Executive Function (Anticipation) Differences Between Soccer Players

With and Without a History of Traumatic Brain Injury

by

Akuadasuo Ezenyilimba

A Thesis Presented in Partial Fulfillment
of the Requirements for the Degree
Master of Science

Approved April 2021 by the
Graduate Supervisory Committee:

Rob Gray, Chair
Erin Chiou
Nancy Cooke
Robert Gutzwiller

ARIZONA STATE UNIVERSITY

May 2021

ABSTRACT

The present study sought to understand traumatic brain injuries (TBI) impact on executive function (EF) in terms of anticipation amongst individuals with a background in soccer; along with other contributing factors of EF curtailments that inhibit athletes. Within this study 57 participants, with a background in soccer (high school, collegiate, and semi-professional), completed five EF tasks: working memory, cognitive flexibility, attentional control, and anticipation; pattern detection and athletic cues (temporal occlusion). The results of this study concluded that when TBI history, gender, and soccer athletic level are factors, athletes with a soccer level of collegiate and semi-professional had decrements related to pattern detection anticipation; meaning athletes at higher levels had lower average scores on the Brixton Spatial Anticipation Test (BSAT). Additionally, female athletes showed more anticipation decrements related to athletic cues, especially those that are reliant on the initiation of judgment. Overall undiagnosed TBIs and limited understanding on how to approach rehabilitation to mitigate EF decrements, continue to impede individual autonomy amongst athletes.

Keywords: Traumatic brain injury, executive function, anticipation, soccer, temporal occlusion, Brixton Spatial Anticipation Test (BSAT), collegiate, semi-professional, pattern detection, rehabilitation

I would like to dedicate my thesis work to God and my family. First and foremost, I would like to thank my parents Matthew and Kelley Ezenyilimba. Thank you both for continually encouraging and inspiring me daily. Words cannot thank you enough for being my constant, believing in me no matter what, and loving me more than the sun has light.

To my younger siblings, Akunnaya, Frederick, and Gloria, my unconditional best friends, you are the reasons that motivate me and instill my drive. Lastly but not least, I dedicate this to my grandparents, Fred and Gloria Cleghorn, and Raphael and Veronica Ezenyilimba. Thank you for your continued affirmations, thank you for being the pioneers, and thank you for paving the way.

ACKNOWLEDGMENTS

I would like to start by thanking my committee members for guiding and helping me with their expertise and time. Thank you Dr. Rob Gray for being my committee chair, and your continued direction. Thank you Dr. Nancy Cooke, Dr. Erin Chiou, and Dr. Robert Gutzwiller for not only being a part of my committee, but your continued support.

A special thank you to Dr. Troy McDaniel and Dr. Eric Luster for their efforts and assistance in my thesis culmination. Additionally, a special thank you to all the Soccer coaches who were willing to assist in the recruiting of participants.

Finally thank you to the entire Human Systems Engineering faculty at Arizona State University for allowing your students to explore their passions within multiple disciplines. Thank you all for the bountiful opportunities and willingness to assist all your students.

TABLE OF CONTENTS

CHAPTER Page

APPENDIX

LIST OF TABLES

LIST OF FIGURES

Figure Page

Executive Function (Anticipation) Differences between Soccer Players with and without a History of Traumatic Brain Injury

Executive function (EF; interchangeable with executive control) manages a person's cognitive processes (working memory, attention, and multi-tasking; Tapper, Gonzalez, Roy, and Niechwiej-Szwedo, 2016). EF ultimately can be defined as "the ability to maintain an appropriate problem-solving set for the attainment of a future goal" (Gioia & Isquith, 2004). In order for this to be achieved the mind must implement EF as a supervisory function to elicit control over both thoughts and actions. Both actions and thoughts are heavily reliant on one another. These two components are also monumental when it comes to higher levels of cognitive control such as anticipation (Gioia & Isquith, 2004).

Anticipation can be classified as an action that is needed to prepare for the execution of a superior or subsequent action (Botezatu & Andrei, 2014). Within soccer players, the elicitation of anticipation as an action can be seen within athletes through assuming the athletic stance (slightly squatted, legs shoulder width apart, and readily on toes) to prepare to derail their opponent in either direction. Therefore, anticipation can be viewed as both a voluntary and involuntary response in preparation for an event that is expected to happen soon.

For an action such as anticipation to be able to occur, an individual must be able to have full control over their intended action and be able to direct it toward a specific goal or complex situation (Miller & Wallis, 2009). These specific actions that are reliant on anticipation can be seen on a regular basis amongst individuals with an athletic background, especially in an athletic arena. In an athletic arena these specific actions are better known as sport specific anticipation tasks, which naturally evoke action anticipation within athletes (Smith, 2015).

Daily athletes are faced with complex situations in which they must maneuver through without hesitation and with ease to achieve an overarching goal. These situations can vary from scoring a point to get your team ahead, or simply blocking an opponent from being able to assist their teammate. To achieve these actions an athlete must be capable of innately implementing anticipation in their respective fields by relying on the extraction of information that brings on familiar schemas. These 'schemas' then can be associated with relevant body parts, equipment, or even associated movements within a familiar arena on either the athlete's behalf or their opponent (Smith, 2015).

Executive Function Impairments via Traumatic Brain Injury

Long term deficits in EF are shown to be associated with a history of concussion (Tapper et. Al. 2016). Impairments within EF are one of the highest reported issues amongst individuals who have a history of traumatic brain injury (TBI; Arulsamy, Corrigan, Collins-Praino, 2019). Individuals who have had a TBI, even 'mild' can appear relatively fine to the naked eye, and under the initial guise appear fully functional.

What has failed to be realized is that underneath the initial appearances the damage caused from a TBI can be devastating to everyday life (Miller & Wallis, 2009). After a traumatic brain injury, the brain is susceptible to anomalies that can inadvertently impair EF. These anomalies within EF include but are not limited to issues with visual processing, motor, and limbic decline, as well as other issues associated with executive cognition (Stevens, Lovejoy, Kim, Oakes, Kureshi, and Witt, 2012).

EF is a pivotal component for someone to be able to successfully achieve various aspects of social cognition and interpersonal behavior. These aspects that are innate as a result of having effective EF from birth unfortunately can be inhibited by one simple interruption in the form of a TBI. These prevalent anomalies that persist because of a decline in EF, can compromise relationships, mental ability, and even an individual's independence within their daily life (Wood & Worthington, 2017).

Those who have a history of TBI, especially one that has specifically affected the prefrontal cortex, are unable to engage in actions that require the implementation of anticipation to address potential unforeseen goals. This newly acquired latent response, even if executive function actions are taking place in a once familiar environment, result in actions that can be initiated in environments that are not necessarily deemed acceptable (Miller & Wallis, 2009).

Prefrontal Cortex and Executive Function

The prefrontal cortex is situated within the frontal lobe, an area associated with deficits that persist from a TBI. Within this area we can find the source for control attention, concentration, inhibition, set shifting, and task management making it the hub for EF. These tasks come into play specifically for non-routine instances. Impairments to the prefrontal cortex can additionally have a negative impact on instances that require one to emulate self-correction, decision making, and even judgment, altering daily life for an individual in an unprecedented manner (Zappalà, 2008).

Injury to the frontal lobe following a TBI can show damage that is visible all the way up to ten years post injury (Zappalà, Schotten, and Esinger, 2012). Damage to this area can inhibit someone's ability to plan efficiently. Athletes who have a history of being concussed are prone to showing weaker activation patterns due to the damage that may have occurred in the prefrontal cortex upon injury (Chen, Johnston, Frey, Petrides, Worsley, and Pitto, 2004). A lack of activation in the dorsolateral prefrontal cortex can be linked and attributed to a gray matter loss (Chien et. al., 2004).

This degradation can lead to the onset of symptoms within the brain that mimic that of depression. These 'depressive like' symptoms can then impede on performance in the form of functional disabilities that then add to the stagnation of an individual's development as an athlete. This is especially so when it comes to undiagnosed and misdiagnosis of an athlete with a TBI (Chen, Johnston, Petrides, & Pitto, 2008). For example, instead of properly being treated for the persistent issues that follow a TBI, an athlete could be misdiagnosed and only being treated for depression instead of addressing both issues (Talavage et. al., 2014).

Traumatic Brain Injury Neural Impairment

Following a TBI individuals can struggle with anything that requires them to complete multiple steps (Zappalà, 2008). There has been prominent evidence that shows there is an increase in neural decline in individuals with a TBI (Frasca, Tomaszcyk, McFayden, and Green, 2013). This decline, especially as a result of prefrontal cortex damage results in a disruption in the necessary mechanisms needed for cognitive control systems, i.e. EF (Miller & Wallis, 2009).

As a result of neural decline there cannot be an effective amount of neural processing, which inhibits the brain thus affecting the operator's performance strategy. With the acquired decrement imposing cognitive control, individuals have shown to have impaired performance when it comes to attention, concentration, abstract thinking, and hand eye coordination (Alexander, Shuttleworth-Edwards, Kidd, and Malcolm, 2015). A single TBI alone can have negative recourse on both white and gray matter resulting in neurodegeneration (McKee & Robinson, 2014). For an athlete, neural decline's impact on thinking and judgement is especially limiting due to the negative impact on a key component of EF, selective attention (Wickens & McCarley, 2008).

Anticipation and Athletes

For an athlete to be deemed successful at any level (high school, collegiate, professional, etc.) visual reaction time and visual anticipation time are essential. The skills in which an athlete must develop handle the cognitive processes that are needed for the brain to respond instantly to a stimulus in the form of anticipation (Kuan, Zuhairi, Manan, Knight, and Omar, 2018). Although it could be argued an athlete may already have the upper hand in comparison to their non-athletic counterparts, especially when it comes to higher levels of EF such as anticipation, the deficit that persists in recovery post-TBI can be deemed career ending for an athlete.

The prefrontal cortex is primarily responsible for EF. EF plays a pertinent role in our ability to regulate long term goal-oriented tasks that can be associated with schemas. These schemas that we abide by cannot solely rely on our ability to predict, but instead are reliant on the use of our EF. Through implementation of EF we are able to play out these schemas with the assistance of anticipation (Gioia & Isquith, 2004). Anticipation enables the human being to hold necessary information on an active basis and apply it to a perceived future goal (Gioia & Isquith, 2004). This implementation of EF can be physically seen in athletes when it comes to action anticipation.

As an athlete it is pertinent to the success of their career to be able to perceive and attempt to predict the oncoming actions of their opponent, whether it be related to the direction of a shot, or a deceptive move from the opposition (Smith, 2016). This predictive behavior also known as action sequences/schemas within athletes is a necessary component for an athlete to be deemed proficient (Smith, 2016). With the potential deficit that is placed on athletes due to the possibility of acquiring a TBI, the ability to be proficient when it comes to this crucial task can ultimately be hindered, therefore limiting an athlete's performance and career, causing more issues when it comes to re-acclimation post injury.

Athletes success can be seen through four essential factors anticipation, planning, execution, and self-monitoring (Garcia-Madruga, Gómez-Veiga, and Vila, 2016; Luria, 1966). These four components are essential to finding success at any athletic level. An athlete cannot persevere without being able to anticipate upcoming events with limited information; plan how they are going to act accordingly with the information they have; figure out how to execute a stored plan at the right time; or figure out how to implement all of these working parts without losing focus through the ability to effectively self-monitor. Anything that compromises the forementioned capabilities can perpetually stagnate the longevity of an individual’s career.

Athletes and Traumatic Brain Injury

Athletes, more specifically soccer players have been known to show elevated levels of EF in comparison to non-athletes, especially when it comes to problem solving (Jacobson & Matthaeus, 2014). This is especially with soccer players being deemed externally paced athletes; meaning they need to be able to adapt and make quick decisions that are brought on by external cues (Jacobson & Matthaeus, 2014). The levels in which athletes can achieve cognitive abilities when it comes to EF is one of the driving forces behind their success in athletics (Jacobson & Matthaeus, 2014). Unfortunately, the acquisition of a TBI can potentially reduce or remove the benefits an athlete has developed in terms of their superior EF.

With the prefrontal cortex being one of the last structures within the brain to fully develop, it is not surprising that a majority of young athletes who have been impacted by a TBI have decrements that can be associated with prefrontal cortex damage (Daneshvar, Riley, Nowinski, McKee, Stern, and Cantu, 2011). Many athletes acquire some sort of TBI in the initial stages of their career or early on in their youth, with the highest number of sports related TBIs being reported between the ages of 10-25 years (Tsushima, Siu, Ahn, Chang, & Murata, 2018).

Since athletes are predisposed to acquiring a TBI earlier on in life than their non-athletic counterparts, athletes are more likely to experience issues with attention deficits, hyperactivity, or other issues that can inhibit a person's ability to effectively elicit the task of anticipation. These decrements, as a result to early exposure to TBIs at a younger age, can be associated with the damage that comes with prefrontal cortex impairments (Daneshvar et. al., 2011; Tsushima et. al., 2018).

Arguably EF plays a vital role in players being effective on a team sport. These athletes require attention and working memory to process copious amounts of sensory information during dynamic game situations (Tapper et. al., 2016). With that being said, the deficits associated with a TBI can be career altering, inhibiting athletes from being equipped with the necessary innate tools to process information in a fast-paced environment such as an athletic arena (Tapper et. al., 2016).

Present day rehabilitation is important but may not be enough to allow re-engagement in athletics. Often proper rehabilitation is cut short due to the demands placed on the program and the athlete to return to competition. In addition to rehabilitation limitations, many clinical practices are not capable of successfully identifying neurological deficits in individuals with TBIs. Often this leaves many athletic individuals undiagnosed even though cognitively they have impairments that resemble that of a traumatic brain injury (Talavage et. al., 2014). All in all, rehabilitation for post-TBI needs to better address how to take clinical efforts and focus them on truly improving cognitive abilities (Zimmerman, Mograbi, Hermes-Pereira, Fonesca, and Prigatano, 2017).

Clinical approaches for TBI rehabilitation do not fully address cognitive functions, therefore limiting understandings and best approaches to address TBI deficits. Additionally, clinical predictors for TBI are limited to expectations rather than addressing potential predictors that could be associated with TBIs (Zimmerman et. al., 2017). Rather settling for principles put in place to address functionality, issues that potentially compromise individual's overall health need to be better addressed.

For an athlete, the conjunction of both ‘hot’ and ‘cold’ EFs are crucial to being prosperous at any level of athleticism. The ability to use EF when it comes to decision making is pertinent. This is especially so when an athlete is reliant on their actions that are dependent on muscle memory. Muscle memory can be better understood as people performing an action without actively paying attention, much like reaction time after a certain period of time (Norman & Shallice, 1986).

For athletes, a majority of what they do can be attributed to this learned behavior that is naturally innate. Meaning that there does not have to be much deliberation behind their actions for them to put in effort to achieve a desired task such as playing defense, blocking a shot, or looking to score. According to Norman and Shallice this perpetuation of learned behavior can be attributed to the increase in dopamine within the body. This increase in dopamine then leads to the innate ability of recollection of associated schemas with the environment an individual is in that can be linked to our executive system when it comes to regulating attention (Norman & Shallice, 1986).

For innate actions to continue to be implemented EF cannot solely rely on subconscious knowledge, the ability to successfully mandate decisions is key (Norman & Shallice, 1986). This association must be made for supervisory attention to be able to take place. For an athlete who has been affected by a TBI, being able to properly execute supervisory attention can be challenging, and ultimately impedes on their performance (Norman & Shallice, 1986). This impediment on performance also inhibits an individual from being able to initiate delayed actions. These delayed actions such as processing of new information and regulating control of interference are needed for the initiation of effective problem-solving skills such as anticipation (Gioia & Isquith, 2004).

Issues of this magnitude continue to persist especially in younger athletes (Sim, Terryberry-Spohr, Wilson, 2008). Not being able to properly execute these functions in younger athletes can be linked to them not being fully developed enough to execute these processes in the form of a 'procedural system,' therefore inhibiting them. These limitations established in youth continue to have a long-lasting effect, despite an athlete's ability to adapt and function around such circumstances (Zappalà, 2008).

EF oversees attentional control, cognitive inhibition, inhibitory control, working memory, and cognitive flexibility (Jacobson & Matthaeus, 2014). As an athlete, any type of hindrance to these functions controlled by EF can stand between them and them being able to reach their next desired level athletically. This is especially so if proper measures are not taken into consideration during an athlete's rehabilitation.

Athletes post TBI are also more prone to experiencing issues with orientation as a result of a deficit impacting EF (Shah, Goldin, Conte, Goldfine, Mohamadpour, Fidali, Cicerone, Schiff, 2017). Predicaments related to orientation can hinder attention, stagnating their ability to notice cue-related actions resulting in inferior performance. Limitations of this nature have shown to have an impact on those with even the mildest form of a TBI (Shah et. al., 2017)

Athletes have also shown to be more likely to experience damages to their frontal lobes as a result of a traumatic brain injury (Talavage, Nauman, Breedlove, Yoruk, Dye, Morigaki, Feuer, and Leverenz, 2014). Deficits associated with orientation and attention have been linked to damages within the frontal lobe near the prefrontal cortex (Shah et. al., 2017). The damage that is generated from a TBI to the frontal lobe has proven to have a negative impact on working memory, resulting in reduced levels of activations within the prefrontal cortex (Talavage et. al., 2014).

With athletes being more susceptible to experiencing damage to their frontal lobe as a result of a TBI, especially at a younger age, issues can arise with inhibition (Beaumont, Théoret, Messier, Leclerc, Tremblay, Ellemberg, and Lassonde, 2009). TBI damage to the frontal lobe can cause interference with how an athlete is able to perceive an oncoming threat such as an opponent and hinder how they are able to focus while in their athletic environment, setting back their careers (Beaumont et. al., 2009). To further analyze impairments within EF for athletes, experimentation would need to focus on specific areas in which EF has been altered. This would need to be done by prioritizing and making the most advantageous decisions that are most beneficial to the athlete.

