mean rank = 5.30) and the experimental group (mean rank = 4.63), $U = 8.50$, z = -0.37, $p = 0.73$. A visual representation of participant's number of hits on trials one through six are included in Table 7.

Table 7.

Number of Hits – Mode B – Trials (1-6)

Participant	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6
Comparison Group						
1	74	74	77	69	72	84
2	72	74	67	77	85	78
4	68	72	83	75	79	87
6	79	78	83	90	87	90
9	83	75	84	86	84	84
Experimental Group						
3	63	66	68	59	67	84
5	50	58	64	51	59	59
7	77	80	74	85	89	85
8	80	79	81	90	91	87

Heart Rate Response.

Change in heart from the beginning to after a Mode B trial (ΔHR) was analyzed using two Wilcoxon-signed rank tests. The first test was conducted to determine the effect of the imagery intervention on ΔHR in the experimental group. The difference scores were approximately symmetrically distributed, as assessed by a histogram with superimposed normal curve. Data are median unless otherwise stated. Of the four participants in the experimental group, two participants saw an increase in ΔHR post-intervention, and two participants saw a decrease in ΔHR post-intervention. There was a median decrease in ΔHR (*Mdn* = 4 bpm) from pre-intervention (30 bpm) to post-intervention (26 bpm), but this difference was not statistically significant, $z = 0.37$, $p = 0.715$.

The second test was conducted to determine the effect of time on ΔHR in the comparison group. The difference scores were approximately symmetrically distributed. There was no statistically significant median increase or decrease (1 bpm) from pre-intervention ΔHR (26 bpm) to post-intervention ΔHR (26 bpm), $z = -1.604$, $p = 0.109$.

The results from the independent-samples Mann-Whitney U test run to determine between group differences for ΔHR pre-intervention revealed that experimental group (mean rank = 5.25) and comparison group (mean rank = 4.80) were not statistically significantly different, $U = 11.00$, $z = 0.245$, $p = 0.81$. Results from another Mann-Whitney U test that was conducted to determine between group differences for ΔHR post-intervention revealed no statistically significant difference between the experimental group (mean rank = 5.50) and the comparison group (mean rank = 4.60), $U = 12.00$, $z = 0.498$, $p = 0.618$. A visual representation of participant's ΔHR for trials one through six are included in Table 8.

Table 8.

Heart Rate (ΔHR) bpm – Mode B – Trials (1-6)

Participant	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6
Comparison Group						
1	36	38	36	34	32	31
2	23	28	18	18	19	28
4	16	27	25	26	25	27
6	22	18	16	17	17	21
9	28	29	37	23	33	37
Experimental Group						
3	31	30	19	26	27	26
5	21	18	15	22	25	31
7	34	27	36	41	49	56
8	33	36	31	24	25	19

CHAPTER 4

DISCUSSION

General Discussion

The primary purpose of this study was to measure the effects of motivational-general mastery imagery on reaction times of Division I college student-athletes. There was no statistically significant effect of the use of MG-M imagery on participant's reaction times. It was hypothesized that participants who underwent the imagery training intervention would achieve quicker reaction times in a post-test and increase their average number of hits on the Mode B trial administered with the Dynavision. Analyses did not support either hypothesis.

The secondary purpose of this study was to examine the effect of MG-M imagery on heart rate responses of participants before they began Mode B testing. It was hypothesized that MG-M imagery would allow athletes to perceive anxiety elicited by cognitive load as facilitative to their performance, thus experiencing less of a heart rate change from beginning to end of a Mode B trial. However, no statistically significant effect was observed in heart rate change from the beginning to end of Mode B testing in participants who underwent imagery training. The results of the post imagery manipulation check revealed that participants perceived the imagery to be realistic, meaningful to their performance, easy to see, and evoked a visceral, emotional response (see Table 5).

While no statistically significant effect was found, the findings provide insight into a theoretical question regarding issues associated with generating unpredictable stimuli during imagery (McNeil et al., 2019; Munroe et al., 2000; Paivio, 1985; Spittle & Morris, 2007). The results are consistent with findings from McNeil and colleagues, who found evidence that imagery rehearsal enhanced stimulus-decision time variables but not overall reactive agility.

These findings allude to imagery being less effective for reactive tasks involving unpredictability, which supports the moderating effect between task type and the effectiveness of imagery (Driskell et al., 1994). While motor imagery was used in the study authored by McNeil, this is not directly related to the effect of motivational-general mastery imagery on a reaction time task used in the present study. However, a lack of overall improvements in reaction times and the number of hits suggests that MG-M imagery may not be the appropriate type of imagery to implement with the goal to quicken reaction times. Explanations for these findings offer some understanding of this phenomenon within this area of research.

MG-M imagery scripts do not allow the individual using imagery to imagine unpredictable or spontaneous stimuli during imagery. MG-M imagery does work to enhance or maintain an individual's confidence level and focus, which can facilitate the self-efficacy of their belief in their ability to react to rapidly changing stimuli when possible. However, MG-M imagery does not allow individuals to rehearse reactive tasks that involve unpredictability, complementary to findings examining motor or cognitive types of imagery.

For example, it is important to consider the relationship between functions and outcomes that result from MG-M imagery and the Mode B task on the Dynavision. Mode B is a complex reactive task that involves striking illuminating lights while simultaneously reciting random five-digit numbers on the LCD screen of the Dynavision apparatus. The task is meant to mimic the challenging degree of multitasking that is representative of dynamic open skilled sports (Picha et al., 2018). Participants were required to react quickly, while their attention was actively shifting from and between the lights appearing randomly on the board and a new five-digit number in the middle of the screen. The functions and outcomes of MG-M imagery include staying focused, gaining or maintaining confidence, regulating stress and arousal, and enhancing motivation

(Nordin & Cumming, 2008). Due to the multidimensional nature of the task used in the present study, MG-M imagery was implemented, as functions of MG-M imagery have been found to be statistically indistinguishable from other types of motivational imagery.

Interestingly, all participants successfully completed trials by correctly reciting all the five-digit numbers that appeared on the screen during testing regardless of their group placement. Participants were instructed to focus on reciting the digits correctly and were told that they must recite all digits for a task to be deemed successful. It is possible that if the instructions given for Mode B were revised and participants were given the autonomy to decide how they were going to allocate their attentional resources, participants who utilized MG-M imagery would have recited more numbers, reacted quicker, and hit more illuminated lights compared to a control group. In other words, if the instructions of the task were changed to state that it was not necessary for a participant to recite all the digits correctly to deem a task successful, participants may have differed in their ability to respond to varying attentional demands.

A possible explanation for the lack of improvement in reaction time performance when comparing the two groups is the lack of a sport specific perceptual-cognitive skill when testing with the Dynavision. Imagery has been shown to be an effective performance enhancement tool for perceptual-cognitive skills (Guillot et al., 2007; Jordet, 2005; Smeeton et al., 2013). In these studies, despite the lack of physical rehearsal, participants imagining a stimulus presentation enabled quicker reaction speeds. The lack of improvement in reaction time and the number of hits during testing suggests that crucial task components that would enhance a participant's response to unpredictable stimuli was not represented in the imagery script. In other words, components involved in the transition between perceptual detection of a stimulus into real actions of movement that are representative of physical reaction time performance were not apparent in the imagery script. It is likely the imagery script enabled participants to home in on strategies that centered around maintaining focus, staying confident, and how to best allocate their attentional resources.

The findings from this study are dissimilar with previous findings in the literature. One study reported cognitive and motivational imagery were effective in enhancing reaction time, but both types of imagery influenced reaction time by means of separate mechanisms (Alikhani et al, 2011). It should be noted that the authors in the study did not report what type of motivational imagery was used. It was suggested that while cognitive imagery influences response selection and programming stages that are important in making effective relation between stimulus and response, motivational imagery influences reaction time by regulating arousal rate by means of emotional and motivational factors that function to enhance the stimulus and response relationship. In our study, it seems MG-M imagery was not effective in enhancing the stimulus and response relationship, illustrated by the lack of reaction time improvements when comparing participants in the experimental and comparison groups. An investigation comparing specific cognitive and motivational types of imagery regarding practice and type of task is warranted.

