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# Visual Tracking Speed and Soccer Performance Metrics

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VISUAL TRACKING SPEED AND SOCCER PERFORMACNE METRICS

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**Abstract**

Visual training has previously been shown to correlate to sport specific level of training and sport specific performance measures in controlled conditions. However, it remains unclear if these relationships exist between visual tracking thresholds and in competition decision making metrics over the duration of a soccer season. Therefore, the purpose of this study was to investigate the relationship between visual tracking speed (VTS) baseline scores and soccer-specific performance measures. In total, 19 NCAA Division I soccer players were tested before the 2021 spring soccer season, after exclusionary criteria only 13 were utilized for analysis. VTS was measured from 1-core session (20 trials) on a 3-demensional multiple object tracking (3D-MOT) software Neurotracker (NT; CogniSens Athletic, Inc., Montreal, Quebec, Canada). The soccer performance metrics were obtained from WyScout (Wyscout, Chiavari, Italy). Spearman's rank order correlation coefficient was utilized to examine potential correlations between criterion variables. There was weak nonsignificant correlation between VTS score and passing accuracy ($r = -0.380$, $p = 0.20$). However, there was a strong correlation found between consistency score and passing accuracy ($r=0.650$, $p = 0.016$). When examining players based on their role of attackers compared to defenders, there were strong correlations for attacking players consisting of a nonsignificant strong correlation with consistency and passing accuracy ($r = 0.730$, $p = 0.063$) was observed. For defenders, consistency and defensive win rate had a strong correlation ($r = 0.731$, $p = 0.099$). This is the first study to examine NeuroTracker (NT) VTS and soccer performance metrics related to in-game decision-making. While consistency was found to correlate with some of the decision-making metrics, VTS did not correlate with any team performance metrics. Future research should seek to include multiple teams for improved sample size while also exploring a potential transfer effect through training.

## List of Abbreviations and Symbols

| | |
|---|---|
| 3D-MOT | 3-Demensional Multiple Objects Tracking |
| VTS | Visual Tracking Speed |
| IAB | Individual Alpha Bands |
| TBI | Traumatic Brain Injury |
| EEG | Electroencephalography |
| MPTF | Modified Perceptual Training Framework |
| ERD | Event Related Desynchronization |
| 1-v-1 | One versus One |
| ERP | Event Related Potential |
| CI | Confidence Intervals |

**TABLE OF CONTENTS**

**LIST OF TABLES**

**LIST OF FIGURES**

# CHAPTER I

# INTRODUCTION

Individual differences in executive function are primarily genetic in origin (Friedman et al., 2008), however the development of the brain is postulated to be epigenetic (Fagiolini et al., 2009).This suggests genes alone cannot fully elucidate brain development, whereas specific experiences and or cognitive training on specific skills are required to further enhance development (Meon, et al., 2018B). 3-demensional multiple object tracking (3D-MOT) has previously been utilized to improve processing speed (Parsons et al., 2014) and peripheral vision (Nyquist et al., 2016). The theoretical concept behind NeuroTracker 3D-MOT suggests when neurons and or a group of neurons build stronger associations into networks in the brain, these networks can transfer to other tasks that utilize the same networks. There are two main theories to potentially explain NeuroTracker (NT; CogniSens Athletic, Inc., Montreal, Quebec, Canada) and transferability. The first is Edelman's theory of "neural group selection" which claims learning and development are caused by specific neural brain development in which specific experience will influence specific neurons that are needed for a particular skill and organize the neurons into groups that connect different areas of the brain for execution of that skill (Moen et al., 2018A). The second theory to support the idea is  neural plasticity, which claims neurons or a group of neurons that are active at the same time will strengthen their connection and fire simultaneously (Meon et al., 2018B). These two theories are used to explain cognitive training and executive function and transfer to real world experience and sports performance benefits.

Sports performance at the highest level requires attention, decision making and working memory to functional at optimal levels in stressful and cognitively demanding environments (Walton et al., 2018). Executive functions are part of specific task related perceptual-cognitive functions and are related to level of expertise in performance (Vestberg et al., 2012). For example, greater perceptual-cognitive function is seen in high level professional division soccer males and females (mean score: 15.52AU) than lower division male and females players (mean score: 13.18AU), but both have superior scores compared to standard population (mean score: 9.51AU) when using a design fluency test (Delis-Kaplan Executive Function System- assesses flexibility of thinking, inhibition, problem solving, planning, impulse control, concept formation, abstract thinking and creativity) (Hommack et al., 2005; Vestberg et al., 2012). Cognitive training has also been shown to benefit and have transfer to general population in specific tasks and those with brain injuries. These benefits appear to have a stimulus threshold, when analyzing 3D-MOT improvement curves there appears to be a plateau beyond 40 sessions and a new stimulus needs to be introduced to see further improvements (Faubert & Sidebottom, 2012). While there is evidence to support a link between cognitive training and improvements in athletic performance, further research is justified within this paradigm and specifically with the use of 3D-MOT training. Potentially the utilization of 3D-MOT in soccer could be beneficial to improve performance related decision-making statistics, but this concept is yet to be examined.

*Purpose*

The purpose of this study was to examine visual tracking speed and efficiency measures (passing accuracy, intercepted passes, dribble success rate, and packing/impect rate) to determine if visual tracking speed was correlated with decision making performance variables.