Temporal Occlusion

To achieve the design for a study focused on evaluating anticipation in athletes with a history of a TBI, the utilization of temporal occlusion as a tool will be needed. Temporal occlusion employs editing a film to focus on an event, in most cases sports related, by breaking it down into certain time phases to focus on a specific action (Causer, Smeeton, and Williams, 2017). Temporal occlusion also allows for the manipulation of an observed event (especially in athletics) so that the focus can be on certain visual information aspects. This allows for the pinpointing of an athlete's perceived knowledge of their respective athletic fields, which can then be tested in the form of isolated events that vary in difficulty (Smith, 2015).

Temporal occlusion is an effective tool used to assess the information needed to make effective anticipatory judgements when an athlete is in opposition of an opponent (Farrow, Abernethy, & Jackson, 2005). With visual identification being a critical component of anticipation for an athlete's success, a tool such as temporal occlusion will aid in further understanding the decrements post TBI (Loffing & Hagemann, 2014). Temporal occlusion has successfully been used as a tool to aid in training anticipation skill (Müller & Abernethy, 2014).

Athletes gage their anticipation by noticing visual information from an opponent's movement (Müller & Abernethy, 2014). EFs impairments from a TBI can inhibit effective anticipation. The incorporation of temporal occlusion serves as a useful aid to assess the skill level in which the intended audience should be at or aspires to be at. By using temporal occlusion, it will help to enforce the general aim of temporal occlusion, which is to see a positive progression in individuals progress over time. Meaning participants' results will get better towards the end of the experiment (Causer, 2017).

Temporal occlusion is utilized for pinpointing a certain time frame, allowing for associated cues within each event to be identified by the individual athlete. Therefore, the inclusion of this tool is beneficial by providing no additional prompts from outside sources to participants, other than any associated cues the participants have on their end. The use of temporal occlusion is also be beneficial as an aid in identifying what information is needed by breaking down a sports related event into steps that achieve the intended action, for example scoring a goal. This approach allows athletes to make decisions related to anticipation when it comes to isolated events within an athletic setting (Causer et. al., 2017).

As an athlete it is pertinent to be able to make decisions off pure instinct alone, while not allowing their instinct to negatively impact the overarching goal, winning. In the realm of soccer, a player being able to think ahead and anticipate their opponent's next move is crucial. For instance, as a Goalkeeper, or any defending position on the team, being able to predict the trajectory of your opponent's attempts to score is pertinent to maintaining your spot on the team and helping your team advance.

Temporal occlusion also aids in introducing the inclusion of environmental enrichment (EE; the stimulation of the brain in a familiar surrounding) within the experiment (Frasca, et. al, 2013). Environmental enrichment increases the brain's activity to enable participants to be more involved due to familiarity. This familiarity does not just appeal to participants, but also supply relevant context, in this instance a simulated soccer arena (Frasca et. al., 2013).

Research has shown that studies focused on TBIs that do not include various aspects of environmental enrichment have shown to not be useful aids in helping with the furthering of future research for TBI rehabilitation, causing a strain on reliability and validity (Frasca, et. al, 2013). In conjunction with the incorporation of environmental enrichment, studies have also shown that the incorporation of computerized cognitive interventions during the post-TBI stage showed improvements in participants' recovery (Bogdanova, Yee, Ho, and Cicerone, 2016). By simulating a familiar environment for participants within this study, results yielded will be able to be generalized and applicable to the real-world instances, in which an athlete would have to engage in anticipation.

The use of temporal occlusion and environmental enrichment serve as an instrumental aid in generating various stimuli that are associated with anticipation, also known as temporal anticipation. Temporal anticipation will be invoked through the combination of both temporal occlusion and environmental enrichment which serves as a positive feature to promote the perception of anticipated events within the task (Cravo, Rehenkohl, Santos, and Nobre, 2017).

Brixton Spatial Anticipation Test

The Brixton Spatial Anticipation Test (BSAT) assesses individual ability to detect and follow a rule by assessing one's ability to adjust and utilize their working memory once a new rule is implemented (Berg, Nys, Brands, Ruis, Zandvoort, Kessels, 2009). Typically, participants are presented with grids that consist of numbers that are continuous, in which rule has been implemented that goes both forward and back. The utilization of this test is reliant on inductive reasoning. The BSAT is a measure that assesses a person's ability to detect and follow a rule efficiently, which is an important aspect of EF (Berg et. al., 2009).

The inclusion of the BSAT would be in the form of a general anticipation assessment regardless of sporting expertise or environment. The incorporation of the BSAT would be used as a complementary tool to further assess EF. To do this a slight modification of the BSAT was made to make it relevant to soccer athletes in a more game like manner.

EF and self-regulation are heavily reliant on an individual's ability to elicit working memory, cognitive flexibility, and self-control (Diamond, 2013). Mental flexibility is reliant on being able to take in new information and adapt behavior accordingly. As a result of TBI the issue that arises even after a mild TBI is mental inflexibility causing individuals to ‘feel stuck’ (Pang, Dunkley, Doesburg, Costa, and Taylor, 2015). The feeling of being ‘stuck,’ better described as the inability to integrate new information to modulate individual behavior, further impeded on individual autonomy (Pang et. al., 2015). Issues with mental inflexibility can be linked to deficits in the prefrontal, frontal, and posterior cortical regions resulting in a lack of activation in these areas along with delayed reaction times. (Pang et. al., 2015).

Issues that persist post TBI have been clinically deemed ‘small, but clear’ (Pang et. al, 2015). To those affected, these ‘small, but clear’ issues impact their lives in a way in which clinically we are not able to yet quantify, especially regarding how daily life is changed. For those who have a history of TBI self-control is another EF controlled by the frontal lobe. With limitations in identifying these ‘small, but clear’ changes clinically, because of a TBI, the best way to quantify these changes is as a shifting in the order in which brain activation occurs. This shift is especially prevalent for mental flexibility tasks that require a change in rules or unexpected demands (Pang et. al., 2015).

A disruption caused by a TBI can have an impact on the process of self-control, thus limiting a person’s ability to make decisions about certain strategies. This is especially so in instances where a situation is commonly prone to change. Post TBI individuals tend to struggle with starting, adjusting, initiating, or confidence when it comes to their skills regarding self-control (Kennedy & Coelho, 2005). Impairments as a result of a TBI impact how self-control functions can cooperate with one another, impacting how individuals go about executing anticipation.

Brixton Spatial Anticipation Test is normally used in older adults, but with individuals who have a history of TBI being known to have some similarity to older individuals, as it relates to decrements within the brain function after the deficit of a TBI. The Brixton Tests is useful for an experiment of this nature because it is effective in instances where there is limited testing time and in instances where you are trying to monitor change over time, i.e. during the temporal occlusion task. This questionnaire will be used to assess their cognitive ability as it relates to anticipation. The aim of this task is to create a general standard amongst all participants regardless of TBI history.

Constructs of Executive Function

EF as previously mentioned can be broken down into four main categories: anticipation, planning, execution, and self-monitoring (Garcia-Madruga et. al., 2016; Luria, 1966). It is important to understand these components separately but understanding how they work together is essential. This is especially so when it comes to understanding the importance of EF especially for an athlete.

The previously mentioned four main categories assist in breaking down the overarching picture that is EF and highlight that one cannot fully function without the other. The aim of the intended study is to assess how each one of these four components are impacted based on soccer experience, previous history of TBI, and other pre-existing precursors that may account for differences in EF amongst participants. To properly assess this question appropriate measurements of each component must be put into place. By focusing on these four (anticipation, planning, execution, and self-monitoring) components in an experimental design a better understanding will be able to be made regarding where deficits persist in one's EF.

*** Numbering in () = the following four aforementioned factors are in rank order of importance

Anticipation's role in Pattern Detection and Athletic Cues (1)

Anticipation is the most important factor for measuring EF, within the design of this study. Perception of structured patterns and postural cues are pivotal factors to anticipation, especially within athletes (North, Hope, and Williams, 2016). Anticipation aids in measuring one's ability to act on predictions or expectations in preparation of pre-learned schemas. Deficits as a result of a TBI have shown to inhibit individuals' ability to effectively recognize perceived patterns that may have been once recognizable pre-injury (Leunissen, Coxon, Geurts, Caeyenberghs, Michiels, Sunaert, & Swinnen, 2013).

Additionally, adolescent brains that have experienced or have a history of TBI, have shown to be more prone to exhibit issues when it comes to executing anticipation. Anticipation is often associated with assessment of reward or penalty for future consequences. With adolescents being predisposed to being more likely to have damage to the prefrontal cortex because of a TBI proper functioning of the prefrontal cortex cannot be guaranteed.

In a study conducted by Cook et. al., TBI adolescents were tasked with predicting social actions and consequences in a virtual environment in which there were both legal and moral repercussions (Cook, Hanten, Orsten, Chapman, Li, Wilde, Schnelle, and Levin, 2013). Adolescents with TBIs were unable to elicit anticipation when it comes to actions that are reliant on proper decision making (Cook et. al., 2013). Meaning TBI adolescents were unable to properly identify the long-term consequences of the avatar's actions. The observed difference appeared to correlate to notable differences in prefrontal cortex thickness between typically developing adolescents and TBI adolescents. (Cook et. al., 2013).

Working Memory's role in Planning (2)

Working memory allows us to gather new information, temporarily maintain that information, and eventually turn around and apply it to relevant schemas (Dehn, 2011). The functionality of working memory similar to how we go about anticipation. In contrast to anticipation, working memory enables us to hold onto necessary information on an active basis. After the initial preparation that is initiated by anticipation, the information can then be utilized and applied to a perceived future goal. Therefore, making working memory a monumental aid that help us plan.

When confronted with a TBI individuals have shown to have long lasting complications that result in deficits in information maintenance that become increasingly more noticeable when there has been a lapse from onset of TBI (Dunning, Westgate, and Adlam, 2016). This ultimately ends up affecting not only our working memory but our ability to plan accordingly especially in high stakes environments, such as athletics, where there is more at risk, for example repeat injury.

Cognitive Flexibility role in Execution (3)

Cognitive flexibility allows for someone to be able to actively switch between two or more working concepts at the same time (Leunissen et. al., 2013). Cognitive flexibility is fundamental to being able to enact cognitive control, but when a TBI has occurred proper execution of cognitive flexibility cannot occur correctly. Individuals with a history of TBI have been prone to have an inability to effectively complete tasks that require them to switch their attention (Leunissen et. al., 2013).

Cognitively when TBI individuals have been tasked with switching their attention they have shown to not be able to have limited control their actions impeding their ability to execute the intended task (Leunissen et. al., 2013). This deviation is especially so when TBI individuals are in comparison to those without cognitive decrements (Leunissen et. al., 2013). This inability to pick up on patterns especially in instances that require attention to switch can be damaging to an athlete's ability to function at full capacity, especially if proper treatment is not taken.

Attentional Control role in Self-Monitoring (4)

Attentional control allows for a person to choose what they do and do not pay attention to (Ríos, Periáñez, and Muñoz-Céspedes, 2004). Attentional control is hard to isolate in terms of what it is directly linked to. Literature has also not been able to assess just yet how damaging it is to EF that is directly impaired by a TBI. What has been noted across the board is that in incidents that require some sort of time pressure placed upon people, result in individuals with a history of TBI showing an impediments placed on their processing speed, due to a feeling of lack of control (Ríos et. al, 2004). The concept of attentional control can also be referred to as the ability to concentrate. When impacted by a TBI, attentional control not only impacts what one is able to pay attention to but the processing speed of the information that is being taken in (Ríos et. al., 2004).

Study Design Rationale

The aim behind the design of this experiment is to look at an individual's EF, with the focus being on how a traumatic brain injury can potentially have negative impacts on an athlete's ability to elicit the action of anticipation within an experimental. The focus for the proposed experiment is to look at the decrements that occur once an athletic individual has had a traumatic brain injury vs. that of individuals who have not. Additionally, the goal is to assess how this decrement alters an individual's ability to facilitate executive control regarding anticipation.

For athletes, perception is crucial to being able to effectively execute action as well as other EFs (Bagatin, Padilha, Milheiro, Rodrigues, Tavares, Casanova, 2017). Therefore, the focus is to examine soccer players both with and without a history of TBI in an attempt to establish a basis for potential differences in their levels of EF.

The aim was then to see if they are capable of effectively using EF to make correct and urgent decisions. These decisions were presented to participants in the form of them being in opposition of potential opponents in a familiar field (soccer arena) that requires correct use of anticipation using temporal occlusion. Leading up to the implementation of temporal occlusion assessments, the four pillars of EF, anticipation (pattern detection and athletic cues), planning (working memory), execution (cognitive flexibility), and self-monitoring (attentional control), were used to assess potential differences that may exist.

The premise for incorporating these four components of EF is to mitigate the generalizations associated with the overall diagnosis of TBI. By doing so the aim of this experimental design was to further assess how individuals with a TBI have been negatively affected by their history of TBI when it comes to eliciting EF, and more specifically action anticipation skills.

The Norman-Shallice Model shows a representation of what is known as executive control or function. The model is reliant upon the process of potential schemas being triggered by our perceptual systems (Wickens & McCarley, 2008). But these schemas cannot be successfully activated if there is no or a lack there of an innate trigger within our EF's supervisory attention ((Niki, Kumada, Maruyama, Tamura, and Muragaki, 2019; Wickens & McCarley, 2008).

By incorporating temporal occlusion within the experimental design, damage to the frontal lobe via TBI will be able to be further assessed. Temporal occlusion will prove to be useful by breaking down what should be a simple innate schema driven task for a soccer player into at least three sequential steps. By breaking down the anticipation of an opponent getting ready to score, a further assessment of this anticipation associated with the schema can take place; thus, enabling the task to be broken down gradually and decrements will be assessed in a sequential manner.

For a soccer player being able to know how to stop an opponent from scoring can be referred to as a goal-driven schema (Wickens & McCarley, 2008). By breaking down the tasks associated with blocking an opponent, activation will be able to be gauged in terms of it being effectively started and completed. If the participant can complete the simulation successfully for each temporal occlusion task, then a proper implementation of executive control will be noted; but if not, a potential disconnect in executive control will be seen by the lack of a 'trigger' in the relevant tasks (Wickens & McCarley, 2008).

Experimental Design

Aim. To assess potential EF differences that may exist, specifically decrements related to anticipation, amongst soccer players both with and without a history of traumatic brain injury. By analyzing EF as four separate facets, anticipation, planning (working memory), execution (cognitive flexibility) and self-monitoring (attentional control), areas of potential decrements will be able to be identified, specifically focused on anticipation amongst athletes with a soccer background. Additionally, this study will allow for the identification of contributing factors both preexisting (age and gender) and acquired (TBI history, years of experience, and level of soccer experience) that may increase individuals risks for EF decrements.

Methods

Participants

Table 1. Participant variables

Independent Variable	**Participants**	
TBI History	TBI History	**18**: > 1 year, but< 3 years ago: **7** > 3 years ago: **11**
	No TBI	**39**: Unsure at end of study: **4**
Gender	Female: **17** Male: **40**	
Age	18 – 20: **26** 21 – 23: **13** 24 – 26: **6** 27 – 29: **9** 30+: **3**	
Soccer Athletic Level	High School: **15** Collegiate: **37** Semi-Professional: **5**	
Years of Experience	1 – 9 years: **13** 10+ years: **44**	

The study consisted of 57 participants who have an athletic background as soccer (fútbol) players. All participants were 18 years or older. Participants were recruited via emails sent to collegiate coaches initially, social media posts, and word of mouth from initial email correspondence/posts. Participant sign-ups were done through Calendly, a Google Chrome extension. Participants' athletic background fell into one of three prime athletic levels (high school, collegiate, semi-pro/professional).

Equipment

In light of COVID-19, the study was conducted remotely via Zoom with the assistance of Qualtrics and Google slide links. To participate in this study participants needed a working and up to date computer and have access to WIFI. Participants completed the study while sharing their screen with the experimenter during the duration of the study (approximately 30 minutes).

All questionnaires and anticipation assessments were completed within Qualtrics. Additionally, working memory and cognitive flexibility assessments were administered through a link to google slides. Throughout the study, participants continued to share their screen with the experimenter, and their responses were recorded through the recording function via Zoom.

Figure 1. Temporal occlusion environment.

To complete the temporal occlusion tasks, participants were presented with a view that mimics that of a right defender (the person to the right of the goalie who aids in helping the goalkeeper defend the goal). The simulation was composed using a previously recorded FIFA (Fédération Internationale de Football Association) 18 Xbox 360 game. All videos garnered through FIFA were displayed on the screen via Qualtrics.

Measures

Participants were asked to complete various questionnaires and tasks throughout this study. All tasks had training sessions associated with them that were administered prior to the task. Participants' responses were recorded via Zoom and Qualtrics:

Demographic information

The demographics questionnaire consisted of nine questions. Questions covered participant's age, gender, athletic experience, and duration of experience. Participants responded to six questions via multiple choice options, and three questions were open ended. Participants were then grouped based on their responses to the demographic questionnaire; history of TBI, gender, years of experience, and soccer athletic level.

Brief Medical History

All participants were asked three questions that briefly covered their medical history as it relates to their experience with traumatic brain injury. Questions were not invasive in nature and strictly focused on whether they have had a TBI (concussion).

Executive Function Assessments

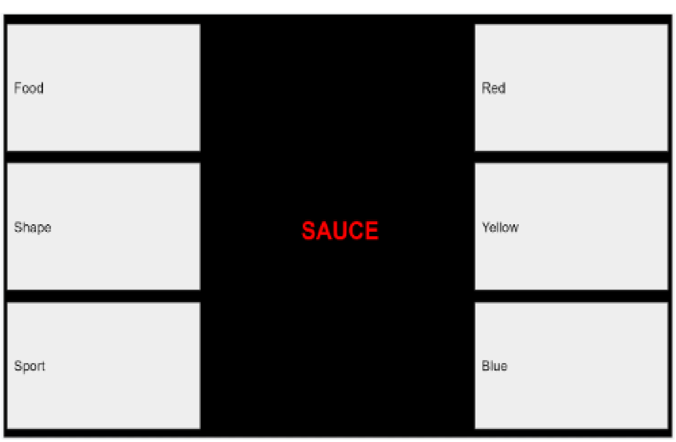


Figure 2. Cognitive flexibility task.