It is possible that one imagery training session is not sufficient to facilitate strong physiological responses by participants to somatic response propositions that were present in the guided imagery script. Also, it is likely that imagery alone was not causing increased activation levels, as the Mode B test included a cognitive load protocol, and participants may have experienced pressure to successfully complete the test by correctly reciting all the five-digit numbers presented. An alternative explanation is imagery implemented with the intention of increasing activation levels, like the script used in this study, was interpreted differently by athletes based on the type of appraisal emphasized (Cumming et al., 2007).

It was expected that participants' heart rate response immediately prior to the Dynavision trial would differ based on group allocation. For example, it was expected that participants in the imagery intervention group would experience less of a spike in heart rate when transitioning from imagery to the Dynavision compared to participants in the comparison group who were transitioning from rest to the Dynavision (between-group difference) and compared to their own scores from visit one (within-group difference). No evidence was found in support of this hypothesis. Despite no statistically significant results, it is possible that any change in heart rate was appraised by participants to be facilitative to performance on the Dynavision trial. Based on the findings from the manipulation checks, participants did perceive the imagery script as easy to image, meaningful, emotion evoking, an accurate reflection of the Dynavision task, and realistic. It is important to note that the imagery script did include physiological response propositions. It is impossible to know if participants appraised their heart rate response as facilitative or debilitative to their performance, despite the results from the manipulation checks.

Limitations

The findings from this study should be considered with the practice/time effect of testing using the Dynavision D2 device. Previous research has suggested that due to the complexity and randomness of the Mode B task, any training curve associated with the test may be delayed (Wells et al., 2014). Furthermore, performance improvements on the Mode B test have been found to cease after four trials (Wells et al., 2014). Although statistically significant effects on reaction time were not observed, most of the participants in the study, in the comparison and experimental groups, performed better their second time coming into the lab and testing. Given this information, it is likely that the more a participant uses the Dynavision they will see performance improvements regardless of the testing protocol. It is possible that the effect of imagery on reaction times measured by the Dynavision may be mitigated by practice effects or training curves in future research. The Dynavision D2 device used as the laboratory assessment of reaction time is another limitation for this study. It is unknown how reaction time measured in the laboratory translates to specific sport skills, if at all. It is possible that MG-M imagery may be an effective imagery type implemented to elicit performance improvements in specific sport skills or situations.

Another limitation worth mentioning is participants in the experimental group may have had internal biases in their ability of imagery and its effectiveness. These biases could have had an influence on the individual's preparation for Mode B trials, their motivation or effort while completing trials, and how they perceived the importance of the imagery training. The only evidence of this was the difference between participants' level of engagement perceived by the researcher, during the imagery training. Although it cannot be confirmed if some participants perceived imagery to be more effective than others, it is possible that some athletes simply believed imagery was facilitative to performance before engaging in the imagery training, or before trials with the Dynavision. Also, imagery training was implemented via Zoom, which could have impacted the effectiveness of the imagery training exercises. For example, it may have benefitted participants if they were able to utilize a heart rate monitor while practicing the imagery script during training. This would allow participants to strengthen their awareness of personal physiological responses to somatic response propositions in the imagery script.

The generalizability of the results can be questioned due to the small number of participants recruited, and the small convenience sample chosen from only one college institution in the southeast region of the United States. The sample may not suitably represent the general college student-athlete population. Furthermore, inclusion criteria only designated those participants from open-skilled sports participate in the study. Of the sports represented in this study, it is difficult to ascertain the specific sport skill and task requirements that are similar and different between student-athletes based on their sport participation. Additionally, specific positional responsibilities based on sport participation could have had an impact on how comfortable participants were using the Dynavision apparatus. For example, some of the participants recruited for this study were tennis players. Tennis specific skills involve hand to eye coordination as players track a tennis ball and choose a motor response, like the visuomotor reaction time tasks tested by the Dynavision. In contrast, some of the athletes who participated in this study were soccer players. While soccer is an open-skilled sport and players continuously react and respond to rapidly changing stimuli, most soccer specific skills (exception being goalkeepers) are performed with the lower extremities of the body. Thus, it may have been more difficult for the soccer players than the tennis players to transfer their visuomotor skills to the Dynavision, which only involves movement of the upper extremities.

Future Directions

There are several areas related to the current study that could be investigated in future research. Future research into the relationship of motivational-general mastery imagery and other types of motivational imagery on reaction time is warranted to validate the findings of this study. Specifically, repeated measures designs can be used to analyze within- and between-group differences across MG-M, MG-A, motivational specific, and cognitive types of imagery. A statistical analysis of imagery ability measured by the MIAMS revealed that participants in this study significantly differed on the ease subscale of motivational general-arousal imagery. Investigating differences in ability of using MG-A imagery could aid in understanding athletes' physiological changes of arousal and how they perceive those changes in terms of performance (facilitative or debilitative). While mastery imagery is used to build confidence, stay focused and represent mastery of challenging situations, arousal imagery would enable athletes to alter undesirable arousal levels in a stressful or anxiety inducing situation by activating response propositions in imagery. Utilizing MG-M and MG-A imagery in conjunction with one another could prove to be valuable in terms of examining the influence of imagery on performance enhancement in complex tasks and physiological responses in preparation and during complex tasks.

Future research may utilize different methodological designs than was used in the current study. Firstly, longer periods of training with the Dynavision can be implemented for the purpose of collecting more data for reaction time and the number of hits during testing. Second, more rigorous imagery training should be implemented with participants. Specifically, longer periods of training and more frequent imagery training sessions can be implemented to ensure participants are able to transfer the imagery skills learned in training to actual imagery use. Imagery training protocols such as layered stimulus response training can be implemented (Cumming et al., 2017; Marshall & Wright., 2016; Weibull et al., 2017; Williams et al., 2013). Single subject designs such as an ABA design (baseline, intervention, return to baseline) may be effective in eliminating any potential learning effects experienced with Dynavision testing.

As previously discussed as a limitation, more research utilizing sport specific skills or tasks to measure reaction time may provide important information to understanding the association between physiological mechanisms involved with reaction time and mental representations formed when using imagery. As it is difficult to develop reliable and valid testing protocols for sport specific tasks, different modes of testing on the Dynavision may be implemented to examine the effects of MG-M imagery on reaction time. Simpler modes of testing that do not induce cognitive load could lead to a clearer understanding between the use of motivational imagery and reaction time. Or choice reaction time could be implemented to assess the use of MG-M imagery on reaction time and accuracy of response simultaneously.

A final consideration for future research could be to explore whether reaction time performance differences occur because of task demands of specific open skill sports, or positional demands based on what sport an athlete participates in. Sport expertise could also play a role in reaction time performance differences. Research investigating these questions could further support the use creating a specialized imagery training program for athletes.

Conclusion

In conclusion, to date, this is the only known study that has systematically investigated the effects of MG-M imagery on reaction time. The results from this study provided a preliminary empirical understanding of the theoretical use of MG-M imagery to enhance or quicken reaction times that involve responses to unpredictable and spontaneous stimuli. MG-M imagery provided an opportunity to rehearse performance in terms of maintaining confidence and staying focused. However, components associated with reacting were not visibly enhanced with the use of imagery based on the data. Athletes, coaches, and practitioners should utilize cognitive or motor types of imagery for rehearsing tasks involving reaction or response time. More research is needed to understand the theoretical underpinnings associated with the use of motivational imagery for reactive tasks in sport settings.

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APPENDIX A

DELIMITATIONS & ASSUMPTIONS

Delimitations

Delimitations for this study are as follows:

1. This study only focuses on Division 1 college athletes from a university in the southeast, that are actively participating in their sport, not barred from participation due to academic or disciplinary reasons and are also not barred from practicing or competing due to an injury.
2. Participants were between the ages of eighteen and twenty-five.

