THE EFFECTS OF VIRTUAL REALITY ON STRESS AND PERFORMANCE IN FEMALE SOCCER PLAYERS

by

Kaitlyn Paige Harrison

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Howard Payne University
Brownwood, Texas

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Kaitlyn Paige Harrison

Thesis Approved by:

Dr. Robyn Trocchio, Major Professor

Dr. Adam King, Committee Member

Dr. Deborah Rhea, Committee Member

Dr. Deborah Rhea, Associate Dean
Harris College of Nursing & Health Sciences

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Chapter I: Introduction

Coaches, athletes, and practitioners are always seeking strategies to optimize performance. One area that has received a great deal of attention in collegiate athletics is stress. Stress can be defined as “a physical, mental or emotional, demand, which tends to disturb the homeostasis of the body” (Bali, 2015, p. 92). For decades, researchers have known that the body adapts to the stresses placed on it and a certain amount of stress (i.e. eustress) is needed to adapt and progress, but too much (distress) can lead to under-recovery, overtraining, and deterioration of health and performance (Andersen & Williams, 1988; Bali, 2015; Lazarus & Folkman, 1984; Selye, 1951). Eustress is a constructive stress form compatible or protective of good health, whereas distress (or too much stress) is destructive and said to damage health (Lazarus, 2006, p. 32). Stress can be physiological and/or psychological. Physical stress refers to the physical fatigue induced during training and/or competition (Kellmann & Beckmann, 2018). Psychological stress is “a relationship between the person and the environment that is appraised by the person as taxing or exceeding his or her resources and endangering his or her well-being” (Lazarus & Folkman, 1984, p. 19). When an athlete faces a stressful environment, the athlete’s attention is no longer on the task at hand, but scattered to other stimuli, possibly exposing them to an injury (Andersen & Williams, 1988). Andersen and Williams (1988) explained that failure to balance this stress-injury relationship leads to two basic mechanisms – an increase in general muscle tension and a decrease in mental focus. In regard to muscle tension, this negative reaction to stress interferes with motor coordination and reduces flexibility, while the shifting of attention leads to a narrowing of the visual field causing athletes to miss vital cues (Andersen & Williams, 1988). This stress-injury relationship is important to consider in student-athletes with all the various physical and psychological stressors they must balance within and outside of their sport.

College itself can create a significant increase in psychological stress, with an added element of being a collegiate athlete can compound the stress placed on the student (Cosh & Tully, 2015). Student-athletes must balance their time and attention on academics, social life, family life, money, possibly work, and much more. Compared to the average student, a student-athlete's level of stress is presumably higher which in turn could negatively affect their performance in their sport and in the classroom (Cosh & Tully, 2014; Fogle & Pettijohn, 2013). Mann and colleagues (2016) examined National Collegiate Athletic Association (NCAA) Division I football players facing increased stress throughout the course of a semester. Results showed that whether the stress was from their sport (pre-season) or in the classroom (exam weeks), a positive correlation was seen with the number of injury restrictions per week and the more stressful periods of the semester. Injury restrictions were defined as injuries that would cause any restrictions to a drill or other parts of practice. In times of high physical stress there were 19 injury restrictions, periods of high academic stress brought about 13 injury restrictions, and areas of low academic stress (regular season weeks without scheduled academic examinations) only had about 5 injury restrictions (Mann et al., 2016). These results coincide with the 2015 GOALS Study that the NCAA performed. The NCAA surveyed mental well-being in collegiate athletes and found that approximately 30 percent of collegiate student-athletes admitted that they felt overwhelmed during the past month and about ¼ of student-athletes claimed the mental demands of their sport left them exhausted (*NCAA GOALS Study of the Stuent-Athlete Experience Initial Summary of Findings*, 2016).

There is also literature about psychological stress and how it projects physically in high anxiety situations. For instance, researchers have analyzed the effectiveness of golfers' performances in low and high anxiety situations by analyzing the putting accuracy and found that the golfers' performances were worse under the high anxiety condition (Mullen et al., 2005). This highlights the issue that athletes are negatively affected by stressful situations. This reduction in performance has also been seen in soccer players taking penalty kicks. Wilson, Wood, and Vine (2009) examined fourteen soccer players' performances in penalty kicks in low and high anxiety conditions. With a significant difference in state anxiety ($p < .01$ for cognitive anxiety and $p < .01$ for somatic anxiety), participants performed significantly lower in the high anxiety condition compared to the low anxiety condition ($p < .05$) (Wilson et al., 2009). In the high anxiety condition, participants shot their kicks more centrally to the goalkeeper, making it easier to save for the goalkeeper. This study also examined gaze behaviors and found that participants looked at the goalkeeper earlier and for a longer amount of time in the high anxiety condition, having a negative effect on shot placement (Wilson et al., 2009). This altered gaze pattern gives a physical indicator of increased anxiety and along with Mullen et al. (2005), shows that increased psychological stress can translate physically in athletes and result in negatively affecting performance in various sports.

Additionally, psychological stress, in excess, can cause individuals to have decreased performance through increased tension of the muscles resulting in altered motor patterns and decreased flexibility, increasing the risk of injury (Andersen & Williams, 1988; Cagle et al., 2017). Sekiya and Tanaka (2019) examined the kinematic performance of novice table tennis players when faced with high psychological pressure. Pressure, or stress, was induced by offering monetary rewards for successful performances and cancelling poor performances. Researchers analyzed the participants' kinematics by measuring the racket head and ball movements along with grip force and found that in higher pressure, participants altered their movements. The participant's back swing and forward swing were reduced in length, speed of the forward swing and ball speed decreased significantly ($p < .008$) under high pressure, and the ball and racket contact point shifted forward significantly ($p < .008$), contributing to a decrease in performance (Sekiya & Tanaka, 2019). Despite changing strategies to avoid error, higher pressure resulted in poorer performance. Increased stress and anxiety also altered the kinematics of individuals in a study conducted by Williams, Vickers, and Rodrigues (2002). Eight male and two female table tennis players were to score as many points as possible by hitting the bullseyes of targets across the tennis table. In the high anxiety condition, participants were to specifically aim for certain targets based off the server's position while still trying to get the highest score possible. Kinematics were obtained through four high-speed video cameras and a computerized system with the participants wearing reflective markers attached at the elbow and wrist of the striking arm. Results indicated that participants used a shorter tau (tau is used to measure twisting actions such as of arm/wrist) margin when anxious and had longer movement times in the high anxiety condition that was paired with a lower performance score compared to the low anxiety condition (Williams et al., 2002). Together, these studies show that increased stress can affect a person's movement. Their motor patterns shift to adapt to the stress and maintain performance, which could actually be doing the opposite.

Therefore, stress management can be advantageous to modulate throughout the fluctuations of the season and academic year to maintain performance and health (Mann et al., 2016). In order to assist with the increasing psychological stress of collegiate student-athletes, various interventions have been implemented including mindfulness interventions, relaxation imagery, deep breathing, and muscle relaxation (Pelka et al., 2017; Vidic et al., 2017). For instance, Pelka and colleagues (2017) examined the effects of progressive muscle relaxation, yoga, deep breathing exercises, and power naps in participants between two sprinting tasks and concluded that all methods were perceived to relax the participants after their respective intervention was implemented. However, deep breathing and power naps were the only interventions to demonstrate improved sprint times. Furthermore, Vidic, Martin, and Oxhandler (2017) investigated how mindfulness interventions impacted stress, athletic coping skills, and personal perceptions over the course of a regular basketball season in a Division I women's basketball team. The team performed ten sessions once a week for 16 weeks, and each session consisted of one hour. Results showed that the intervention decreased stress and increased the participants' coping skills, while the reflections showed that the participants improved their awareness, control, focus, presence, and relaxation as a result of the sessions.

Now, with the increased use of technology, relaxation interventions are finding their way into technology devices and have become incredibly accessible with mobile apps (e.g. Calm and Headspace), and VR head mounted displays (HMD). VR specifically has become affordable with the improvements in technology and has grown exponentially (Bird, 2019; Cotterill, 2019). In the sport literature, VR has been utilized to analyze and enhance performance by simulating stressful, real game scenarios (Ross-Stewart et al., 2018; Runswick et al., 2018). Other research has focused on VR exposure therapy to treat chronic ailments (i.e. PTSD and phobias) by exposing participants to their anxiety triggers in a safe manner so they can learn coping strategies (Miloff et al., 2019). VR has also been used on other non-athletic populations to analyze anxiety reduction with VR over multiple sessions, with slightly different VR strategies used in these studies. For instance, intensive care unit patients have seen relaxing effects from VR through immersive, natural scenes through head-mounted displays (Gerber et al., 2017). Additionally, VR has been utilized to provide nurses and teachers an "interreality protocol" to reduce their stress by providing experiential virtual scenarios to better prepare them for stressful situations (Gaggioli et al., 2014).

Unfortunately, there is a lack of evidence on the efficacy of VR relaxation in stress reduction in student-athletes and how stress reduction via VR translates to their movement patterns. Evidence on athletes and VR exists but is scarce. More specifically, literature that is available addressing athletes tend to examine one aspect of the effects of VR. For example, only examining general relaxation and finding that general relaxation does indeed reduce the feelings of stress in athletes (Liu & Matsumura, 2019; Vidic et al., 2017). Despite all the research conducted on VR, relaxation, or stress reduction, it is all segmented and there is hardly any research combining all these factors together. Little research has been conducted on how VR relaxation specifically affects student-athletes motor patterns in performance settings and if there are benefits of psychological stress reduction via a VR platform. One could hypothesize from the outcomes of the previous studies that VR relaxation would reduce stress and improve motor patterns, thus reducing the potential risk of injury by preventing the increased muscle tension and disruption of attention. In order to extend the previous literature, the purpose of this study was to analyze how VR relaxation techniques affect psychological stress levels in female soccer players and how the potential changes translated to their movement patterns during a penalty kick. It was hypothesized that cognitive anxiety and somatic anxiety, will be higher on the Mental Readiness Form (MRF)-3 during the stress-induced block compared to the VR relaxation block and baseline block, while the self-confidence subscale would be lower in the stress-induced block compared to the VR relaxation block and baseline block. It was hypothesized that providing the stress-inducing scenario to the participants would heighten their sense of cognitive and somatic anxiety, but also decrease their level of self-confidence in performing successfully. After receiving the VR intervention, it was hypothesized that the participants would feel more relaxed, reducing their cognitive and somatic anxiety about the task, and in turn, increase their level of self-confidence in performing well. It was hypothesized that the participants would exert more effort in the stress induced block to maintain performance, thus scores on the Rating Scale of Mental Effort (RSME) would be higher during the stress-induced block compared to the VR relaxation block and baseline block. After the VR relaxation, it was hypothesized that the intervention would reduce their sense of stress, thus leading to less effort exerted during that block of penalty kicks. It was also hypothesized that accelerometer data from the anterior thigh would be greater in the stress-induced block compared to the VR relaxation block and baseline block. It was hypothesized that while induced with stress, the participants would strike the soccer ball more forcefully and faster in order to perform their best, resulting in higher accelerometer data points in the anterior to posterior axis. It was also hypothesized that this change in their movement patterns would result in their shots to be hit more centrally to the goalkeeper, giving them lower scores. Additionally, after receiving the VR relaxation intervention, it was hypothesized that the participants would be more relaxed and would have a slower, less forceful shot that is more similar to their baseline accelerometer data. This should allow the participants to place their shots more correctly into the four corners of the net, or wider areas away from the goalkeeper, making it harder for the goal keeper to make the save and producing higher scores on this block as opposed to the stress-induced block. It was hypothesized that HR would be higher in the stress induced block compared to the VR relaxation block and baseline block. The stress-induced block was expected to increase the participants' levels of stress/anxiety which would be reflected in an increase in HR. Then, after the participants received the VR intervention, the participants would be less stressed and anxious as opposed to the stress-induced block, and their HR would decrease to reflect similar values to their baseline data. It was also hypothesized that participants' scores would be lower compared to the VR relaxation and baseline blocks due to the increased stress. It was hypothesized that based on the results, this study would have the potential to give possible insights on the opportunity of incorporating VR as a therapeutic intervention technique in the prevention of injury and reason for further exploration on the topic.

Significance of the Study

It is important to research immersive VR relaxation techniques because of the heightened immersive effects it could provide compared to traditional relaxation, resulting in a better imagery experience (Ross-Stewart et al., 2018). As previously stated, psychological stress, in excess, can cause individuals to have decreased performance via increased tension of the muscles resulting in altered motor patterns and decreased flexibility. These negative effects can increase the risk of injury (Andersen & Williams, 1988; Cagle et al., 2017). Some stress is beneficial to student-athletes, but it is important to modulate psychological stress for optimal performance and well-being (Pelka et al., 2017). The medical team could further prevent injuries by taking into consideration the psychological component of a student-athlete's life and manage psychological stress in student-athletes through VR. It is also possible that VR may be more engaging for the student-athletes which would elicit more investment and in result, receive greater benefits. Some student-athletes when using traditional relaxation may have trouble imaging a relaxing scene and/or ignoring the distractions of the outside world and VR can help mitigate that. Therefore, VR has the potential to be a useful preventative measure for injuries to assist with keeping student-athletes healthy physically and psychologically.

Research Questions

- Will the scenario used to induce stress to the participants make the participants stressed enough to see an effect from the VR relaxation intervention?
- Is there a difference in the participants' levels of stress at baseline, before the VR relaxation intervention, and after the VR relaxation intervention?
- Is there a difference in the participants' motor patterns at baseline, before the VR intervention, and after the VR intervention?
- Is there a difference between the participants' shooting performances at baseline, before the VR intervention, and after the VR intervention?

Definition of Terms

- Anxiety: "an altered state of mind through emotional reactivity, arousal, nervousness and an unpleasant state of mind" (Bali, 2015, p. 94).
- Virtual Reality Head Mounted Display: A virtual reality device that provides an immersive experience that is worn on the head, over the eyes, that provides sound.
- Injury: damage to the body that impairs normal functioning of the individual or impairs a part of an organ system resulting in an inflammatory response.

- Penalty Kick: A free kick at the spot marked within the penalty box that is twelve yards away from the goal that only the goalie can defend while standing on the goal line; which is awarded to the opposite team when the defending team commits a foul inside the penalty box.
- Physical Stress: The physical fatigue induced during training and/or competition (Kellmann & Beckmann, 2018).
- Psychological stress: “a relationship between the person and the environment that is appraised by the person as taxing or exceeding his or her resources and endangering his or her well-being” (Lazarus & Folkman, 1984)
- Relaxation: The process of an individual releasing tension and stress within their body to bring a sense of calmness and ease.
- Stress: “a physical, mental or emotional, demand, which tends to disturb the homeostasis of the body” (Bali, 2015, p. 92)
- Student-athlete: An individual who plays a sport at a varsity level or club level at a college or university.
- Virtual Reality Relaxation Intervention: Computer technology that simulates an environment to induce relaxing effects on the user through a VR HMD.

Assumptions

It was assumed that participants in this study completed the instructions to the best of their abilities. It was also assumed that the participants answered questionnaires honestly and truthfully. The VR instrumentation used was assumed to accomplish the VR setting and level of immersion effectively, and that the instruments used to gauge motor patterns were of sufficiency to do so.

Delimitations

A delimitation in this study is that the population was limited to only female soccer players attending a Division-I university. Another delimitation is that this study was that the goalkeeper was a member of the research team. This may have increased the participants' scores due to the lack of experience of the research team member. Also, a delimitation in this study was that the participants' actual game performances were not used or analyzed due to the fact that the not all participants were actively participating in a competitive season. Therefore, the experiment was conducted when the participants were available outside of a practice or game.

Limitations

One limitation is that the study only examined one particular population to be representative of all student-athletes because of the delimitation of only examining female soccer players at different levels of experience. The different levels of experience may have resulted in a variance of the effect the VR intervention had on the participants. The type of VR system used is another limitation because of expenses for the devices. Other VR systems that are more expensive may produce a better immersive environment than the one that was used in this study. Another limitation is that the individuals only used the intervention one time and were not able to become familiar with the relaxation strategy prior. There was also the limitation that using the VR system or performing the experiment that was unfamiliar to the participant may have induced separate stress or anxiety unintentionally. The quality of the relaxation application used was another limitation in the study. Due to limited availability of relaxation applications, there were only a few options to choose from that may not have provided the most realistic scene on a developer standpoint. This also ties in with the limitation that the study used a relaxation application that was not created specifically for this study, which could have limited its effectiveness.