Prior to the temporal occlusion task, participants each completed four EF related assessments. To garner a better understanding of potential decrements amongst soccer players regarding EF deficits, the multifaceted umbrella that is EFs needs to be assessed as individual components in order to achieve a potential individualized approach to treatment of TBIs within this special population. In order to achieve this EF was assessed through four pillars, planning (working memory), execution (cognitive flexibility), self-monitoring (attentional control), and anticipation (pattern detection and athletic cues). Table 1 details the components, features, and interface delivery of each of the four pillars used to distribute assessments:

Table 2. Executive function assessments.

Assessment	**Interface**	**Task**
Working Memory (Planning)	Google Slides	***Picture matching:*** Consisted of various shapes and images that participants needed to find all the matching pairs (4 x 5 table, ten pairs.). Participants had two minutes to complete the task; time constraint was not shared with participants, instead participants were informed to keep going until instructed to stop. *Training:* Covered what is expected of participants through a 2 x 3 table, three pairs) *Dependent Variable:* The amount of correct picture pairs participants matched was tracked. Participant scores were out of ten, scores were converted to a decimal.
Attentional Control (Self-monitoring)	Qualtrics	***Questionnaire:*** Questionnaire assessed how participants believe they are capable of focusing their attention willingly (Abasi, 2017). Reliant on self-report, consisted of five questions from Abasi's 2017 validated 20-item Exploratory Factor Analysis of the attentional control scale (see Appendix C). *Dependent Variable:* Participants responded using a seven-point Likert scale ranging from strongly disagree to strongly agree.
Cognitive Flexibility (Execution)	Google Slides	***Task switching:*** Two tasks; 11 words, 11 objects (see *Figure 2*) ● *First task:* participants presented with a word in the center of the screen;, based on the text color participants are instructed to select the color of the text on the right ● *Second task:* participants presented with an object in the center of the screen, based on the object participants are instructed to select the best category on the left *Training:* Two samples of actual task; one word, one object

		Dependent Variable: Correct selection of category for the two associated tasks was tracked. Participants scores were out of 22, scores were converted to a decimal.
Anticipation: Pattern Detection	Qualtrics	***Brixton Spatial Anticipation Test (BSAT):*** Participants were presented with a continuous grid that consists of a scale of one to ten, a soccer ball was be present in one of the ten locations. *Participants responsible for:* Detecting the pattern of the soccer ball. The soccer ball jumped spaces both forward and back. Participants only went off their knowledge from the grids shown in each block. Participants chose their answer from a multiple-choice format, from one of six possible answers. Each block had a different pattern ● Training: five grids, pattern: forward two, back one ● Block 1 (*higher difficulty*): 11 grids, pattern: forward three, back five (refer to *Figure 3*) ● Block 2 (*lower difficulty*): 11 grids, pattern: back one, forward three *Training:* Tutorial video; five grids *Dependent Variable:* Correct detection of intended patterns were tracked in each block. Each block score was taken out of 11, and then converted to a decimal. From there the average of both blocks (in decimal form) was also recorded.

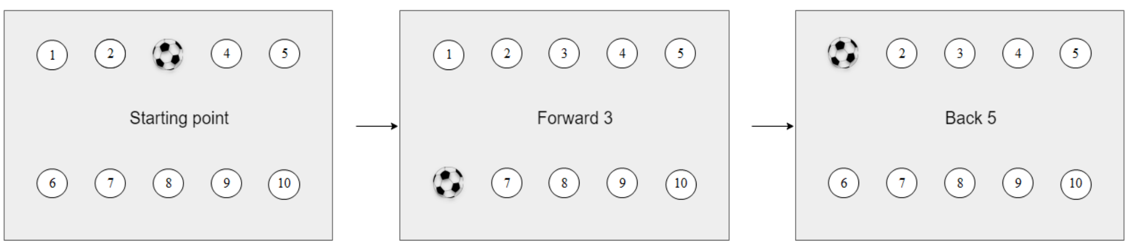


Figure 3. Brixton spatial anticipation test (BSAT); Pattern: forward three, back five.

Temporal Occlusion Task (Athletic Cues)

All participants were informed to allow the video to play out completely before selecting their answer, participants were also monitored via Zoom. Video prompts were displayed separately, and participants were forced to respond before moving on. Participants were not informed if their responses were correct or incorrect, but instead after selecting their answer they were instructed to proceed to the next prompt. Each video sequence consisted of at most three possible tasks. The amount of times participants replayed temporal occlusion video tasks before selecting an answer was noted as well.

Tasks and Decision Making. Participants were responsible for making decisions related to temporal occlusion videos. A total of ten videos, broken into three tasks, resulting in 30 clips. Participants had control over playing each video. Prior to participants being able to select their answer for each task, the video being played went black at the conclusion of each clip.

Participants were then instructed to 'please answer below', from a multiple-choice format that was displayed below the video. Participants repeated this process for a total of ten times. All participants completed this task from the point of view of an onlooker observing the 'opposing team' who is getting ready to come up and score on the goalkeeper:

Table 3. Temporal occlusion tasks.

T.O. Task	**Role in Anticipation**	**Purpose**	**Implementation**
Task 1	Postural cues	Assess ability to initiate judgement	***Participants responsible for:*** decided if the goalie would have needed help or not (Does the goalie need help?) ***Multiple choice options;*** yes, no, or unsure.
Task 2	Cue detection	Assess ability to implement perception	***Participants responsible for:*** decided which direction they believed the soccer ball went within the net (What direction do you think the ball will go in the net?) ***Multiple choice options;*** left, right, center, or unsure.
Task 3	Cue utilization	Assess ability to perceive an oncoming action	***Participants responsible for:*** decided outcome of the ball if the ball was a miss, goal, block, or unsure (Will the ball be a miss, goal, or block?)

Multiple choice options; miss, goal, block, or unsure

******Dependent Variable:*** Correct responses were tracked. Participant scores were out of 10 for each individual task, and then converted to a decimal. Individual task score was added to the overall score, which was out of 30, and then converted to a decimal.

Data Analysis

Participants were grouped based on four independent variables: TBI history, years of soccer experience, gender, and overall soccer athletic level. Participants were not grouped based on age, due to the fact that although there was a variance in soccer experience, the majority of participants were relatively close in age. On the demographic questionnaire years of soccer experience originally was classified into three categories: one to four years, five to nine years, and ten plus years. After data collection participant responses for one to four years and five to nine years were grouped and classified as one to nine years collectively due to smaller sample sizes. This resulted in years of soccer experience being classified into two categories for data analysis (one to nine years of experience, and ten plus years of experience).

Grouping of participants based on TBI history, was reliant on participant self-report to a brief medical history questionnaire. At the conclusion of the study four participants (7 percent) reported being unsure of previous TBI history, after previously reporting no TBI history. To reduce misrepresentation of participant sample, participants were kept in TBI group based on what they reported on the brief medical history questionnaire. Additionally, participants were grouped based on self-report responses to the demographic questionnaire and grouped as either male or female. Soccer athletic level was also classified through participant self-report based on three categories: high school, collegiate, and semi-professional.

Years of soccer experience was used to analyze participants responses to the attentional control questionnaire, through a Multivariate Analysis of Variance (MANOVA). Participants answered the attentional control questionnaire using a Likert scale (strongly disagree – strongly agree; 1-7). Participant variables, TBI history, gender, and soccer athletic level was used to further assess differences in participants scores regarding EF assessments (working memory, cognitive flexibility, and athletic and non-athletic anticipation) through a multiple regression.

Results

Attentional Control Results

The attentional control assessment delivered to participants in the form of a questionnaire was reliant on self-report from participants (Abasi, 2017). Within the five questions from the questionnaire, two yielded statistical significance in relation to years of soccer experience. Soccer experience was classified by two categories one to nine years, and ten plus years.

The MANOVA revealed that there was a significant effect of years of soccer experience on two out of five attentional control questions (alternating between two task; easily distracted while reading or studying if other people are talking in same room); $F(2,54) = 3.755$, Wilks $\lambda = 0.878$, $p = 0.030$.

Figure 4. Two tasks: Soccer experience means of attentional control questionnaire.

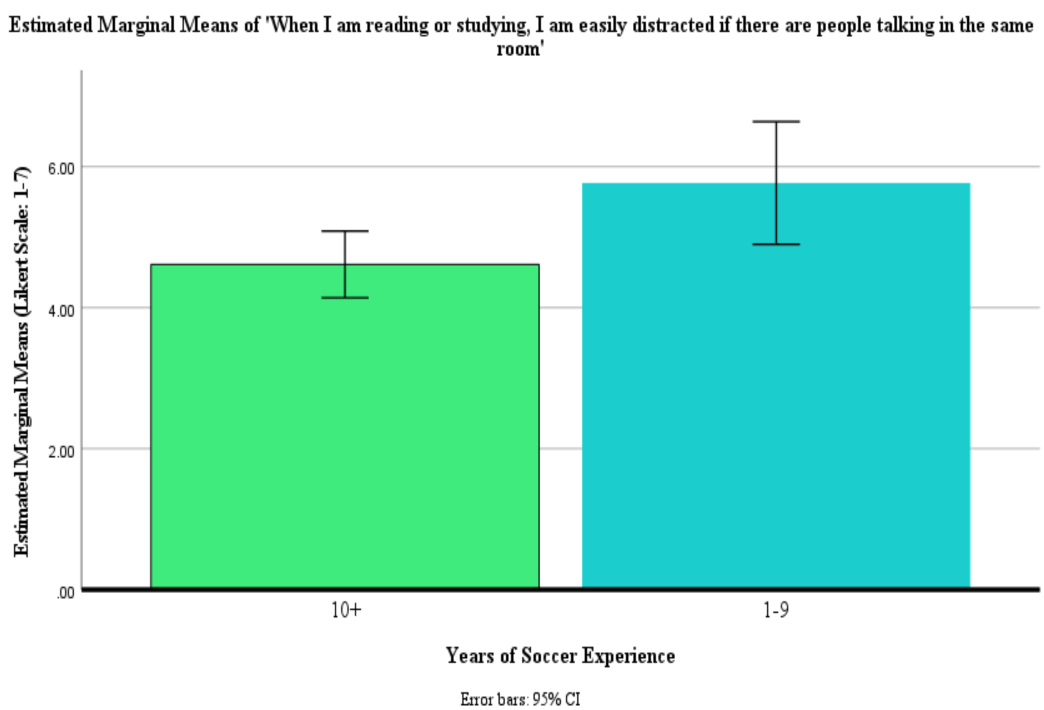


Figure 5. Distractions: Soccer experience means of attentional control questionnaire.

Anticipation

Both EF anticipation assessments (pattern detection and athletic cues) yielded significance. Four multiple linear regressions were used to predict participant's second BSAT score, BSAT Average, Overall Temporal Occlusion score, and Temporal Occlusion Task One based on TBI history, gender, and soccer athletic level.

BSAT. The linear regression analysis performed on the second BSAT scores indicated that one predictor explained 9.3% of the variance ($R^2 = 0.120$, $F(2,53) = 2.406$, $p = 0.078$). The significant predictor was soccer athletic level ($\beta = -0.126$, $p = 0.045$).

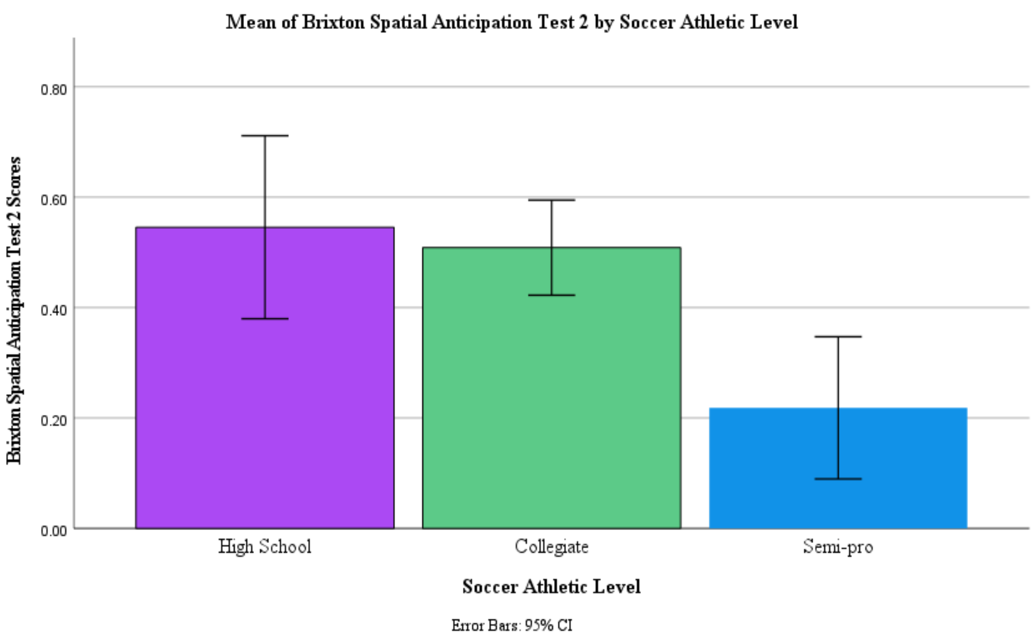


Figure 6. Brixton spatial anticipation test 2 group means.

Table 4. Overall data: Brixton spatial anticipation test 2 score.

Assessment	Variable	Coefficient	Std. Error	t-Statistic	Significance
BSAT 2	Soccer Athletic Level	-0.126	0.061	-2.056	0.045

The linear regression analysis performed on the BSAT Average scores indicated that one predictor explained 8.9% of the variance ($R^2 = 0.093$, $F (2, 53) = 1.805$, $p = 0.157$). The significant predictor was soccer athletic level ($\beta = -0.09$, $p = 0.034$).

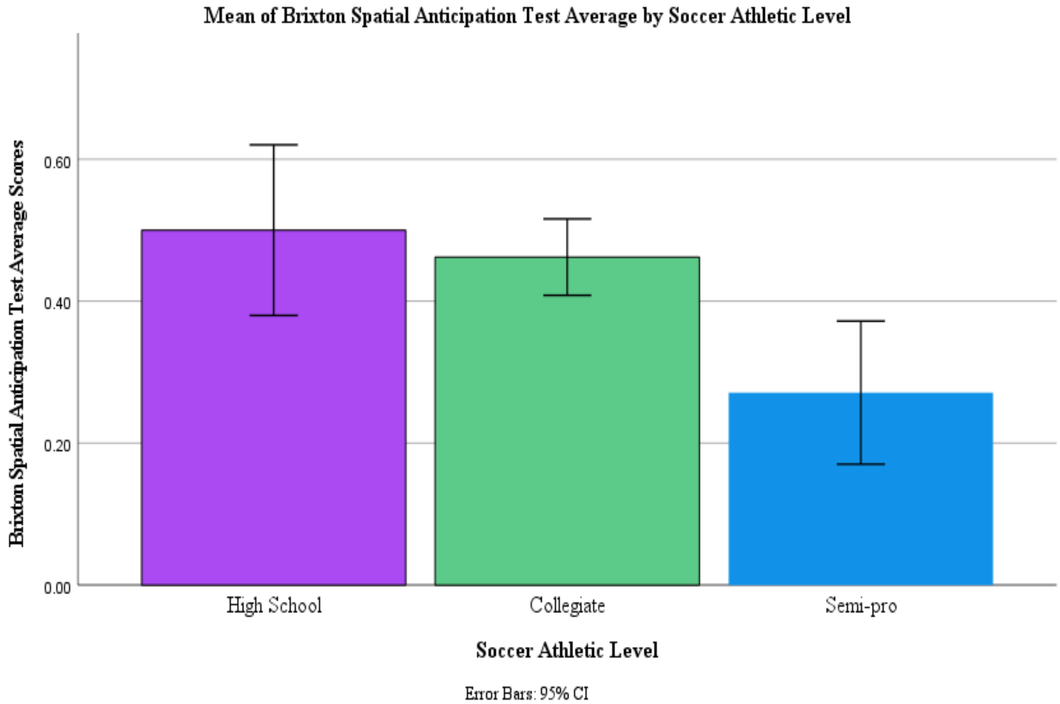


Figure 7. Brixton spatial anticipation test average group means

Table 5. Overall data: Brixton spatial anticipation test average score.

Assessment	Variable	Coefficient	Std. Error	t-Statistic	Significance
BSAT Average	Soccer Athletic Level	-0.090	0.042	-2.175	0.034

Temporal Occlusion. The linear regression analysis performed on the Temporal Occlusion Overall scores indicated that one predictor explained 10.8% of the variance ($R^2 = 0.135$, $F (2,53) = 2.746$, $p = 0.052$). The significant predictor was gender ($\beta = -0.078$, $p = 0.017$).