Assumptions

Assumptions researchers made during the study are as follows:

1. Equipment will work properly.
2. Participants will put forth their best effort.
3. Athletes are honest while answering questions on the demographics sheet that pertain to inclusion and exclusion criteria.
4. Athletes are honest while answering questions on the pre-screening questionnaire that deem them fit to continue with their session the laboratory.
5. Athletes in the imagery intervention group will follow the imagery scripts precisely as they were trained. Likewise, athletes in the comparison group will not use any mental skill while using the Dynavision.

APPENDIX B

DEFINITION OF TERMS

DEFINITION OF TERMS

1. *Reaction time* - the time it takes to initiate a response after the presentation of a sensory stimulus.
2. *Response time* - the amount of time from presentation of a stimulus to the completion of an action.
3. *Visuomotor Response time* - The time required to recognize and respond to sequentially appearing visual stimuli in which responses are typically multisegmental movement precision through a specific test sequence (Bigsby et al., 2014).
4. *MG-M imagery* - Imagery that represents effective coping and mastery of challenging situations, such as being mentally tough, confident, and focused during sport competition.
5. *Dynavision D2* - a light-training reaction device, developed to train sensory motor integration through the visual system.

APPENDIX C

DEMOGRAPHIC QUESTIONNAIRE

Directions: Please complete the following demographic information.

Name of person filling out this form (please write): ___________________________

Age: _______________

Gender Identity: ___________________

Current sport involved in at your university: ______________________________

Athlete’s class status based on athletic eligibility: _______________________

Amount of *prior* experience competing in sport (in years): ________

Have you had a head injury in the last six months? (ex. Concussion)

a. Yes

b. No

Do you use nicotine or tobacco products?

a. Yes

b. No

Have you utilized imagery/guided imagery with a mental skills professional in the past?

a. Yes

b. No

Do you any vision problems not correctable without prescription lenses (glasses and/or contact lenses)?

a. Yes

b. No

Are you currently eligible to participate within your sport (i.e., academically, and athletically eligible, and not suspended)?

a. Yes

b. No

APPENDIX D

PRESCREENING QUESTIONNAIRE

1. Have you consumed alcohol in the last 24 hours?

    a. Yes

    b. No

2. Have you used a pre-workout supplement within the last 24 hours?

    a. Yes

    b. No

3. Have you ingested caffeine in the last 5 hours?

    a. Yes

    b. No

APPENDIX E

MOTIVATIONAL IMAGERY ABILITY MEASURE FOR SPORT

Age: _________ **Gender: _________**

Primary Sport: (indicate one only) _________

Current Level of Participation in Primary Sport: (tick appropriate box)

Recreational/Club ¤ Varsity/Provincial ¤

National ¤ International ¤

This questionnaire involves creating images of eight situations in sport. After you image each scene, you will rate the imagery on two scales. Your ratings will be made on a 7-point scale, where 1 indicates difficulty forming the image or no emotional experience, and 7 is an easily formed image or a very strong emotional experience. Images that fall between these two extremes should be rated accordingly along the scale. There are no right or wrong ratings. Be as accurate as possible and take as long as you feel necessary to arrive at the proper ratings for each scene.

The two scales are: **emotional** – emotions experienced while imaging the scene
ease – the ease of forming the image

Scene 1 (MG-M)

STEP 1 (read): Imagine you are participating in an important competition for your sport, you feel very fatigued physically and mentally, but can imagine yourself overcoming these feelings and giving your full effort. Your muscles feel heavy and tired, but you feel yourself starting to become more energized. See yourself pick up the pace and perform with extra effort. Notice how your mood lifts and you observe more of your surroundings.

STEP 2: Now create and experience your image of the scene in your mind.

STEP 3: Next, complete the two scales below.

1. How strong was your **emotional** experience created by the image?

No emotion Very strong emotion

1 2 3 4 5 6 7

2. How **easy** was it to form the image?

Not at all easy to form — Very easy to form

1 2 3 4 5 6 7

Scene 2 (MG-A)

STEP 1 (read): Imagine yourself about to begin a competition in your sport. As you finish your preparations in the final few minutes before the competition begins you notice the feeling of some ‘‘butterflies in your stomach’’. You notice your palms are a bit sweaty and your heart is beating a little quickly. You know these symptoms indicate that you are a little bit excited, this is good, and that you are ready to compete.

STEP 2: Now create and experience your image of the scene in your mind.

STEP 3: Next, complete the two scales below.

1. How strong was your **emotional** experience created by the image?

No emotion — Very strong emotion

1 2 3 4 5 6 7

2. How **easy** was it to form the image?

Not at all easy to form — Very easy to form

1 2 3 4 5 6 7

Scene 3 (MG-M)

STEP 1 (read): Imagine that following a break in the competition you are having a difficult time ‘‘getting back into it’’, have made some errors and are having a difficult time overcoming these feelings. You clear your mind and let that mental tension leave you. You then return your focus to the competition and feel more aware of your surroundings. You see your opponents and the competition setting and feel in control of the situation.

STEP 2: Now create and experience your image of the scene in your mind.

STEP 3: Next, complete the two scales below.

1. How strong was your **emotional** experience created by the image?

No emotion — Very strong emotion

1 2 3 4 5 6 7

2. How **easy** was it to form the image?

Not at all easy to form — Very easy to form

1 2 3 4 5 6 7

Scene 4 (MG-M)

STEP 1 (read): Imagine you are performing a drill during practice in your sport that is very difficult. Notice your frustration as you attempt to do the drill properly. Now imagine yourself starting to complete the drill successfully. Notice your satisfaction as you see and feel yourself performing the entire drill correctly.

STEP 2: Now create and experience your image of the scene in your mind.

STEP 3: Next, complete the two scales below.

1. How strong was your **emotional** experience created by the image?

No emotion — Very strong emotion

1 2 3 4 5 6 7

2. How **easy** was it to form the image?

Not at all easy to form — Very easy to form

1 2 3 4 5 6 7

Scene 5 (MG-A)

STEP 1 (read): Imagine yourself performing your warm-up in preparation for a competition in your sport. As you notice the sights and sounds of the competition venue you feel yourself becoming excited. The anticipation of competing makes your muscles twitch. You're feeling ‘‘psyched up’’ and ready.

STEP 2: Now create and experience your image of the scene in your mind.

STEP 3: Next, complete the two scales below.

1. How strong was your **emotional** experience created by the image?

No emotion — Very strong emotion

1 2 3 4 5 6 7

2. How **easy** was it to form the image?

Not at all easy to form — Very easy to form

1 2 3 4 5 6 7

Scene 6 (MG-A)

STEP 1 (read): Imagine yourself competing in your sport. During a break in the competition you observe how loose and relaxed you feel. Your breathing is deep and rhythmical. Mentally you feel at ease and are focused only on what you have to do. See yourself re-entering the competition, relaxed and ready to go.

STEP 2: Now create and experience your image of the scene in your mind.

STEP 3: Next, complete the two scales below.

1. How strong was your **emotional** experience created by the image?

No emotion — Very strong emotion

1 2 3 4 5 6 7

2. How **easy** was it to form the image?

Not at all easy to form — Very easy to form

1 2 3 4 5 6 7

Scene 7 (MG-A)

STEP 1 (read): Imagine yourself participating in an important competition for your sport. You feel as though your arousal is at an optimal level. You sense excitement and anticipation within yourself, yet feel calm and in control.

STEP 2: Now create and experience your image of the scene in your mind.

STEP 3: Next, complete the two scales below.

1. How strong was your **emotional** experience created by the image?

No emotion — Very strong emotion

1 2 3 4 5 6 7

2. How **easy** was it to form the image?

Not at all easy   Very easy
to form   to form
1   2   3   4   5   6   7

Scene 8 (MG-M)

STEP 1 (read): Imagine yourself at a competition in your sport. Your opponents have been successful in the past and you will need to be ‘‘on’’ to beat them. As you look around the competition venue you see others that you have competed against in the past when you were successful. As you remind yourself that you deserve to be in the competition you feel your back straighten and your head being held high as you regain your confidence in yourself.

STEP 2: Now create and experience your image of the scene in your mind.

STEP 3: Next, complete the two scales below.