Independent and Dependent Variables

- Independent Variables: Time (baseline, after stressor induced, after VR relaxation)
- Dependent Variables: stress-levels based on questionnaires, the participants' motor patterns during penalty kicks, the participants' heart rate, and the participants' scores from each block.

Chapter II: Review of Literature

The information following is a review of the literature that is appropriate for the utilization of VR as a relaxation technique to improve motor patterns in collegiate athletes. The psychological component of athletic performance has been well established (Bali, 2015; Eysenck et al., 2007; Eysenck & Calvo, 1992; Lazarus & Folkman, 1984; Mann et al., 2016; Mullen et al., 2005; Vine et al., 2016), however, the utilization of VR in sport psychology has grown in interest in recent years (Cotterill, 2019; Neumann et al., 2018; Ross-Stewart et al., 2018). With evolving technology, VR has become commercialized and easily accessible for use. With VR's technological evolution, the possibilities of what VR technology can do has steadily been analyzed (Cotterill, 2019; Ross-Stewart et al., 2018). The purpose of this literature review is to integrate information obtained from previous research on how VR impacts psychological stress, and how psychological stress and anxiety affects motor patterns. Reviewing the literature will provide a comprehensive understanding of the potential use of VR as a relaxation technique to decrease psychological stress and consequently optimize motor pattern execution, and in turn performance. Topics that will be addressed include: (1) the relevant theories addressing the effects of psychological stress and anxiety; (2) psychological stress and anxiety in collegiate student athletes; (3) the effects of psychological stress and anxiety on kinematics and performance, (4) relaxation techniques in sport, and (5) VR as a therapeutic modality.

Theories Addressing the Effects of Psychological Stress and Anxiety

Various theories attempt to explain the reactions to psychological stress and anxiety to performance. The processing efficiency theory claims that worry affects the memory system in two ways that decrease efficiency in performance. The attentional control theory builds off the processing efficiency theory and claims that anxiety causes an attentional shift, and the model of stress and athletic injury connects the relationship between stressful stimuli and the physiological responses the body experiences. The inverted-U theory claims that there is an optimal level of anxiety, or arousal, needed for best performance, but too little or too much arousal can lead to decrements in performance. The individual zone of optimal functioning theory takes the inverted-U theory concepts but claims this level of optimal arousal varies from athlete to athlete and is not the same for everyone. The catastrophe theory is another alternative to the inverted-U theory that postulates that small changes in arousal can result in catastrophic decrements in performance. These theories are further explained and are the basis for this study.

Processing Efficiency Theory

The processing efficiency theory (PET) was designed to explain the "effects of state anxiety on performance" (Eysenck & Calvo, 1992, p. 414). Through this theory, state anxiety is the key factor in determining performance outcomes in stressful situations, but it is important to note that it does not exclude trait anxiety since state anxiety can be highly correlated with each other (Eysenck & Calvo, 1992). State anxiety has the cognitive components of worry, which is related to avoidance motivation, and arousal, giving vigor and activation, that is determined by trait anxiety and situational stresses (Eysenck & Calvo, 1992). According to Eysenck and Calvo (1992), a significant part of PET is the effect of worry on the working memory system. It is assumed that worry, or self-preoccupation or concern over level of performance, affects the central executive loop on working memory, so when worry alters an individual's state anxiety during performance, the effects are greater with tasks imposing higher demands on the working memory; however, contenders of the theory claim that putting forth more effort into the task allows for a greater working memory capacity and counterbalances the aversive effects of worry (Eysenck & Calvo, 1992).

Individuals that tend to be more highly anxious (or have higher trait-anxiety) deal with the negative effects of worry more than individuals that are less anxious. Highly-anxious individuals focus more resources on their worry and other task-irrelevant processes (i.e. processing stimuli that does not affect the outcome of the task) which can result in impaired performance (Eysenck & Calvo, 1992). Furthermore, highly-anxious individuals tend to set unreasonably high standards of performance for themselves, and are also more sensitive to detecting threat-related stimuli (or potential factors that can cause stress) and mismatches between performance and expectations making them more susceptible to allocating more effort to these detections (Eysenck & Calvo, 1992). Essentially, highly anxious individuals are more likely to spend additional effort on detecting potential stressful situations and on the possibilities of failing at the task resulting in less effort spent on the execution, impairing performance. The individual has more attention on the “what-ifs” rather than actually performing the task. Thus, Eysenck and Calvo (1992) defined processing efficiency as performance effectiveness divided by effort. If individuals dedicate a high level of effort to a task, but their effectiveness is minimal, their processing efficiency can diminish.

There are four limitations of PET. The first limitation is that PET fails to identify which central executive functions are most negatively affected by anxiety. The second limitation is that there is no theoretical assumption addressing distracting stimuli on anxious individuals. Thirdly, PET places more emphasis on neutral or non-emotional stimuli, but threat-related stimuli have a larger effect on performance in anxious individuals compared to neutral stimuli. Finally, the fourth limitation of PET is that it fails to consider the occasions where anxious individuals have a better performance compared to non-anxious individuals (Eysenck et al., 2007). However, these limitations are addressed by the attentional control theory.

Attentional Control Theory

The attentional control theory (ACT) is a theory that builds upon the PET and was developed by Eysenck and colleagues (2007). In accordance to ACT, it is assumed that anxiety reduces the attentional focus for the current task because anxiety is allocating more resources to respond to the threat-related stimuli the individual is perceiving (Eysenck et al., 2007). ACT addresses the limitations in PET and identifies that shifting (going back and forth between several tasks) and inhibition (resisting disruption from task-irrelevant stimuli) are the main executive functions that are most affected by anxiety. Thus, anxiety increases the influence of the stimulus-driven attentional system and less influence on the goal-directed attentional system (Eysenck et al., 2007). The goal-directed system is influenced by expectations, knowledge, and current goals while the stimulus-driven system is influenced by conspicuous stimuli and their balance is disrupted by anxiety (Eysenck et al., 2007). Essentially, the individual gets distracted from task-irrelevant stimuli that poses a potential threat to them and their attention is focused on processing the irrelevant stimuli rather than on the relevant stimuli and less processing is allowed for the execution of the task, affecting performance. For example, if a soccer player is in a goal-scoring position to tie the game, but his/her attention is focused on the pressure from their coach and teammates yelling at them to shoot, the player is less focused on where the goalkeeper is located in the goal box. In result, their odds of scoring the goal is lower due to the shift in attention to the coach and players.

In general, ACT addresses the limitations in PET. The first limitation addressed by Eysenck and colleagues (2007) was that ACT accounted for which central executive functions, such as shifting attention between tasks, planning subtasks for goal completion, selective attention and inhibition (or filtering and acting on relevant and nonrelevant stimuli), and updating working memory, are most affected by anxiety which PET did not. The second limitation is that ACT explained that distraction affects performance and not just worry in anxiety which PET was originally not concerned about, which was the third limitation. Finally, the fourth limitation being that PET did not differentiate the interactions between threat-related and neutral stimuli which ACT addresses stating that adverse effects are greater with threat-related stimuli compared to neutral, or non-emotional, stimuli (Eysenck et al., 2007). Thus, a shift or change in attention to factors that are irrelevant to the task at hand or to factors that appear as a threat to the individual, take their focus away from the key factors that they need to be focusing on in order to successfully complete the task at hand, affecting performance according to ACT. Therefore, if a golfer is trying to make the putt to take the lead, but he/she are stressed over their academics or an issue at home, the golfer will have a greater tendency to have a lack of focus on the putt itself and be scattered between their academics/home life and even other stimuli around them that do not even effect their putt like the smell of someone’s food or a bird chirping in the distance. In result, the golfer’s focus is shifting and cannot completely focus on what is most important or key for success.

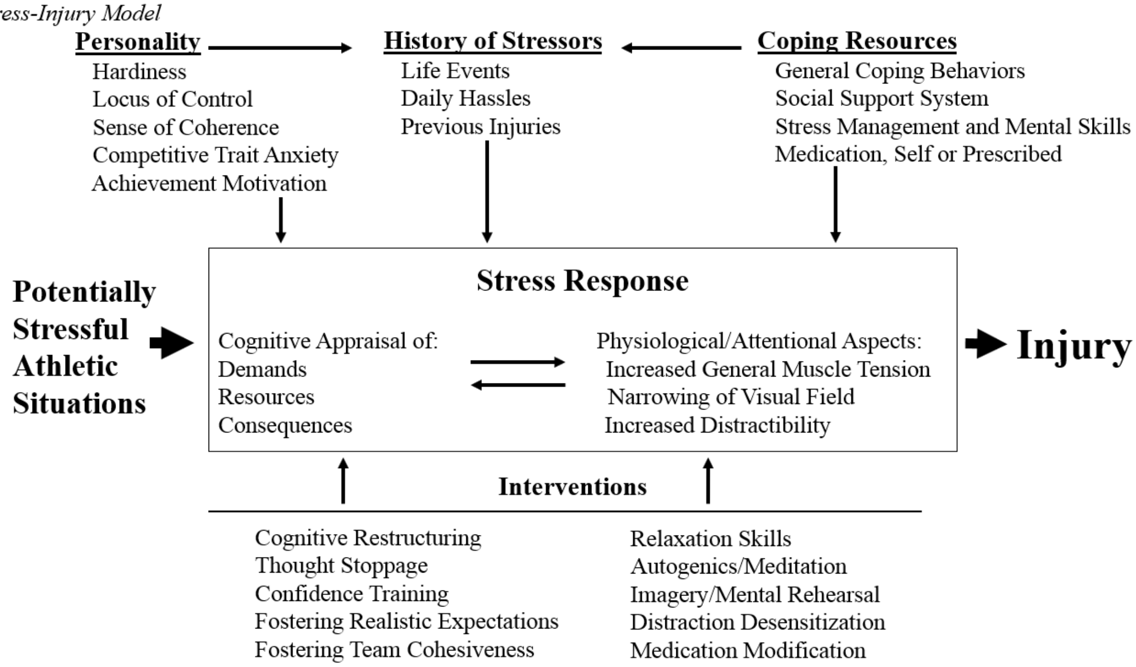
Model of Stress and Athletic Injury

Addressing stress from an injury perspective, Andersen and Williams (1988) examined the psychosocial factors that lead to injury and developed a theoretical framework of the stress response in a multifactorial perspective. According to the model (as seen in

Figure 1), the first aspect is the cognitive appraisal. If an athlete perceives the demands they are facing to exceed the resources they perceive to have, this can elicit a significant stress response that can be compounded if the consequences are of major importance to the athlete (Andersen & Williams, 1988). For example, if the athlete is in a weight-lifting session during preseason and is expected to lift a certain amount of weight in a back squat, but they do not think they can lift that weight, this can be extremely stressful especially if it plays a role in deciding if the athlete gets the starting position over another talented player. The appraisal and reappraisal of the situation by the athlete can be affected by physiological and/or attentional aspects of the situation because the physiological and attentional reactions can behave as feedback information (Andersen & Williams, 1988). Altered attention can result in a narrowing of the visual field leading the athlete to miss important cues in the periphery, and their attention scatters towards the irrelevant stimuli (Andersen and Williams 1988). Athletes may experience greater muscle tension that can alter motor coordination and reduce

Figure 1

Stress-Injury Model



flexibility, and they may experience diminished attention to the task at hand, resulting in injury because of the stress (Andersen & Williams, 1988).

Andersen and Williams (1988) also address that an individual's history of stressors including life events (i.e. traumatic experiences or loss of a job/income), daily hassles (i.e. traffic or school/workload) and previous injuries (i.e. severity, type, perceived cause, recovery status)) are all factors that can affect the stress response of an individual. An individual's personality and ability to handle stress, along with the coping resources (i.e. social support, coping behaviors, stress management, and attentional strategies) that are available or they have obtained, can affect how the individual responds to the stressful stimuli they encounter (Andersen & Williams, 1988). For example, if an individual has a large history of stress in their lives with personality traits that exacerbate the stress (such as higher competitive trait anxiety) combined with few coping resources, the individual will be more likely to determine a stressful situation as stressful as opposed to someone with better coping resources or more hardiness in their personality (Andersen & Williams, 1988).

Inverted-U Theory

The inverted-U theory was created based on the foundational work of Yerkes and Dodson (1908) on dancing mice subjects. Through this study, the Yerkes-Dodson law clarified that different tasks required different levels of electrical shock based off their difficulty. Difficult tasks required weaker levels of electrical shock and easy tasks required more intense electrical shocks (Robert M. Yerkes & Dodson, 1908). Throughout this experiment, an optimal point of performance for the given task was found before performance dropped off, representing an inverted-U.

To translate this to human performance, the inverted-U theory specifies that the more complex the skill is, the lower the amount of arousal is needed for optimal performance. For example, putting in golf would need a lower level of arousal than for bench pressing in weight lifting (Cox, 2012b). This also applies in athletes relative to their skill level. As the athlete becomes more advanced, the less complex the skills of the sport become, resulting in a higher level of arousal needed for optimal performance. For beginners, learning the basics of the sport starts off as very complex, thus a lower level of arousal is needed, which partly explains why novices do not perform as well in competitive situations compared to advanced players (Cox, 2012b).

This theory highlights the importance of athletes being optimally aroused, but also that athletes can be too aroused and finding the “sweet spot” is critical for optimal performance. Thus, if an athlete is dealing with a large amount of psychological stress and anxiety, they could become overly aroused for their sport, and suffer in their performance. It is important that athletes are able to regulate their levels of arousal for best performance. However, the inverted-U theory fails to explain the complexities of the anxiety-performance relationship. For instance, a limitation of the inverted-U theory is that it assumes the same level of arousal is needed for everyone for that respective task at the same skill level. This is where the individual zone of optimal functioning theory (IZOF) comes into play.

Individual Zone of Optimal Functioning Theory

The IZOF theory claims that the necessary level of arousal needed for best performance varies from individual to individual (Hanin, 2000). This theory also highlights the importance of an individual’s optimal precompetitive anxiety, or level of anxiety before competition starts. Over time, this theory has evolved to encompass emotions generally rather than anxiety specifically, to evolve into the individual affect-related performance zone (IAPZ) (Cox, 2012a). This probabilistic model allows individuals to calculate what specific level of affect would result in optimal performance. This theory builds off the inverted-U theory and attempts to explain differences between individuals when it comes to performance.

This theory can help explain when teammates enter a competition with similar levels of precompetitive anxiety but have major differences in their performance. Each individual may need their own routine to achieve their individual optimal level of arousal and can be affected by increased levels of psychological stress and anxiety (Hanin, 2000). For example, an athlete may need a lower level of arousal to achieve optimal performance in their sport, however, if the athlete is having increased psychological stress and anxiety over academics or personal matters, their level of arousal may be too high and the athlete may not perform as well. Another athlete though may have trouble being under-aroused and may not be affected by this and their increased stress could actually help them get to the higher level of arousal needed for them to perform successfully.

Catastrophe Theory

The catastrophe theory postulates that cognitive and somatic anxiety have interactive effects on performance and puts the smooth bell-shaped curve of the inverted-U theory into question (Hardy, 1990). This theory predicts that cognitive anxiety directly influences performance while somatic anxiety will differentially influence performance depending on cognitive anxiety (Krane, 1992). Somatic anxiety has a smaller effect on performance and could possibly have a facilitative effect if cognitive anxiety is low, however if both cognitive and somatic anxiety are high, a catastrophe occurs. Performance severely decreases and large changes in cognitive and somatic anxiety will be necessary to return to a moderate level of performance (Krane, 1992).

Thus, the catastrophe theory gives more complexity than the simple bell-shaped curve that the inverted-U theory does. Cognitive anxiety has the largest effect on performance, thus only a small change in cognitive anxiety can have catastrophic effects in performance. The recovery to their previous level of performance will also take time and is dependent on the athletes ability to reduce their level of arousal (Hardy, 1990). Thus, if an individual is suffering from increased psychological stress and anxiety from what they are accustomed to, then catastrophic reductions in performance could ensue.

Psychological Stress and Anxiety in Collegiate Student-Athletes

Anxiety and stress have been compared; as anxiety being an altered state of mind through emotional reactivity, arousal, nervousness and an unpleasant state of mind, while stress is a physical, mental, or emotional demand that can alter homeostasis (Bali, 2015). A certain level of arousal is needed to perform at an optimal performance and too much stress can over-arouse an athlete and reduce performance levels (Bali, 2015). Therefore, research in this literature review may refer to stress or anxiety, depending on whether the research is biomechanical or psychological in nature and both are necessary to review.