## *Research Questions*

1. Can visual tracking speed be utilized as a tool for correlating a NCAA Division I women's college soccer players (amateur) performance metrics?
2. Is visual tracking speed only beneficial for predicting position specific metrics or a certain efficiency measure (passing, dribble rate success, etc.)?
3. What positional group will have the highest visual tracking speed?

## *Hypothesis*

Visual tracking speed will have a moderate correlation with efficiency and performance measures for NCAA Division I women's college soccer players.

Strength of correlation between visual tracking speed and efficiency measures will be associated with different positions.

Midfielders will have the highest visual tracking speed.

## CHAPTER II

## LITERATURE REVIEW

### Cognitive Function, Development, and Application

Intellectual capacity within humans is connected to certain brain structures like the thickness of the cerebral cortex (Menary et al., 2013). The cortex is composed of a tightly folded sheet of neurons ranging from 1.5 to 4.5 mm in thickness (Parent & Carpenter, 1995). A correlation between brain volume and intelligence ($r = 0.39$) has been observed to be most valid measure (Gignac & Bates, 2017). Current neuroscience literature further signals general intelligence is positively linked to cortical thickness in areas of associated cortices distributed in both brain hemispheres (Kamara et al., 2009; Menary et al., 2013). Positive associations of cortical thickness with general intelligence were indicated by significant frontal and parietal clusters in the left hemisphere and significant frontal, lateral occipital and precuneus (superior parietal lobe) clusters on the right hemisphere (Menary et al., 2013). For example, cortical thickness changes are significantly associated with cognitive function in healthy elderly populations and that multidomain (combination of several cognitive functions) cognitive training has been shown to be more effective comparatively to single-domain training (Jiang et al., 2016). It has been suggested that cortical thickness of specific areas is related to level of and stimulus of training. For example, when examining professional divers to non-athletes, the divers had three regions (left superior temporal sulcus, right orbitofrontal cortex and parahippocampal gyrus) with significant increased cortical thickness (Wei et al., 2011). The specificity of training stimulus was significantly correlated with cortical thickness of the right parahippocampus gyrus, which suggests experience/learning induces plastic changes in the particular brain structures related to the task but can only be inferred due to the nature of the study (Wei et al., 2011). Further, this concept has been demonstrated even within a multitude of occupational paradigms including taxi driver experience and volume of right posterior hippocampus (Maguire et al., 2000), musician status and grey matter volume (Gaser & Schlaug, 2003), meditation experience and cortical thickness (Lazar et al., 2005), and learning knowledge and grey matter of posterior hippocampus (Draganski et al., 2006). This could explain the results observed by Moen and colleagues (2018B) noting specific benefits on skills used when training with a cognitive 3D-MOT training system (NeuroTracker) but does not show significant improvements on different aspects of executive function, nor transfer to other executive function brain tasks (Moen et al., 2018B). This suggests that specificity of the executive function training is critical and does not transfer to other non-related forms of executive function. The tasks will target specific regions of the brain relevant to the task.

In addition to the precise structure of the brain targeted by task specific stimuli, specific brainwaves can be impacted. Neuronal oscillations fluctuate between two states known as the up state, where neuronal depolarization and firing bursts of action potential happen, and the down state with resting activity and hyperpolarization of the membrane (Cossart et al., 2003). The neuronal oscillations, termed "brain waves", interact across different frequencies to modulate each other by sensory or motor experiences and engage in specific behaviors (Buzsáki, 2006; Maris et al., 2016). Brain waves either compete or cooperate with each other to participate in distinct physiological processes, such as bias input selection, temporarily link neurons into assemblies, and facilitate synaptic plasticity, which supports temporal representation and long-term consolidation of information (Buzsáki & Draguhn, 2004). There are five different brain waves: Delta waves (1-4 Hz), Theta waves (4-10 Hz), Alpha (8-12 Hz), Beta (12-30 Hz) and Gamma (>30 Hz) (Buskila et al., 2019). Alpha band and individual alpha band (IAB) activity is closely related to cognitive functions (attention, memory, perception) (Nan et al., 2014). Gamma bands represent the "binding rhythm" in the brain reflecting underlying large-scale cortical cooperation for attention and memory while playing an important role in synaptic plasticity (Jensen et al., 2007). Improvements in attention has been shown to correspond with decreases in 2-11 Hz, which is associated with Theta waves, while there were relative increases in Beta activity (Parsons et al., 2014). The opposite can be observed in those with attention deficits, where individuals have high amplitudes of slow waves (2-11 Hz) and deficits in Beta activity (12-20 Hz) (Arns et al., 2014). When the brain is relaxed and calm, more Delta and Theta waves are produced, and when alert and awake, there are more Alpha and Beta activity (Dunn et al., 1999).