1. How strong was your **emotional** experience created by the image?

No emotion   Very strong emotion
1   2   3   4   5   6   7

2. How **easy** was it to form the image?

Not at all easy   Very easy
to form   to form
1   2   3   4   5   6   7

APPENDIX F

POST IMAGERY MANIPULATION CHECK

1. How easy was it to form the image?

Very hard to see						Very easy to see
1	2	3	4	5	6	7

2. How strong was your emotional experience created by the image?

No emotion					Strong Emotion	
1	2	3	4	5	6	7

3. To what extent did the imagery scenario realistically reflect the thoughts and feelings that you experienced while completing the Dynavision tasks?

Not at all						Exactly
1	2	3	4	5	6	7

4. To what extent did you image the scenario as described?

Not at all						Exactly
1	2	3	4	5	6	7

5. How meaningful was the imagery to you?

Not at all						Completely
1	2	3	4	5	6	7

6. Did you use any other mental techniques during the trials?

a. YES

b. NO

APPENDIX G

MODE B – DYNAVISION SCRIPT

- Please stand in a comfortable position in front of the LCD screen. The spot you choose will be measured from the board to the tip of the toes.
- The screen will be adjusted to the height of the participant, where the LCD screen is in front of their eyes and they will be able to reach all of the potential stimuli.
- For this test you will be allowed to use both hands for this test. You will also be allowed to either use the front or the back of your hand. Whichever you choose you will need to continue with that method for the entity of the test and the next test session.
- For this test you will have three practice trials before each of the three tasks.
- For this test you must try your hardest to continuously look at the LCD screen. (this will be repeated before each of the test trials begin)
- The LCD screen will countdown from 5 and a red button will light up. You must try and strike that button as quickly as you can. The light will remain illuminated for only one second before changing location. You will have to be actively reactive in order to hit as many lights as you can. You must successfully identify and strike each stimulus before it changes positions and score as many strikes as possible within 60 seconds.
- In addition to reacting to the changing light on the board and attempting to successfully strike stimuli, you will also verbally recite a five-digit number that will be presented on the LCD screen of the apparatus. The five-digit number will be presented a total of 11 times throughout the 60 second test and will remain illuminated for 0.75 seconds each

time. You must successfully recite all eleven 5-digit numbers in order for a trial to be deemed successful.

- Utilize your peripheral vision, keep your hands raised, avoid crossing the hands over the body and use any part of the hand you desire.

APPENDIX H

LITERATURE REVIEW

Reaction time can be an important factor in determining the level of performance exhibited by athletes across varying sport domains. Sport skills can be divided into reaction-time (RT) based sports skills, and non-reaction time-based sport skills. Reaction time-based sports skills refer to skills that require the processing of external stimuli before actions are initiated (e.g., upcoming pitch in baseball, opponent's dribbling move, offender's shot trajectory, attacker's punch or kick) (Wang, 2009). In reaction time-based sports, athletes must rely on immediate external stimuli before taking an action because their ability to predetermine their actions is reliant on said stimuli (Wang, 2007). In open, dynamic sports, such as basketball, tennis, netball or soccer, athletes must constantly adapt their actions based on changes in the sporting environment by means of reactive tasks (Araujo et al., 2006). Athletes process varying degrees of temporal and spatial complexity during reactive tasks. For example, an athlete may have to process a simple reactive task such as the flight of a ball, compared to a complex reactive task in processing and interpreting the movements and actions of opponents and teammates simultaneously (McNeil et al., 2019). Reactive tasks have been deemed synonymous with unplanned and unanticipated performance rather than self-determined or pre-determined performance that rely predominantly on perceptual cognitive skills (Paul et al., 2016). Reaction time has been found to be a deciding factor in determining success during competition for athletes (Rosenbaum, 1980; Ward et al., 1980; Williams et al., 2004).

Defining Reaction Time

Reaction time is a strong contributing factor of superior sport performance. Reaction time is also an important aspect of fine and gross motor skills. Reaction time has been researched and defined in the literature both inside and outside the context of sport. However, at times there are conflicting definitional aspects to reaction time in research. Some of this is partly due to the structural components of sport. Reaction time in a sport may often be defined uniquely due to the physical and cognitive demands of the sport. For example, Collet (1999) defined reaction time in track and field sprint events as the time from the gun signal until the production of force against the starting blocks. Examining Collet's example, reaction time includes the sound traveling time between the starting gun and the athlete, the athlete's reaction to the starting gun shot, and the mechanical delay of false start equipment that is integrated into the starting block.

Reaction time has also been defined as "the time that elapses between receiving an immediate and unexpected stimulus and reaction given to it" (Atan & Akyol, 2014). Del Rossi and colleagues (2014) defined reaction time as the time it takes to initiate a response after the presentation of a sensory stimulus. While some researchers use the terms "reaction time" and "response time" interchangeably (Spierer et al., 2011), others view them as separate constructs. Shelly et al. (2019) defined response time as the amount of time from presentation of a stimulus to completion of an action, whereas reaction time is the amount of time between an individual receiving a stimulus and beginning the action. Nederhof (2007) suggested that reaction speed, response time, response speed, processing time, processing speed, psychomotor time, psychomotor speed, and other variations including choice reaction time or inhibition reaction time are all terms that are functionally equivalent to reaction time. The term reaction time (RT) in the literature is commonly referred to as the speed of response to an environmental stimulus, but the complexity of stimulus interpretation required for initiation of a correct response and the criterion used to define initiation or completion of the response is determinate of the amount of time between presentation of stimulus and subsequent response (Eckner et al., 2010; Miller & Low, 2001; Schwab & Memmert, 2012).

A definition of reaction time provided by Bankosz and colleagues (2013) proposes reaction time consists of five segments that characterize the period of time that elapses between the occurrence of a stimulus and initiation of movement: (1) stimulation of the receptor, which depends on concentration levels, precision of peripheral vision, and other physiological processes, which can be trained; (2) transmission of stimulation to the central nervous system, which depends on the constant conduction speed in nervous tracts; (3) transmission of stimulation through nervous centers and formation of an executory signal, both of which depend on the motility of nervous processes - it is the longest and quantitatively most diversified parameter determining the general time of reaction; (4) transmission of the signal from the central nervous system to the muscle, whose speed remains constant and cannot be improved by training; (5) stimulation of the muscle - a change in its tension, an initiation of movement.

In addition to reaction time and response time there are other terms and definitions in the literature that are associated with reaction time that measure specific aspects of behavioral responses to external stimuli. Simple reaction time (ST) refers to the time required either to initiate a motor response or the execution of a simple task in response to a single visual or auditory stimulus (Miller & Low, 2001). Choice reaction time (CRT) refers to the amount of time required to respond when multiple stimuli are presented in a sequential manner where the stimuli presented may or may not represent a correct cue for the specific corresponding response (Miller & Low, 2001; Schwab & Memmert, 2012). The term visuomotor reaction time (VMRT) refers to the time required to recognize and respond to sequentially appearing visual stimuli in which responses are typically multisegmented movement precision through a specific test sequence (Bigsby et al., 2014).

Significance of Reaction Time in Sport

The ability to react following the processing and integrating of relevant visual cues within a changing environment is a key determinant of sporting success (Adam et al., 1992). Most sports are performed under conditions of stress because of the physical demands, psychological demands, environmental demands, and expectations and pressure to perform to a high standard (Gould et al., 1993). Under such conditions, an athlete's ability to quickly and accurately pick up relevant information will reduce decision time and will allow for more time for preparation of motor behavior (Savelsbergh et al., 2005; Shim et al., 2005). Athletes who possess the ability to process a greater amount of visual information in a shorter period may have a competitive advantage over their slower counterparts (Spiteri et al., 2013). Processing a greater amount of visual information in a shorter period allows for the facilitation of both decision-making ability and motor response time (Mori et al., 2002; Ando et al., 2001).