Psychological stress is an aspect of life that every individual experiences and handles differently. Stress is good for an individual to a certain degree, but too much can have negative effects on a person and becomes an issue (Bali, 2015). Good stress is often referred to as *eustress,* which is constructive and associated with "empathetic concerns for others and positive striving that would benefit the community," and good health (Lazarus, 2006, p. 32). *Distress* is when too much stress becomes destructive and is related to anger, aggression, and damaging health (Lazarus, 2006, p. 32). Some individuals have better coping skills (i.e. diaphragmatic breathing, relaxation, imagery, and focusing on what can be controlled) than others (Bali, 2015). In college, students encounter psychological stress from a multitude of variables that they must balance throughout their collegiate career (Cosh & Tully, 2015). With school, family, friends, and work just to name a few, college students must learn to divide their time appropriately amongst these demands. With student-athletes, this only increases with their sport that takes up much of their time from meetings, practices, games, and traveling. In some cases, student-athletes will put a higher priority on their sport over their academics by choosing easier majors or classes to help modulate the psychological stress sports and academics bring (Cosh & Tully, 2014). Despite the attempt to decrease the stresses the student-athletes must face, they still must balance their sport, academics, and personal lives which is still extensive. According to Cosh and Tully (2015), student-athletes faced several stressors with few appropriate coping mechanisms to handle the psychological stress they experienced. In this study, twenty Australian athletes at a collegiate level participated in semi-structured interviews. As a result of these interviews, scheduling, fatigue, coaches, and finances were the main overarching themes that the student-athletes encountered .Additionally, the athletes had limited coping-strategies to appropriately handle the psychological stressors(Cosh & Tully, 2015).

With the struggle of balancing sport, school, and personal demands, the increased levels of psychological stresses translate physically. Mann and colleagues (2016) found that psychological stress played a key role in injury rates in collegiate football players. For this particular study, a Division I college football team's injury restrictions were observed over the course of a 20-week season. An injury restriction consisted of an injury limiting the participation of the student-athlete in a drill or practice. Periods of high physical stress (e.g. training camp), high academic stress (e.g. mid-terms and finals weeks), and low academic stress were highlighted in the season, and researchers discovered that periods of high academic stress were associated with higher numbers of injury restrictions along with the period of high physical stress (Mann et al., 2016). Therefore, school itself was a major stressor that increased injury rates among the team.

Effects of Psychological Stress and Anxiety on Kinematics and Performance

In addition to increased injury restrictions in sport, psychological stress and anxiety can also affect the kinematics in athletes, hindering their performance. More specifically, periods of high stress have been correlated with higher injury restriction rates as previously discussed (Mann et al., 2016). This next section examines the correlation between periods of high psychological stress and kinematics in relation to performance.

Several studies have analyzed the effects of increased levels of pressure or anxiety-induced conditions on participant kinematics and their execution of sport specific tasks (Mullen et al., 2005; Runswick et al., 2018; Wilson et al., 2009). For example, Mullen, Hardy, and Tattersall (2005) examined putting efficiency in amateur male golfers in three different conditions, once in an evaluative condition and once in a neutral condition. The neutral condition reflects a low anxiety condition while the evaluative condition reflects a high anxiety condition. The golfers either putted as they normally would in a single task condition, putted while performing a tone-counting condition, or putted while demonstrating task-relevant coaching points that aimed to effect conscious processing. For the tone-counting condition, they were to count the number of high-pitch tones during each putt, and for the coaching point condition, they were to shadow coaching cues that were given by a researcher and have them guide their performance for each putt. Each participant executed ten putts in each condition (e.g. three blocks of ten trials) in the neutral and evaluative conditions. Anxiety was induced by explaining to the golfers that they could win prize money for their performance and would be judged by their putting skills by a golf professional. The results indicated that for mean performance scores, the putts were significantly less accurate in the high anxiety tone-counting and coaching point conditions. Evaluative instructions also significantly increased cognitive anxiety levels ($p < .01$). When looking at main effects, there was a significant effect of anxiety in the tone-counting and coaching point conditions, indicating less accurate putts with high anxiety ($p < .05$). Additionally, there was a significant effect for putting conditions when performers were anxious ($p < .05$) (Mullen et al., 2005). As a result, attention overload from high anxiety situations negatively influenced performance in high-anxiety situations by distracting or overwhelming the individual from the task at hand and limiting their focus. Through this, without the necessary attention needed to perform adequately, one can miss subtle movements resulting in a poorer execution of the necessary movements needed to succeed.

Additionally, Wilson, Wood, and Vine (2009) examined fourteen soccer players as they took penalty kicks in low- and high-threat conditions and analyzed their eye movement patterns with a gaze registration system and found that attention was also negatively affected by high-anxiety situations as seen from Mullen and colleagues (2005). Each participant performed seven penalty kicks in the low- and high-threat conditions. Informing the participants that a prize for the kicker with the best score would be awarded and a leaderboard available for all participants to see, manipulated the high-threat level. Before the first four kicks and after the last three, participants completed the Mental Readiness Form-3

(MRF-3) used to gauge anxiety levels along with the collection of the gaze tracking system data. The results expressed that performance was diminished among participants in the high-threat condition due to the fact that their gaze lasted longer on the goalkeeper making their shots hit more centrally (closer within the goalkeeper's reach) and less accurate. In the low-threat condition, their gaze fixated on the goalkeeper on an average of twelve times with a total duration of three seconds while the high-threat condition elicited sixteen fixations with a total duration of five seconds (Wilson et al., 2009). The researchers indicate that the increased gaze time shows that the participants had changes in attentional control as a higher threat was perceived, with one factor being that the goalkeeper is a threat to goal achievement. These findings revealed an attentional bias toward the keeper (Wilson et al., 2009). This study demonstrates that individuals placed in a stressful state will have their attention shifted elsewhere during task execution, instead of their intended target, giving potential supporting evidence to the ACT theory.

The ACT theory is then further supported by Runswick and colleagues (2018) by investigating the performance of cricket batsmen under low and high anxiety and situation-specific context conditions, very much similar to Wilson and colleague's (2009) study. In this specific study, twelve skilled cricket batsmen batted in each condition until they completed fifteen satisfactory deliveries while the Mobile-Eye gaze tracking system collected their visual search gazes and their kinematics recorded from two high-definition video cameras. By telling the participants that performance would be analyzed and falsely telling the participants they were not meeting the needed standard of bat-ball contacts, anxiety was manipulated. Researchers found that anxiety manipulation significantly affected the quality of bat-to-ball contacts with about 57.8% of good contacts in the high anxiety condition and about 70.6% of good contacts in the low anxiety condition. Additionally, the high anxiety conditions, participants contacted the ball significantly further behind the their front foot than in the low anxiety conditions ($p = .04$) (Runswick et al., 2018). Average fixation duration was shorter in high anxiety conditions, revealing an attentional shift within the participants, which correlates with the findings from the study conducted by Wilson and colleagues (2009). Additionally, the number of fixation locations was higher in the high anxiety conditions, thus these findings show a diminished performance at the attentional level (Runswick et al., 2018). Both studies provide evidence that in higher anxiety situations, attention is less directed at the intended target, whether it be from shorter fixations on the target or from longer fixations on the threat, attention is taken away from the intended target and placed more on the “threatful” stimuli. These studies reveal the physical translation of attention deficits with increased anxiety through gaze patterns, but there are other studies that show more physical translations of anxiety reducing performance.

For example, Sekiya and Tanaka (2019) examined the kinematic performance of novice table tennis players when faced with high psychological pressure. Pressure, or stress, was induced by offering monetary rewards for successful performances and cancelling poor performances. Researchers analyzed the participants’ kinematics by measuring the racket head and ball movements along with grip force and found that in higher pressure, participants altered their movements. The participant’s back swing and forward swing were reduced in length, speed of the forward swing and ball speed decreased significantly under high pressure ($p < .008$), and the ball and racket contact point shifted forward significantly ($p < .008$), contributing to a decrease in performance (Sekiya & Tanaka, 2019). Despite changing strategies to avoid error, higher pressure resulted in poorer performance. Increased stress and anxiety also altered the kinematics of individuals in a study conducted by Williams, Vickers, and Rodrigues (2002). Eight male and two female table tennis players were to score as many points as possible by hitting the bullseyes of targets across the tennis table. In the high anxiety condition, participants were to specifically aim for certain targets based off the server's position while still trying to get the highest score possible. Kinematics were obtained through four high-speed video cameras and a computerized system with the participants wearing reflective markers attached at the elbow and wrist of the striking arm. Results indicated that participants used a shorter tau (tau is used to measure twisting actions such as of arm/wrist) margin when anxious and had longer movement times in the high anxiety condition that was paired with a lower performance score compared to the low anxiety condition (Williams et al., 2002). Therefore, increased anxiety can reduce optimal performance despite individuals attempting to compensate for it. These studies only expose the problem of anxiety affecting performance, with no possible solutions to fix it.

Relaxation Techniques in Sport

Relaxation techniques are a potential remedy for the effects of anxiety and stress. Relaxation techniques are utilized to reduce all types of stress in an individual and relieve tension in the body by modulating the central nervous system and reducing sympathetic activation (Pelka et al., 2017). Thus, reviewing relaxation techniques and its effect on stress reduction in athletes is necessary. First, "relaxation technique" is a broad term used in research and can include various strategies such as progressive muscle relaxation, yoga, deep breathing, and imagery, which all aim for the same results of reduced stress and better performance (Pelka et al., 2017; Vidic et al., 2017).

With the relaxation techniques of breathing, yoga, progressive muscle relaxation, and power naps, Pelka and colleagues (2017) examined their effects on sprinting performance. The aim of this study was to compare the four relaxation techniques via physiological and psychological measures. In result, the relaxation techniques had little differences between each other with all interventions positively affecting their physiological state (heart rate) to a similar degree (Pelka et al., 2017). In this same study researchers found that participants subjectively described all interventions as relaxing but not significantly different from each other, yet there was a tendency for the power nap to be perceived as less efficient and appreciated (Pelka et al., 2017). This study did not show that relaxation techniques acutely improved sprint times, but it did show that participants gained increased relaxation from the techniques given.

Mindfulness is one of the relaxation techniques that has sparked more interest in recent years in relation to the sport setting despite being around for centuries as a Buddhist meditation practice (Vidic et al., 2017). Mindfulness is a technique that aims for the individual to become more self-aware allowing the individual to be intentional with their responses to experiences rather than being reactionary, which can improve coping skills and reduce stress (Vidic et al., 2017). According to Vidic and colleagues (2017), mindfulness practices had positive impacts on stress levels, athletic coping skills, and overall well-being. A U.S. NCAA Division I basketball team underwent a mindfulness training over the course of their 16-week season for a total of ten sessions with an experienced practitioner focusing on the tenets of awareness, presence, relaxed ease, and spaciousness. The Perception of Stress Scale-10 and the Athletic Skills Coping Inventory-28 were completed by the participants before the intervention, halfway through the intervention, and then post-intervention. Reflective journals were also used for qualitative data. Researchers found a significant decrease in stress and improvements in athletic coping skills over the course of the entire 10-session intervention, and even some improvements observed through the first five sessions. The participants also claimed that the mindfulness intervention improved other areas of their lives, including athletics, academics, and personal domains (Vidic et al., 2017). This study did not evaluate their performance throughout the season, but it did show that this form of relaxation improved the well-being of the athletes in short and long-term practice.

Similar to the previous study, athletes have utilized various relaxation techniques to improve their performance in ways other than immediate performance enhancement. Athletes use relaxation techniques to improve performance by enabling them to cope with competitive anxiety as well as to promote recovery (Kudlackova et al., 2013). How relevant the athlete finds relaxation techniques varies on the level of the athlete (i.e. college, professional, or recreational). Specifically, college and professional athletes rate relaxation techniques as more relevant to enhance performance. The authors suggested since higher level athletes have more stress and anxiety associated to their sport, that increases their need and utilization of it (Kudlackova et al., 2013). In this same study, the researchers found that imagery and deep breathing were the most utilized technique compared to other methods of relaxation including meditation, muscle relaxation, and stretching (Kudlackova et al., 2013). Relaxation techniques can improve performance by improving the state of mind and not just the physiological reactions.

In conjunction, these studies show that relaxation techniques can improve overall well-being in the athlete and be facilitative towards performance. There is a place for relaxation techniques in sport to reduce stress and anxiety in athletes. It is important to note that it is just as important to ensure psychological performance and health is focused on just as much as physical performance and health. This is especially true at higher levels of competition where the physical capabilities are all relatively the same.

Virtual Reality (VR) as a Therapeutic Modality

VR is an emerging technology that has gained interest in the realm of sport psychology in recent years (Neumann et al., 2018). The advancements made in VR technology has made its price, accessibility, and mobility of VR systems more reasonable for commercial and personal use (Cotterill, 2019). VR shows positive results in various settings including mental health disorders. VR is used for various phobias like spider phobias or public speaking (Lindner et al., 2019; Miloff et al., 2019). Additionally, VR is seen in other clinical populations with those suffering from substance use disorders, like alcohol dependency (Son et al., 2015; Worley, 2019). VR can go much farther than just treating psychological disorders. There are several strategies used in VR for sport purposes. VR has been simulated to replicate training or real-game scenarios to improve perceptual-cognitive skills, to increase relaxation and stress reduction for psychological health, and for injury rehabilitation by addressing the stressors athletes faces during the onset, rehabilitation, and return to sport phases of injury (Bird, 2019). It is important to review and understand the entire scope VR has to offer to the world of sport.

VR in Clinical Populations

Other areas of psychology utilize VR to assist with mental and physical ailments such as phobias and substance use disorders (Hone-Blanchet et al., 2014; Lindner et al., 2019; Miloff et al., 2019; Son et al., 2015; Worley, 2019). These studies show how widely applicable and beneficial VR is in other areas and populations (Miloff et al., 2019; Worley, 2019). It is necessary to review this area of the literature to demonstrate how VR can work not just for entertainment purposes, but in various aspects of the rehabilitative sector, both in the physical and psychological realms.

In the first aspect of rehabilitation, VR has helped individuals with substance use disorders (SUDs). SUDs are difficult to treat with an average of 50% in the relapse rate despite the resources available for treatment (Worley, 2019). VR has shown positive results in managing cravings through cue exposure therapy by exposing participants to craving cues and desensitizing them to those triggers (Worley, 2019). In addition to exposure therapy, Worley (2019) also concluded that VR could also be of use to SUDs in areas related to pain, which is often the initiation of the abuse of the substance, and to learn new life skills. VR has been seen to activate the brain in similar ways that substance use does, thus potentially being an alternative to substance use itself (Worley, 2019). The use of VR therapy for SUDs is further supported by a study examining VR therapy for alcohol dependence (Son et al., 2015). Fifteen clinically alcohol-dependent subjects went through a VR therapy program in this study by Son et al. (2015) where they analyzed the participants' brains with positron emission tomography (PET) and computerized tomography (CT). Additionally, 15 healthy individuals were scanned as a control group. The alcohol-dependent group received VR therapy twice a week for five weeks. A baseline PET scan was completed before the therapy and a posttreatment scan was completed one week after the 10th VR therapy session. The VR therapy program consisted of five minutes of relaxation, ten minutes of a high-risk situation (at a restaurant with alcohol being served), and ten minutes of an aversive situation (people vomiting after drinking) that was in line with Pavlovian conditioning to obtain habit formation in the basal ganglia (Son et al., 2015). Thus, associating drinking with a negative outcome. Results from the participants PET scans indicated that those with alcohol dependence had significantly higher metabolism in the right lentiform nucleus and right temporal lobe and lower metabolism in the left anterior cingulate compared to the control group. After the VR therapy, the alcohol-dependent group had significantly decreased brain metabolism in the right lentiform nucleus and right temporal lobe compared to baseline (Son et al., 2015). These results indicate that VR therapy can help regulate the neurobiological imbalances in the limbic system for those with alcohol dependence, therefore a recommended strategy to treat alcohol dependence (Son et al., 2015). In the sector of SUDs, VR has shown to be a helpful tool in treating these disorders and preventing the probabilities of relapses.

VR therapy for various phobias also uses the method of exposing individuals to their triggers and desensitizing them to their fears. Traditional exposure therapy consists of a one session treatment with a medical professional. With the utilization of VR exposure therapy (VRET), patients can have the experience of therapy without visiting a therapist in a safe environment. Miloff and colleagues (2019) compared VRET to the traditional one-session treatment by having participants be evaluated pre- and post-treatment with follow-ups 3- and 12-months post-treatments with a behavioral approach test and with self-rated fear of spider, anxiety, depression, and quality-of-life scales. Results showed that participants in both groups showed significant reductions in behavioral avoidance, self-reported fears post-treatment, and did not give less benefit in the long-term compared to the one-session treatment (Miloff et al., 2019). VRET sufficiently reduced spider phobia symptoms acutely and performed just as well as the gold-standard one-session treatment showing that VR is a viable means for exposure therapy that could provide easier, more affordable access to patients who could benefit from exposure therapy without going to a therapist and be utilized as a self-help treatment (Miloff et al., 2019).