Dynamic peripheral visual performance related to alpha activity in soccer players has a significant positive inter-individual correlation with amplitudes in the alpha bands and IAB during a peripheral vision task (Nan et al., 2014). Increases in alpha power appears over cortical areas responsible for processing distracting information and sustained focal increases in alpha power increase prior to an anticipated stimulus (Foxe & Snyder, 2011). The results suggest individuals with higher alpha activity during a visual task possess better peripheral visual ability, which engages a more extensive cortical network compared to the central visual field (Nan et al., 2014). Far peripheral visual field is likely to involve a distinct network of specialized cortical areas, which are located in the depths of the calcarine sulcus and interhemispheric fissure (Hu et al., 2014). The anterior portion of the occipital lobe and the parietal lobe is separated by the calcarine sulcus, which with greater amplitudes of IAB could suggest greater activity being transmitted to the parietal lobe. This aids in visual attention and spatial reasoning and coordinating information from other parts of the brain (Nan et al., 2014). This could plausibly explain the results in the previously mentioned studies that visual training could improve the network between the occipital and parietal lobe, as well as increase the occipital lobes alpha activity. In a non-athletic college population using 3D-MOT (NeuroTracker) improved cognitive function and changes in brain function were observed (Parsons et al., 2014). The 5-week training showed improvements in visual information processing speed and increases in the gamma bands in the occipital cortex responsible for visual processing were observed, which could explain the improvements in visual information processing speed (Parsons et al., 2014). This potentially signals an improvement in cognitive function has the potential to lead to transfer in other activities with similar training stimulus.

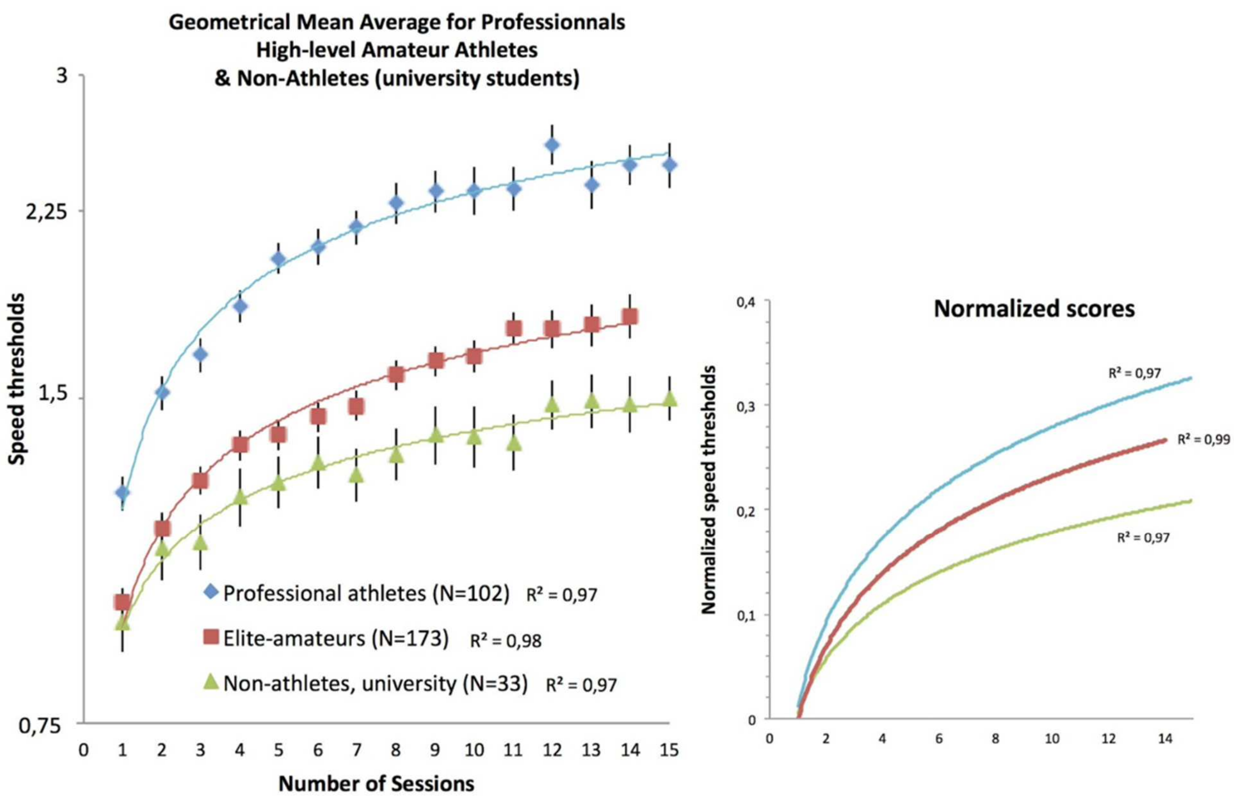
The Modified Perceptual Training Framework (MPTF) provide grounds to be a strong predictor of transfer-effects of cognitive training. There are three interactive factors of effective tasks: 1: perceptual process that link 2: Information and 3: Action that align with three factors that differentiate modified perceptual training tools 1: Target perceptual function 2: Stimuli and 3: Response time (Hadlow et al., 2018). This suggests that cognitive training that incorporates these three interacting factors would plausibly have benefits and transfer effects. MPTF's key prediction of stronger transfer effects are approaches that demonstrate maximal training-to-competition for skill being trained and stimuli used (Hadlow et al., 2018). This is demonstrated when comparing volleyball players and sprinter auditory reaction time and anticipatory skills (Nuri et al., 2012). Sprinters had significantly faster reaction times in response to the auditory stimuli possibly attributed to the nature of their sport as the start of the race is initiated by an auditory stimulus (i.e., gunshot). While the opposite was true for volleyball players, which performed worse on the auditory reaction time, but were significantly better in anticipatory skill and correct reaction times