Anticipatory skill plays an important role in successful decision-making (Vaeyens et al., 2007), particularly in team ball sports such as volleyball, basketball and handball in which players must monitor the activities and positions of multiple players simultaneously. Reaction time and anticipatory skills are critical aspects of perceptual abilities in sport domains that are considered to be advantageous to a player's successful performance (Mori et al., 2002). The combination of physical and motor capabilities and sensory-cognitive skills contribute to excellence in sport performance (Mann et al., 2007).

As has been previously reported in the literature, elite and non-elite athletes display differences in visual sensorimotor processing including the speed of signal conductivity in the visual pathway (Delpont et al., 1991; Ozmerdivenli et al., 2005; Zwierko et al., 2010; Zwierko et al., 2011). Elite and non-elite athletes also exhibit differences in simple and choice reaction to stimuli that appear in the central field of vision (Bankosz et al., 2013; Dogan, 2009; Wimshurst et al., 2012). Reaction time to peripheral stimuli is another variable that differs between elite and non-elite athletes that has been reported in the literature (Muinos & Ballesteros, 2014; Zwierko, 2008). Studies have also shown that athletes have shorter reaction times compared to non-athletes when responding to visual stimuli (Ando et al., 2001; Kokubo et al., 2006). Zwierko and colleagues (2014) investigated the effect of prolonged visuomotor task performance on the ability to maintain attention in athletes versus nonathletes and found that nonathletes in comparison to athletes had longer total time of test execution, longer reaction time, and higher variability in results during task performance. Interestingly, previous research suggests that athletes who participate in open-skill sports have significantly shorter reaction times than athletes in other types of sports (Dogan, 2009). These findings contrast with research by Nuri and colleagues (2013) examining differences in sensory-cognitive skill, reaction time, and anticipatory skills between sprinters and volleyball players. Results suggested that sprinters were better in auditory reaction times and volleyball players were better in anticipatory skill tests. However, no significant differences were found in visual choice reaction time tests. Reaction time is crucial for closed-skilled sports as well. For example, the difference between success and failure in the men’s canoe and kayak 200-meter event is measured in milliseconds (Christie & Werthner, 2014). Reaction time is different in a closed-skill sport compared to an open-skill sport because athletes must respond to only one unanticipated stimulus with one possible response (simple reaction time).

There is increasing interest in visual training for athletes. In most sports, including combat sports, important factors in determining performance is quick reaction times and the ability to process visual information (Gierczuk et al., 2016). An awareness or “court sense” that allows athletes to see and integrate large volumes of information, and react while playing on the field, may help them gain an edge on a competitor (Knudson & Kluka, 1997). Eighty percent of all sports-related stimulus is visual based. General visual ability with speed in visual processing is another critical factor as well for reaction time and injury prevention (Feldhacker et al., 2019), as “mean human reaction time to a visual stimulus amounts to approximately 250 milliseconds, with athletes showing lower values (Mankowska et a., 2015). Mankowska and colleagues (2015) examined visual perception and its effect of reaction time and time-movement anticipation and found that the ability to quickly assess the position and direction of an object correlated significantly with reaction time and motor time. Furthermore, players who were better able to predict the position of an object in space and time reacted faster to visual stimuli. Pawelak, Lyakh, and Witkowski (2009) obtained similar results in their study, which involved conducting fitness tests in a group of female handball players and in a study with female soccer players. Both studies observed average correlations, primarily between the indicators of spatial orientation and reaction rate. With respect to the other abilities studied, 70% to 95% of the cases showed no statistically significant correlations.

Sports Vision Training and Reaction Time

There is an increasing interest in implementing sport vision training programs for athletes. Sports vision training can lead to improvements in sport performance because the visual system responds positively to overload and to progressive increases in environmental demands (Wilson & Falkel, 2004). Erikson (2007) identified five visual skills that are fundamental for sports vision training. Those five skills include peripheral awareness, eye-hand coordination, eye-body coordination, visual reaction time and visual-motor response time, and anticipation timing. Visual reaction time and visual-motor response time are included with one another because reaction time is an aspect of response time. Both visual reaction time and visual-motor time can be practiced and improved together or separately (Davranche et al., 2006).

Visual reaction time is the elapsed time between the onset of a visual stimulus and the initiation of a motor response (Erikson, 2007). Visual reaction time can be broken down into similar categories identified in other areas of research of reaction time including simple reaction time, recognition reaction time, and choice reaction time. Research of differences between expert and novice athletes identifies choice visual reaction time as an important distinguishing characteristic because it involves pattern recognition and decision-making processes (Abernethy, 1996). Experts and novices read sport specific cues at different speeds. Experts recognize cues quicker, so the time needed to make an optimal decision and then execute a motor response is faster, whereas novices may have slower recognition rates leading to less time for decision-making or initiation of movement.

Visual-motor response time is another skill that is sought to be enhanced in sport vision training programs. Bressan (2003) defined visual-motor response time as the total amount of time from the presentation of a stimulus to completion of an action. Visual reaction time is an aspect of visual-motor response time because the process begins with the presentation of visual stimuli. Visual-motor response time includes the time to initiate a response to the visual stimuli as well as the time until the completion of the response. Sports require athletes to respond to changing environmental demands and selected visual stimuli in order to execute specific motor responses. Visual-motor response time has been identified as a key performance indicator of proficiency in many ball sports (Buys & Ferreira, 2008).

Sport-specific vision training programs have shown improvements in various visual skills. Previous research indicates that there is a marked difference in training protocol within the sports vision training literature, including frequency and duration of training sessions. Taylor, Burwitz, and Davids (1994) utilized a training of one 60-minute training session to examine the effect on coincident anticipation and visual motor response time in 16 novice badminton players and found an improvement in both coincident anticipation and visual motor response time. Farrow et al., (1998) implemented a vision training program consisting of eight sessions of fifteen minutes per week for four weeks to examine the effect of coincident anticipation and visual motor response time in 24 novice tennis players and found significant improvements in speed of response time. In a third study, Tsetseli et al. (2010) implemented a training program consisting of three 20-minute sessions per week for five weeks and found a significant improvement of visual-motor reaction time in 24 youth tennis players.

Measuring and Assessing RT

The Dynavision D2 Visuomotor Training System (D2) is an assessment tool that is used to measure RT. The Dynavision D2 is used to assess visual scanning, peripheral vision awareness, visual attention, and visual-motor reaction times (RTs) in numerous populations (Klavora et al., 1994; Klavora, Gaskovski, & Forsyth, 1995; Klavora et al., 1995; Blackwell et al., 2020). In an athletic population the Dynavision can be used to improve reaction time, peripheral visual awareness and decision making under stressful conditions (Dynavision, 2016). The device is designed to challenge users to expand their range of motion, improve visual scanning skills, quicken reaction times, and improve cognitive functions (Klavora & Warren, 1998; Vesia et al., 2008; Wells et al., 2014). The Dynavision has also been used in clinical rehabilitation settings with people suffering brain injuries to assess and improve psychomotor skills for everyday tasks (Crotty & George, 2009; Klavora, Gaskovski, Martin, et al., 1995; Klavora & Warren, 1998; Vesia et al., 2008).

The Dynavision is a 5 x 4- foot light board that consists of 64 raised tactile targets (buttons) arranged in five rings, four quadrants, with a central tachistoscope (T-scope) LED screen. Preprogrammed and customizable protocols are used to measure and train reaction time. The targets illuminate at random intervals for an individual to strike as quickly as possible to extinguish in order for the next button to light up. An auditory stimulus is present and heard simultaneously as a button is struck. The device enables users to measure the number of successful “hits”, reaction time, and overall response patterns.

Previous studies have examined the test-retest reliability of Dynavision protocols. Wells and colleagues (2014) found intraclass correlation coefficient values of .63 to .84 in recreationally active individuals with the shortest between-session duration of 48 hours. When the between-session duration was separated by 2 weeks, Klavora et al. (1994) found moderate interclass reliability (.71 and .73) for each of the two protocols examined. Klavora et al., (1995) found excellent scores of test-retest reliability (.88, .92, and .97) for 3 protocols of varying complexity over a period of 8 weeks. Picha et al., (2018) investigated the test-retest reliability of 5 novel Dynavision protocols that stress additional cognitive load similar to the dual tasking of athletes during competition and found moderate to good reliability (ICC = .75 - .90) at both 1-hour and 14-day intervals. Of the six preprogrammed psychomotor tests that the Dynavision utilizes to establish reaction time, it has been found to be significantly correlated to six common psychomotor tests that assess similar psychomotor abilities and visuomotor skills, such as eye-hand coordination, speed, and dexterity (Vesia et al., 2008).