VR has also shown beneficial results for those with public speaking anxiety. In a study by Lindner et al. (2019), 50 participants were randomized to either a group who received one-session therapist-led VR exposure therapy or to a waiting list. The therapist led group completed a three-hour session with a therapist using a VR headset compatible with a smartphone (Samsung Gear VR), and then completed a four week in-vivo program afterwards. The VR therapy provided three public speaking scenarios, a large auditorium, a meeting room, and a wedding reception. Once the therapist led group completed their four-week in-vivo program, the waitlist then conducted a self-led one session treatment using the simple Google Cardboard headset to use with their own smartphone that was as similar as possible to the therapist led session (Lindner et al., 2019). Results from the program showed a significant, large decrease in self-reported public speaking anxiety in both groups and results were maintained or improved at six- and twelve-month follow-ups. This study was the first to show that even low-cost, off-the-shelf consumer VR hardware could be used to conduct exposure therapy for public speaking anxiety in either a traditional one-session format or even a nvel self-led, at-home format (Lindner et al., 2019). Thus, it is not necessarily necessary to receive the positive benefits that these studies have shown with VR with the high-end equipment available. Even the cardboard version may suffice, which can make VR’s usability much more feasible in settings where budgets may be small.

From SUDs to spider phobias, VR’s wide usability is only more apparent with these research studies. Previous research shows that the thought of utilizing VR in sport is a viable idea within reach of accomplishing the necessary objectives in sport psychology (Fominykh et al., 2018; Liu & Matsumura, 2019; Ross-Stewart et al., 2018; Stinson & Bowman, 2014). VR has been beneficial to treat psychological and physical ailments in various clinical populations, therefore there is a natural extension to utilize VR in sport populations. Thus, this next subsection will review the current literature that addresses VR utilization in sport.

VR in Sport

In sport, repetitions are not only vital for physical practice, but also for the mental processes required for proper decision-making during games in order to make the right game-play decisions, whether it be passing the ball to a different teammate or picking up on a blitz after the snap in a football game. Perceptual-cognitive skills training entails the practice of athletes utilizing critical cues in game-like scenarios that may not be present during practice or allows the athlete to get more repetitions in without the physical toll on the body. VR has the capability to simulate the large crowds and key scenarios for the athletes to enhance their perceptual-cognitive skills training in a more immersive method. The efficacy of VR to induce these high-pressure situations that would reflect a real game is limited, thus Stinson and Bowman (2014) utilized the Virginia Tech Visionarium VisCube, which is a four-screen CAVE-like projection system (where the virtual environment surrounds the participant), to investigate the ability of VR to induce these game-like scenarios. Stinson and Bowman (2014) investigated 28 participants acting as the goalkeeper to defend penalty kicks in a virtual penalty shootout. The participants were graduate students, with ages ranging from 22 to 32, 9 were female and 15 were male. 15 of the participants had competitive soccer experience and 7 had goalkeeper experience. The virtual environment was simulated with the Virginia Tech Visionarium VisCube. The application used the Instant Reality framework and the primary kick animation came from the Carnegie Mellon University Motion Capture

Database and edited as needed to correct posture (Stinson & Bowman, 2014). Each participant, acting as a goalkeeper, faced 15 shots and were to take a step quickly in the direction of the shot being taken to indicate their save attempt. While examining the participant's heart rate, galvanic skin response, and questionnaire data, researchers found that anxiety was increased from their baseline levels to their levels in-condition, showing that VR sport simulations can induce anxiety in participants similar to a real practice (Stinson & Bowman, 2014). However, a limitation of this study was that the participants were not all experienced at goalkeeping, thus goalkeeping experience between novices and experienced players may impact the anxiety effects from the VR sport simulation. Nonetheless, Stinson and Bowman (2014) found that VR can be a viable tool to expose athletes to those high-anxiety situations.

VR intervention has also been examined in baseball players for the high pressures of an at-bat. Ross-Stewart and colleagues (2018) created an individualized approach to VR interventions by creating an imagery assisted VR protocol designed for each participant with individual recordings of their pre-hitting performances in first person and third person viewing options. This study utilized ColorCross VR goggles due to the effectiveness and affordability to create the immersive experience for the participants. A total of 27 participants who were a part of a NCAA Division I baseball team were used for this study. Participants ages were 18 to 23 (m = 19.8) and consisted of 17 hitters and 10 pitchers. On average, participants had 14 years of baseball experience with an average of 1.65 years on the current team (Ross-Stewart et al., 2018, p. 22). The VR protocol was specific to the participant, taking the participants through their sequence of events of getting ready to hit against a pitcher with intermittent bouts of assisted imagery in between. For example, the participants watched themselves go to the dugout with their teammates, followed by a guided imagery script, then watched themselves put on their gloves, followed by an imagery script, and so-on until they saw themselves be successful on their hit or getting walked (Ross-Stewart et al., 2018). Imagery scripts were designed for each player, based on what they felt they needed the most work on, whether it was nervousness before skill execution, or confidence throughout their routine and seeing themselves perform successfully. During the imagery script, a blank space was inserted, thus VR was only used to watch themselves at-bat and not for the imagery script. Researchers found that through the participants' protocols, imagery ability improved from baseline from 5.14 to 5.72, $p = 0.01$. Psychological skills were utilized more after the protocol (partly because the protocol required the utilization of such skills), with skills increasing from 5.62 to 5.97, $p = 0.04$. Relaxation was increased in practices from a mean of 2.71 to a mean of 3.65, $p = 0.00$. In competition, self-talk increased from 3.51 to 3.95, $p = 0.04$, imagery increased from 3.50 to 4.02, $p = 0.02$, and an improvement was seen in negative thinking during competition from a mean of 3.74 at baseline to 4.01 at Time 2, $p = 0.05$ (Ross-Stewart et al., 2018, pp. 26–27). These results give the notion that VR relaxation can improve the psychological aspect of hitting in baseball by providing necessary skills for athletes to use psychologically to improve or maintain their performance during competition (Ross-Stewart et al., 2018).

By using the type of VR intervention from the study by Ross-Stewart and colleagues (2018), players were allowed to experience more at-bat repetitions without physically having to do so. This could be beneficial for players who do not play regularly, like incoming freshmen, and can help teach them the cognitive skills to modulate their anxiety in game-situations and gain confidence by seeing themselves perform successfully (Sanz et al., 2015).

Utilizing the VR intervention from the study conducted by Stinson and Bowman (2014), also gives the potential to get more repetitions in without the physicality of the act in order to improve the cognitive processing involved in such high-stake situations.

VR in Relaxation

Relaxation, via imagery, is a tool that is utilized in sport psychology to help athletes manage and cope with the demands of being an athlete which can be enhanced by VR (Bird, 2019). VR has already shown to have relaxing benefits in non-sport populations, such as patients in the ICU unit and other young adults not invested in sports (Fominykh et al., 2018; Gao et al., 2014; Gerber et al., 2017). VR technology can be utilized to assist in imagery interventions by helping the athlete become fully immersed in the relaxation intervention and provide an enhanced version of this technique (Liu & Matsumura, 2019). There are a variety of applications available for use for VR interventions that can make it easily accessible to obtain for the user as well as the opportunity for researchers and practitioners to create their own applications (Bird, 2019).

More specifically, VR relaxation interventions can be very useful for collegiate student-athletes since it has been found that individuals aged 18-24 may experience higher levels of acute stress reduction than an older population of 25-34 years of age (Gao et al., 2014). Utilizing heart rate is a common physiological marker that is used to measure stress reduction and was the measure used in a market study by Gao and colleagues (2014). In this specific study they examined how “Positive Technology” reduced stress in eleven participants. Participants were between the ages of 18 and 34 and participated anonymously. The mobile application utilized biofeedback from a heart rate monitor to control the VR scene in the application and the results showed that the participants found the application to be beneficial in reducing their perceived stress levels and were pleased with the end result of the session (Gao et al., 2014). With VR being such a unique method of inducing a state of relaxation, it has quite the appeal to users of the technology showing acute benefits not only in college adults, but also in adults in different professional backgrounds.

For instance, Fominykh and colleagues (2018) aimed to create a conceptual framework for VR therapeutic training by designing their own therapeutic application. The aim of this research study was to facilitate future developments in therapeutic VR applications that provided educational opportunities for therapeutic training of relaxation. Their target group consisted of 25 participants. Their ages ranged from 22 to 46, with an average age of 29.04, and consisted of 12 males and 13 females with different professional backgrounds. Only three of the participants had previous experiences with VR (Fominykh et al., 2018, p. 66). They created a prototype application for a fully immersive, advanced VR intervention through the Oculus Rift, which is connected to a PC, and also a version that is available through a mobile app on an Android smart phone that could be done in "VR mode" with 3D glasses or a 2D mode. All modes were able to connect to the heart rate sensor for biofeedback. For their prototype, participants were exposed to a beach scene paired with a biofeedback relaxation training session. When heart rate increases, the waves on the beach grow and the clouds become darker with higher wind gusts, thus the goal is to make the scene as calm as possible. While using custom questionnaires with a Likert-scale rating, researchers found that their prototype achieved its goal of relaxation but needed work on the biofeedback connectivity; despite the early stages of their simulator, participants enjoyed the application and twelve participants agreed while five fully agreed that they would refer the app to their friends, and eleven agreed while five fully agreed that the application was a possible tool for training (Fominykh et al., 2018). VR therapeutic training has the potential to be engaging for users to learn these psychological skills to handle stress based on the feedback provided, but future research is still needed to see the long term effects of such training in order to determine if users actually acquire these skills (Fominykh et al., 2018).

Fominykh and colleagues' findings correlate with the findings from Liu and Matsamura's (2019) study on VR relaxation in 40 NCAA Division I student-athletes in regard that VR relaxation interventions do provide acute relaxation. The participants were 18 to 25 years of age with the specific sport of each participant being unknown. From Liu and Matsamura (2019), they utilized a WORLDS Virtual Reality environment from IFGworld as their application. Created by IFGworld™ (Los Angeles, CA), the WORLDS Virtual Reality contains environments designed for relaxation and mental wellness. These environments could be both indoor and outdoor settings like the beach or a teahouse and were administered with the Oculus Go VR headsets (Liu & Matsumura, 2019, p. 568). Participants were allowed to choose from any of the nine virtual environments and were also allowed to switch between different environments at will. After the relaxation session, which varied from five to fifteen minutes depending on the participant's preference, a follow-up questionnaire to assess the athletes' perceptions of the intervention was provided. This study examined a VR relaxation intervention acutely from the student-athletes' perspective. Researchers found that out of the forty participants who responded to the questionnaire, 74.4% of participants thought the VR intervention helped them relax or reduce any anxiety they had, 80% of the sample had never utilized wellness apps previously and 90% of the total participants would use the intervention again (Liu & Matsumura, 2019). It was also found that out of the twenty participants who had a pre-performance routine, fourteen said the VR intervention would help them relax before the competition (Liu & Matsumura, 2019). This shows a very positive impact that VR relaxation has on student-athletes however, the relaxation sessions were not standardized and varied between length and type of environment, which may have possibly affected those who had a negative experience with the session. Additionally, there was no information obtained as to why the participants found it relaxing or not, still leaving further questions about this type of intervention.

In conclusion, college is a stressful time for young adults and being an athlete does not make the experience any easier when their attendance to the university relies on their performance. Non-VR relaxation methods have shown to reduce psychological stress in the athlete and improve their performance, so with the wave of popularity in VR technology, it is necessary to investigate if this enhances the relaxation experience. VR has been beneficial in other areas of psychology and could have the potential to be a great tool for athletes. The literature reveals that it is apparent that the usefulness of VR relaxation in the athletic population is minimal and more research needs to be conducted. Thus, the need to examine the effects of VR relaxation in collegiate athletes and their performance is warranted.

Chapter III: Methodology

Participants

The present study consisted of 13 healthy female participants, at least 18 years of age (20.54±1.127), with at least two years of soccer experience, participated in this study. Out of the 13 participants, 11 participants were Caucasian, 1 was Asian, and 1 was African American. The total sample consisted of freshmen (*n*=1), sophomores (*n*=4), juniors (*n*=2), and seniors (*n*=6). For soccer position, participants consisted of a goalkeeper (*n*=1), defenders (*n*=3), midfielders (*n*=5), and forwards (*n*=4). Overall soccer experience of the participants averaged about 13 years (12.62±3.62). Out of all participants, only one had prior experience to using VR. The participants consisted of players of the university's club team as well as the university's intermural soccer league. Three of the participants were starters on the university club team and ten were currently not on a team and played in the intermural soccer league.

Due to COVID-19, the original sample of this study was unable to be achieved. Originally, participants were to be recruited from the university's varsity and club teams. With the agreeance of the coaches, participants were going to be told this study would determine playing time to induce stress and would not be told otherwise until all participants completed the study. Despite best efforts, access to the varsity team was denied and club team recruitment was minimal. The club team's season was cancelled due to COVID, so no active practices were taking place and some players were not on campus, limiting our recruitment. Thus, the present study had to adapt to a broader population and ask participants to imagine their performance would influence their playing time due to the fact that participants were not currently in a competitive season with a team. The goalkeeper for the study originally was intended to be the goalkeeper from the university teams, however because of the circumstances just stated, members of the research team was used instead.

Instrumentation

Informed Consent

The informed consent form explained the purpose of this study and what was expected for each participant. This form also explained to the participants their rights, including their right to terminate participation if they would like to do so and an assurance of anonymity. This was the first form they completed to continue participation, or opt out of participation, in the study.

Demographic Questionnaire

A demographic questionnaire was used to obtain information about the participants. The included items were age, race, sport history such as position and years of playing experience, and previous experience with virtual reality. VR items consisted of the use of VR as a relaxation technique and frequency of VR use for relaxation. Additionally, the questionnaire obtained information about the participants' injury history, including last date of most recent injury and the amount of time restricted from full participation.

Mental Readiness Form-3 (MRF-3)

The MRF-3 was used to measure cognitive anxiety, somatic anxiety, and self-confidence (Krane, 1994). This instrument has three questions participants respond to on a Likert-scale from 1 to11 (see Appendix B). Cognitive anxiety is assessed by rating thoughts about performance from 1 "being worried" to 11 "being not worried". Somatic anxiety is assessed by rating physical manifestations from 1 "being tense" to 11 "being not tense". Self-confidence is assessed from 1 "being confident" to 11 "being not confident". Krane (1994) developed the MRF-3 to address the concerns about the terms in the MRF-Likert being truly bipolar opposites and compared the results to the Competitive State Anxiety Inventory-2 (CSAI-2) with correlations of 0.76 for cognitive anxiety, 0.69 for somatic anxiety, and 0.68 for self-confidence ($p < .01$). Krane (1994) concluded that the MRF-3 is a suitable tool in the field of sport anxiety research due to its brevity and simplicity to complete the questionnaire and could be advantageous to use than the CSAI-2 when facing time constraints. This form of the MRF has been used in a similar study by Wilson and colleagues (2009) when assessing attentional control theory (ACT) in soccer players.

Rating Scale for Mental Effort (RSME)

The RSME was used to assess the mental effort the participants invested in the penalty kick tasks (see Appendix C). This is a one-dimensional scale on a vertical axis with a range of 0 to 150 (Zijlstra, 1993). There are three descriptors on the scale with corresponding numbers to act as verbal references at 0, 75, and 150. 0 is stated as "not at all effortful", 75 as "moderately effortful", and 150 as "very effortful" and participants mark the scale according to their perceived effort on the task. This scale is reliable (0.88 in laboratory settings and 0.78 in real life settings) and valid and has been accepted as a reliable measure of mental effort (Causer et al., 2011; Veltman & Gaillard, 1996).

Kinematics

Kinematic data of the task was collected using the DELSYS Trigno Avanti (DELSYS Incorporated, Massachusetts, United States) sensors to gather accelerometer data (see Appendix K). Two sensors were used with one being placed at the fifth lumbar / first sacral vertebrae, between the posterior superior iliac spines. The second sensor was placed on the anterior thigh at the midway point between the superior aspect of the patella at the knee and the anterior superior iliac spine at the hip. Accelerometer data obtained from the Trigno Avanti sensors were collected and analyzed with the EMGworks (DELSYS Incorporated, Massachusetts, United States) software that works seamlessly with the Trigno Avanti sensors. The sensors recorded acceleration data in 3 planes and an integral (area under the curve) approach of the signals was used to obtain velocity and/or displacement data. From there, mean/peak velocity was analyzed as our primary indicator of kick production.