(Nuri et al., 2012). This demonstrates the specificity of the training stimuli importance and transfer effect pertaining to sport specific game stimulus. Alternative examples of MPTF application also currently exist in the literature. Soccer referees (n=33) utilized 2D to 3D simulated training in offside calls for one session of 40 video clips. Higher accuracy scores for correct offsides decisions were noted for near (within 15 yards of ref) 3D offsides (81.8%) compared to 2D (72.7%) (Put et al., 2014). Interestingly, Put's previous research demonstrated the efficacy for web-based online training (2D) video simulations resulted in a positive direct transfer to on-field offsides decisions in games as well (Put et al., 2013). The results comparing 3D to 2D would suggest that 3D offside simulations would allow for an even greater transfer to in-game decisions by referees because 3D provides a more dynamic and complex scene with simultaneously moving objects that provide more visual information. However, the effectiveness may be limited to closer distances (15 yards) to the referee given lack of significance observed at a distance 30 yards or greater (3D: 77.8% vs. 2D: 77.8%, $p = 0.25$) between training modalities (Put et al., 2014). Similarly, the direct transfer effect has been examined in elderly driving abilities comparing different cognitive training modalities over 4-weeks (3D, 2D, and crossword puzzles). Significant improvements on the driving aptitude test and on-road evaluation for the 3D group, which did in-vehicle cognitive training reacting to lights and colors with the steering wheel and brake pedal were observed (Nozawa et al., 2015). While the 2D group (PC with a 3-button mouse with same reaction training) did not show significant improvements or a training effect (Nozawa et al., 2015). Interestingly the group that performed crossword puzzles for 20-minutes a day had significant improvements on the driving aptitude measure, but not the on-road driving safety test indicating individuals may have had improvements of general cognitive function (Nozawa et al., 2015). The results of the previous study suggest 2D cognitive training may be ineffective for transferability and benefits of cognitive function. However, cognitive training using computer oculomotor rehabilitation (COR) have been shown to be successful in individuals with traumatic brain injury (TBI) (Ciuffreda et al., 2017). Individuals were seen to have better oculomotor control after 9-hours of the COR program and shown to transfer over to the daily life activity like reading (Ciuffreda et al., 2017). In the previous decade, it has also been used for injury/concussion prevention and management for concussions (Clark et al., 2012; Clark et al., 2015B). For example, a NCAA Division I football team utilized vision training over the 2010-13 seasons resulting in a significant reduction in the rate of concussions from 9.2 diagnosed concussions to 1.4 concussions per season (Clark et al., 2015B). This significant reduction occurred while the NCAA college football concussion rates increased over the same 2010-13 time period. Although this could be due to stricter concussion protocol and implementation (Zuckerman et al., 2016). Although not fully elucidated, this concept warrants further examination in the efficacy of the utilization of vision training to monitor concussions and return to play as the data is currently limited. Chermann et al. (2018) examined this concept utilizing NeuroTracker to determine if 3D-MOT performance was correlated with the number of symptoms post-concussion. There was an observed negative impact on processing and learning the perceptual-cognitive 3D-MOT task 48-hours post-concussion compared to individuals that were cleared to return to play (Chermann et. al., 2018). This demonstrates similar 2D or 3D-MOT systems could potentially be a beneficial tool for assessing athlete's ability to return to play from a concussion, as well as potentially aid in concussion prevention. Furthermore, Clark et al. (2015A) found the incidence of concussions decreased in players who participated in vision training compared to those who did not. Interestingly this was shown in two different training models; both in two sessions per week for six-weeks and six sessions a week for two and a half weeks for preseason (depending on length of preseason) and one maintenance session a week in-season improved the depth perception of elite athletes (Clark et al., 2015A). Additionally, an increase in reaction time (pre = 0.354 ± 0.034s, post = 0.315 ± 0.031s) and peripheral vision on a light board (pre = 70.25 ± 9.61 hpm, post = 89.9 ± 10.5 hpm; $p \leq 0.01$) in the athletes were also observed in the study (Clark et al., 2015A). These two factors together could plausibly aid in a decrease injury occurrence rate due to the ability to have a greater awareness of field surroundings, processing and reaction. Additionally, multiple investigations have observed that a lesser neurocognitive function of an athlete can be associated with a potentially higher risk of musculoskeletal injury (Wilkerson, 2012). Wilkersons group (2012) further suggested reaction times that were ≥ 0.545s were at twice the risk of injury. In addition to reaction time, cognitive tests appeared to reveal an association with injury risk. Previous studies have shown with the ImPACT cognitive test (Verbal memory, visual memory, processing speed, and reaction time); individuals who suffered non-contact ACL injuries had significantly lower scores compared to non-injured athletes (Swanik et al., 2007). Further, Méjane et al. (2015) examined 3D-MOT trainings cognitive load to examine lower body biomechanical changes during landing to determine if there is a link between injuries. The results showed landing performance simultaneous with 3D-MOT resulted in changes in knee abduction angle, which was the only parameter significantly affected for every subject: four had more abduction (greater risk of ACL injury) and three had reduction in abduction compared to no MOT (Méjane et al., 2015). Beyond concussion and injury prevention, cognitive training may potentially be advantageous within sport performance paradigms as well.