The Dynavision has different types of assessment that vary in terms of protocol and what variables are being measured. One of those assessments is known as the Choice Reaction Test or CRT. This test starts with the participant's dominant hand on the home button or LED screen and is followed by a single button illuminating in one of four locations adjacent to the home button on the same horizontal plane. Participants would strike the illuminated button and return back to the home button and continue for the remainder of the test. The CRT measures visual reaction or the amount of time it took for a participant to identify the illuminated button and initiate a reaction by leaving the home screen. The CRT also measures motor response time or the amount of time between the hand leaving the home screen and striking the illuminated button. Visual RT and motor response time both showed significant time effects ($p = 0.001$) and showed no significant differences between consecutive sessions indicating that a learning curve is not present which may be due to a lack of task complexity (Wells et al., 2013). Visual RT showed strong reliability (ICC = 0.84), similar to the ICC of 0.84 found by Wells et al. (2013), while motor RT showed moderate reliability (ICC = 0.63), (Wells et al., 2014).

Another assessment that can be utilized with the Dynavision is Mode A. This mode measures a participant's ability to react to a stimulus as it changes positions rapidly and randomly on the board. The mode starts with a five second countdown on the board's home screen, and then a random button will illuminate on the board. Each button that is illuminated on the board remains lit until the participant strikes that particular button. Once the participant strikes the button, another button in a random location is illuminated in its place. This test lasts 60 seconds in total. The number of successful hits and the average time per hit are recorded for each participant. A significant time effect was seen for both the number of hits and average RT per hit in Mode A and session 1 was significantly different from all other sessions (Wells et al., 2014). Moderate to strong reliability were demonstrated for the number of hits in Mode A (ICC = 0.75, 0.80, 0.88) and moderate reliability for average RT per hit (ICC = 0.68) (Klavora et al., 1995; Wells et al., 2013; Wells et al., 2014).

A third assessment that can be used with the Dynavision is Mode B. Mode B is a reactive mode similar to Mode A but with an added cognitive stress component. Participants react to a visual stimulus via the illuminated buttons of the Dynavision board as they randomly change positions. However, the visual stimulus only remains illuminated for one second before changing location on the board. In addition to reacting to the visual stimuli, participants must verbally recite a five-digit number that appears on the LCD screen. The five-digit number is presented a total of eleven times during a 60 second test and remains on the screen for a total of 0.75 seconds each time. The number of successful hits and the average reaction time per hit are recorded for Mode B and participants must correctly recite all eleven 5-digit numbers. The intraclass correlation coefficients for the number of hits and average reaction time in Mode B were 0.73 and 0.72, respectively (Wells et al., 2014). A similar reliability value of Mode B hits was found to be 0.82 in another study (Wells et al., 2013). Klavora et al. (1995) reported an ICC of 0.92 for Mode B for trials 2 through 5.

Improvements in reaction time performance on the Dynavision D2 device have been attributed to learning effects (Klavora et al., 1994; 1995). Familiarization trials are to be included in the testing protocol to eliminate learning effects (Wells et al., 2014). For example, in the CRT assessment only one familiarization trial is necessary because no significant differences were found between consecutive trials for both visual or motor RT, indicating that a learning curve was not present in the task, possibly facilitated by the simplicity of the task compared to other modes (Wells et al., 2013). Significant differences were observed between trials 1-3 for both Mode A and Mode B tasks, indicating a significant learning effect was present (Klavora et al., 1994; Wells et al., 2014). The reliability values observed in Mode A and Mode B were taken from trials after 1-3, allowing for three familiarization trials to establish a baseline before assessing the data (Wells et al., 2014).

Dynavision Training Programs

The Dynavision D2 is used to assess and improve an individual's reaction to central and peripheral stimuli, and sensory motor integration (Wells et al., 2014). The Dynavision has also been used for enhancing eye-hand coordination and visual performance of ball sports. Clark and colleagues (2012) implemented the Dynavision D2 device in a sports vision training program and found that it significantly increased the visual abilities and eye-hand coordination of Division I baseball athletes. Another study examined Dynavision D2 training of young hockey players and determined that the training enhanced perceptual skills represented by improved visual and motor reaction times (Schwab & Memmert, 2012). Feldhacker et al., (2019) examined the efficacy of high-performance vision training and determined the effectiveness of the Dynavision D2 apparatus in comparison to traditional, non-machine vision training of collegiate softball players. Results indicated that the Dynavison D2 group compared to the visual training group demonstrated a larger effect ($\eta p^2 = .87$ vs. $\eta p^2 = .66$). The athletes that participated in the Dynavision D2 training group experienced an 8% larger decrease in reaction time than the standard vision training group from pretest to posttest and a 0.07 second faster average reaction time at two-month retention for proactive testing. The minimal improvement proved to be statistically significant and fraction-second timing is critical to success in softball (Feldhacker et al., 2019; Uchida et al., 2013). Cross et al., (2013) found that Dynavision training successfully improved the visual motor skills of collegiate volleyball players over six weeks.

Physiological processes related to RT

Reaction time processes are affected by both brain and spinal column (central) communication as well as musculoskeletal (peripheral) communication (Harvey et al., 2011). With the use of brain imaging technology, central mechanisms in reaction time learning have been identified. Nakataa and colleagues (2010) showed brain changes occurring during athlete training that were “induced by the acquisition and execution of compound motor skills during extensive daily physical training that requires quick stimulus discrimination, decision making, and specific attention.” Research focused on understanding the communication between the central and peripheral motor systems have examined understanding the somatosensory and corticospinal communication systems. The somatosensory cortex and its effects on corticospinal communication are directly involved in processes related to reaction time training (Kida et al., 2004; Leocani et al., 2000). According to Paul and colleagues (2012), reaction time provides an indirect index of the processing capability of the central nervous system and a simple means of determining sensorimotor performances.

Imagining a motor action enhances corticospinal excitability (Rossini et al., 1999; Stinear and Byblow, 2004). For example, motor evoked potentials (MEPs) to single-pulse transcranial magnetic stimulation (spTMS) are of larger amplitude when subjects imagined a sustained muscle contraction compared to a resting state (Yahagi and Kasai, 1998; Rossini et al., 1999). Movement preparation also has the potential to modulate motor cortical activity (Touge et al., 1998; Hasbroucq et al., 1999; Sinclair and Hammon, 2008). In simple reaction time (SRT) tasks, MEP to spTMS shows a progressive increase in its size (MEP facilitation), beginning at about

100 milliseconds preceding the onset of an EMG (Pascal-Leone et al., 1992; Chen and Hallet 1999; Leocani et al., 2000; Hashimoto et al., 2004). Previous research has shown that imagining a simple reaction time task causes an enhancement in the excitability of the corticospinal motor pathway like that of a real simple reaction time task, but smaller in magnitude at certain intervals (Kumru et al., 2008).

Many studies have found similar effects of visual perception and mental imagery (Kosslyn 1973, 1978; Kosslyn et al., 1978; Kosslyn et al., 1999; Shepard & Metzler, 1971). Broggin and colleagues (2012) found that an increase in luminance, contrast, visual motion, and orientation yielded a decrease in reaction time for both visually presented and imagined stimuli. These results support overlap between the structural representation of perception and imagery. All processes of motor learning and motor preparation are activated when athletes use imagery to imagine a skill, similar in magnitude if the athlete were performing the activity (Iftikhar et al., 2018). Neural changes that facilitate self-focused attention are interconnected with imagining a motor action (Qin & Northoff, 2011). Davis and colleagues (2012) believe that athletes who utilize self-focused imagery can stimulate cognitive evaluations that change physiological and psychological conditions to benefit sport performance. Davis and colleagues (2012) also found that when more successful athletes are asked to imagine a previous performance after the presentation of a self-referencing stimuli, a more positive impact, less negative effect and amplified blood oxygen-level dependent activation in the appropriate premotor cortex and sensorimotor cortex is promoted. Neuroscientific research reinforces the notion that reaction is both learned and trainable. Cerebral potential amplitude in the premotor prospective spikes when a new motor skill is acquired, which represents the decision to act in a reactive task. Elite athletes have a higher potential of predictability compared to novice athletes (Collet, 1999).