Virtual Reality Head Mounted Display (VR HMD) and Application

The apparatus utilized for the VR intervention was the Oculus Quest (Facebook Technologies, LLC). The relaxation intervention that was played by the Oculus Quest was an already created virtual relaxation session from the Liminal VR application (Liminal VR, Abbotsford, Victoria, Australia) that guides the participant through multiple experiences that the user can choose from. This application has been developed from five years of research and development in areas such as neuroscience and psychology to bring immediate positive changes to peoples' cognitive and emotional states through the benefits of virtual reality ("Liminal Platform"). This application gives five different categories of sessions to choose from (the lab, calm, energy, pain relief, and awe based off the individual's goals for the session) and then from each category there are several different sessions to choose from to experience. For the purpose of this study, the calm category was used, and the same "Campfire" scene was chosen for each participant (see Appendix I).

Heart Rate (HR)

HR was obtained utilizing the Polar H10 heart rate sensor with a Pro Strap (see Appendix L) that sent data to the Polar Beat app via an iPad (Polar Electro Oy, Kempele, Finland). Gilgen-Ammann, Schweizer, and Wyss (2019) tested the RR interval measurements of the Polar H10 sensor compared to the 3-lead ECG Holter monitor (Schiller Medizintechnik GmbH, Baar, Switzerland) that is referred to as the gold standard for heart rate data collection. RR intervals are the two consecutive R-waves in an electrocardiogram and the signal quality of these RR intervals is what is important for measurement devices quantifying HR and HR variability (Gilgen-Ammann et al., 2019). Results showed that the Polar H10 was as accurate as the Holter monitor during low- and moderate-intensity activities and even had a higher RR interval signal quality than the Holter monitor during intense activities. Both systems had less than a 2% difference among each other in 97.1% of measured RR intervals and had a high correlation with each other (r = 0.997), thus the Polar H10 monitor is an accurate measurement of HR (Gilgen-Ammann et al., 2019). For each participant, HR was recorded prior to each penalty kick and then averaged to represent the overall HR for each condition (see Appendix D).

Commitment Check

For a commitment check the Igroup Presence Questionnaire (IPQ), was utilized (www.igroup.org – project consortium). The questionnaire measured the sense of presence individuals experience in VR. It consists of 14 questions divided among three subscales of spatial presence (i.e. “I did not feel present in the virtual space”), involvement (i.e. “I was not aware of my real environment”), and experienced realism (i.e. “the virtual world seemed more realistic than the real world”) (igroup.org, 1995). All items included in each subscale are presented in Appendix E. All 14 questions were answered on a 7-point Likert-scale from -3 to +3 (i.e. “fully disagree” at -3 and “fully agree” at +3, with 0 being neutral). The reliability of the spatial presence subscale is 0.80, the involvement reliability is 0.76, and the experienced realism subscale has a reliability of 0.68; overall, the IPQ has a reliability of

0.85 with all reliabilities using Cronbach's alpha (igroup.org, 1995). Igroup.org (1995-2016) conducted two studies to determine the IPQ's reliability to determine VR presence along with a factorial analysis that can be referenced from their website.

Four additional questions were asked after the IPQ questionnaire to assess how relaxing the participants found the VR session to be. The questions were answered with a 5-point Likert scale ranging from "not at all" to "very much so." The first question asked, "Did this help you relax?" The second question asked, "Did this help you reduce any anxiety you might have had?" The third question asked, "Would you use this again?" Then the fourth question asked, "Do you think this VR session would be helpful in relaxing you before an athletic competition to perform better?" These questions were based on a previous study from Liu and Matsumura (2019) who assessed a VR relaxation intervention on NCAA DI student athletes with the IFGworld VR application available on the Oculus Go.

Penalty Kick Scoring

Scores were obtained to gather information that participants were told that will be compared with other participants and communicated with their coach to make playing time decisions. They were also scored in order to compare their shot placements and thus overall performance in their penalty kick blocks. Wood and Wilson's study (2012) was duplicated in this study. The goal box was divided into twelve zones, with each half of the goal consisting of six zones of 61 cm, starting from an 'origin' in the center (0 cm) and moving out to 366 cm at each post. A picture of the goal divided into scoring sections can be seen in Appendix F. Shots that were hit in the zones further from the central origin of the goal reflected shots that were further from the goalkeeper's reach, which would give the participants higher scores. If the goalkeeper made a save for a penalty kick, then the participant did not receive any points. If the participant completely missed the goal, the participant lost five points. The zones were set with points in increments of five, thus the four corners of the goal box had the highest points available. To determine where the shot was hit, a researcher had a paper representation of the goal with its given zones labeled and marked where each shot was placed for that given block on the goal scoring sheet and then scores were totaled for each penalty block.

Soccer Equipment

The equipment that was used for the penalty kick sessions was a goal box on a game-regulated sized field. The dimensions of the goal (7.32 m x 2.44 m), ball type (size 5), and distance to the penalty mark (11 m) were in accordance with NCAA regulations (NCAA, 2020). The penalty kick was taken within the goal box at the designated penalty spot on the field. A goalkeeper was used to add another factor of stress and anxiety for the participant to score as opposed to no goalkeeper and was a member of the research team.

VR Intervention

The participants all used the same VR relaxation intervention application with the same parameters to standardize the session. The relaxation intervention lasted four minutes and was completed with the Oculus Quest, with the participants seated, as they were during their rest periods. This study used the “calm” category and used the “Campfire” experience. The “Campfire” experience is an audiovisual experience on the shore of a lake. There is an active campfire next to the participant with fireflies floating around, and a large rising moon that takes up the night sky as the session progresses. Relaxing music plays in the background while the participant takes in their surroundings and immerses themselves in the campfire scene.

Procedure

Before the study began, Institutional Review Board (IRB) approval was confirmed. All participants were asked to participate voluntarily in this study. Before they participated, they signed the informed consent document and then proceeded to the demographic questionnaire. Next, the participants were familiarized with the DELSYS Trigno Avanti sensors, heart rate monitor, and the penalty kick procedure. Once the participants were familiarized with the tools and apparatus, they were allowed to have a warm-up period of five minutes that consisted of their normal warm-up routine before games and/or practices. Participants had the sensors placed on their back between their posterior superior iliac spines, around the L5-S1 vertebrae, and the anterior thigh at the midway point between the anterior superior iliac spine and superior aspect of the patella on the participant’s dominant leg. The sensors were wrapped to secure them on the participants body to prevent them from coming off during the session. Participants were then fitted with the heart rate monitor. Once all measurement tools were appropriately placed, participants completed the three blocks of five penalty kicks. The first block of penalty kicks was used to obtain baseline data. The second block represented the participants taking the penalty shots under a high-anxiety situation. The third block represented the participants taking the penalty shots after their VR relaxation intervention in the high-anxiety situation. Each block is explained further below.

Penalty Kick Block 1: Baseline

While wearing the HR monitor and accelerometer sensors, the participants were told that they would take five penalty kicks. The participants were told that the main purpose of these penalty kicks was to ensure the HR monitor and the Trigno Avanti sensors were working accordingly, aiming to relieve any stress and anxiety in this first session. They first completed the MRF-3 questionnaire and then proceeded to take the five penalty kicks. There was a 60 second break between each penalty shot to allow enough time for the participant and goalkeeper to reset for the next shot and for the researchers to reset for the next kick. Once the participants completed the five penalty kicks, they completed the RSME questionnaire. This initial round served as a baseline measure.

Penalty Kick Block 2: Stress Induced with No VR Intervention

Participants rested for 5 minutes before proceeding to the next round of penalty kicks. After their rest, while wearing the HR monitor and accelerometer sensors, the participants were told that they would take five penalty kicks and to successfully score on as many of the five shots as they could against the designated goalkeeper. Each shot was scored based off where they shot their ball in the net. Participants lost points if they missed the goal completely. They were told that their scores would be analyzed and totaled after the session so there would be no way to know how they were currently doing compared to other participants, therefore they ought to do the best they can. They were told that their scores would be compared to the other participants and to see these penalty kicks as game-winning opportunities. Participants were also told to imagine that their performance would be communicated with their coach to help with playing time decisions to further heighten the participants' anxiety (see Appendix G).

They then completed the MRF-3 form after the stress had been induced from the scoring-comparison situation stated before they proceeded to take their penalty kicks. After the MRF-3 form was completed, they completed the five penalty kicks in the same manner as the first block of penalty kicks. Once all shots were taken, participants completed the RSME questionnaire and rested while seated for 5 minutes in a shaded area either with a tent, or if too windy for the tent, then in the shade provided by the trees.

Penalty Kick Block 3: Stress Induced with VR Intervention

After a 5-minute rest period, the participants were then told again that their scores will be compared to the other participants and to see these penalty kicks as game-winning opportunities to reinforce the anxiety. They were also reminded to imagine that their performance would be communicated with their head coach for playing time decisions (see Appendix H). Before they completed the penalty shots, the participants watched the four-minute relaxation intervention with the VR HMD. After they finished the relaxation intervention, the participants completed the MRF-3 and then completed the five penalty kicks the same as they had for the first two blocks. Participants completed the RSME form right after and then proceeded to fill out the IPQ questionnaire and the additional questions for their commitment check. Once all forms were completed, the participants were debriefed and told that their performance on this study did not have any effect on playing time; they were only told this to induce a stress response and were then thanked for their participation.

Data Analysis

After all data was collected, all variables were analyzed using SPSS. Demographic information was analyzed with descriptive statistics to calculate means and standard deviations. A Multivariate Analysis of Variance (MANOVA) was used to examine the effect that the VR relaxation had on the MRF-3 questionnaire within participants across the three kicking conditions. An Analysis of Variance (ANOVA) was used to examine the effect that VR relaxation had on the RSME scale within participants across the three kicking conditions. HR at baseline, pre-, and post-intervention were analyzed with an ANOVA within participants across the three kicking conditions. Kinematic measures were analyzed using an ANOVA to examine the average mean peak amplitude within participants across the three kicking conditions. Lastly, the effect of the VR relaxation on the participants' penalty kick scores was analyzed with an ANOVA within participants across the three kicking conditions. Post-hoc analyses were performed by using the Tukey post-hoc analysis to analyze the individual mean difference comparisons between the penalty kick tasks. A commitment check was utilized to ensure full participation from the participants and those with a score lower than zero were excluded from the study.

Chapter IV: Results

Once all 13 participants completed their session, data was analyzed with SPSS statistical software. The hypotheses were tested with the participants' data between the penalty block conditions. Tukey's post-hoc analyses were completed if significant differences were found between conditions. If significant differences were found, the null hypothesis was rejected. Significance was set at $p < .05$.

Hypothesis Testing

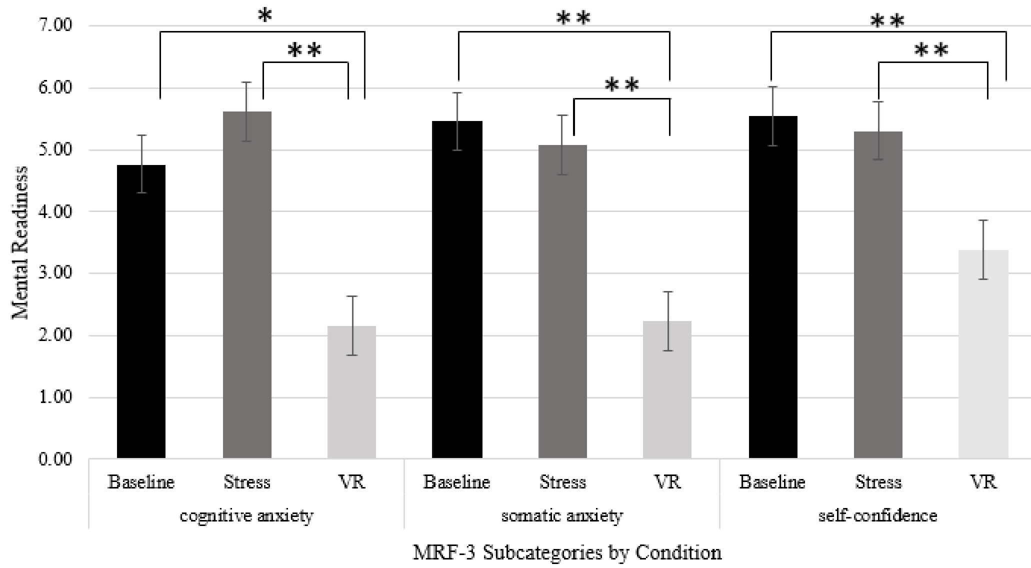
MRF-3 Questionnaire

The MRF-3 questionnaire assessed the current anxiety levels the participants felt prior to each penalty kick block. It was hypothesized that participants would have lower ratings on the MRF-3 questionnaire prior to the VR block compared to the stress and baseline blocks.

A MANOVA was calculated examining penalty block conditions differences on the MRF-3. A significant main effect was found for condition (*Wilk's* $\lambda = .324$, $F(6,68) = 8.56$, $p < .001$, $\eta_p^2 = .430$). Follow up univariate ANOVAs indicated significant differences in levels of cognitive anxiety ($F(2,36) = 16.37$, $p < .001$, $\eta_p^2 = .48$), somatic anxiety ($F(2,36) = 24.93$, $p < .001$, $\eta_p^2 = .58$), and self-confidence ($F(2,36) = 16.75$, $p < .001$, $\eta_p^2 = .48$) (see figure 1).

Figure 2.

Mean MRF-3 subcategory ratings between penalty block conditions



Note. * = *p* < .05 and ** = *p* < .001.

Tukey's HSD post hoc analyses were performed to examine individual mean difference comparisons across the penalty block conditions (i.e. baseline, stress, and VR). On the subscale of cognitive anxiety, results revealed that VR was significantly different from VR (*p* = .001) and stress (*p* < .001). Comparison of the mean scores for each of the significant dependent variables suggests that VR (*M* = 2.15, *SD* = 1.14) reported lower scores compared to the mean of baseline (*M* = 4.77, *SD* = 1.36) and stress (*M* = 5.62, *SD* = 2.14). On the subscale of somatic anxiety, results revealed that VR was significantly different from VR (*p* < .001) and stress (*p* < .001). Comparison of the mean scores for each of the significant dependent variables suggests that VR (*M* = 2.23, *SD* = 1.17) reported lower scores compared to the mean of baseline (*M* = 5.46, *SD* = 1.39) and stress (*M* = 5.08, *SD* = 1.26). On the subscale of self-confidence, results revealed that VR was significantly different from

VR ($p < .001$) and stress ($p < .001$). Comparison of the mean scores for each of the significant dependent variables suggests that VR (*M* = 3.38, *SD* = 1.12) reported lower scores (higher self-confidence) compared to the mean of baseline (*M* = 5.54, *SD* = .78) and stress (*M* = 5.31, *SD* = 1.18).

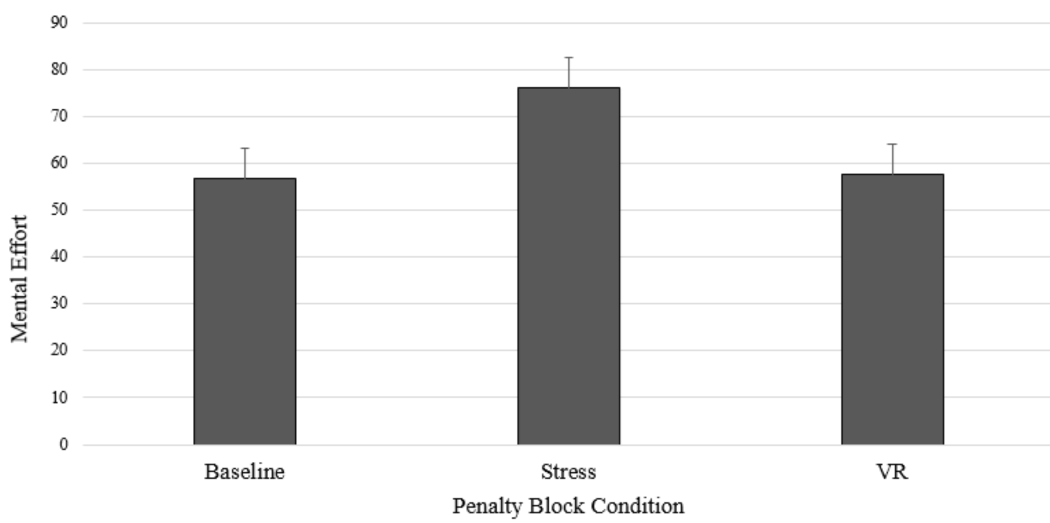
RSME Scale

The RSME scale examined the perceived level of mental effort participants felt they exerted to perform well after each penalty block. It was hypothesized that the participants' RSME ratings would be lower in the VR block compared to the stress and baseline blocks.