**Sports and cognitive training**

Vision sports training has multiple categorizations and the current literature supports improvements in sports. Ultimeyes reduced strikeouts and increased runs created compared to previous season (Deveau et al., 2014); NeuroTracker improved small sided-game performance in university level soccer players compared to a control (Romeas et al., 2016); Neurotrainer has evidence of improving far periphery vision persisting for 12-months (Nyquist et al., 2016); Dynamavision's light board improved batting average, slugging percentage and on-base percentage compared to the previous season and other teams (Clark et al., 2012); and compared to baseline Quite eye training improved golf putting performance (Vine and Wilson, 2010), jump shot performance in games (Oudejans et al., 2005), and better shooting accuracy for international level skeet shooters (Causer et al., 2011). Vision training and lights boards are commonly utilized in a multitude of sports with the aim to improve awareness of athlete's space and moving factors, like opposing team and teammates. Currently the literature suggests the separation between elite decision makers from amateur and novices are better pattern recognition (Gorman et al., 2012), anticipation (Müller & Abernethy, 2012), different visual search strategies (Klostermann et al., 2018) and knowledge structures (Sutton & McIlwain, 2015). NeuroTracker 3D-MOT has been utilized to examine an assortment of sports and in diverse levels of expertise of athletes in support of this concept. When comparing professional athletes (English premier league, National hockey league, French Top 14 Rugby League), elite-amateurs (NCAA athletes) , non-athlete university students' visual tracking speed (VTS) over 15-sessions, professional athletes differed from the other two in their capacity to learn shown in Figure 1 (Faubert, 2013). Interestingly, these individual's baseline speed thresholds were greater than the amateurs and non-athletes demonstrated professional athletes unique capacities to process complex visual scenes suggesting rapid learning (Faubert, 2013). It also suggests professional athletes appear to be able to hyper-focus for short durations in learning compared to amateur athletes and non-athletes functions for the NeuroTracker VTS tasks, as seen in the Figure 1. When comparing expert, elite and amateur table tennis players' electroencephalogram (EEG) as the individuals watched serves and were instructed to imagine their return hit, the expert players showed stronger 8-10 Hz ERD (events related desynchronization)

**Figure 1.**




*Note:* Visual speed threshold comparing professional athletes, elite-amateurs, and non-athletes learning complex and neutral dynamic visual scenes (Faubert, 2013)

(Wolf et al., 2014). As previously mentioned, 8-10 Hz is the frequency of alpha waves, which is closely related to cognitive function (attention) (Nan et al., 2014). Plausibly elite athlete's brains have greater stimulation of brain waves that allows for greater attention or perception of the specific task.

3D-MOT training has also been suggested to improve archery athlete's concentration metrics measured by increases in competition scores. However, conventional training (Examples: warming up, shadow shooting training without arc, concentration training using flaming candles, meditation training, and imagery training followed by shooting at varied distances) has also had significant effects (NT pre: 11.2 AU vs. post: 19.7 AU - gain score of 8.5 AU; Conventional pre: 11.1AU vs. post: 15.6 AU - gain score of 4.5 AU) on archery's concentration measures (Komarudin et al., 2020). Interestingly, even though both modalities improved concentration in archery athletes, 3D-MOT training effects were shown to be significantly better post-test ( 19.7 AU vs 15.6 AU) than conventional training with the pre-test being similar (11.2 AU vs 11.1 AU) (Komarudin et al., 2020). Furthermore, investigations comparing cognitive training modalities have examined VTS and light board reaction times ability to predict in-game performance related decision statistics (assists, turnovers, assist-to-turnover ratio, steals) during a professional basketball season (82 games). Reaction time was not related to any performance measures (visual reaction time; $p = 0.829$, motor reaction time; $p = 0.747$, physical reaction time; $p = 0.716$) (Mangine et al., 2014). However, VTS was determined a "most likely positive" relationship with magnitude-based inferences between VTS and assists ($r = 0.78$; $p = 0.003$), steals ($r = 0.77$; $p = 0.003$, and assist-to-turnover ratio ($r = 0.78$; $p = 0.003$) throughout the NBA season (Mangine et al., 2014). In regard to other sports, NCAA Division I men's and women's hockey team's forwards (compared to other positions) observed a 69% variance ($p < 0.01$) in goals scored during 2011-2013 season were predicted by faster reaction times to visual stimuli, better visual memory, better visual discrimination, and a faster ability to shift their focus between near and far objects measured by the Nike SPARQ Sensory Performance System (Nike Inc., Beaverton, OR)(Poltavski & Biberdorf, 2015). Nike SPARQ Sensory Performance System is a computer-based vision assessment that evaluates athletes on 10-sport relevant visual and sensory performance skills: Visual Clarity, Contrast Sensitivity, Depth Perception, Near-Far Quickness, Target Capture, Perception Span, Eye-Hand Coordination, Go/No Go, and Reaction Time (Erickson et al., 2011; Poltavski & Biberdorf, 2015). Approximately 33% of variance of in game points were significantly related to better discrimination among competing visual stimuli and reaction time to a visual stimulus accounted for 34% of variance in average duration of all players penalty time (Poltavski & Biberdorf, 2015). Similar improvements with visual training and reaction time have been observed in NCAA Division I baseball players engaging in peripheral training (3-times a week during preseason and once a week in season). The observed team's batting average increased from the season prior (2009-10: 0.251 vs 2010-11: 0.285) and slugging numbers, while the rest of the leagues numbers decreased by 0.034 ($P < 0.01$) (Clark et al., 2012). While the data is limited, the change noted in batting average, slugging, decrease in fielding errors (15%), on-base percentage were significantly different from the other Big East teams ($p = 0.02$) (Clark et al., 2012). However, this concept warrants additional investigation to fully determine the impact of peripheral training given the limited sample. Subsequently, youth field hockey players (12-16 yr.) underwent 6-weeks of vision training (DynamicEye Sports Vision Training) 3-times a week for 45-minutes and observed improvements in peripheral perception ($p < 0.001$) and choice reaction times ($p < 0.001$) that suggest are trainable with the D2 board training (Schwab & Memmert, 2012). Contrary to other MOT trainings, improvements in 2D-MOT training ($p = 0.792$) compared to the control group were not observed (Schwab & Memmert, 2012). Despite this finding, many studies have provided evidence of the application of cognitive training to have benefits that translate into sports and ability to potentially predict decision making ability.