Imagery training and Perceptual-cognitive tasks

Research that has examined the effects of imagery training on sport-specific perceptual-cognitive tasks has provided unclear evidence. Previous studies have identified positive effects from imagery training for anticipation, visual search behavior and tactical awareness using sport-specific tasks (Caliari, 2008; Guillot et al., 2009; Jordet, 2005; Robin et al., 2007; Smeeton et al., 2013).

Caliari (2008) examined whether mental practice was an effective preparation for performing a forehand task in table tennis and whether mental practice is more effective with an external focus on the movement technique. Results showed that the mental practice group that focused on the trajectory of the racket was more effective than the control group receiving the same scripts but not benefitting from a previous phase of mental practice. The mental practice on the trajectory of the racket was more effective than mental practice on the trajectory of the ball.

Guillot et al. (2009) investigated the effect of motor imagery on the learning of basketball tactical strategies in 10 female national players. Three attack movements were evaluated and one strategy was physically and mentally practiced twice a week over a 6-week period. The second was physically performed, while the third movement was not trained. The combination of motor imagery and physical practice was found to significantly improve motor performance during a post-test, while motor imagery alone was not found to be significantly more efficient than physical practice alone.

Jordet (2005) examined whether an ecological imagery intervention program would affect perception in three elite soccer players. The author defined perception as “exploratory activity and prospective control of future actions”. The methodology utilized was a single case, multiple baseline across participants design was implemented. The imagery training program lasted 10-14 weeks. Two of the three players appeared to increase their visual exploratory activity, but only of the players marginally increased his performance with the ball. The author concluded that elite players can improve components of perception through imagery training, however, the extent to which that leads to sport specific performance enhancement through prospective control of action was equivocal.

Robin and colleagues (2007) investigated whether imagery training could improve the accuracy of the service returns, and whether this improvement may be influenced by an athletes' imagery ability. Skilled tennis players were assigned to three groups based on their respective score on the Movement Imagery Questionnaire (good imager, poor imager, control group). The motor imagery training period included physical training for 15 sessions and each session consisted of two series of 15 imagined trials and 15 physical trials. The combination of physical practice and motor imagery significantly improved the accuracy of the service returns in skilled performers. Additionally, good imagers significantly improved their accuracy for direction and were less variable when compared to poor imagers.

Smeeton and colleagues (2013) examined the effectiveness of interventions involving imagery, video, and outcome feedback in improving anticipatory behaviors in skilled junior cricket players. Participants were allocated to one of three groups matched on imagery ability or a no practice control. The experimental groups received a four-week, film-based training intervention. All of the experimental groups improved anticipation performance during training. All experimental groups improved visual imagery ability, measured the VMIQ-2, but only the imagery intervention group improved in the kinesthetic dimension.

Other studies have indicated limited or no effects of imagery training for sport-specific cognitive skills. Munroe-Chandler and colleagues (2005) examined the effectiveness of a cognitive general imagery intervention on three distinct soccer strategies in a young elite female soccer team. The authors utilized a staggered multiple baseline design across behaviors to evaluate the effect of imagery on the three strategies. Results suggested that the execution of soccer strategies was not significantly enhanced with the implementation of a cognitive general imagery intervention. Post and colleagues (2018) examined the effects of a PETTLEP imagery intervention in learners' coincident anticipation timing performance. Participants were randomly assigned into one of four training groups: physical practice, imagery practice, imagery practice + physical practice, or a control group. The study consisted of three phases: pretest, intervention, posttest. Results revealed that the physical practice group and the combination of imagery and physical practice group had significantly lower absolute timing error compared to the control group on the posttest. The combination of imagery and physical practice was the only group to have lower variable error compared to the control group on the posttest.

Imagery training and Reaction time

Imagery is a psychological technique that has been proposed for athletes to rehearse reactive tasks (MacIntyre & Moran, 2007; Paivio, 1985; Williams & Grant, 1999). McNeil and colleagues (2019) cited that no research has directly examined the question of whether imagery can improve reactive task performance. Several studies have indirectly investigated the effect of imagery on reaction time (Grouis, 1992; Hanshaw & Sukal, 2016; Iftikhar et al., 2018; McNeil et al., 2019; Shanks & Cameron, 2000). Several questions regarding the effectiveness of imagery in reducing reaction time remain to be addressed. This section reviews the literature related to the effect of imagery on reaction time.

Grouios (1992) investigated the effect of mental practice on reaction time in a pre-treatment/post-treatment experiment. Pre-post comparisons were made between five groups, a physical practice group, mental practice group, combined physical and mental practice group, combined mental practice and physical practice group, and a no practice control group. Participants in this study were matched by age, imagery ability, intelligence, kinesthesis, motivation, sex, skill level, and speed of reaction time. Reaction time was measured in a choice reaction time task using a lightboard apparatus. Results indicated that reaction time was significantly reduced in the mental practice group from pre to post-test. The author suggested that the reduction in reaction time due to mental practice was due to mental practice influencing memory comparison and/or response selection processes. It is important to note that the physical practice group improved significantly more than the mental practice group alone, and that a combination of physical practice and mental practice is more effective than physical practice or mental practice alone.

Shanks and Cameron (2000) investigated the effect mental practice on performance in a dot-location reaction task. Participants were asked to respond to a target dot appearing in one of four locations on a computer display and the dot appeared in a repeating sequence so that participants could learn to anticipate the next dot appearance. Similarly to the methodological design used by Grouios (1992), participants were assigned to a mental practice group, a physical practice group, or a no practice group, however, this study included an incorrect mental practice group. This study also utilized a pre/post treatment design. Improvements in the reaction task were only seen in the physical practice group. Despite previous evidence cited by the authors that mental rehearsal does enhance performance in perceptual-motor tasks, neither mental practice groups (correct/incorrect) significantly impacted sequence learning.

Another study by authors Alikhani, Mousavi, and Mokhtari (2011) compared cognitive and motivational imagery effects on choice reaction time. Participants were assigned to 3 groups including a cognitive imagery group, motivational imagery group, and a control group. Participants completed 40 trials in a pre-test and 40 trials in a retention test. The authors found that both cognitive and motivational imagery groups significantly improved reaction time compared to the control group. Unfortunately, the authors in this study did not delineate what type of cognitive or motivational imagery was utilized. The authors were not specific as to what the imagery intervention process entailed.

Only a few works in the literature demonstrate the positive impact of imagery on reaction time in a sporting environment. Hanshaw & Sukal (2016) examined the effects of cognitive-specific imagery and motivational self-talk on the response times of trained martial artists. The authors utilized a within- and between-subjects pre-post treatment design. Participants were assigned to one of four groups including a motivational self-talk group, cognitive-specific imagery group, a combination of self-talk and imagery group, and a control group. Reaction time was measured with the HitMaster Personal Trainer System, a device designed to measure the time from signal to target contact. Participants who used both self-talk and imagery had a significant reduction in response times, along with large effects when compared to the control group, self-talk group. and imagery group. The method used by Hanshaw and Sukal (2016) has the advantage of having participants utilize cognitive-specific imagery with a specific movement/skill in martial arts (back-leg roundhouse kick). Cognitive-specific imagery has shown to be beneficial for skill learning, execution, and performance (Martin et al., 1999; Nordin & Cumming, 2008; Paivio, 1985).

A study by Iftikhar and colleagues (2018) examined the effects of motor imagery on reaction time in elite sprinters. Participants were divided into two groups, control and experimental (imagery). Reaction time in this study was measured on the starting blocks before a

30-meter run. The PETTLEP model (Holmes & Collins, 2001) was used for imagery scripts. Athletes in the imagery group had motor imagery practice for 15 minutes every day. Results revealed that motor imagery positively impacted reaction time from pre to post test. Findings also revealed that the motor imagery group improvement was more rapid and significant than the control group.