An ANOVA was calculated examining penalty block conditions differences on the RSME. A non-significant difference was found among the conditions ($F(2,36) = 1.80$, $p = .18$, $\eta_p^2 = .091$). The mental effort did not differ significantly across the penalty block conditions (see Figure 2).

Figure 3.

Mean RSME ratings between penalty block conditions



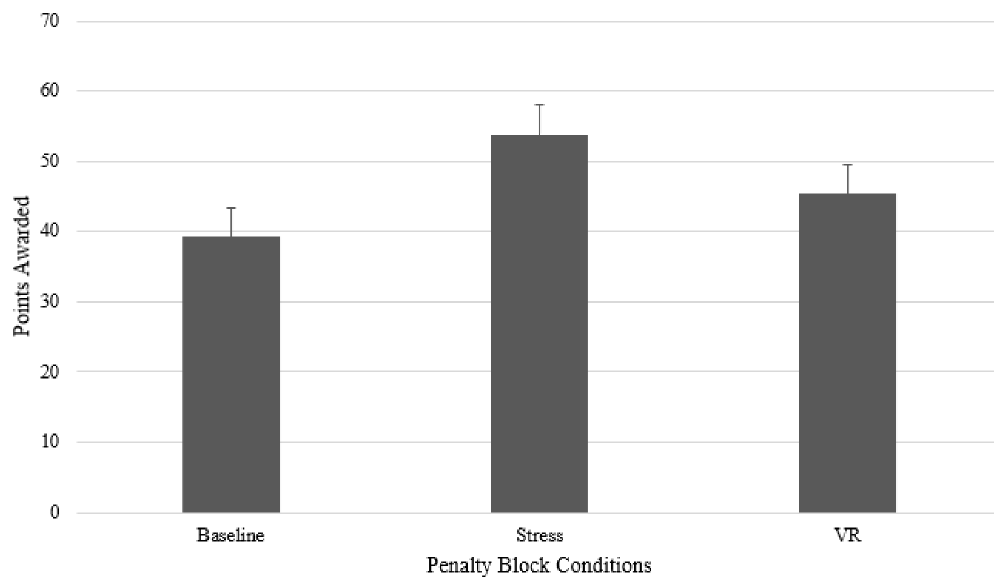
Penalty Kick Performance

Penalty kicks scores examined the differences in performances of the participants between each penalty kick block. It was hypothesized that the participants' penalty kicks scores would be lower in the stress block compared to the VR and baseline blocks.

An ANOVA was calculated examining penalty block conditions differences on the penalty kick scores. A non-significant difference was found among the conditions ($F(2,36)$ = 1.129, p = .335, η_p^2 = .059). The total penalty kick scores did not differ significantly across the penalty block conditions (see Figure 3).

Figure 4.

Mean penalty kick scores between the penalty block conditions



Heart Rate

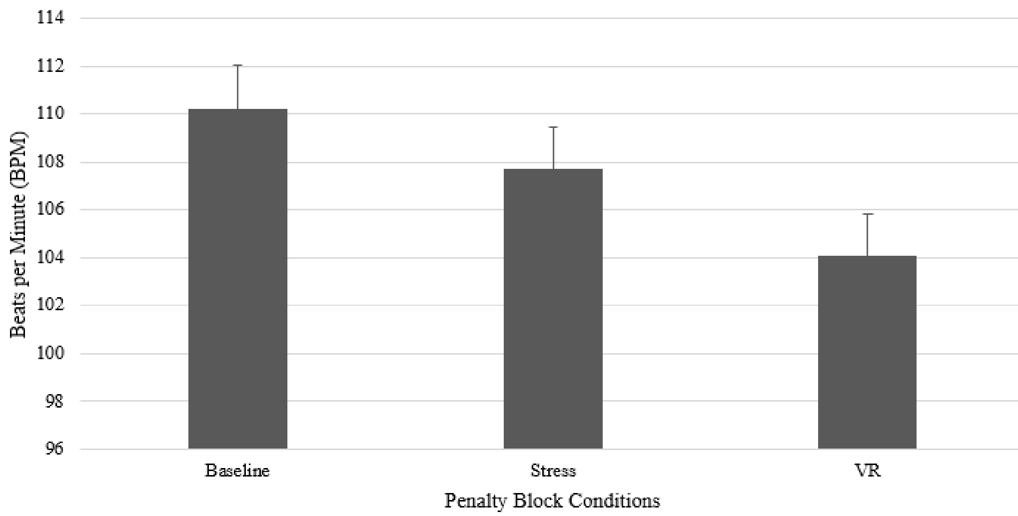
Heart rate examined the physiological effects of the induced stress and VR intervention on the participants. It was hypothesized that heart rate would be higher in the stress induced block compared to the VR and baseline blocks.

An ANOVA was calculated examining penalty block conditions differences on heart rate. A non-significant difference was found among the conditions ($F(2,36)$ = -415, p = .663,

η_p^2 = .023). Heart rate did not differ significantly across the penalty block conditions (see Figure 4).

Figure 5.

Mean heart rate (BPM) between penalty block conditions



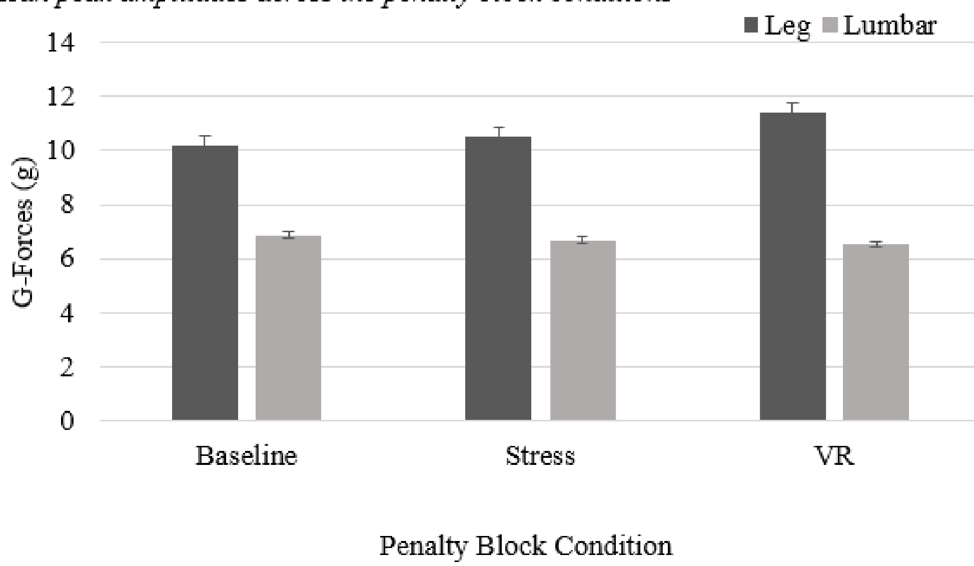
Accelerometry

Accelerometer data, via mean peak amplitude, examined physiological differences within the participants in the three penalty kick blocks. It was hypothesized that mean velocity would be higher in the stress block compared to the VR and baseline blocks. Due to a data collection error, two participants were excluded from data analysis.

An ANOVA was calculated examining penalty block conditions differences on the peak amplitudes of the lumbar spine. A non-significant difference was found among the conditions ($F(2,30) = .171$, $p = .843$, $\eta_p^2 = .011$). Peak amplitude did not differ significantly across the penalty block conditions (see Figure 4). An ANOVA was calculated examining penalty block conditions differences on the peak amplitudes of the kicking leg. A nonsignificant difference was found among the conditions ($F(2,30) = .344$, $p = .712$, $\eta_p^2 = .022$). Peak amplitude did not differ significantly across the penalty block conditions (see Figure 5).

Figure 6.

Mean peak amplitudes across the penalty block conditions



Commitment Check

According to the commitment check, all participants actively engaged with the VR relaxations scene based of the results of the commitment check. All 13 participants felt that the VR helped relax them and 11 participants (84.62%) felt that it helped them reduce any anxiety. In terms of using VR again, 11 participants (84.62%) reported that they would use the VR relaxation again and the remaining 2 (15.38%) participants were indifferently. Regarding how participants felt about using VR before competition, 8 participants (61.54%) said they felt that the VR relaxation would help them before competition to perform better. The other 5 participants (38.46%) either selected “no” or “indifferent”. Through the commitment check, it was evident that the participants’ engaged with the VR and found it a positive experience for them.

Chapter V – Discussion

The purpose of the present study examined the effects of a VR relaxation intervention on stress and performance of penalty kicks in female soccer players. The results indicated that the VR relaxation intervention reduced cognitive and somatic anxiety, while increasing performance compared to the stress condition. All participants felt that the VR helped relax them prior to their last 5 penalty kicks. Additionally, even though nonsignificant, the VR was seen to bring participants closer to their baseline levels by lowering their perceived effort, while also reducing their HR. However, despite these relaxing effects, the participants penalty kicks scores in the VR condition were lower compared to the stress condition, and there were no changes in the participants peak amplitudes throughout.

Perceived Stress

One of the main research questions in this study was examining if the VR relaxation technique would significantly reduce the perceived stress levels of the participants compared to the stress and baseline conditions. Based on the results of the participants' perceived mental effort and cognitive anxiety, the method of inducing stress was sufficient enough to create a stress response. The method of stress inducement was similar to other studies who also had successfully induced stress on their participants (Runswick et al., 2018; Sekiya & Tanaka, 2019; Wilson et al., 2009). It was hypothesized that the VR intervention would significantly reduce the participants' levels of cognitive and somatic anxiety and increase their self-confidence compared to the stress and baseline conditions. After the VR relaxation intervention, participant's perceived stress levels were reduced significantly while their self-confidence significantly increased, showing that the VR intervention had a positive effect, supporting this hypothesis. These results support the study from Liu and Matsumura (2019), who surveyed Division-I student-athletes about the relaxing effects of a VR intervention and found that the athletes significantly reported the VR to be relaxing and beneficial to them. In the present study, the commitment check revealed that 100% of the participants found the VR to help them relax as well, which is further supported by other studies who found VR to be relaxing in other populations such as young (Gao et al., 2014) and middle-aged (Anderson et al., 2017; Blum et al., 2019) adults and intensive care unit patients (Gerber et al., 2017).

This relaxation effect was also reflected in the participants' HR. It was hypothesized that the VR intervention would significantly reduce the participants' HR compared to the stress and baseline conditions. Even though results showed the differences to be nonsignificant, accepting the null hypothesis, the participants' HRs were lower in the VR condition. Their HR reflects a physical component of perceived stress, which is aligned with the participants' perceptions of their stress levels. Considering that the participants perceived the intervention as relaxing, it is not surprising to see their reduction in HR. This non-significance has been supported by Gao et al. (2014) and found that VR relaxation intervention to be relaxing. However, the effects did not always translate to their HR measures leading to no correlation in the relationship between HR and perceived relaxation. With the novelty of VR, participants' HRs could have been elevated with using an unfamiliar, new piece of equipment, which might have occurred in the present study. Only one participant had prior use of VR, thus the concept of using VR could have altered the participants HRs masking the true relaxing effects.

Performance

The other main research question was if the VR relaxation technique would relieve the stress in participants and help improve their performance in penalty kicks compared to the stressful and baseline conditions. Despite these improvements in the participant's perceived levels of perceived stress, their performance, even though nonsignificant, actually declined compared to the stress condition (45 ± 19.20 vs. 54 ± 25.83). It was hypothesized that the participants' penalty kick scores would be lower in the stress condition and higher in the VR condition, however the results accept the null hypothesis. One aspect that was interesting to see in the results was that the standard deviation in the stress condition was larger than the VR condition. This larger standard deviation could have resulted from the varying reactions participants had with the stress condition. Some participants may have had a worse performance in response to the stress while others may have benefitted from the added stress and had a positive reaction resulting in performance improvement. Then, when experiencing the VR intervention, participants had a much more similar relaxing effect that affected their performance more consistently. Also, when comparing the scores from the stress condition to the baseline condition, participants seemed to do better in the stress condition as well (54 ± 25.83 vs. 39 ± 28.71). These findings contradict other studies when examining induced stress on performance (Mullen et al., 2005; Runswick et al., 2018; Sekiya & Tanaka, 2019; Wilson et al., 2009; Yoshie et al., 2008). Previous studies have shown that when stress has been induced on participants, their performances suffer. Runswick et al. (2018) reported that when inducing anxiety on the participants reduced the good bat-ball contacts in cricket batsmen. Furthermore, Wilson et al. (2009) found that inducing anxiety on soccer players significantly reduced the shooting accuracy of participants, with their shots being hit closer to the goalkeeper in the stressful condition. Because of the results of these previous studies, it was unexpected to see the juxtaposing results of this study.

Additionally, peak amplitudes of the thigh and lumbar were very similar across all conditions showing no physical alterations in the participants' shots on each condition. It was hypothesized that peak amplitudes would be higher in the stress condition due to the increased pressure of performing well, so the null hypothesis was accepted. Therefore, there was no evident alteration of kinematics in result of the stress induction. In the present study, participants seemed to have an opposite reaction to the stress inducer that was extremely similar to the stress induction in the Wilson et al. (2009). In both stress inductions, participants were told that their scores would be compared among participants in a ranked order with a scoreboard being circulated to other participants, and that there was no way of knowing their score during the task so it was important to do their best. However, in the Wilson et al. (2009) study, they did not use a game regulated size goal on the field and instead used a much smaller version of a goal, thus making it more challenging for participants. In the present study, participants completed their kicks on a game-regulated field on a much larger goal, which could play a factor in the differences in performances between these studies, making it more difficult to compare.

With the reduced performance in the VR condition and improved performance in the stress condition, it is possible that the stress inducer aroused participants to their appropriate arousal level and the VR intervention under-aroused them. According to the IZOF theory, there is a necessary level of arousal that varies from individual to individual which builds off the inverted U-theory (Yerkes & Dodson, 1908) in terms of being over- or under-aroused (Hanin, 2000). In respect to these theories, the stress induction in the present study may have aroused participants to an "optimal" level for performance, who may have been under-aroused when coming into the study. Then, once participants experienced the VR intervention, the VR may have brought them back down below their optimal level, and thus performed worse.

In addition to these theories, the catastrophe theory may also further explain the effects of their performance in regard to their cognitive and somatic anxiety (Hardy, 1990). The catastrophe theory states that cognitive anxiety will directly influence performance while somatic anxiety will have a smaller effect that is dependent on cognitive anxiety. If cognitive anxiety is low, somatic anxiety could help facilitate performance, but if both are too high, the "catastrophe" occurs and performance plummets (Krane, 1992; Woodman & Hardy, 2001). In the present study, even though cognitive anxiety was higher, participants may have been brought to that peak point in their performance right before the catastrophe effect occurs, resulting in their better scores in the stress condition. Despite trying to mitigate initial stress in the baseline condition, participants were already stressed due to the novelty of the task and having to perform in front of the research team, with some participants taking a penalty kick for the first time in an extended period of time. This ultimately raised their stress levels as well, which would be compounded with the stress inducer. Then, when they experienced the VR intervention, this resulted in a reduction of their cognitive and somatic anxiety, bringing them back down to an under-aroused point as similarly explained in the previous theories discussed, even though the stress inducer was effective in increasing the perceived stress in participants, it may not have been enough stress to reach the catastrophe point for all participants and they were able to improve in their performance.

When measuring the participants' perceived mental effort between conditions, it was hypothesized that the VR relaxation intervention would significantly reduce the level of perceived effort participants exerted in the VR condition compared to the stress and baseline conditions. Results showed a nonsignificant difference between the conditions, accepting the null hypothesis. In particular, the stress condition increased their perceived effort while the VR intervention brought participants closer to their baseline levels. The higher level of effort in participants in the stress condition could also have helped maintain their performance as explained by PET. With increased worry and anxiety, individuals can exert more effort to counterbalance the aversive effects of worry to help maintain performance (Eysenck & Calvo, 1992). Participants exerted more effort in the stress condition to counteract the reduced attentional capacity from increased anxiety and maintained their performance. In the VR condition, participants exerted effort similarly to their baseline, and thus may not have put as much effort as necessary to maintain performance to effectively manage the stressful situation they were induced to.