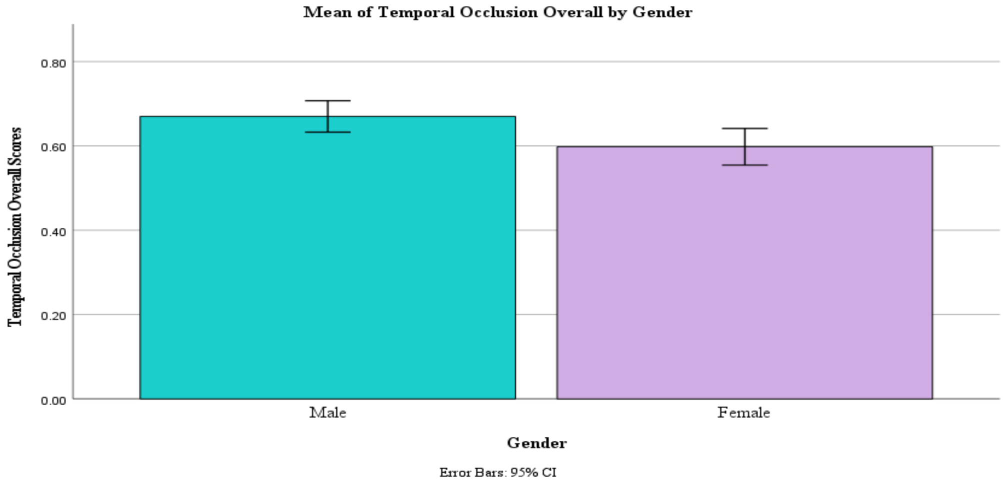


Figure 8. Temporal occlusion overall gender means.

Table 6. Overall data: Overall temporal occlusion score.

Assessment	Variable	Coefficient	Std. Error	t-Statistic	Significance
TO Overall	Gender	-0.078	0.032	-2.456	0.017

The linear regression analysis performed on the Temporal Occlusion Task One scores indicated that one predictor explained 8% of the variance ($R^2 = 0.081$, $F(2,53) = 1.554$, $p = 0.211$). The significant predictor was gender ($\beta = -0.097$, $p = 0.051$).

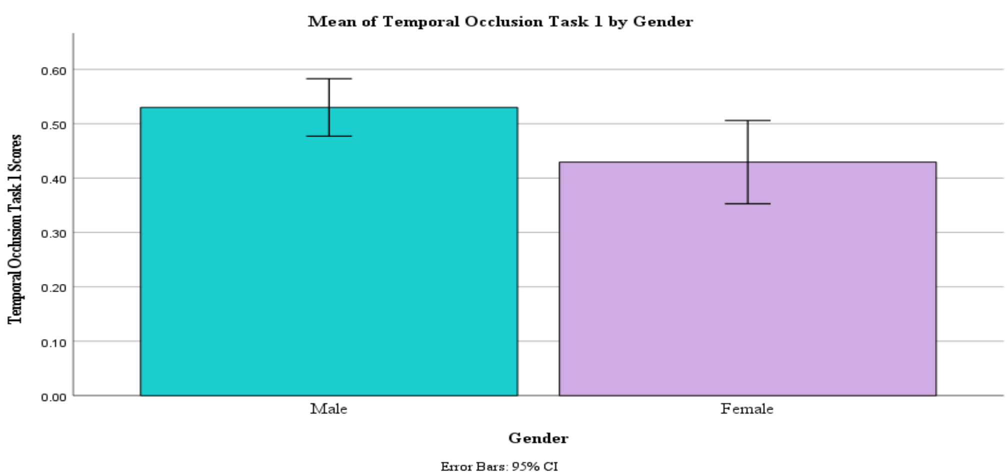


Figure 9. Temporal occlusion task 1 gender means.

Table 7. Overall data: Temporal occlusion task 1 score.

Assessment	Variable	Coefficient	Std. Error	t-Statistic	Significance
TO Task 1	Gender	-0.097	0.049	-1.996	0.051

Discussion

For proper anticipation to be initiated, especially within a team sport, appropriate pattern recognition and postural cues must be able to be attained (North et. al., 2016). The results from this study highlight that when history of TBI, gender, and level of soccer experience were factors, soccer players with higher levels of soccer experience (collegiate and semi-professional) and female athletes were at a disadvantage for completing anticipation-based tasks that require the utilization of pattern detection and athletic cues.

Higher soccer levels faced issues with detecting simple patterns in comparison to their counterparts with lower levels (high school) of soccer experience. Demonstrating that the more soccer one plays the more likely they are to be exposed to anticipatory executive function decrements as a result of increased exposure to possible TBIs. Participants who competed at both the collegiate and semi-professional level exhibited that in comparison to their novice counterparts (high school) the initiation of pattern recognition was ascertained at lower rates, specifically for the BSAT 2 block scores when TBI history, gender, and soccer athletic level were potential contributing factors. Additionally, the overall average score of both the BSAT 1 and BSAT 2 blocks were less in comparison.

Exposure to competing at higher levels within the realm of soccer illustrated that expert individuals' EF has been stagnated in terms of regulating anticipation. Higher soccer athletic levels showed deficits in self-correction and making judgements, suggesting prefrontal cortex impairments amongst younger athletes. Additionally, expert participants showed limited ability to effectively plan in terms of pattern recognition. This decline potentially could be linked to ongoing neuronal injuries that are associated with TBIs (Arlusamy et. al., 2019).

The older an athlete gets the more likely they are to be at risk of acquiring a TBI, have more issues related to EF, and experience drawbacks related to recovering from a TBI altogether (Beaumont et. al., 2009). It is also important to note that even though an athlete may be younger when initial acquisition of a TBI occurs, although their recovery time may be quicker than their older counterparts, developmental impacts are more likely to occur (Beaumont et. al., 2009).

In addition to problems that persist with age, frontal lobe injuries heighten athletes' chances of further decrements months after initial injury (Arlusamy et. al, 2019). Outside of an athletic arena anticipation can be deemed as one of our most important survival skills (Petrovich, 2018). Decrements to anticipation due to associated risks from exposure to TBIs linked to higher soccer athletic levels, not only impeded individuals athletically, but impede individual autonomy, compromising quality of life.

It is expected that expert soccer players, with 10 years of experience or more, would be able to quickly perceive structured patterns within a familiar environment. Through the initiation of perceived schemas early on in a competitive environment this action can take place (North et. al., 2016). By triggering anticipation, the intake of perceived future events allows for the assessment of potential consequences. In the arena of soccer, initiation of pattern recognition is at its most pivotal when the individual is far away from the ball (North et. al., 2016).

The principal purpose of Task 1 of the temporal occlusion assessment was to assess individual ability to initiate anticipatory judgement appropriately. For female soccer players there were apparent decrements regarding anticipation that limited female soccer players from being able to properly complete the associated task at an effective rate. Additionally, female soccer players overall temporal occlusion score was at a lower rate in comparison to male soccer players.

These gender differences may be attributed to female athletes being at higher risk for acquiring a TBI or TBI-like injuries (Sollmann et. al., 2017). Furthermore, female athletes in comparison to males have been known to have worse outcomes post TBI and typically experience more post concussive and sever symptoms in comparison (Sollmann et. al., 2017). Female brains have also shown to be more vulnerable to being affected by repetitive sub-concussive head impacts (Sollmann et. al. 2017). Meaning that although female athletes may not be directly diagnosed or impacted with a concussion or TBI resulting in immediate symptoms, female brains have shown to be more susceptible to acquiring damages as a result of repeat impact to the head in the form of repetitive bumps or jolts that do not result in symptoms immediately (Sollmann et. al. 2017). Ultimately resulting in repeat exposure without proper time to heal.

Future Studies

Subsequently to build upon this study, temporal occlusion as well as other technological initiatives need to be implemented as standardized testing given to athletes prior to the start of their season. Results garnered from said 'standardized testing' then should be recorded to set benchmark criteria that in the event an athlete acquires a TBI, their results would be cross referenced to their pre-TBI results. This would then establish a merit to decipher when an athlete can return to practice.

Limitations

Subject pool limitations

Most participants ages ranged from 18 to 23. With brains not being fully developed especially male brains, the impact of a TBI may have even more of an impact than on older individuals (Frasca et. al., 2013). Additionally with a majority of the sample population being younger individuals, impacts of TBI on older individuals with a soccer background were not able to be properly assessed, especially with implications that suggest the older you are the harder it is to recover post-TBI (Niki, 2019).

Assessment limitations

Moreover, there were limitations associated with assessments utilized in this study. The lack of statistical significance could possibly be attributed the lower level of difficulty associated with the working memory and cognitive flexibility assessments. The inclusion of these two assessments was to enhance the approach of assessing EF as four distinct pillars: anticipation, planning, execution, and self-monitoring.

Additionally, questionnaires such as attentional control and the brief medical history questionnaire were reliant on self-report. With a majority (56 percent) of participants still actively competing at a collegiate or semi-professional level there is an expect inherent hesitance with divulging this type of information, especially where there is a lot at stake for athletes, despite this study being confidential.

Conclusion

It is evident that TBIs have a substantial impact on the ability to enact EF in terms of anticipation. Within the realm of athletics and traumatic brain injuries there is still a substantial amount of information that we do not know. The impact of TBIs alter an individual's ability to not only anticipate, but hinders judgement, perception, as well as other key factors associated with EF.

As a result of decrements within anticipation, cue utilization and detection not only hinder an athlete on the field, but impact individual autonomy on an everyday basis, impeding on survival skills and subjective control (Gucklesberger & Plani, 2014). Based on perceived limitations to anticipation amongst soccer players, the enigma that is EF has proven to be multifaceted. Therefore, TBI rehabilitation needs to incorporate an individualized EF approach with customized solutions. In addition to technological innovation, athletic assessments should not be limited to testing skill level and athletic excellence, but instead need to serve as an aid in assessing, correctly diagnosing, and rehabilitating individuals post-TBI.

References

Abasi, I., Mohammadkhani, P., Pourshahbaz, A., & Dolatshahi, B. (2017). The Psychometric Properties of Attentional Control Scale and Its Relationship with Symptoms of Anxiety and Depression: A Study on Iranian Population. *Iranian Journal of Psychiatry*, *12*(2), 109-117.

Arulsamy, A., Corrigan, F., & Collins-Praino, L. E. (2019). Age, but not severity of injury, mediates decline in executive function: Validation of the rodent touchscreen paradigm for preclinical models of traumatic brain injury. Behavioural Brain Research, 368, 111912.

Alexander, D. G., Shuttleworth-Edwards, A. B., Kidd, M., & Malcolm, C. M. (2015). Mild traumatic brain injuries in early adolescent rugby players: Long-term neurocognitive and academic outcomes. *Brain Injury, 29*(9), 1113-1125.

Bagatin, R., Padilha, M., Milheiro, A., Rodrigues, G., Tavares, F., & Casanova, F. (2017). Perception and action in soccer: Performance comparison under different perceived effort intensities in Small-Sided and Conditioned Games. Revista Portuguesa De Ciências Do Desporto, 2017(S1A), 367–374.

Beaumont, L. D., Theoret, H., Mongeon, D., Messier, J., Leclerc, S., Tremblay, S., . . . Lassonde, M. (2009). Brain function decline in healthy retired athletes who sustained their last sports concussion in early adulthood. *Brain, 132*(3), 695-708.

Berg, E. V., Nys, G. M., Brands, A. M., Ruis, C., Zandvoort, M. J., & Kessels, R. P. (2009). The Brixton Spatial Anticipation Test as a test for executive function: Validity in patient groups and norms for older adults. Journal of the International Neuropsychological Society, 15(5), 695-703.

Bogdanova, Y., Yee, M. K., Ho, V. T., & Cicerone, K. D. (2016). Computerized Cognitive Rehabilitation of Attention and Executive Function in Acquired Brain Injury. Journal of Head Trauma Rehabilitation, 31(6), 419-433.

Botezatu, C., Andrei, C., & Hillerin, P. J. (2014). Neuromuscular Aspects of Anticipation in Preparing the Body for the Contact Structure in Motrice Performance. *Sport Science Review*, *23*(1-2), 1-22.

Causer, J., Smeeton, N. J., & Williams, A. M. (2017). Expertise differences in anticipatory judgements during a temporally and spatially occluded task. Plos One, 12(2)

Chen, J., Johnston, K., Frey, S., Petrides, M., Worsley, K., & Ptito, A. (2004). Functional abnormalities in symptomatic concussed athletes: An fMRI study. NeuroImage, 22(1), 68-82.

Chen, J., Johnston, K. M., Petrides, M., & Ptito, A. (2008). Neural Substrates of Symptoms of Depression Following Concussion in Male Athletes With Persisting Postconcussion Symptoms. Archives of General Psychiatry, 65(1), 81.

Cook, L. G., Hanten, G., Orsten, K. D., Chapman, S. B., Li, X., Wilde, E. A., . . . Levin, H. S. (2013). Effects of Moderate to Severe Traumatic Brain Injury on Anticipating Consequences of Actions in Adolescents: A Preliminary Study. *Journal of the International Neuropsychological Society, 19*(5), 508-517.

Cravo, A. M., Rohenkohl, G., Santos, K. M., & Nobre, A. C. (2016). Temporal anticipation based on memory.

Daneshvar, D. H., Riley, D. O., Nowinski, C. J., Mckee, A. C., Stern, R. A., & Cantu, R. C. (2011). Long-Term Consequences: Effects on Normal Development Profile After Concussion. Physical Medicine and Rehabilitation Clinics of North America, 22(4), 683-700.

Dawson, P., & Guare, R. (15, August 13). Executive Skills Questionnaire. Retrieved June 21, 2020, from https://www.ocali.org/up_archive_doc/EF_QUESTIONAIRRES-8-13-15.pdf

Dehn, M. J. (2011). *Working Memory and Academic Learning: Assessment and Intervention*. Hoboken: John Wiley & Sons.

Dennis, J. P., & Wal, J. S. (2009). The Cognitive Flexibility Inventory: Instrument Development and Estimates of Reliability and Validity. *Cognitive Therapy and Research, 34*(3), 241-253.

Diamond, A. (2013). Executive Functions. *The Annual Review of Psychology, 64*, 135-168.

Dunning, D. L., Westgate, B., & Adlam, A. R. (2016). A meta-analysis of working memory impairments in survivors of moderate-to-severe traumatic brain injury. *Neuropsychology, 30*(7), 811-819.

Farrow, D., Abernethy, B., & Jackson, R. C. (2005). Probing Expert Anticipation with the Temporal Occlusion Paradigm: Experimental Investigations of Some Methodological Issues. Motor Control, 9(3), 330-349.

Frasca, D., Tomaszczyk, J., Mcfadyen, B.J., & Green, R. E. (2013). Traumatic brain injury and post-acute decline: What role does environmental enrichment play? A scoping review. Frontiers in Human Neuroscience, 7.

Garcia-Madruga, J. A., Gómez-Veiga, I., & Vila, J. Ó. (2016). Executive Functions and the Improvement of Thinking Abilities: The Intervention in Reading Comprehension. *Front Psychology*, *7*(58).

Gioia, G., & Isquith, P. (2004). Ecological Assessment of Executive Function in Traumatic Brain Injury. Developmental Neuropsychology, 25(1), 135-158.

Guckelsberger, C., & Polani, D. (2014). Effects of Anticipation in Individually Motivated Behaviour on Survival and Control in a Multi-Agent Scenario with Resource Constraints. *Entropy, 16*(6), 3357-3378.

Jacobson, J., & Matthaeus, L. (2014). Athletics and executive functioning: How athletic participation and sport type correlate with cognitive performance. Psychology of Sport and Exercise, 15(5), 521–527.

Kennedy, M. R., & Coelho, C. (2005). Self-Regulation after Traumatic Brain Injury: A Framework for Intervention of Memory and Problem Solving. Seminars in Speech and Language, 26(04), 242-255.

Kuan, Y. M., Zuhairi, N. A., Manan, F. A., Knight, V. F., & Omar, R. (2018). Visual reaction time and visual anticipation time between athletes and non-athletes. Malaysian Journal of Public Health Medicine, 1, 135-141.

Leunissen, I., Coxon, J. P., Geurts, M., Caeyenberghs, K., Michiels, K., Sunaert, S., & Swinnen, S. P. (2012). Disturbed cortico-subcortical interactions during motor task switching in traumatic brain injury. *Human Brain Mapping, 34*(6), 1254-1271.

Loffing, F., & Hagemann, N. (2014). Skill differences in visual anticipation of type of throw in team-handball penalties. Psychology of Sport and Exercise, 15(3), 260-267.

Luria, A. R. (1966). *Human Brain and Psychological Processes*. New York, NY: Harper and Row

McKee, A. C., & Robinson, M. E. (2014). Military-related traumatic brain injury and neurodegeneration. *Alzheimer's & Dementia, 10*.

Miller, E., & Wallis, J. (2009). Executive Function and Higher-Order Cognition: Definition and Neural Substrates. Encyclopedia of Neuroscience, 99-104.

Müller, S., & Abernethy, B. (2014). An Expertise Approach to Training Anticipation Using Temporal Occlusion in a Natural Skill Setting. Technology, Instruction, Cognition and Learning, 9, 295-312.

Niki, C., Kumada, T., Maruyama, T., Tamura, M., & Muragaki, Y. (2019). Role of Frontal Functions in Executing Routine Sequential Tasks. Frontiers in Psychology, 10.

Norman, D. A., & Shallice, T. (1986). Attention to Action. Consciousness and Self-Regulation, 1–18

North, J. S., Hope, E., & Williams, A. M. (2016). The relative importance of different perceptual-cognitive skills during anticipation. Human Movement Science, 49, 170-177.

Pang, E. W., Dunkley, B. T., Doesburg, S. M., Costa, L. D., & Taylor, M. J. (2015). Reduced brain connectivity and mental flexibility in mild traumatic brain injury. Annals of Clinical and Translational Neurology, 3(2), 124-131.

Petrovich, G. D. (2018). Feeding behavior survival circuit: Anticipation & competition. *Current Opinion in Behavioral Sciences*, *24*, 137-142.

Ríos, M., Periáñez, J. A., & Muñoz-Céspedes, J. M. (2004). Attentional control and slowness of information processing after severe traumatic brain injury. Brain Injury, 18(3), 257-272.

Shah, S. A., Goldin, Y., Conte, M. M., Goldfine, A. M., Mohamadpour, M., Fidali, B. C., … Schiff, N. D. (2017). Executive attention deficits after traumatic brain injury reflect impaired recruitment of resources. NeuroImage: Clinical, 14, 233–241.