A recent study by McNeil and colleagues (2019) investigated the effects of imagery training on reactive agility and whether reacting to unpredictable stimuli could be improved using imagery. Participants were randomly assigned to a physical training group, imagery training group, or a control group. Seven performance variables of reactive agility were measured, including two decision-time variables, three movement/running variables, and two variables related to overall reactive agility performance. The physical training group improved both decision time components and overall reactive agility performance. The imagery training only improved stimulus-decision time and stimulus-foot performance, not overall reactive agility performance. The findings support imagery use in improving decision time variables associated with light-stimulus reactive agility performance. Interestingly, the authors suggest that the lack of improvement in overall reactive agility performance in the imagery training group is due to the self-generational nature of imagery being incongruent in rehearsing unpredictable stimuli.

A closer look at the studies in this section reveal several gaps and shortcomings regarding the effect of imagery on reaction time. For example, there is a discrepancy between how reaction time has been measured. Some studies measure reaction time via a lightboard apparatus or computer display (Alikhani et al., 2011; Grouios, 1992; Shanks & Cameron, 2000),whereas other studies measure reaction time in a specific sporting context (Hanshaw & Sukal, 2016; Iftikhar et al., 2018). Additionally, there is an issue with what type of imagery has been utilized and how participants use imagery in the context of the procedural design. For example, many of the studies previously mentioned examined the effect of motor imagery or mental practice on reaction time (Grouios, 1992; Iftikhar et al., 2018; McNeil et al., 2019; Shanks & Cameron, 2000). Mental practice is defined as a training technique in which the procedures required to perform a task are mentally rehearsed in the absence of actual physical movement (Driskell et al., 1994). Similarly, motor imagery is defined as the mental simulation of movements without actual body movements (Jeannerod, 1994). Despite previous research findings that imagery training is beneficial for motor skill learning and performance (Driskell et al., 1994), imagery rehearsal may be problematic for reactive task performance because imagery involves the conscious, cognitive effort to imagine a predetermined scenario (Paivio, 1985; Raisbeck et al., 2012). In other words, an individual generating an image may not be able to imagine an environment in which there is unpredictability or spontaneous stimuli because the imager must consciously generate the image themselves (Munroe et al., 2000; Spittle & Morris, 2007). Furthermore, other researchers have argued that the inability to imagine or generate reactive components in imagery is due to differences in cognitive processes, as imagery is a top-down process, and perception linked to reactive tasks is environmentally driven (Borst & Kosslyn, 2008).

In short, the literature pertaining to the effect of imagery on reaction time strongly suggests that imagery can effectively improve reacting to the presentation of a stimulus (Grouios, 1992; McNeil et al., 2019), similar to that of perceptual-cognitive performance improvement from imagery rehearsal (Guillot et al., 2007; Jordet, 2005; Smeeton et al., 2013, however, imagery may not be effective in improving overall reactive agility performance. A comprehensive discussion of this issue is highlighted in the study by McNeil and colleagues

(2019). They argue that the difference between decision time variables and reactive agility performance in the imagery training group potentially demonstrates that not all components of a reactive task can be rehearsed with imagery. This is supported by research that suggests that the type of task directly influences the effectiveness of imagery (Driskell et al., 1994). There are conceptual issues related to imagery and the ability to consciously create an unpredictable event (Munroe et al., 2000; Paivio, 1985; Spittle & Morris, 2007). Imagery has been found to improve perceptual-cognitive skills and performance that can be predetermined, however, unpredictability in the context of sport may not be imagined or rehearsed exactly as it occurs in a real, physical sport specific scenario (McNeil et al., 2019).

There is another possible explanation that is discussed by McNeil and colleagues (2019) that is also supported by other research that has been previously cited in this review (Grouios, 1992; Hallman & Munroe-Chandler, 2009; MacIntyre & Moran, 2007). The explanation poses that imagery primes performance responses to specific stimuli that may or may not occur. It is argued that imagery is beneficial for bolstering the stimulus-response relationship related to performance in a specific task if a stimulus happens to occur rather than improving the ability to react. This explanation is conceptually similar to Lang's (1977, 1979) bioinformational theory of imagery. In this theory imagery is described as a cognitive schema made up of propositions (different units of information). Each image is believed to be made up of stimulus propositions, response propositions, and meaning propositions. Stimulus propositions are information pertaining to external stimuli in the environment and the context in which they occur. Response propositions describe the physiological responses of an individual to the imagined stimuli, representing how the individual would react to that stimulus in a real situation. Connecting this back to imagery training and reactive tasks, quicker reactions may occur as a result of imagery training because participants rehearsed a predetermined image of the task which facilitated their understanding of the stimulus (stimulus proposition) presented and the required performance outcome (response proposition).

An important question associated with the effectiveness of imagery on reaction time is if it is pertinent to use imagery to focus on improving skills associated with reacting to unpredictable stimuli or use it to improve stimulus-response performance. A new approach is therefore needed to investigate the effect of imagery on reaction time. Specifically, that new approach is to examine motivational imagery on reaction time performance, as opposed to motor imagery or cognitive imagery which is more associated with specific skill rehearsal. For example, motivational general mastery imagery may be more effective in allowing athletes to react and respond optimally to unpredictable stimuli. Motivational general mastery imagery has been shown to raise levels of self-confidence (MGM; Hall et al., 1998) and is used by athletes to be confident, focused, positive, and mentally tough (Munroe et al., 2000). There is a considerable body of research on athletes who use MGM imagery reporting higher levels of both self-confidence and self-efficacy (Martin et al., 1999; Nording & Cumming, 2008). This is important because the ability to adapt to the environment is crucial to performance in sport (Williams & Ford, 2008), and athletes perform under conditions of stress due to physical demands, psychological demands, environmental demands, and expectations and pressure to perform to a high standard (Gould et al., 1993). All of these factors may interfere with an athlete's ability to react to unpredictable stimuli in the environment. Mastery cognitions allow athletes to better cope with the demands of a situation (Jones, 1995). MGM imagery may be a useful tool that enables athletes to respond quickly to reactive tasks, because athletes must respond while under stress and different cognitive demands. Hanton et al., (2004) explained that high levels of self-confidence may protect athletes from interpreting anxiety responses negatively. Also, athletes with high levels of self-confidence rationalize thoughts and feelings that enable them to perceive that they can remain in control in the pressure environment of sport.

Anxiety, Reaction time, Sport Performance

Research has provided evidence that there is a correlational or causal relationship between anxiety, motor performance, and reaction time (Hainaut et al., 2006; Panayiotou & Vrana, 2004; Whelan, 2008). Ciucurel (2012) found that anxiety increases activation of the nervous system, which facilitates quicker reaction times, but leads to behavioral inhibition. Etnyre & Kinugasa (2002) found that high levels of anxiety only facilitates performance in easy tasks but debilitates performance in more complex and difficult tasks. The relationship between anxiety and motor performance has been conceptualized in several ways: anxiety may impair external performance by means of attentional interference (Calvo et al., 1990), the anxiety and motor performance relationship defined as an attentional interpretation (Mullen & Tattersall, 2005), and a psychobiological approach signifying the interaction between affect, cognition, and physiology (Neiss, 1988).

To further support the investigation into the effect of motivational imagery on reaction time is the relationship between anxiety, reaction time and performance before and after sport competitions. Ciucurel (2012) established that before competition some anxious athletes have the tendency to obtain significantly quicker reaction times, but this is associated with disorganization at the behavioral level, decreasing motor performance. In contrast, other anxious athletes experienced an increase in response latency, associated with behavioral inhibition and a decrease in motor performance. The author noted that these findings highlight that the optimal and non-optimal arousal states for athletes differ from individual to individual. Again, MGM imagery in this case may enable athletes to view symptoms of anxiety as facilitative opposed to debilitative to enhance performance and reactive ability, while maintaining behavioral organization.