The attentional focus of the participants may also be a possible contributor to the contradictory results. Attentional focus is similar to arousal in which the right type and level of focus is needed for best performance. According to the attention control training (ACT) principles (Nideffer, 1976), different sport situations require different attentional demands, and alterations in physiological arousal affect concentration and vice versa. Individual differences exist in attentional abilities, similar to optimal arousal. Thus, when participants were induced with stress, participants may have increased their focus on the task to perform to the demands, in relation to their increased levels of arousal. Then, when participants watched the VR intervention, they may have lost their required level of attentional focus due to the relaxing effects of the intervention, resulting in a poorer performance. In the present study, attentional focus was not examined, but is still a factor to consider. Future research should examine the attention levels of participants in relation to their arousal levels with VR relaxation to understand this relationship more clearly.

Based on the contradictory results between perceived stress and performance, it may be that VR relaxation may be inappropriate to use prior to competition due to a needed level of arousal for optimal performance (Kellmann & Beckmann, 2018). VR relaxation may be more appropriate following competition to relax or throughout the competitive season to modulate psychological stress throughout the season. Student-athletes must manage all aspects of their lives in college, which can be highly stressful during certain times of the season (Cosh & Tully, 2014). Thus, with VR showing to be relaxing for the participants, it could be useful if implemented systematically throughout the season. Systematic use of relaxation techniques entails practicing relaxation consistently in an organized manner. This can help develop coping strategies for increased periods of stress and help reduce the risk of injury. During periods of high academic or physical stress, the injury incidence rate is higher (Mann et al., 2016), thus systematically practicing relaxation techniques can serve as a buffer to these high stress periods. It is important to modulate psychological stress in student-athletes since psychological stress can increase the chances of athletic injury and college is one of the most stressful times in a student-athletes life (Andersen & Williams, 1988; Cosh & Tully, 2015).

Limitations and Future Research

This study does not come without its own limitations and caution should be used when generalizing the results of this study to other, realistic situations in soccer. Due to

COVID-19 and other factors related, there were several limitations to this study. Regarding COVID-19, participants were required to wear a face covering while participating which is not worn in actual competition and therefore participants may not be used to it. Because of this, participants may have had some of their attention focused on their mask (more internally), potentially making it uncomfortable with the participant. The influence of the mask could have affected the overall performance of the participants and influenced their stress levels. Future research should revisit this study design and examine the effects of VR relaxation on performance when participants no longer have to wear a mask to eliminate this possibility.

Continuing with the limitations of this study, one limitation is that this study had a very small sample size that only examined female soccer players. This limits the generalizability of this study and future research should examine gender differences on the effects of VR relaxation in a larger sample. Females tend to experience stress and anxiety significantly differently than males, thus the benefits of VR relaxation may be different in males and gender differences should be examined (Jones et al., 1991). This study also only had an inclusion criterion set to a minimum of 2 years of soccer experience. This low threshold may have lowered the overall skill level of the participants which could influence the performance scores and overall outcomes. With a lower skill level, there could have been greater variations in their penalty kicks as opposed to a highly skilled player who has an established motor schema for their kicking motion which could result in a more consistent or higher penalty kick score. This increased variance could have affected results from the accelerometer data and the participants' performance scores. Additionally, higher skilled participants typically face more stressful situations in their sport and may be more accustomed to coping with these stressful situations, so the stress responses from the participants may have been higher compared to a skilled soccer player. Future research should investigate the effects of VR relaxation on highly skilled soccer players to examine if their performances are similar to this study and to investigate if their reactions to the stress vary.

Not only is there possibly a variance in the participants' kicks, but there could also be a learning effect in play. How recently participants had participated in soccer was not something that was controlled. Thus, due to some participants not actively playing competitive soccer, there is a limitation of participants learning the kick they need to take in order to score and possibly improve as the study progressed. Less skilled players may learn and refine their technique as they continue to take repetitions as opposed to higher skilled players who consistently practice their shots and have a more consistent kick overall. This limitation could have affected the overall performance scores of the participants, giving them lower scores in their baseline condition, and future research should attempt to minimize the learning effect by giving practice kicks before starting and using highly skilled players. This could minimize the chances of having a false baseline and give a better reflection of where participants really lie in a stress-free situation. There is also the possibility that participants could have become fatigued by the end of the study. Despite rest breaks, general fatigue may have impacted their performance possibly playing a role in the poorer performance in the VR condition which was last. Future research should investigate the effects of VR relaxation on stress and performance while limiting the effects of fatigue in a repetitive skill task. Performance may be different if it is examined earlier in the study, or over different days to allow recover and minimize the fatigue effect.

When taking the goalkeeper into consideration, the individuals used for the penalty kicks was not a true goalkeeper, but instead a member of the research team with little to no prior goalkeeping experience. This could have inhibited the realness of the penalty kicks since they did not employ proper goalkeeping technique and made it easier and possibly less stressful for participants. This limitation could have inflated scores and also reduce the effectiveness of the stress inducer. Also, due to schedule availability, the same goalkeeper was not used every time, therefore the variation in goal keepers could have made it easier for some participants and harder for others depending on the goalkeeper used. Future research should use a trained goalkeeper, that matches the skill level of the participants, that is to be used for all participants to standardize the goalkeeper for each session and to provide consistency and proper defending of the penalty kick. Having a consistent, appropriately skilled goalkeeper would provide a more accurate representation of participants' performances and help maintain the heightened sense of stress. This could result in different performance outcomes that might better reflect the psychological stress the participant experiences.

Furthermore, this is an initial study analyzing VR relaxation on performance, and future research should examine other methods of evaluating the effects of VR relaxation on stress and performance. Alternative measures such as sweat rate or cortisol sampling to evaluate the effects on stress. HR can be elevated for a multitude of factors, so sampling a physiological measure more definitive of stress could provide better insight. Also, the present study examines the effects of the relaxation intervention acutely where the participants experienced the VR relaxation for just one, 4-minute session. This one-time session was also a pre-determined session selected by the researchers. With the preselected relaxation scene to standardize the relaxation session for all participants, some participants may not have enjoyed the preselected scene as much as other options due to personal preferences. Participants might have a better experience if they were to select their own scene out of the multiple options available. This limitation could have diminished the relaxation effect the VR intervention could have had on some participants and future research should allow participants to self-select their VR scenes. By having participants choose their own scene, they might experience greater enjoyment resulting in a more effective relaxation intervention. This could result in a greater/more consistent impact the VR has across all participants. The effects of stress and VR relaxation should also be examined in a long-term study as opposed to an acute session to explore the long-term effects VR may have. There is a possibility that the one-time relaxation session did not have as great as an effect as it could have if used for an extended period of time, or the VR intervention could have a greater initial effect and lose its effectiveness over time.

It is also important to consider the limitation of the sport task utilized. This study examines the performance over a series of penalty kicks rather than an actual match performance. Penalty kicks do not happen far too often in soccer, however, are very impactful to the outcomes of a match, which can bring stress to the athlete, but never done repeatedly. Even though stress was induced, the stress was still a simulated stress and is not a replica of the stress experienced in actual competition. Even though the significant results with the MRF-3 in the present study support the validation studies of Krane (1994) when using the MRF-3, indicating a significant stress response was achieved, participants still experienced a different form of stress. To really examine how VR relaxation can impact performance, future research could examine the performances of practices or games to have a more applied approach to the topic. When examining the effects to actual competition, different effects may occur as opposed to a simulated, stressful, task.

Additionally, the effects of an audience on penalty kick performance was not examined. Traditionally, players are performing in front of audiences that could have a significantly stressful effect on the athlete when taking a penalty kick that could be the difference between winning and losing. In this study, an audience was not facilitated and the effects of the research team watching the participants was not explored. An audience effect could add to the stress, while making the penalty kicks feel more realistic, which the participant may feel bringing different results. This effect should be explored in future research to examine whether VR relaxation could aid in the anxiety of a crowd during crucial moments of a game and get a more wholistic approach to what the actual competition would feel like.

Future research should also examine other methods of analyzing the kinematics of stress on performance. As this is a first step, accelerometer data was used, which is a fairly simple measure that is not used too often when examining kinematics related to stress. Previous studies have examined the kinematics in relation to increased stress and anxiety with electromyography (EMG), eye gaze systems, and high speed video cameras and future research should utilize these measures to compare the results to previous research and other sports (Causer et al., 2011; Runswick et al., 2018; Sekiya & Tanaka, 2019; Yoshie et al., 2008). These different measures could reveal differences in the participants' kicks that may not be detectable by only peak amplitudes of accelerometer data and be more useful in understanding the effects of VR relaxation on the execution of an open task of taking a penalty kick.

Furthermore, the weather in the current study may have had an effect on the participants' performances. For mostly all participants, the weather conditions were very windy, which could have possibly affected the participants' stress levels as well as their shots due to the perceived inconvenient weather conditions. Future research should examine performance in a more controlled environment or on days where wind is nonexistent as well as comparing performances with different days of weather. Weather may play a larger role in perceived stress and performances and future research should take this into consideration. This limitation is also in relation to the type of sport used for the study. Soccer is easily influenced by weather conditions. Additionally, soccer may provide a different type of stress (due to all of its external factors like weather) to athletes compared to other sports and other athletes may have varying responses to the VR intervention. This difference in demand in sports is also reflected in individual versus team sport athletes. With team sports, the sense of perceived stress in games may be less compared to an individual sport athlete where the consequences of mistakes are much higher. Therefore, future research should investigate the differences in the type of sports using VR as a relaxation intervention as well the differences between individual versus team sport athletes. With the huge variance in sports, VR relaxation may be of better use in certain sports compared to others.

Practical Implications

There are several practical implications VR relaxation can provide for clinicians. VR relaxation could be another viable means to reduce stress, but directly prior to competition may not be appropriate. These results from the current study are insightful for practitioners to utilize when deciding when/if to utilize VR as a relaxation intervention. Especially considering that 8 of the 13 participants (61.54%) felt that the intervention would help them improve performance if they used it before a competition. Despite these opinions, the performance scores indicate the opposite, thus other factors must be taken into consideration when deciding to use VR relaxation before a competitive bout. Caution should still be taken when applying the results of this study to one's practice. It is still important to consider the individual differences of student-athletes in regard to their responses to stress and anxiety. Some athletes may have a severe problem with pre-competition anxiety and being aware of the large relaxation effect VR had on the participants, it may a tool to try for those with severe pre-competition anxiety. However, with the general student-athlete population, other methods of pre-competition preparation ought to be used.

VR relaxation may be a beneficial tool to utilize after competition when it is necessary to wind down afterwards when that heightened level of stress is no longer appropriate to experience. Additionally, VR relaxation can be a viable means to use as a preventative tool to upcoming periods of increased stress, whether it be academic or athletic based. Athletic trainers could employ VR relaxation systematically for athletes who report feeling extremely stressed to help prevent the possibility of injury in the future. Some athletes may have a more difficult time employing imagery-based relaxation interventions in a psychological skills training program; thus, VR can help these athletes with their imagery challenges and also provide a more immersive experience to achieve a higher relaxed state.

VR relaxation can also be utilized as a tool to use during injury rehabilitation. Injury rehabilitation can bring upon an additional source of stress to the athlete and a sense of unknown to them. Utilizing relaxation techniques throughout a rehabilitation program can be beneficial for return to sport by modulating stress to help with improved outcomes and a faster return to sport. Further research in VR with rehabilitation is needed to determine the exact relationship VR can have with a rehabilitation program, but this study does provide insight on how useful VR is for relaxation. Therefore, if reducing stress is a main goal in the rehabilitation program, VR could be a viable technique. With its increased accessibility and decreasing cost, VR is becoming more attainable for practitioners to utilize to help keep patients engaged in the rehabilitation program. As its popularity increases, VR will continue to interest the sporting world, so it is important to understand the benefits and limitations it provides in different settings.

In conclusion, the purpose of this study was to examine the effects of VR relaxation on the stress and performance in soccer players taking a series of penalty kicks. Results indicated that VR relaxation significantly reduced the cognitive and somatic anxiety of the participants while significantly improving their self-confidence. However, there was not a significant effect found on the participants' mental effort ratings, HR, peak amplitudes, and penalty kick scores. Despite no significance, the VR intervention brought participants closer to their baseline mental effort rating and also decreased their HR but was also associated with a worse penalty kick score compared to the stress condition. Thus, VR relaxation may be inappropriate to use prior to competition so caution should be utilized when deciding to employ this relaxation strategy. Instead, VR relaxation may be beneficial to modulate stress after competition and throughout the season, but future research is still needed to understand the relationship between VR relaxation and performance. With several limitations, this study serves as an initial step, establishing a basic framework for future research to build off of and evaluate VR relaxation with a more in-depth approach in regard to the cognitive and physical effects of stress and performance.

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APPENDICES

Appendix A

Demographic Questionnaire

Participant ID:

____

Age:

- o 17
- o 18
- o 19
- o 20
- o 21
- o 22
- o 23
- o 24
- o 25
- o 26
- o 27
- o 28
- o 29
- o 30
- o 31
- o Click to write Choice 3

Gender:

____

Race:

- o American Indian or Alaska Native
- o Asian
- o Black or African American
- o Caucasian/White
- o Native Hawaiian or other Pacific Islander
- o Other

If you chose "other" please provide race down below.

____

Year in College (mark one):

- Freshman (0-29 hrs)
- Sophomore (30-59 hrs)
- Junior (60-89 hrs)
- Senior (90 or more hours)
- Graduate Student

Soccer position (please choose which position best identifies with your role on the team):

- Defender
- Midfielder
- Forward
- Goalkeeper

Current playing status on team:

- Starter
- Second String (Gets some playing time but does not start)
- Third String (Receives hardly any playing time or even no playing time at all)
- Injury Reserve
- Red Shirt Freshman
- Currently not on a team (if selected skips next item)

Number of years playing collegiate soccer:

- 0
- 1
- 2
- 3
- 4
- 5
- 6

- 7
- 8

Number of years of soccer experience in general:

- 1
- 2
- 3
- 4
- 5
- 6
- 7
- 8
- 9
- 10
- 11
- 12
- 13
- 14
- 15
- 16
- 17
- 18
- 19
- 20
- 21
- 22

- 23
- 24
- 25+

Please select how long ago you were last injured:

- 1-3 weeks
- 1-2 months
- 3-6 months
- 6-9 months
- 9-12 months
- 1 year or longer
- never been injured

How long were you out of participation?

- less than a week
- 1-2 weeks
- 2-4 weeks
- 4-6 weeks
- 2-4 months
- 4-6 months
- 6-8 months
- 8-10 months
- 10 months to 1 year
- 1 year or longer

Where was the injury?

- upper body
- lower body
- torso
- head
- other

If you selected other, please specify here:

____

____

Do you experience motion sickness?

- ○ Yes
- ○ No

Have you ever used or experienced virtual reality as a relaxation technique?

- ○ Yes
- ○ No

If yes, on average, how many times per year have you used VR relaxation?

	1 3 5 7 9 11 12 14 16 18 20
I use, per year, VR for relaxation...	

When using VR for relaxation, my sessions typically last...

	1 10 19 28 37 46 54 63 72 81 90
In minutes, my sessions last....	

Appendix B

MRF-3 Questionnaire

Please answer the three questions based on how you are feeling in this exact moment.