Sim, A., Terryberry-Spohr, L., & Wilson, K. R. (2008). Prolonged recovery of memory functioning after mild traumatic brain injury in adolescent athletes. Journal of Neurosurgery, 108(3), 511–516.

Smith, D. M. (2016). Neurophysiology of action anticipation in athletes: A systematic review. Neuroscience & Biobehavioral Reviews, 60, 115-120.

Sollmann, N., Echlin, P. S., Schultz, V., Viher, P. V., Lyall, A. E., Tripodis, Y., . . . Koerte, I. K. (2018). Sex differences in white matter alterations following repetitive subconcussive head impacts in collegiate ice hockey players. *NeuroImage: Clinical*, *17*, 642-649.

Stevens, M. C., Lovejoy, D., Kim, J., Oakes, H., Kureshi, I., & Witt, S. T. (2012). Multiple resting state network functional connectivity abnormalities in mild traumatic brain injury. Brain Imaging and Behavior, 6(2), 293–318.

Talavage, T. M., Nauman, E. A., Breedlove, E. L., Yoruk, U., Dye, A. E., Morigaki, K. E., … Leverenz, L. J. (2014). Functionally-Detected Cognitive Impairment in

High School Football Players without Clinically-Diagnosed Concussion. Journal of Neurotrauma, 31(4), 327–338.

Tapper, A., Gonzalez, D., Roy, E., & Niechwiej-Szwedo, E. (2016). Executive function deficits in team sport athletes with a history of concussion revealed by a visual-auditory dual task paradigm. Journal of Sports Sciences, 35(3), 231-240.

Tornås, S., Løvstad, M., Solbakk, A.-K., Evans, J., Endestad, T., Hol, P. K., … Stubberud, J. (2016). Rehabilitation of executive functions in patients with chronic acquired brain injury with goal management training, external cuing, and emotional regulation: A randomized controlled trial. Journal of the International Neuropsychological Society, 22(4), 436–452.

Tsushima, W. T., Siu, A. M., Ahn, H. J., Chang, B. L., & Murata, N. M. (2018). Incidence and Risk of Concussions in Youth Athletes: Comparisons of Age, Sex, Concussion History, Sport, and Football Position. Archives of Clinical Neuropsychology, 34(1), 60-69.

Wickens, C. D., & McCarley, J. S. (2008). Applied Attention Theory. Boca Raton, FL: CRC Press.

Wood, R. L., & Worthington, A. (2017). Neurobehavioral Abnormalities Associated with Executive Dysfunction after Traumatic Brain Injury. Frontiers in Behavioral Neuroscience, 11.

Zappalà, G. (2008). The Frontal lobes: Executive and behavioral control of human reasoning. Implications for understanding brain injury. Riv. It. Neurobiologia, 54(4), 195-202.

Zappalà, G., Schotten, M. T., & Eslinger, P. J. (2012). Traumatic brain injury and the frontal lobes: What can we gain with diffusion tensor imaging? Cortex, 48(2), 156-165.

Zimmermann, N., Mograbi, D. C., Hermes-Pereira, A., Fonseca, R. P., & Prigatano, G. P. (2017). Memory and executive functions correlates of self-awareness in traumatic brain injury. Cognitive Neuropsychiatry, 22(4), 346–360.

APPENDIX A

DEMOGRAPHICS QUESTIONNAIRE

1. What age group do you fall in?
    a. 18-20
    b. 21-23
    c. 24-26
    d. 27-29
    e. 30+

2. What gender do you identify with?
    a. Male
    b. Female
    c. Prefer not to say

3. How many years have you competed in soccer?
    a. Less than a year
    b. 1-4
    c. 5-9
    d. 10+
4. What position do / did you play in soccer?

5. Do you currently play soccer competitively?
    a. Yes
    b. No

6. What is your highest athletic level (including, but not limited to soccer)?
    a. High school
    b. Collegiate
    c. Semi-pro/professional

7. What other athletic sports do / did you play at the collegiate level? (If you only play / played soccer type 'soccer,' if no sports at the collegiate level put N/A)

8. What sport do you currently play at a competitive level? (If none put 'none')

9. Which is your dominant hand?
    a. Right
    b. Left
    c. Ambidextrous

APPENDIX B

BRIEF MEDICAL HISTORY QUESTIONNAIRE

1. Have you had a concussion / traumatic brain injury
    a. Yes
    b. No
    c. Unknown

2. How long ago did you experience a concussion / traumatic brain injury
    a. Less than a week ago
    b. Less than a month ago
    c. Less than 3 months ago
    d. 4-6 months ago
    e. 7-12 months ago
    f. Over a year ago
    g. More than 3 years ago
    h. Never had a concussion / traumatic brain injury

3. If you have had a concussion / traumatic brain injury, have you had some sort of clinical rehabilitation before returning to practice / work (not including rest or medicine)?
    a. Yes
    b. No
    c. Never had a concussion / traumatic brain injury

APPENDIX C

ATTENTIONAL CONTROL QUESTIONNAIRE

1. It is very hard for me to concentrate on a difficult task when there are noises around
    a. Strongly disagree
    b. Disagree
    c. Somewhat disagree
    d. Neither agree nor disagree
    e. Somewhat agree
    f. Agree
    g. Strongly agree

2. It is ready for me to alternate between two different tasks
    a. Strongly disagree
    b. Disagree
    c. Somewhat disagree
    d. Neither agree nor disagree
    e. Somewhat agree
    f. Agree
    g. Strongly agree

3. I have a hard time concentrating when I am excited about something
    a. Strongly disagree
    b. Disagree
    c. Somewhat disagree
    d. Neither agree nor disagree
    e. Somewhat agree
    f. Agree
    g. Strongly agree

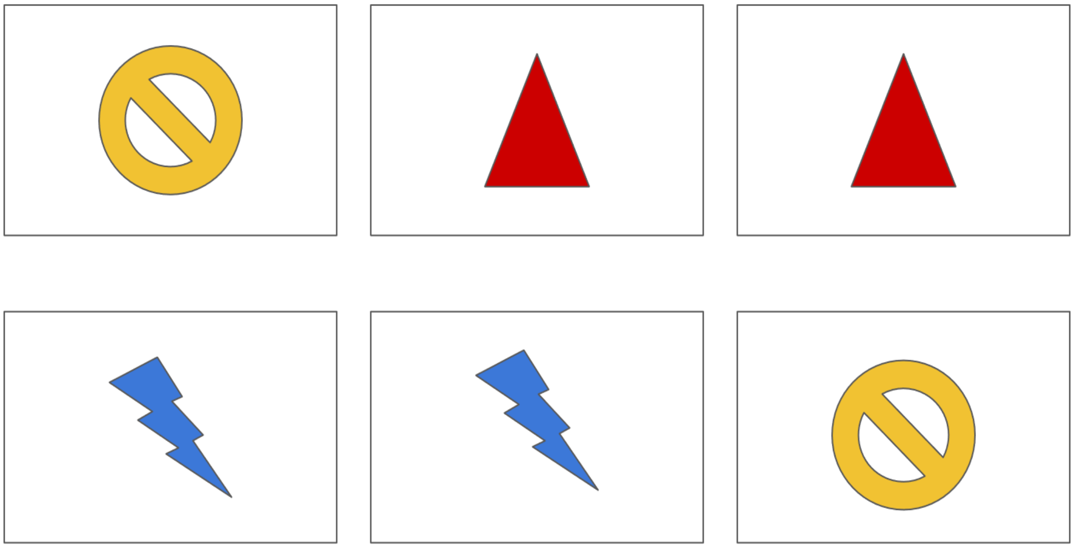
4. When I am reading or studying, I am easily distracted if there are people talking in the same room
    a. Strongly disagree
    b. Disagree
    c. Somewhat disagree
    d. Neither agree nor disagree
    e. Somewhat agree
    f. Agree
    g. Strongly agree

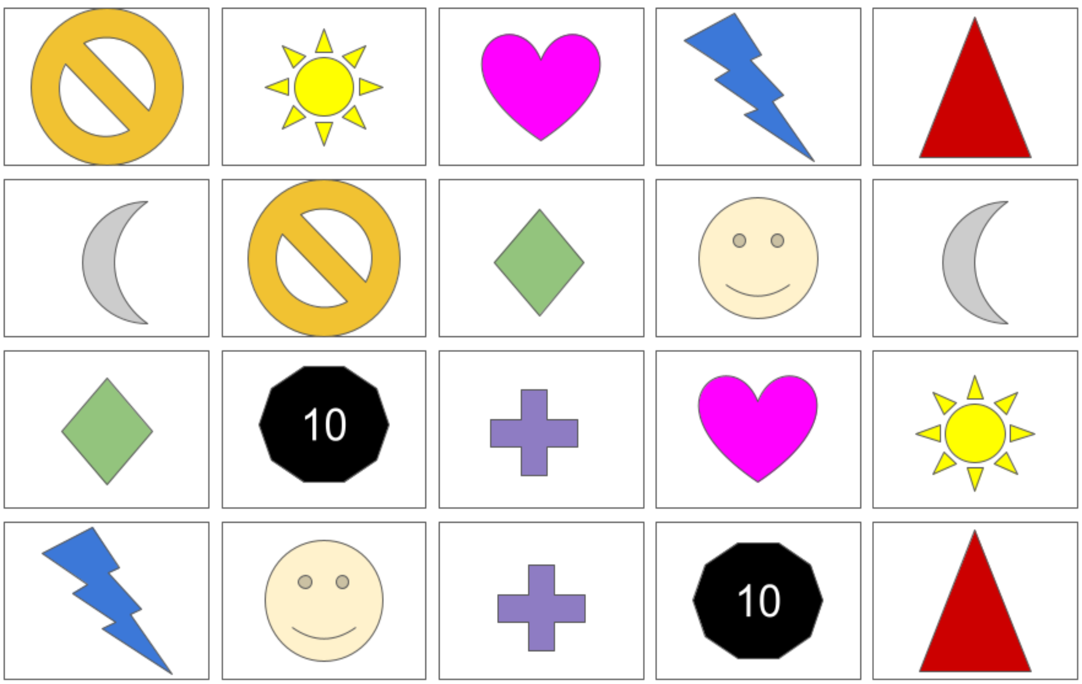
5. I find myself losing my train of thought
    a. Strongly disagree

b. Disagree
c. Somewhat disagree
d. Neither agree nor disagree
e. Somewhat agree
f. Agree
g. Strongly agree

APPENDIX D

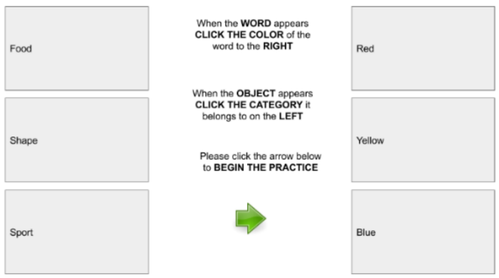
WORKING MEMORY ASSESSMENT

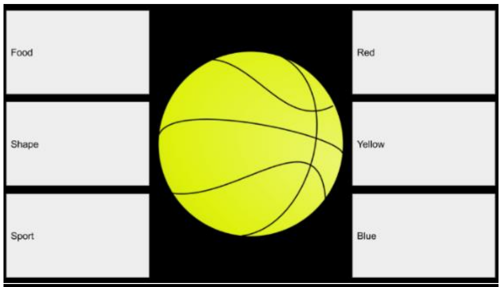


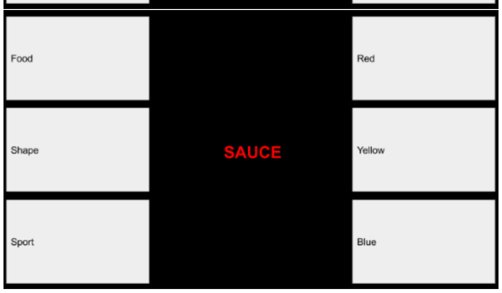

10
10

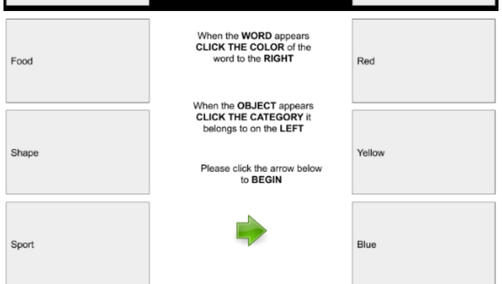
APPENDIX E

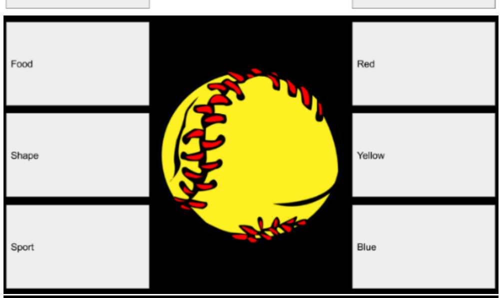
COGNITIVE FLEXIBILITY ASSESSMENT

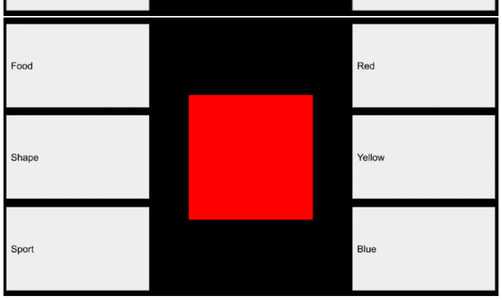

Food
Shape
Sport
When the **WORD** appears **CLICK THE COLOR** of the word to the **RIGHT**
When the **OBJECT** appears **CLICK THE CATEGORY** it belongs to on the **LEFT**
Please click the arrow below to **BEGIN THE PRACTICE**
Red
Yellow
Blue

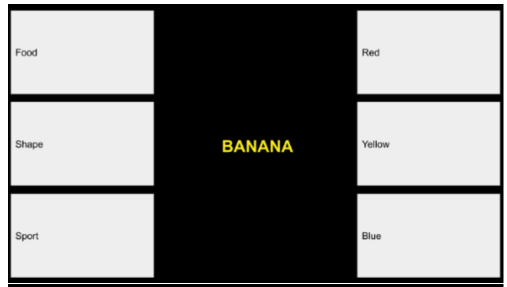

Food
Shape
Sport
Red
Yellow
Blue

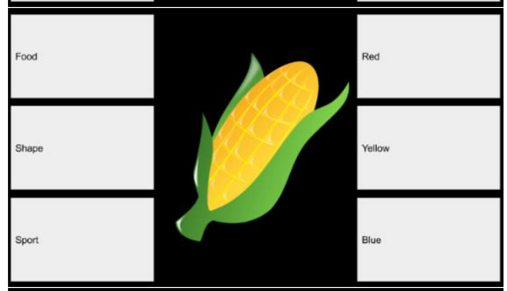

Food
Shape
Sport
SAUCE
Red
Yellow
Blue


Food
Shape
Sport
When the **WORD** appears **CLICK THE COLOR** of the word to the **RIGHT**
When the **OBJECT** appears **CLICK THE CATEGORY** it belongs to on the **LEFT**
Please click the arrow below to **BEGIN**
Red
Yellow
Blue


Food
Shape
Sport
Red
Yellow
Blue

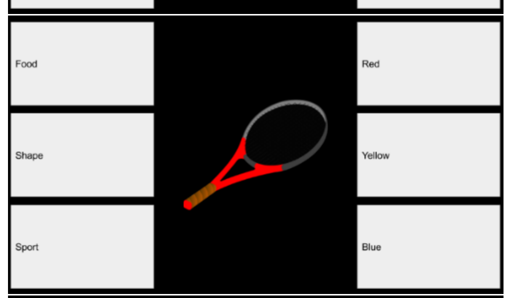

Food
Shape
Sport
Red
Yellow
Blue

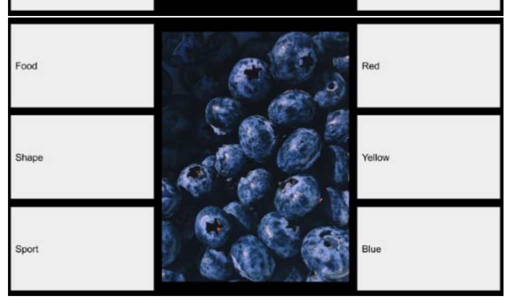

Food
Shape
Sport
BANANA
Red
Yellow
Blue


Food
Shape
Sport
Red
Yellow
Blue


Food
Shape
Sport
BLUEBERRIES
Red
Yellow
Blue


Food
Shape
Sport
TRIANGLE
Red
Yellow
Blue


Food
Shape
Sport
Red
Yellow
Blue


Food
Shape
Sport
Red
Yellow
Blue

Food		Red
Shape		Yellow
Sport		Blue

Food		Red
Shape	TENNIS	Yellow
Sport		Blue

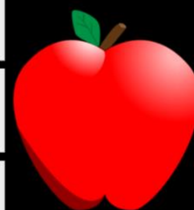
Food		Red
Shape		Yellow
Sport		Blue

Food		Red
Shape		Yellow
Sport		Blue

Food		Red
Shape	SOCCER	Yellow
Sport		Blue

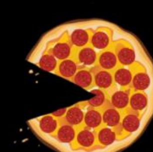
Food		Red
Shape	PIZZA	Yellow
Sport		Blue