**Cognition training and soccer: potential training tool**

Even when retrospectively analyzing results in soccer, no one metric can accurately predict the outcome of a game. Expected goals is the most common factor used because it is the most correlated with the points received. Previous data also supports the importance in decision making and passing accuracy. In a 3-year retrospective study in the Bundesliga, match outcomes in relation to each position found the number of passes by central defenders increased in matches won and the passing accuracy percentage by central midfielders increased in the matches won and drawn (Konefal et al., 2019). Plausibly, the integration of peripheral vision training within programs could benefit soccer athletes within these areas. An investigation with NeuroTracker 3D-MOT soccer videos in male collegiate soccer players (n = 9) examined this concept and observed improved decision-making passing accuracy (15%), but not for shooting and dribbling between the pre-and post-sessions (Romeas et al., 2016). However, there was a trend after 10-sessions for improved dribbling compared to the active and passive control but failed to reach significance (p = 0.078) . Conceivably this result was due to an insufficient training stimulus given previous research has suggested a threshold of 15-sessions.  It should also be noted the smaller sample size could have influenced the results, but will be a common challenge for future research within this paradigm utilizing a single team during practice simulations. Further, decision-making was rated using a subjective decision criterion, where players earned one or no points based on their decision and outcome (Table 1).

**Table 1. Decision-making coding instrument for soccer variables decision-making coding instrument (Romeas, 2016)**

Decision-making coding instrument.

| Decision criterion | 1 point decision | 0 point decision |
|---|---|---|
| Passing | The player made a good decision when the pass went to a teammate who was open and it:<br>- directly or indirectly created a shot attempt, or<br>- went to a teammate who was in a better position than the passer. | The player made a poor decision when the pass was:<br>- made to a player who was closely guarded or when there was a defensive player positioned in the passing line, or<br>- intercepted or turned over, or<br>- made to an area of the field where no teammate was positioned, or<br>- kicked out of the field of play. |
| Dribbling | The player made a good decision to dribble when dribbling if it created:<br>- space for teammates, or<br>- a scoring opportunity, or<br>- space for the dribbler. | The player made a poor decision to dribble when he dribbled:<br>- when the defenders were in good defensive position, or<br>- into a supporting defender that was in good position, and this did not create space for the dribbler or teammates, or<br>- out of the field of play, or<br>- and the immediate defender was in a good position to defend the dribble, or<br>- without a purpose (e.g. not going anywhere). |
| Shooting | The player made a good decision to shoot when he was open for the shot and it was uncontested. | The player made a poor decision to shoot when the shot:<br>- was blocked, or<br>- was taken off balance, or<br>- was taken when one or more defensive players were in good position, or<br>- was taken when it was contested. |

Although this concept has yet to be examined over the duration of a season, potentially the use of a 3D-MOT training system within a soccer season could lead to improvements in decision-making and passing accuracy, which are linked to more positive match results. Interestingly, team success in European leagues and international football throughout the 2007-10 seasons, noted a relationship between greater possession and success in league games (Collet, 2013). Higher possession is associated with higher passing completion rate and being able to retain the ball while identify a teammate and pass the ball to them. Efficiency measures were the strongest predictors of match outcomes, like passing accuracy, shooting accuracy and passes-to-shot on goal ratios (Collet, 2013). Similar to the previous mentioned study, video-based visual training (1-v-1 situations in 40 videos) has been used as a supplemental training tool twice weekly for six-weeks, with each session lasting six-minutes in youth soccer players ($\bar{x}$ = 14 yr; n =18). The vision-training group significantly improved the number of successful decisions, which were 1v1 success rates dependent on if the player was an attacking or defensive player. The vision training group had a 24% increase in reaction time, 34% increase in the number of successful decisions and sprint time by 13% (Nimmerichter et al., 2016). The vision training group significantly improved reaction time during a reactive agility sprint test (pre: 0.41 $\pm$ 0.10 s vs. post: 0.31 $\pm$ 0.10 s; p = 0.006) compared to the control group which averaged an increase (pre: 0.43 $\pm$ 0.09 s vs. post: 0.45 $\pm$ 0.08 s; p = 0.297). As well as significantly improving reactive agility (pre: 2.22 $\pm$ 0.33 s vs. post: 1.94 $\pm$ 0.11 s; p = 0.001) compared slight decrease reactive agility (pre: 2.16 $\pm$ 0.24 s vs. post: 2.09 $\pm$ 0.14 s; p = 0.363) (Nimmerichter et al., 2016). These results plausibly suggest the soccer athletes were able to interpret and react at elevated rates enabling greater success in decision-making. This ability has translated to greater contribution to team success and associated with finishing at the top of the league table. Throughout different professional European soccer leagues the most successful teams maintained higher possession and possession advancement, passing accuracy, shots, and goal attempts, all of which is related to better to decision making (Longo et al., 2019).