1. My thoughts are:

/ 1 / 2 / 3 / 4 / 5 / 6 / 7 / 8 / 9 / 10 / 11 /
CALM WORRIED

2. My body feels:

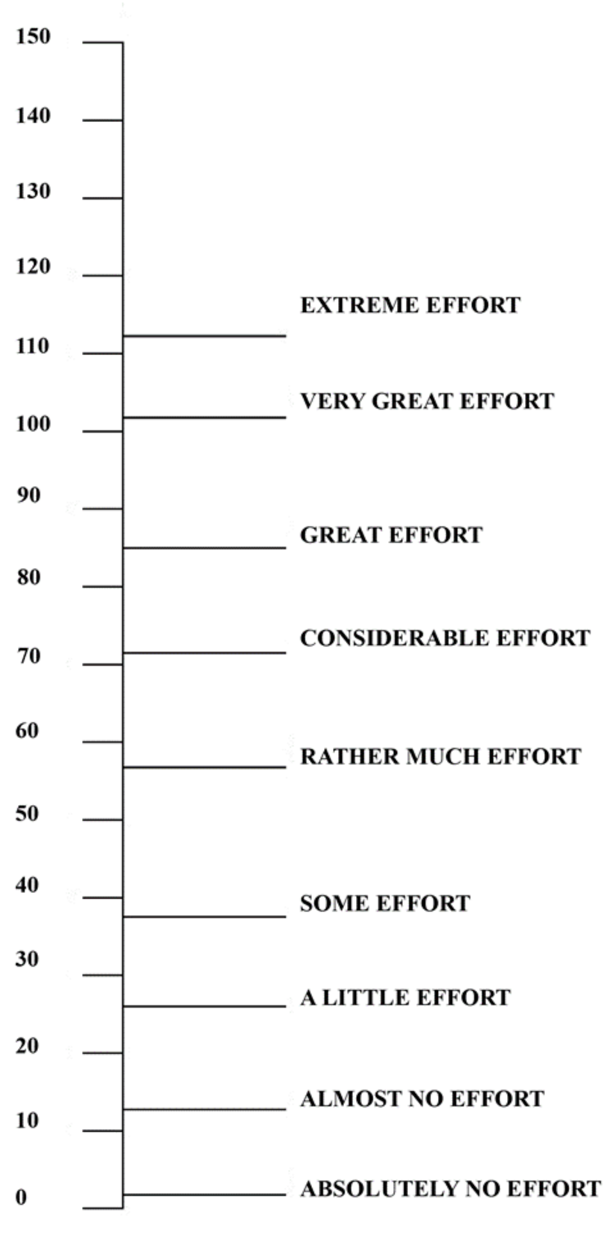
/ 1 / 2 / 3 / 4 / 5 / 6 / 7 / 8 / 9 / 10 / 11 /
RELAXED TENSE

3. I am feeling:

/ 1 / 2 / 3 / 4 / 5 / 6 / 7 / 8 / 9 / 10 / 11 /
CONFIDENT SCARED

Appendix C

RSME Scale


150
140
130
120
EXTREME EFFORT
110
VERY GREAT EFFORT
100
90
GREAT EFFORT
80
CONSIDERABLE EFFORT
70
60
RATHER MUCH EFFORT
50
40
SOME EFFORT
30
A LITTLE EFFORT
20
ALMOST NO EFFORT
10
ABSOLUTELY NO EFFORT
0

Appendix D

Heart Rate Data Collection Sheet

Participant ID: _______________ Investigator: _________________________

Participant HR Data Collection		
Time Point	**HR**	**Time**
Resting HR		
Baseline Session		
MRF form		
Pre-Kick 1		
Pre-Kick 2		
Pre-Kick 3		
Pre-Kick 4		
Pre-Kick 5		
HR beginning of rest		
HR end of rest		
Stress Session		
Pre Stress Induction		
Post Stress Induction		
MRF form		
Pre-Kick 1		
Pre-Kick 2		
Pre-Kick 3		
Pre-Kick 4		
Pre-Kick 5		
HR beginning of rest		
HR end of rest		
VR Session		
Pre-Stress Induction		
Post Stress Induction		
Pre VR		
Post VR		
MRF form		
Pre-Kick 1		
Pre-Kick 2		
Pre-Kick 3		
Pre-Kick 4		
Pre-Kick 5		
Post Session		

Appendix E

Commitment Check - IGroup Presence Questionnaire

Now you'll see some statements about experiences. Please indicate, whether or not each statement applies to your experience. If a question is not relevant to the virtual environment you used, just skip it. You can use the whole range of answers. There are no right or wrong answers, only your opinion counts.

You will notice that some questions are very similar to each other. This is necessary *for statistical reasons* . And please remember: Answer all these questions only referring to this *one* experience.

How aware were you of the real world surrounding while navigating in the virtual world? (i.e. sounds, room temperature, other people, etc.)?

extremely aware	○	○	○	○	○	○	○	not aware at all
	-3	-2	-1	0	+1	+2	+3	
				moderately aware				64/inv1/0

How real did the virtual world seem to you?

completely real	○	○	○	○	○	○	○	not real at all
	-3	-2	-1	0	+1	+2	+3	48/real1/1

I had a sense of acting in the virtual space, rather than operating something from outside.

fully disagree	○	○	○	○	○	○	○	fully agree
	-3	-2	-1	0	+1	+2	+3	31/sp4/2

How much did your experience in the virtual environment seem consistent with your real world experience ?

not consistent	○	○	○	○	○	○	○	very consistent
	-3	-2	-1	0	+1	+2	+3	
				moderately consistent				7/real2/3

How real did the virtual world seem to you?

about as real as an imagined world	○	○	○	○	○	○	○	indistinguishable from the real world
	-3	-2	-1	0	+1	+2	+3	50/real3/4

I did not feel present in the virtual space.

did not feel	○	○	○	○	○	○	○	felt present
	-3	-2	-1	0	+1	+2	+3	28/sp3/5

I was not aware of my real environment.

fully disagree	○	○	○	○	○	○	○	fully agree
	-3	-2	-1	0	+1	+2	+3	37/inv2/6

In the computer generated world I had a sense of "being there"

not at all	○	○	○	○	○	○	○	very much
	-3	-2	-1	0	+1	+2	+3	62/g1/7

Somehow I felt that the virtual world surrounded me.

fully disagree	○	○	○	○	○	○	○	fully agree
	-3	-2	-1	0	+1	+2	+3	44/sp1/8

I felt present in the virtual space.

fully disagree	○	○	○	○	○	○	○	fully agree
	-3	-2	-1	0	+1	+2	+3	33/sp5/9

I still paid attention to the real environment.

fully disagree	○	○	○	○	○	○	○	fully agree
	-3	-2	-1	0	+1	+2	+3	40/inv3/10

The virtual world seemed more realistic than the real world.

fully disagree	○	○	○	○	○	○	○	fully agree
	-3	-2	-1	0	+1	+2	+3	47/real4/11

I felt like I was just perceiving pictures.

fully disagree	○	○	○	○	○	○	○	fully agree
	-3	-2	-1	0	+1	+2	+3	30/sp2/12

I was completely captivated by the virtual world.

fully disagree	○	○	○	○	○	○	○	fully agree
	-3	-2	-1	0	+1	+2	+3	38/inv4/13

Commitment Check – VR Follow-Up Questions

Did this help you relax or reduce any stress or anxiety you might have had?

	Not at all	No	Indifferent	Yes	Very much so
Answer:	○	○	○	○	○

Would you use this again?

	Not at All	No	Indifferent	Yes	Very much so
Answer:	○	○	○	○	○

Do you think this VR session would be helpful in relaxing you before an athletic competition to perform better?

	Not at All	No	Indifferent	Yes	Very much so
Answer:	○	○	○	○	○

Appendix F

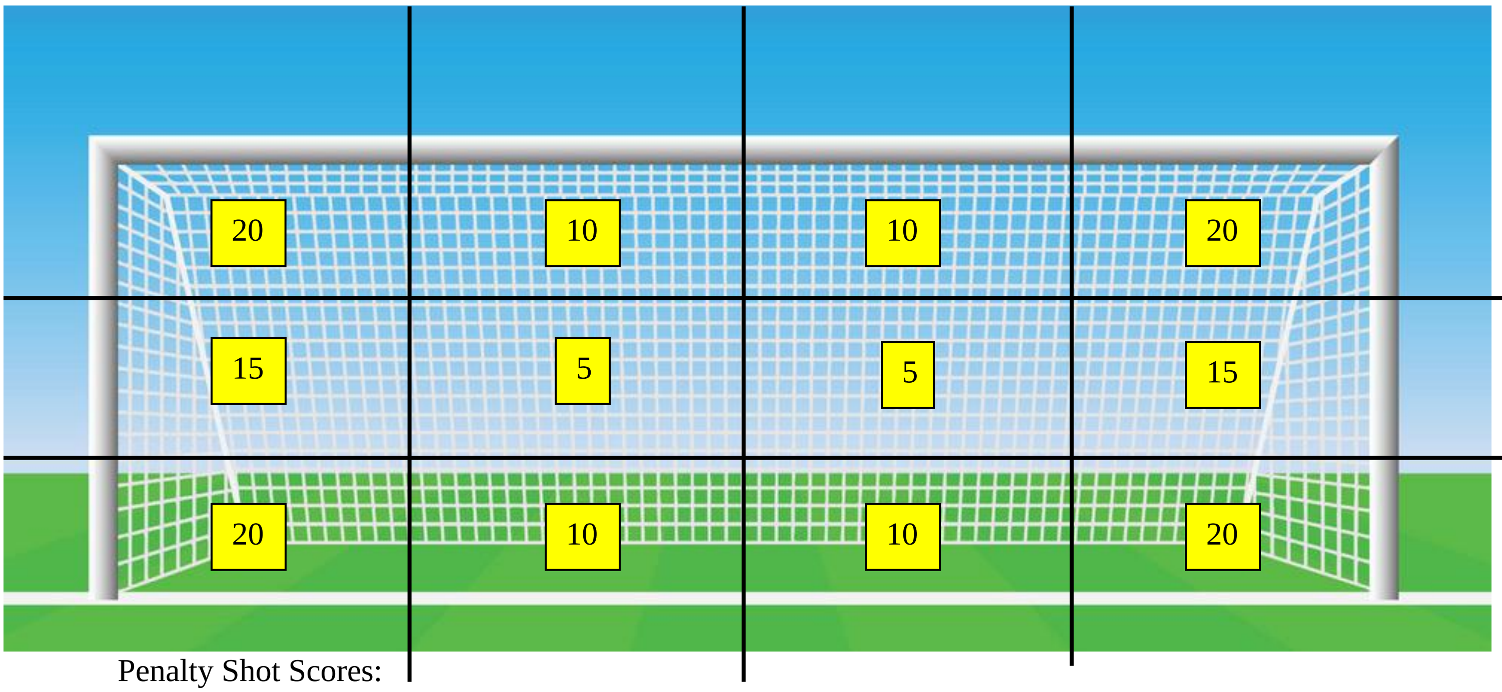
Penalty Kick Scoring Sheet

Soccer Shot Data Sheet

Participant #: _____ Penalty Block: _________________

Investigator: ____________________________

Instructions: After the participant completes a penalty kick, please mark on the goal where the shot was taken and record the number of points received below. If the goalkeeper saves it, then the participant gets ZERO points. If the participant completely misses the goal, they receive -5 points.



Penalty Shot Scores:

Shot 1: ______

Shot 2: ______

Shot 3: ______

Shot 4: ______

Shot 5: ______

Total Points: _______

Appendix G

Stress Induction Script

Stress-Inducing Script for Block 2 Kicks:

"Now you will do the 5 penalty kicks again, but this time your scores from each shot will be used and recorded for comparison to your fellow participants. Please try your best to get the best score that you can and to make every shot to the best of your ability. Your scores will be compared to others and will be shared and posted on a scoreboard for others to see in a ranked order. The scoring system is more than just making or missing the shot and factors in other things; therefore, you will not be able to tell what your score is during this task. Imagine that your total score and the total scores from your fellow participants will be communicated with your coach as well. Your coach will use these scores and your performance during this study to make decisions towards playing time and penalty kick situations, therefore, it is of the upmost importance that you do your best. You will take your kicks the same way as in the previous 5 penalty kicks, with the same 90 seconds to reset between each kick. Do you have any questions?"

Appendix H

Stress Reinduction Script

Stress Re-inducing and VR Script for Block 3:

"Again, you will do another 5 penalty kicks and the scores from each shot will be used and recorded for comparison to your fellow participants just like the previous kicks we just did. Please try your best to get the best score that you can and to make every shot to the best of your ability. Your scores will, again, be compared to others and will be shared and posted on a scoreboard for others to see in a ranked order. Just to remind you, you will not be able to tell what your score is during the task based purely of makes or misses. Imagine that your total score and the total scores from others will be communicated with your coach and he will use these scores and your overall performance during this study to make decisions towards playing time and penalty kick situations, therefore, it is of the upmost importance that you do your best. You will take your kicks the same way as in the previous 5 penalty kicks, with the same 90 seconds to reset between each kick. Before we start these 5 penalty kicks, you will now experience a VR relaxation scene. You are to stay seated with the VR headset on and experience the scene in front of you. While experiencing the VR session, use this session to take deep breaths and relax from any stress and/or anxiety you may be feeling. Once you finish the VR scene, you will then continue with the rest of the penalty kicks like the previous 2 blocks. Do you have any questions?"

Appendix I

Campfire Experience through Liminal VR Application

Appendix J

Debrief

Debrief

Thank you for participating as a research participant in the present study. If you know of any friends or acquaintances that are eligible to participate in this study, we request that you not discuss it with them until after they have had the opportunity to participate. Prior knowledge of the study can invalidate the results. We greatly appreciate your cooperation. Additionally, your overall performance will not be used by your coach for playing time decisions and will have no effect on you whatsoever. You were told this piece of information in order to induce the stress response that was needed for this study and nothing more.

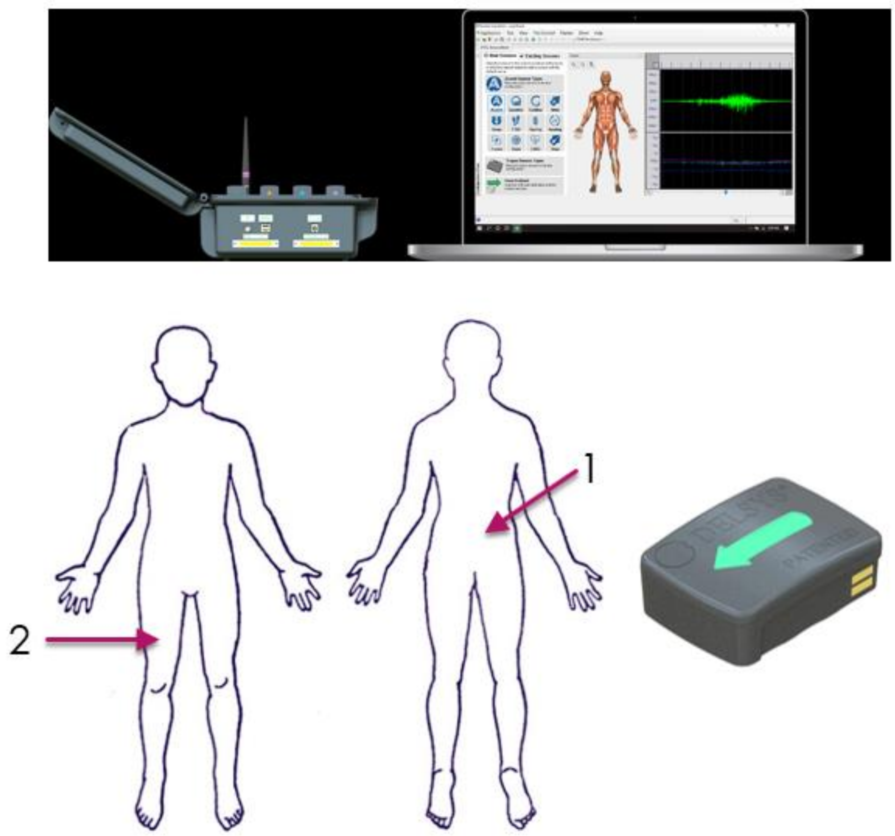
If you have any questions regarding this study, please feel free to ask the researcher at this time Kaitlyn Harrison LAT, ATC (email: k.p.harrison@tcu.edu; telephone: 817-584-0910)

In the event that you feel psychologically distressed by participation in this study, we encourage you to call the TCU Counseling Center at 817-257-7863. If you feel any physical discomfort, please consult with your health care provider.

Thanks again for your participation.

Appendix K

DELSYS Trigno Avanti Sensor and Sensor Placement



DELSYS Incorporated, Massachusetts, United State

Appendix L

Polar H10 Heart Rate Monitor with Pro Strap


POLAR

ABSTRACT

THE EFFECTS OF VIRTUAL REALITY ON STRESS
AND PERFORMANCE IN FEMALE
SOCCER PLAYERS

by Kaitlyn Paige Harrison, LAT, ATC
Bachelor of Science, 2019
Howard Payne University

Thesis Advisor: Dr. Robyn Trocchio, Assistant Professor of Kinesiology

The purpose of the current study was to analyze how a VR relaxation intervention affected psychological stress levels and performance of female soccer players taking a series of penalty kicks. Thirteen female soccer players with at least two years of experience took five penalty kicks each in a baseline, stress, and VR condition. Perceived levels of psychological stress and mental effort, heart rate, accelerometry of the lumbar spine and thigh, and overall performance in each condition was obtained. Results indicated that the VR intervention significantly reduced participants stress levels. All other measures were nonsignificant, but penalty kick performance showed to be worse in the VR condition compared to the stress condition. The VR intervention may have under-aroused participants resulting in the worse performance. VR relaxation may be inappropriate to use prior to competition, but beneficial for modulating psychological stress throughout the season.