Food		Red
Shape	CORN	Yellow
Sport		Blue

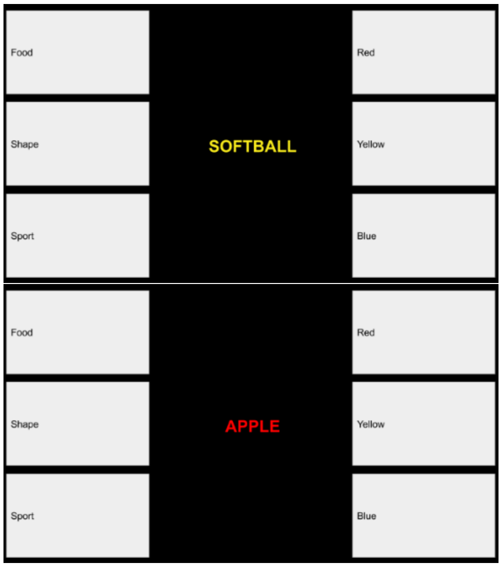
Food		Red
Shape		Yellow
Sport		Blue

Food		Red
Shape		Yellow
Sport		Blue

Food		Red
Shape	SQUARE	Yellow
Sport		Blue

Food		Red
Shape		Yellow
Sport		Blue

Food		Red
Shape	CIRCLE	Yellow
Sport		Blue

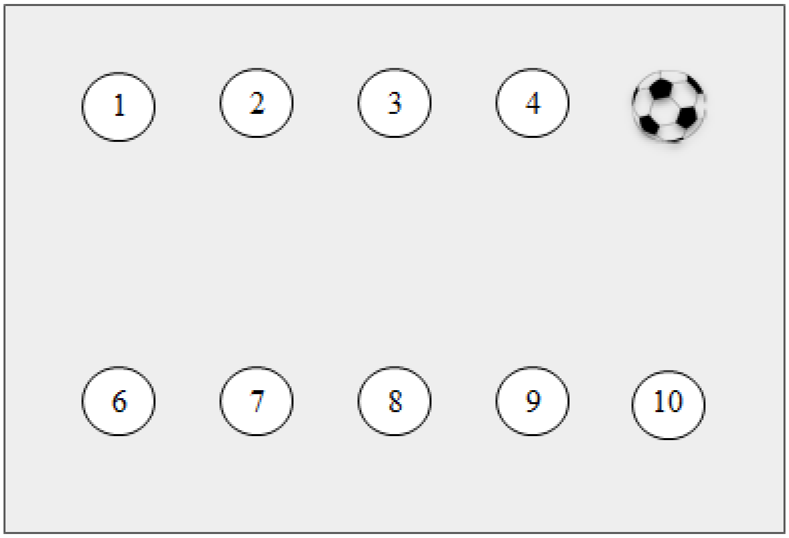

Food
SOFTBALL
Red
Shape
Yellow
Sport
Blue
Food
APPLE
Red
Shape
Yellow
Sport
Blue

APPENDIX F

BRIXTON SPATIAL ANTICIPATION TEST ASSESSMENT

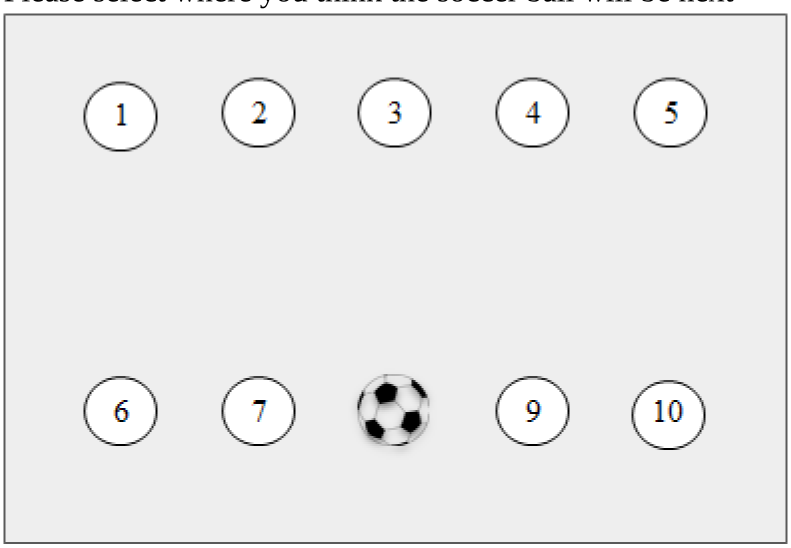
Block 1

1. Please select where you think the soccer ball will be next



   a. 10
   b. 3
   c. 2
   d. 8
   e. 7
   f. None of the above

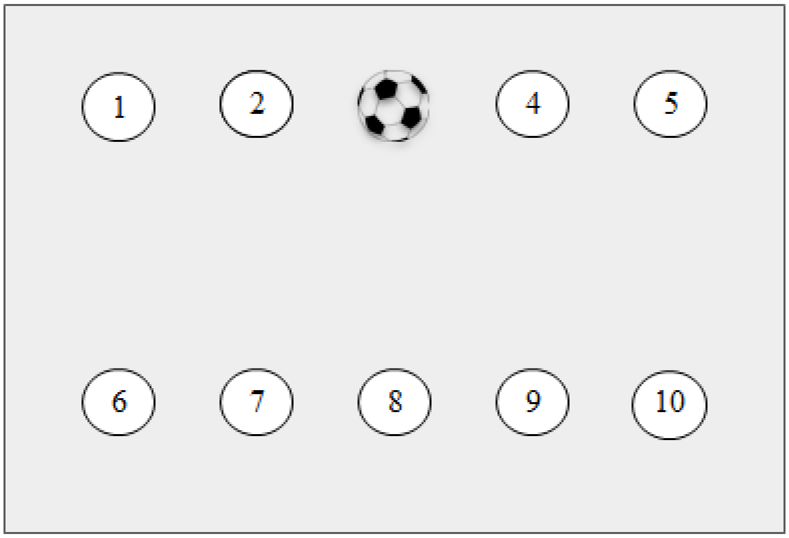
2. Please select where you think the soccer ball will be next



   a. 3
   b. 5
   c. 4
   d. 9

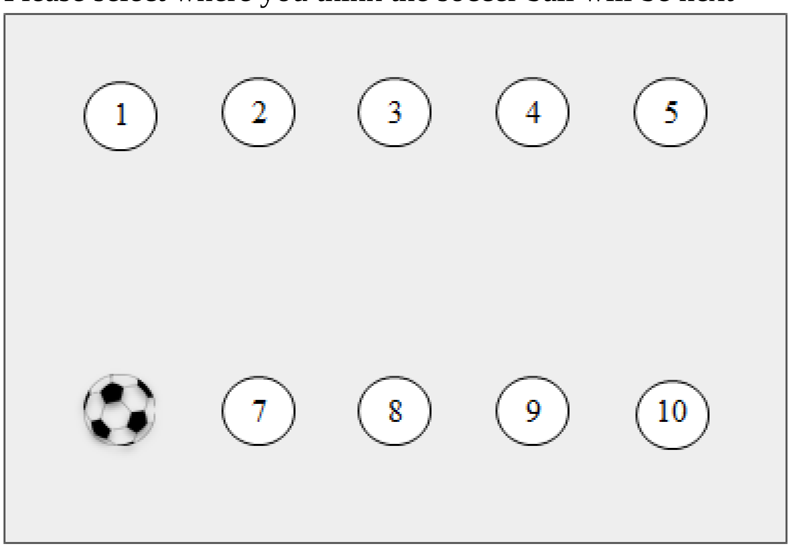
e. 1
f. None of the above

3. Please select where you think the soccer ball will be next



a. 7
b. 2
c. 10
d. 6
e. 3
f. None of the above

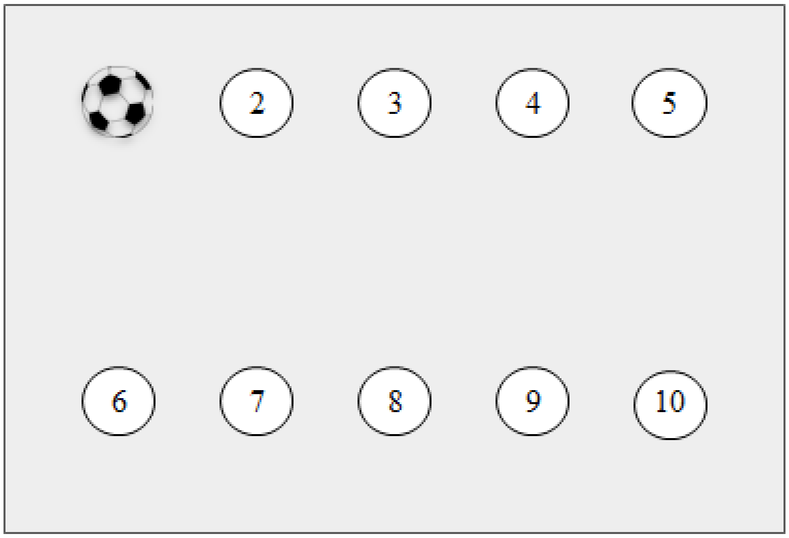
4. Please select where you think the soccer ball will be next



a. 9
b. 1
c. 4

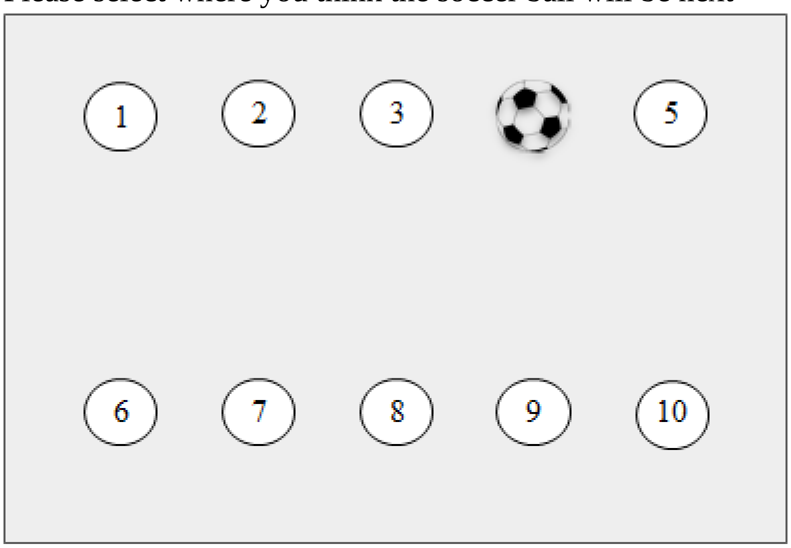
d. 10
e. 3
f. None of the above

5. Please select where you think the soccer ball will be next



a. 1
b. 2
c. 4
d. 7
e. 8
f. None of the above

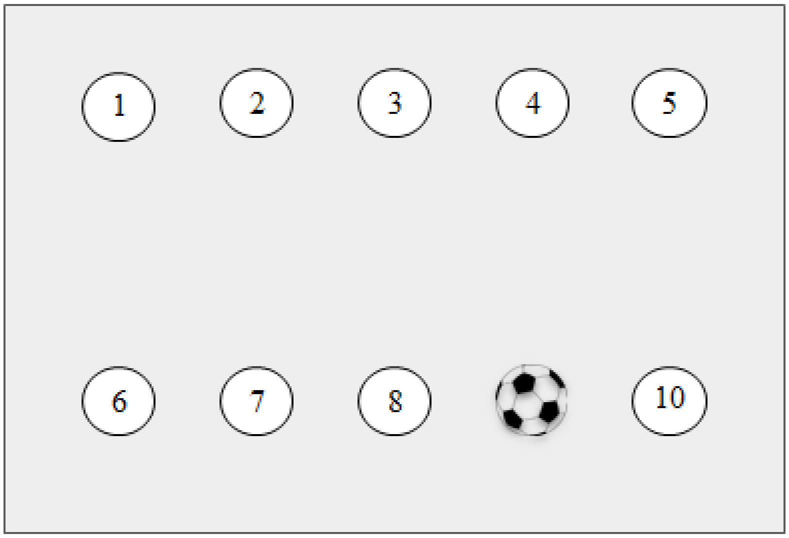
6. Please select where you think the soccer ball will be next



a. 9
b. 1

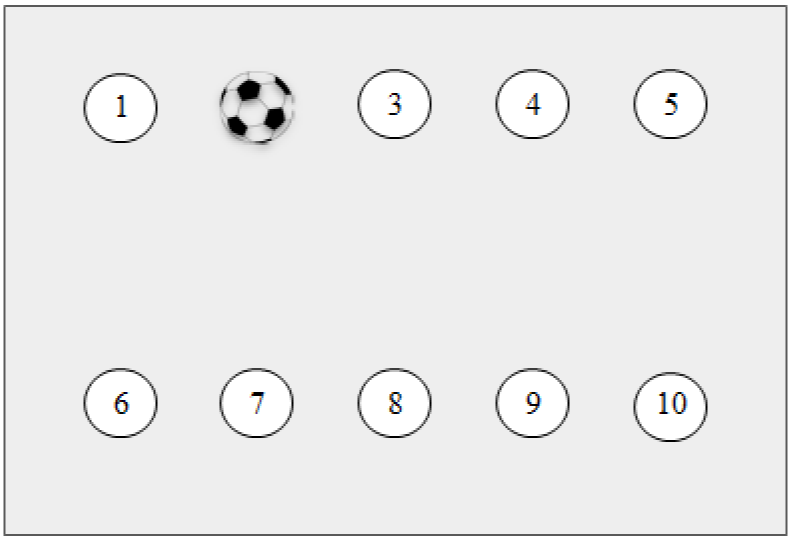
c. 7
d. 2
e. 6
f. None of the above

7. Please select where you think the soccer ball will be next



a. 4
b. 3
c. 1
d. 10
e. 2
f. None of the above

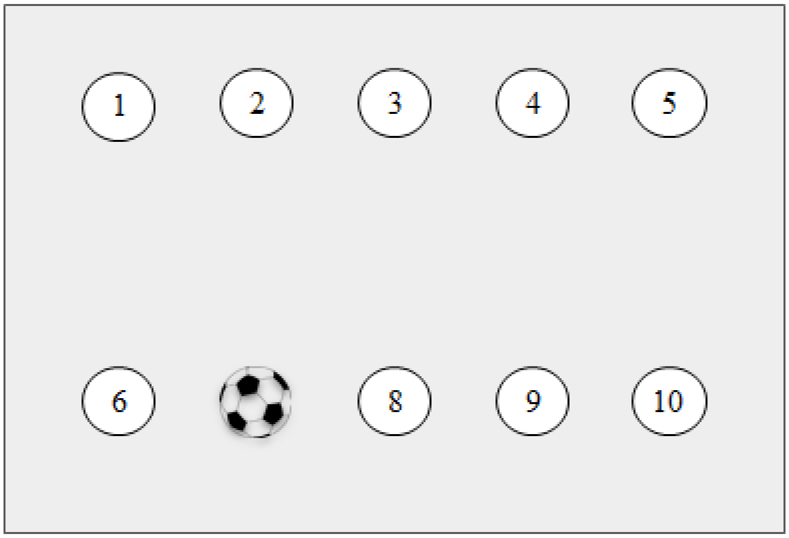
8. Please select where you think the soccer ball will be next



a. 1
b. 10

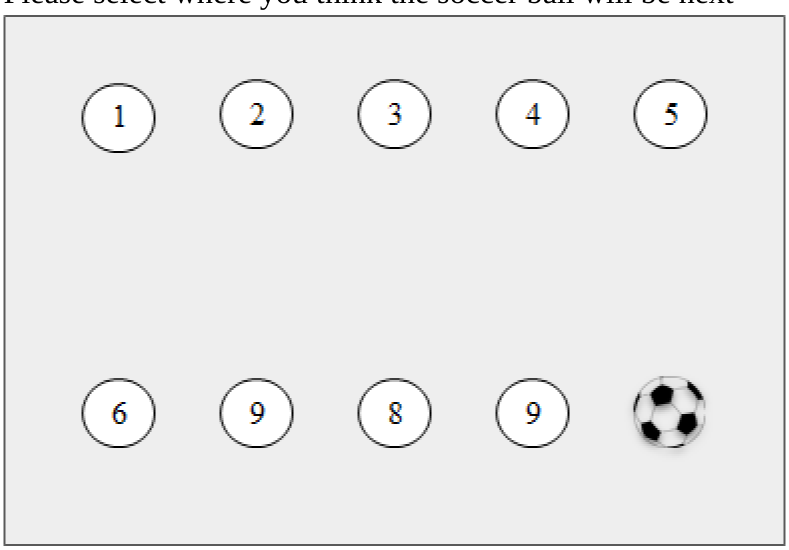
c. 7
d. 9
e. 3
f. None of the above

9. Please select where you think the soccer ball will be next



a. 4
b. 1
c. 2
d. 6
e. 10
f. None of the above

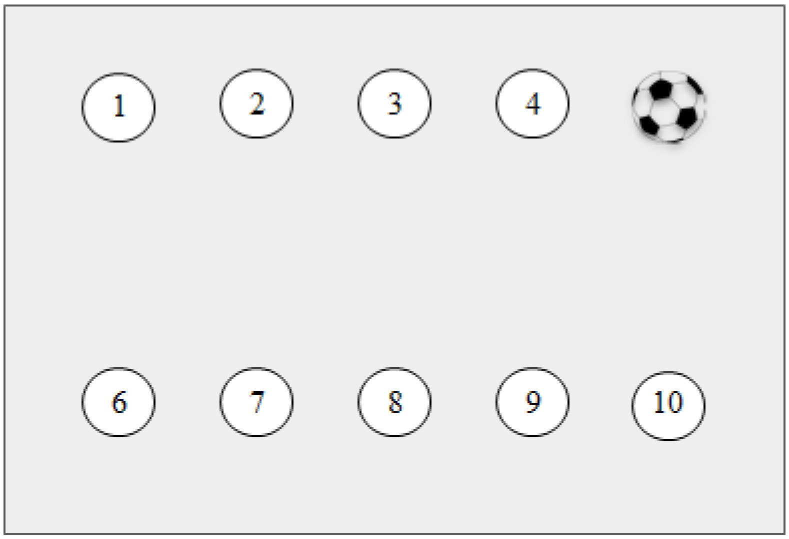
10. Please select where you think the soccer ball will be next