**Summary**

Cognitive training efficacy has been demonstrated in multiple paradigms ranging from TBI to sport specific parameters. Specificity of the task is important when utilizing cognitive training because cortical thickness is related to cognitive training and level of training to induced changes. Specificity is also important for building greater extensive neural connection and cognitive training has caused increases in the amplitude of brain waves which indicates the brain is firing more action potentials across lobes and regions. This is important for cooperation of motor and sensory functions when performing a task, as seen with alpha bands and peripheral vision and gamma bands with visual processing. While cognitive training within sports has been utilized for many years, there is evidence to suggest improvements in sports-specific metrics, but transferability of the training to games are limited. However, the current literature has provided evidence that cognitive training can improve processing speed and VTS, which is associated with level achievement (professional sports compared to lower levels) by athletes. The data for transferability of cognitive training and or the link between VTS and in-game performance is lacking. In terms of this concept within NeuroTracker-3D-MOT, current research is limited to Mangine et al. (2018) examining the correlation between VTS and basketball-specific performance; and Faubert (2013) providing evidence that suggests professionals core sessions VTS were higher than amateurs and normal population. This in addition to the professionals being able to improve VTS at a greater rate compared to the other groups as well. Potentially higher VTS performance could be indicative of predictive performance in soccer related decision-making metrics. Further, each position produces different scenarios and responses within these metrics. Intercepted passes will be more important for defensive players compared to the forwards whereas, dribbling success rate will be more important for attacking players than defensive due to position demands. Potentially positional demands may produce different correlating responses within these sport specific metrics.

# CHAPTER III

# METHODS

## Study Design

This study utilized season statistics from a NCAA DI women's soccer team (n= 19) during the spring 2021 season (9 matches). Players core assessment scores for VTS was found using NeuroTracker 3D-MOT training program (NeuroTracker, Montreal, Canada) prior to the spring season. Players game statistics were collected through Wyscout (Wyscout, Chiavari, Italy), a multi-camera field recording system.

Approval from the university's Institutional Review Board was obtained. All participants were 18 years or older and current members of a NCAA DI women's soccer team. Data was de-identified and coded for all research purposes. The team played a total of 9 matches during the 2021 spring season. Goalkeepers and players who averaged less than 10-minutes per game were also excluded. All participants signed an informed consent form prior to the start of the study.

## Data Collection Procedures

### *NeuroTracker Baseline Measurements*

The player's NeuroTracker baseline measures were the players' VTS and were assessed by completing 1-core session on the NeuroTracker (NT; CogniSens Athletic, Inc., Montreal, Quebec, Canada) device by each player using 3D glasses similar to the methods utilized by Mangine et al.

(2014). Core assessment took place in the Gillom Sports complex prior to training. A core session consisted of 20 individual trials used to quantify spatial awareness by determining the player's threshold speed for effective perceptions and processing of visual information sources while sitting upright in a chair. The session lasted approximately 10 minutes and were given 3 practice trials prior to the 20 trials. The individual trial began with four of the eight total balls being illuminated for two seconds before returning to baseline color. These four balls were the same for all 20 trials. The participants were instructed to track these four balls for the eight second duration of individual trial. During the trial all 8 of the yellow balls moved simultaneously throughout all regions of the 3D cube for eight seconds. After eight seconds, the balls froze and were assigned a number, 1-8, by the computer. The participants were then be asked to identify by number, which four balls out of the eight they believed to be the ones originally illuminated at the start. The numbers were verbally repeated back to the participants by an experimenter to verify they were clicking the correct balls. After each individual trial, the program identified which balls were the correct four. If the participant was able to correctly identify all four balls, the speed was increased for the next trial. If one or more of the balls was incorrect, the speed was slowed down on the next trial until 20 trials are completed. At the end of the 20 trials, VTS was determined to be the fastest speed (meter per second) at which the participants could correctly identify the four illuminated balls 50% of the time. For the first trial (out of 20), the speed of the balls was at a standardized 0.68 meter per second. To avoid a training effect confounder, all players began their core session completely unfamiliar to the NeuroTracker device. Instructions were provided to participants and a demo prior to beginning the test. Participants were asked to abstain from using alcohol 24-hours prior to testing and no caffeine for 4-hours.

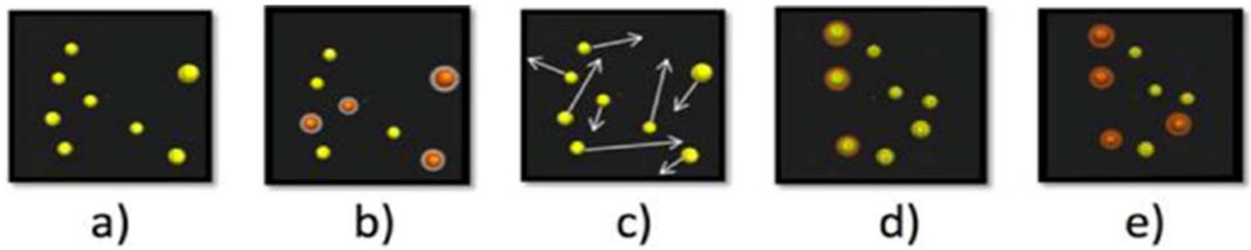



**Figure 2. NeuroTracker single trial stages (Romeas, 2016)**

*Sport Specific Measures*

Wyscout (Wyscout, Chiavari, Italy) camera system was utilized to collect players performance metrics (e.g., goals, assists, passing accuracy, shots, balls lost, and defensive win rates) over the course of the entire season. The games were recorded and uploaded to the online database where the games are tagged and a game report was automatically generated to individual player statistics and team statistics. After each game a packing and impect rate were given for each player, position (forward, defender and midfield) and team totals. This was subjective scoring measure; however, the same researcher scored this metric for all players and matches. Intra-rater reliability was tested prior utilizing a previous match. Scoring criteria (Table 2) below provides an explanation of scoring and defines each measure. Performance data was de-identified from a convenience sample of the NCAA Division I Women's Soccer team and groups within their sport-specific position groups (Defenders, Midfielders, Forwards).