a. 5

b. 3
c. 10
d. 1
e. 4
f. None of the above

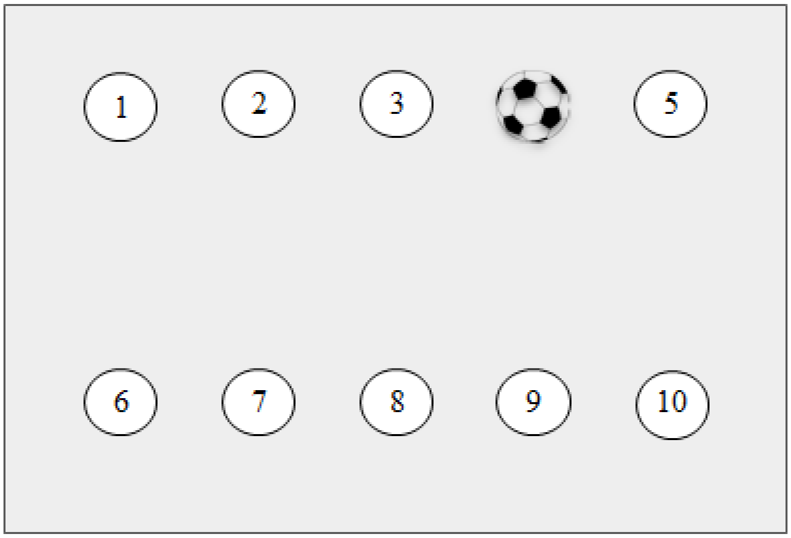
11. Please select where you think the soccer ball will be next



a. 7
b. 6
c. 3
d. 8
e. 2
f. None of the above

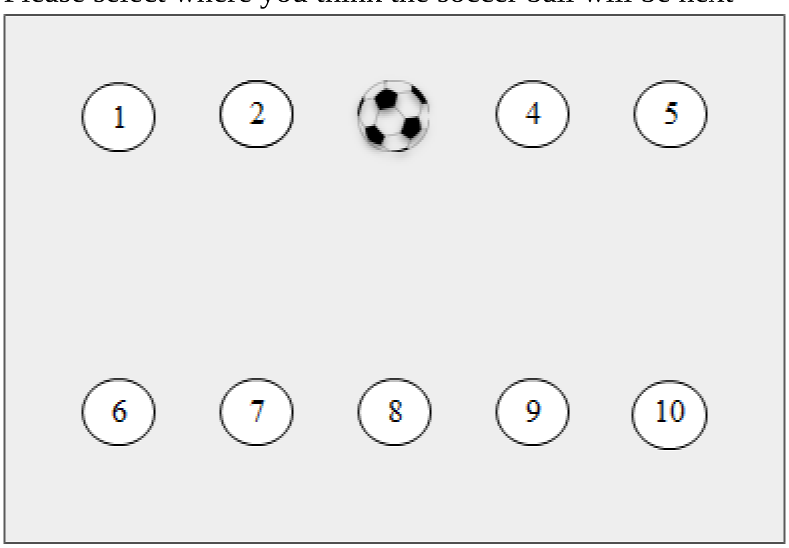
Block 2

1. Please select where you think the soccer ball will be next



   a. 3
   b. 10
   c. 9
   d. 2
   e. 1
   f. None of the above

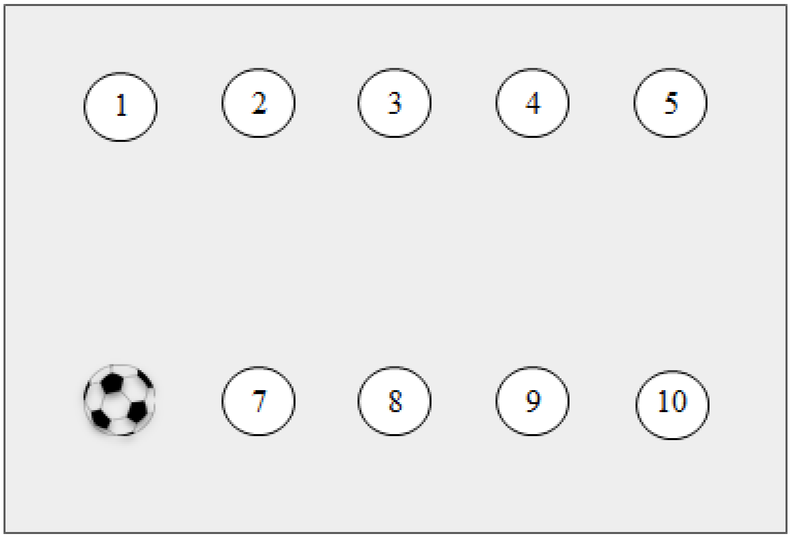
2. Please select where you think the soccer ball will be next



   a. 9
   b. 7
   c. 6

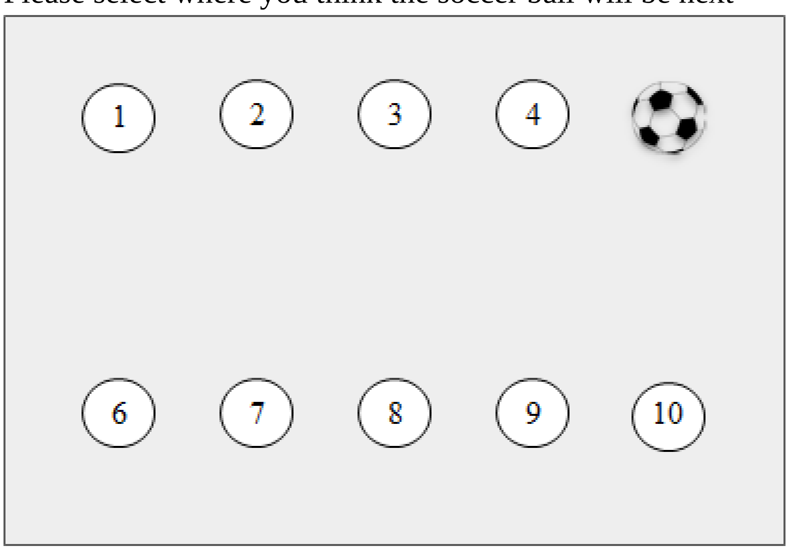
d. 10
e. 1
f. None of the above

3. Please select where you think the soccer ball will be next



a. 5
b. 1
c. 4
d. 7
e. 10
f. None of the above

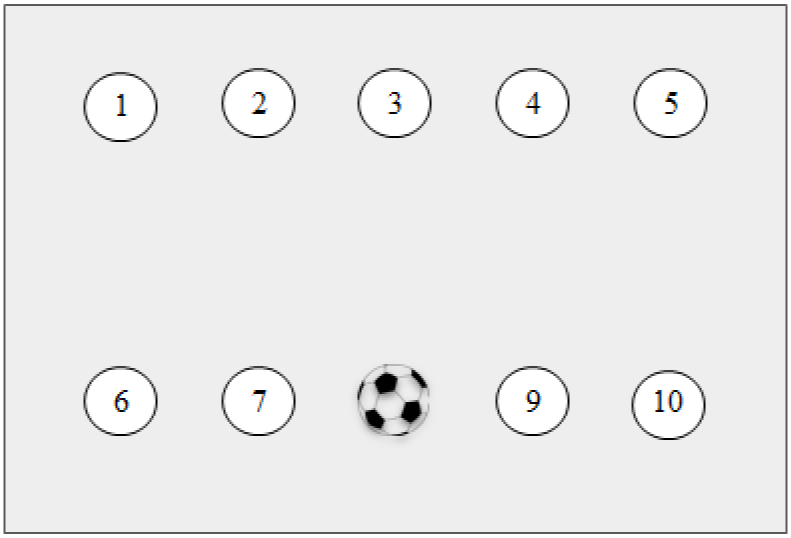
4. Please select where you think the soccer ball will be next



a. 10
b. 1

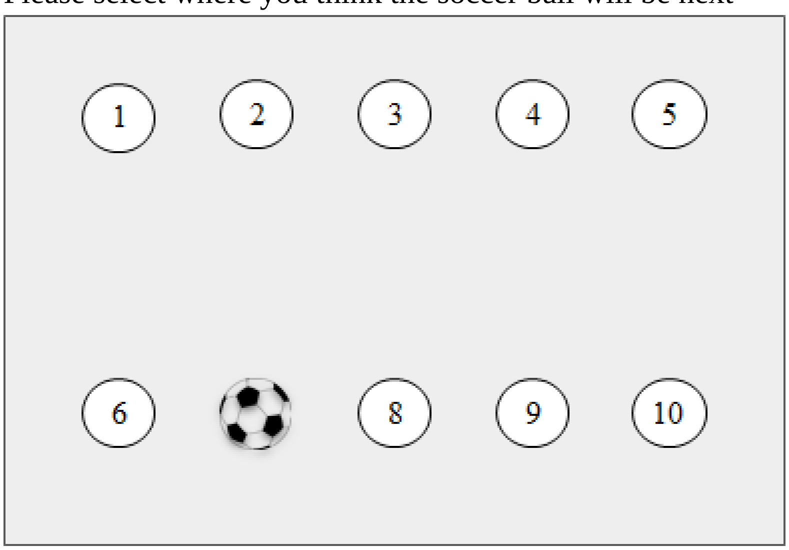
c. 9
d. 7
e. 8
f. None of the above

5. Please select where you think the soccer ball will be next



a. 1
b. 4
c. 2
d. 8
e. 7
f. None of the above

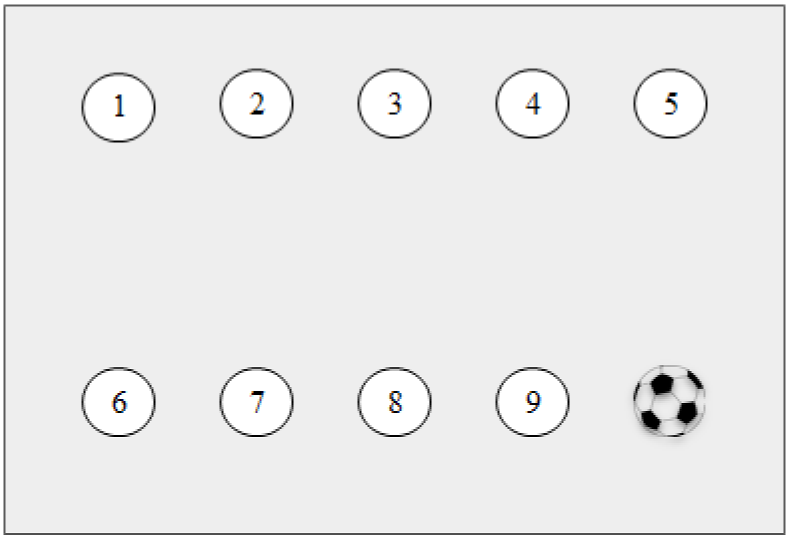
6. Please select where you think the soccer ball will be next



a. 1

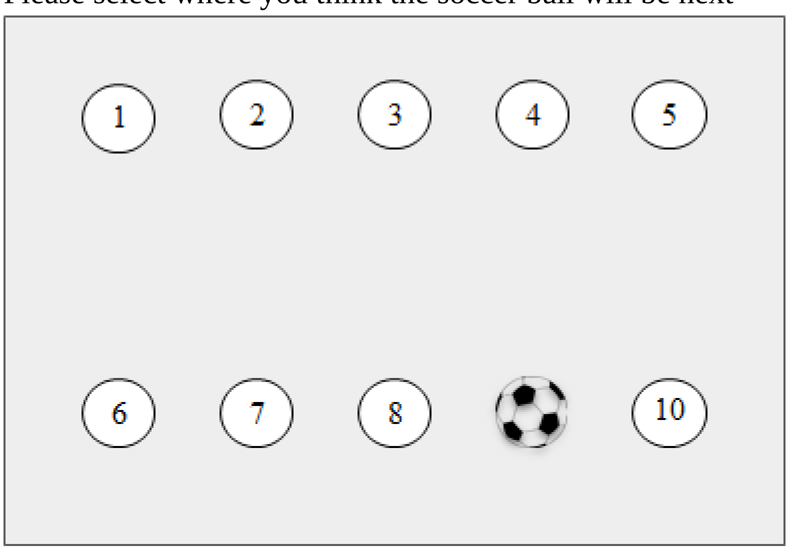
b. 4
c. 7
d. 10
e. 6
f. None of the above

7. Please select where you think the soccer ball will be next



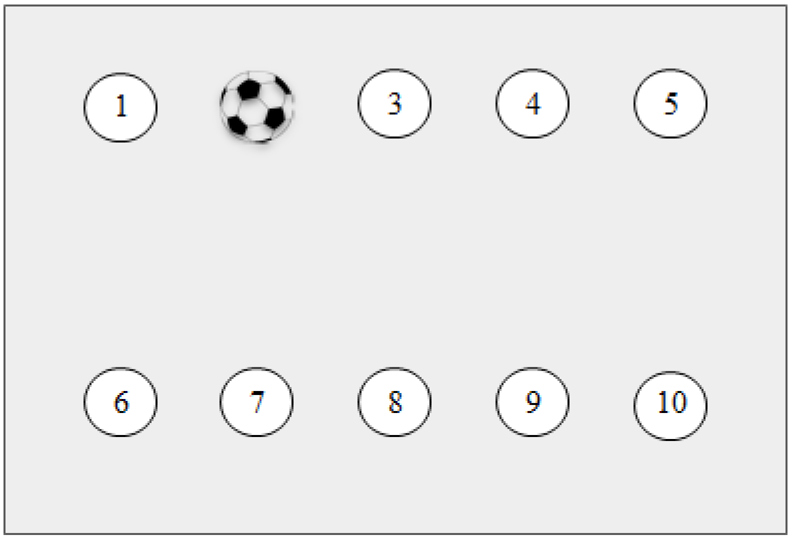
a. 2
b. 9
c. 3
d. 8
e. 5
f. None of the above

8. Please select where you think the soccer ball will be next



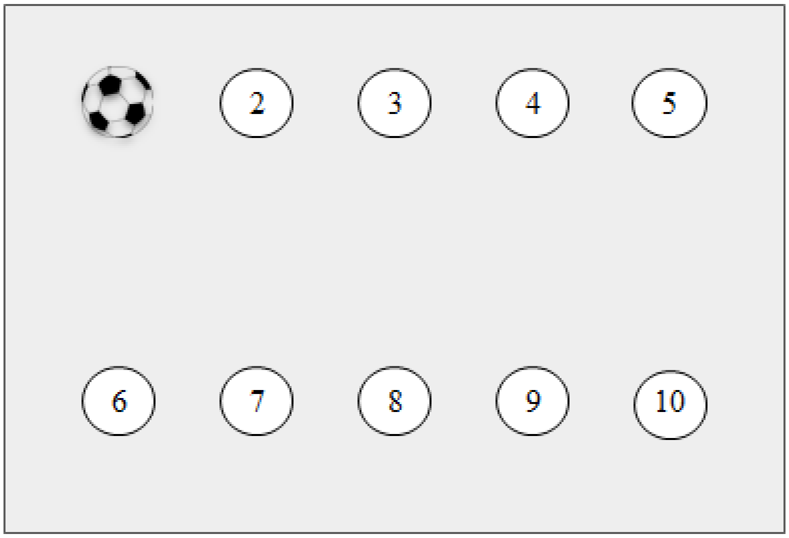
a. 1
b. 10
c. 3
d. 9
e. 2
f. None of the above

9. Please select where you think the soccer ball will be next



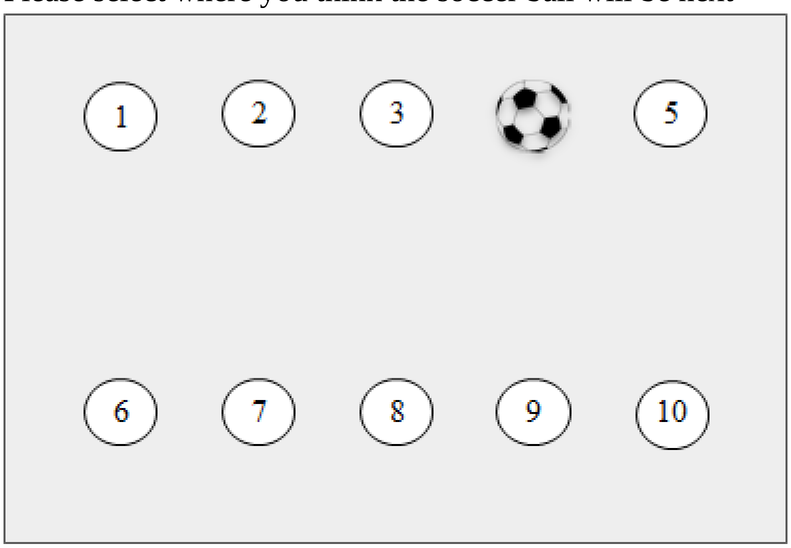
a. 7
b. 8
c. 9
d. 1
e. 10
f. None of the above

10. Please select where you think the soccer ball will be next



a. 3
b. 4
c. 9
d. 2
e. 5
f. None of the above

11. Please select where you think the soccer ball will be next



a. 10
b. 5
c. 3
d. 9
e. 2
f. None of the above

APPENDIX G

CONSENT FORM

Executive Function Differences of (Anticipation) between Soccer Players with and without a history of Traumatic Brain Injury

I am a graduate student under the direction of Dr. Rob Gray in the Human Systems Engineering Department in the Ira A. Fulton Schools of Engineering at Arizona State University. I am conducting a research study to examine the impact on executive function amongst athletic (soccer) individuals with and without a history of traumatic brain injury (concussion) when it comes to anticipation i.e. the ability to perceive an opponent's next move.

I am inviting your participation, which will take approximately sixty (60) minutes of your time, and will involve the completion of executive function tasks, questionnaires, and the viewing of pre-recorded FIFA 18 soccer footage and determine what event you believe is to come next. Your responses and task performance will be recorded (via screen recording through Zoom). You have the right not to answer any question, and to stop participation at any time.

Your participation in this study is voluntary. If you choose not to participate or to withdraw from the study at any time, there will be no penalty. The compensation for the present study is $10.00 and will be dispersed within one (1) week of study completion. You must be 18 years or older, have an athletic background in soccer, be English speaking, have normal color vision, and have normal or corrected-to-normal vision to be eligible for participation.

Although there is no direct benefit to you, the possible benefits of your participation are gaining experience in psychological research and having a better understanding of the role executive function plays in cognition. There are no foreseeable risks or discomforts to your participation.

No personally identifiable information will be collected during this study, all of your responses will be anonymous, and no information collected during this study will be shared with anyone. Participants will be assigned a number that will be connected to any data or information connected in this study. All data collected will be stored on a password protected computer accessible only by members of the research team. The results of this study may be used in reports, presentations, or publications but your name will not be collected nor used.

If you have any questions concerning the research study, please contact the research team at: **aezenyi1@asu.edu,** or **robgray@asu.edu**. If you have any questions about your rights as a subject/participant in this research, or if you feel you have been placed at risk, you can contact the Chair of the Human Subjects Institutional Review Board, through the ASU Office of Research Integrity and Assurance, at (480) 965-6788. Please let me know if you wish to be a part of the study.

By signing the box below, you are agreeing to be part of the study.

APPENDIX H

RECRUITMENT EMAIL LETTER

Hello Coach ______,

My name is Akuadasuo Ezenyilimba. **I am a graduate student under the direction of Dr. Robert Gray in the Human Systems Engineering Department** under the Ira A. Fulton Schools of Engineering at **Arizona State University**. I am conducting a research study to examine the impact on executive function amongst athletic (soccer) individuals, both with and without a history of traumatic brain injury (concussion), when it comes to anticipation i.e. the ability to perceive an opponent's next move.

I am recruiting individuals to take part in an online study to examine the correlation between anticipation and Temporal Occlusion amongst individuals with and without a history of Traumatic Brain Injury (concussion). The study will take approximately **thirty (30) minutes** and participants will receive **$10.00 for participation**.

Participation in this study is voluntary. To be eligible for participation, participants must be 18 years of age or older, have an athletic background in soccer (high school, collegiate, semi-pro/professional), have normal or corrected-to-normal vision, have normal color vision, and be English speaking. **If you have any questions concerning the research study**, please contact me (Akuadasuo Ezenyilimba) at **aezenyi1@asu.edu**.

If any of your athletes would be willing to participate, please feel free to share my contact information with them, pass along their contact information, or share this email with potential participants.

Here is the link to sign up for the mentioned study:
https://calendly.com/aezenyi1/60min

Best,

APPENDIX I

IRB APPROVAL / EXEMPTION FOR HUMAN SUBJECT TESTING

		Page: 1 of 7
	PREPARED BY: IRB Staff	**APPROVED BY**: Heather Clark
DOCUMENT TITLE: HRP 503 A Social Behavioral Protocol	**DEPARTMENT:** Office of Research Integrity and Assurance (ORIA)	**EFFECTIVE DATE**: [3/26/2020]

INSTRUCTIONS
Complete each section of the application. Based on the nature of the research being proposed some sections may not apply. Those sections can be marked as N/A. Remember that the IRB is concerned with risks and benefits to the research participant and your responses should clearly reflect these issues. You (the PI) need to retain the most recent protocol document for future revisions. Questions can be addressed to research.integrity@asu.edu. **PIs are strongly encouraged to complete this application with words and terms used to describe the protocol is geared towards someone not specialized in the PI's area of expertise.**

Protocol Title: Executive Function Differences of Anticipation between Athletes (Soccer) with and without a history of Traumatic Brain Injury through the use of Technology (Temporal Occlusion)

1. Background and Objectives
1.1 List the specific aims or research questions in 300 words or less.
1.2 Refer to findings relevant to the risks and benefits to participants in the proposed research.
1.3 Identify any past studies by ID number that are related to this study. If the work was done elsewhere, indicate the location.

For streamlining the review time:
- Two paragraphs or less is recommended.
- Do not submit sections of funded grants or similar. The IRB will request additional information, if needed.

Response:

For an athlete, the main area impacted when it comes to acquiring most traumatic brain injuries (TBI) is the prefrontal cortex, this is especially so amongst young athletes. Damage to the prefrontal cortex can have a debilitating effect on an athlete's executive function, which can impair their progression in their respective fields. Often in the athletic world TBIs are overlooked, missed, or treatment is rushed due to the codependency on dated rehabilitation approaches.

The aim of this research study is to assess the decrements that persist amongst athletic individuals with a history of traumatic brain injury. This will be further addressed by looking at differences amongst these individuals in comparison to their counterparts who do not have a history of TBI when it comes to eliciting the executive function of anticipation.

When it comes to athletics often the focus is on computerized detection, but the next step which is recovery, which is crucial to the rehabilitation process does not include this essential component that is an added benefit found in technology. By pinpointing and focusing on rehabilitation that includes computerized components traumatic brain injury recovery will benefit immensely (Bogdanova, Yee, Ho, and Cicerone, 2016). This is so especially when computerized recovery includes environmental enrichment to increase active stimulation of the brain and engagement within the recovery process (Frasca, Tomaszyck, McFayden, and Green, 2013). To advance and make positive progress when it comes to TBIs, more research needs to be done on which mechanisms to pinpoint in recovery for athletes, especially when it concerns rehabilitating executive function. With the tool of temporal occlusion proper assessment would be able to be put forth to determine if an individual is making progress in the recovery process due to its natural nature to measure proper anticipation skills amongst athletes.

3. Data Use - What are the intended uses of the data generated from this project?
Examples include: Dissertation, thesis, undergraduate project, publication/journal article, conferences/presentations, results released to agency, organization, employer, or school. If other, then describe.

Response:

The intended purpose of the data generated from this project is to aid in the completion of a Master's Thesis for the Human Systems Engineering program

4. Inclusion and Exclusion Criteria
4.1 List criteria that define who will be included or excluded in your final sample. Indicate if each of the following special (vulnerable/protected) populations is included or excluded:

- Minors (under 18)
- Adults who are unable to consent (impaired decision-making capacity)
- Prisoners
- Economically or educationally disadvantaged individuals

not obvious, what is the rationale for the exclusion of special populations?
hat procedures will be used to determine inclusion/exclusion of special populations?

for streamlining the review time.

- Research involving only data analyses should only describe variables included in the dataset that will be used.
- For any research which includes or may likely include children/minors or adults unable to consent, review content [here]
- For research targeting Native Americans or populations with a high Native American demographic, or on or near tribal lands, review content [here]

rch involving minors on campus, review content [here]

Response:

Individuals that will be included in this study will ideally be at least 18 years of age or older, with an athletic background specifically in Soccer. Participants will have their highest level of athletic expertise be either high school, collegiate, or semi-pro/professional. Participants within this study also will have a history or no history of a traumatic brain injury and have normal or corrected-to-normal vision, have normal color vision, and be English speaking

5. Number of Participants

Indicate the total number of individuals you expect to recruit and enroll. For secondary data analyses, the response should reflect the number of cases in the dataset.

Response:

The total number of participants that are expected to be recruited for this study is 60.

6. Recruitment Methods

y who will be doing the recruitment and consenting of participants.
y when, where, and how potential participants will be identified, recruited, and nsented.
materials that will be used (e.g., recruitment materials such as emails, flyers, vertisements, etc.) Please upload each recruitment material as a separate document, me the document: recruitment_methods_email/flyer/advertisement_dd-mm-yyyy
ibe the procedures relevant to using materials (e.g., consent form).

-

Response:

Recruitment and consenting of participants for this study will be conducted by Akuadasuo Ezenyilimba. Potential participants will be identified via emails sent to NCAA athletic male and female soccer programs throughout the United States. Participants will then be gathered based on responses to emails. Once participants have been identified a consent form will be given to relevant individuals via Qualtrics.

. Study Procedures

7.1 List research procedure step by step (e.g., interventions, surveys, focus groups, observations, lab procedures, secondary data collection, accessing student or other records for research purposes, and follow-ups). Upload one attachment, dated, with all the materials relevant to this section. Name the document: supporting documents dd-mm-yyyy

7.2 For each procedure listed, describe **who** will be conducting it, **where** it will be performed, **how long** is participation in each procedure, and **how/what data** will be collected in each procedure.

t the total period and span of time for the procedures (if applicable the timeline for low ups).

condary data analyses, identify if it is a public dataset (please include a weblink where e data will be accessed from, if applicable). If not, describe the contents of the dataset, w it will be accessed, and attach data use agreement(s) if relevant.

or streamlining the review time.

- Ensure that research materials and procedures are explicitly connected to the articulated aims or research questions (from section 2 above).

- In some cases, a table enumerating the name of the measures, corresponding citation (if any), number of items, sources of data, time/wave if a repeated measures design can help the IRB streamline the review time.

Response:

Total study time will be 60 minutes (broken down as follows**):**

Demographics Survey: **who:** Akuadasuo Ezenyilimba **where**: remotely **how long:** 1 minute **how/what data:** demographics related to age, gender, athletic level, etc.

Brief Medical History: **who:** Akuadasuo Ezenyilimba **where**: remotely **how long:** 1 minute **how/what data:** experience with traumatic brain injury

Working Memory Assessment (1 training, 1 task): **who:** Akuadasuo Ezenyilimba **where**: remotely **how long:** 5 minutes **how/what data:** the ability to hold information for the attainment of a future goal

Cognitive Flexibility Assessment (1 training, 1 task): **who:** Akuadasuo Ezenyilimba **where**: remotely **how long:** 5 minutes **how/what data:** the ability to switch between tasks/multitask and adapt

Attentional Control Questionnaire: **who:** Akuadasuo Ezenyilimba **where**: remotely **how long:** 1 minute **how/what data:** the ability to concentrate

Brixton Spatial Anticipation Test (t training, 2 task): **who:** Akuadasuo Ezenyilimba **where**: remotely **how long:** 20 minutes(10 minutes each) **how/what data:** the ability to detect rules

Temporal Occlusion Task: **who:** Akuadasuo Ezenyilimba **where**: remotely **how long:** 30 minutes **how/what data:** anticipation skill level

. Compensation

8.1 Report the amount and timing of any compensation or credit to participants.
8.2 Identify the source of the funds to compensate participants.
8.3 Justify that the compensation to participants to indicate it is reasonable and/or how the compensation amount was determined.
8.4 Describe the procedures for distributing the compensation or assigning the credit to participants.

or streamlining the review time.

- **If partial compensation or credit will be given or if completion of all elements is required, explain the rationale or a plan to avoid coercion**
- **For extra or course credit guidance, see "Research on educational programs or in classrooms" on the following page: https://researchintegrity.asu.edu/human-subjects/special-considerations.**
- **For compensation over $100.00, review "Research Subject Compensation" at: https://researchintegrity.asu.edu/human-subjects/special-considerations for more information.**

Response:

Participants will be compensated 10 dollars for participation. The source of funding will be from personal savings. Participants will be compensated to increase incentive to participate in the study, and to accommodate for time used to participate. Compensation will be distributed via Qualtrics through the single-instance incentive feature.

). Risk to Participants

List the reasonably foreseeable risks, discomforts, or inconveniences related to participation in the research.

or streamlining the review time.

- Consider the broad definition of "minimal risk" as the probability and magnitude of harm or discomfort anticipated in the research that are not greater in and of themselves than those ordinarily encountered in daily life or during the performance of routine physical or psychological examinations or tests.
- Consider physical, psychological, social, legal, and economic risks.
- If there are risks, clearly describe the plan for mitigating the identified risks.

Response:

Participants will be exposed to minimal/ no risks by participating in this study. There are no foreseeable risks to participation

.0. Potential Direct Benefits to Participants

List the potential direct benefits to research participants. If there are risks noted in 9 (above), articulated benefits should outweigh such risks. These benefits are not to society or others not considered participants in the proposed research. Indicate if there is no direct benefit. A direct benefit comes as a direct result of the subject's participation in the research. An indirect benefit may be incidental to the subject's participation. Do not include compensation as a benefit.

Response:

Potential direct benefits research participants may have from participating in this study is to identify areas in which they can better improve their executive functioning (i.e. anticipation, working memory, cognitive flexibility, attentional control).

1. Privacy and Confidentiality

Indicate the steps that will be taken to protect the participant's privacy.

11.1 Identify who will have **access to the data**.
11.2 Identify where, how, and how long data will be **stored** (e.g. ASU secure server, ASU cloud storage,
filing cabinets).
11.3 Describe the procedures for **sharing, managing and destroying data**.
| Describe any special measures to **protect** any extremely sensitive data (e.g. password protection, encryption, certificates of confidentiality, separation of identifiers and data, secured storage, etc.).
5 Describe how any **audio or video recordings** will be managed, secured, and/or de-identified.

6 Describe how will any signed consent, assent, and/or parental permission forms be secured and how long they will be maintained. These forms should separate from the rest of the study data. 7 Describe how any data will be **de-identified**, linked or tracked (e.g. master-list, contact list, reproducible participant ID, randomized ID, etc.). Outline the specific procedures and processes that will be followed. 8 Describe any and all identifying or contact information that will be collected for any reason during the course of the study and how it will be secured or protected. This includes contact information collected for follow-up, compensation, linking data, or recruitment. 9 For studies accessing existing data sets, clearly describe whether or not the data requires a Data Use Agreement or any other contracts/agreements to access it for research purposes. 10 For any data that may be covered under FERPA (student grades, etc.) additional information and requirements is available at https://researchintegrity.asu.edu/human-subjects/special-considerations.
Response: Participants will be assigned a number to protect their identity. All data that is collected within this study will be recorded by the given number assigned to each participant. All original data will be in a secure location that only authorized users have access to. Consent forms will be kept separate from associated ID numbers and will also be kept in a secure separate location

12. Consent

Describe the procedures that will be used to obtain consent or assent (and/or parental permission).

Who will be responsible for consenting participants?
Where will the consent process take place?
How will the consent be obtained (e.g., verbal, digital signature)?

For streamlining the review time.

- If participants who do not speak English will be enrolled, describe the process to ensure that the oral and/or written information provided to those participants will be in their preferred language. Indicate the language that will be used by those obtaining consent. For translation requirements, see Translating documents and materials under https://researchintegrity.asu.edu/human-subjects/protocol-submission
- Translated consent forms should be submitted after the English is version of all relevant materials are approved. Alternatively, submit translation certification letter.
- **If a waiver for the informed consent process is requested, justify the waiver in terms of each of the following: (a) The research involves no more than minimal risk to the subjects; (b) The waiver or alteration will not adversely affect the rights and welfare of the subjects; (c) The research could not practicably be carried out without the waiver or alteration; and (d) Whenever appropriate, the subjects will be provided with additional pertinent information after participation.** Studies involving confidential, one time, or

anonymous data need not justify a waiver. A verbal consent or implied consent after reading a cover letter is sufficient.

- ASU consent templates are [here].
- Consents and related materials need to be congruent with the content of the application.

Response: Participant consent will be collected via Qualtrics, and participants will be expected to sign the consent form before beginning the study. The researcher will make sure participants provide a valid signature via Qualtrics. The researcher will also sign each consent form during the same session as the participant

.3. Site(s) or locations where research will be conducted.

List the sites or locations where interactions with participants will occur-

- Identify where research procedures will be performed.
- For research conducted outside of the ASU describe:
  - Site-specific regulations or customs affecting the research.
  - Local scientific and ethical review structures in place.
- For research conducted outside of the United States/United States Territories describe:
  - Safeguards to ensure participants are protected.
- For information on international research, review the content [here].

search conducted with secondary data (archived data):

- List what data will be collected and from where.
- Describe whether or not the data requires a Data Use Agreement or any other contracts/agreements to access it for research purposes.
- For any data that may be covered under FERPA (student grades, etc.) additional information and requirements is available [here].
- For any data that may be covered under FERPA (student grades, homework assignments, student ID numbers etc.), additional information and requirements is available [here].

onse: Interactions with participants will occur via Zoom and Qualtrics remotely.

4. Human Subjects Certification from Training.

ovide the names of the members of the research team.

ASU affiliated individuals do not need attach Certificates. Non-ASU investigators and research team members anticipated to manage data and/or interact with participants, need to provide the most recent CITI training for human participants available at www.citiprogram.org. Certificates are valid for 4 years.

or streamlining the review time.

- If any of the study team members have not completed training through ASU's CITI training (i.e. they completed training at another university), copies of their completion reports will need to be uploaded when you submit.
- For any team members who are affiliated with another institution, please see "Collaborating with other institutions" [here]
- The IRB will verify that team members have completed IRB training. Details on how to complete IRB CITI training through ASU are [here]

Response:

Robert Gray and Akuadasuo Ezenyilimba

PROCEDURES FOR THE REVIEW OF HUMAN SUBJECTS RESEARCH

General Tips:

- Have all members of the research team complete IRB training before submitting.
- Ensure that all your instruments, recruitment materials, study instruments, and consent forms are submitted via ERA when you submit your protocol document. Templates are [here]
- Submit a complete protocol. Don't ask questions in the protocol – submit with your best option and, if not appropriate, revisions will be requested.
- If your study has undeveloped phases, clearly indicate in the protocol document that the details and materials for those phases will be submitted via a modification when ready.
- Review all materials for consistency. Ensure that the procedures, lengths of participation, dates, etc., are consistent across all the materials you submit for review.
- Only ASU faculty, full time staff may serve as the PI. Students may prepare the submission by listing the faculty member as the PI. The submit button will only be visible to the PI.
- Information on how and what to submit with your study in ERA is [here]. Note that if you are a student, you will need to have your Principal Investigator submit.
- For details on how to submit this document as part of a study for review and approval by the ASU IRB, visit https://researchintegrity.asu.edu/human-subjects/protocol-submission.