**Table 2. Packing and Impect scoring criteria**

Packing: rewards players on the ball for advancing the ball forward breaking a line with a pass or beating a player or players off the dribble

Impect: rewards players who put themselves in position to receive the ball that breaks lines

**<u>Points breakdown</u>**

Each opposing player is assigned a number based on the position they are playing

- Forwards =1 point
- Midfield = 2 point
- Defender = 3 points

Players receive points for every time the players pass/dribble past an opposing team player or are on the receiving end of a pass that breaks a line (Example: An outside back pass the ball to a midfielder and breaks a line with 2 forwards and a midfielder from the opposing team, the outside back will get 4 points for packing and the midfielder will get 4 points for impect)

Inside the 18-yard box, points are also given on crosses or pass that find a teammate based on how many players it takes out of the play as a result (Example: A player takes the ball endline and cuts a cross back across the box to a teammate and that pass takes out 2 defenders and a midfield, the passer will get 8 points for packing, while the player receiving the pass will get 8 points for impect)

**Statistical Analysis**

The Shapiro-Wilk test of normality was used prior to data analysis to examine for normality of each variable. The data from each participant for passing accuracy from the 9-matches was presented as the mean over the duration of the season and other variables were converted to per minute played to account for differences in playing time. The relationships between the criterion variables were analyzed through Spearman's (rho) rank order correlation coefficient. The 95% confidence intervals (CIs) for the correlation coefficients were calculated through JASP (JASP; JASP 0.9.2; The JASP Team, Amsterdam, Netherlands). The relationship between VTS, consistency and performance metrics were interpreted through ranked data in a nonlinear, monotonic and run through Statistical Software (SPSS; V.27.0.0.0; SPSS, Inc, Chicago, IL, USA) to calculate Spearman's rho and the p-value of the relationship. The magnitude of the strength of the associations was considered very weak if Spearman's rho values are between 0-0.20, weak if between 0.21-0.40, moderate if between 0.41-0.60, strong if between 0.61-0.80, and very strong if between 0.81-1 (Prion & Haerling, 2014). Statistical analysis was performed using Statistics Package for the Social Sciences (version 26.0, SPSS Inc. Chicago, IL) and $p < 0.05$ as a statistical significance criterion.

# CHAPTER IV

## Results

From the 19 participants, 6 participants were excluded from analysis from not meeting minutes and games played criteria. Shown in Table 3, Visual tracking speeds ranged from 33.3 to 121.7 cm/s (avg: 75.3 ± 23.7 cm/s) for the 13 participants. Defenders VTS ranged from 69.4 – 121.7 cm/s (avg: 79.0 ± 23.9 cm/s), midfielders VTS ranged from 33.3 – 102.0 cm/s (avg: 64.9 ± 23.8 cm/s) and forwards ranged from 94.5 – 99.3 cm/s (avg: 96.9 ± 3.4 cm/s) (Table 4). There was weak nonsignificant correlation between VTS and passing accuracy (r = -0.380, 95% CI: -0.770, 0.216, p = 0.20), moderate nonsignificant correlation between VTS and packing rate (r = -0.466, 95% CI: -0.809, 0.114, p = 0.108) and a very weak nonsignificant correlation between VTS and average turnovers per 90-minute game (r = -0.030, 95% CI: -0.572, 0.530, p = 0.922). Similarly, there was a negative nonsignificant moderate correlation between participants fastest trial and passing accuracy (r = -0.491, 95% CI: -0.786, 0.176, p = 0.088) and fastest trial and packing rate (r = -0.489, 95% CI: -0.801, 0.136, p = 0.090) and a very weak nonsignificant correlation between fastest trial and average turnovers per 90-minute game (r = 0.126, 95% CI: -0.345, 0.706, p = 0.681). A weak nonsignificant correlation was observed for consistency and packing rate (r = 0.296. 95% CI: -0.305, 0.728, p = 0.326) and a very weak nonsignificant negative correlation between consistency and average turnover per 90-minute game (r = -0.101, 95% CI: -0.618, 0.476, p = =.742); however, there was a strong significant correlation for consistency and passing accuracy (r = 0.650, 95% CI: 0.158, 0.884, p = 0.016). When examined between attacker (n = 7) and defenders (n = 6), there were some metrics that correlated better based on role. For defenders, there was a nonsignificant strong correlation for consistency and defensive win rate (r = 0.731, 95% CI: -0.197, 0.968, p = 0.099). For attackers, VTS and impect rate per minute (r = 0.607, 95% CI: -0.269, 0.933, p = 0.148) had a moderate non-significant correlation. There was a strong correlation between consistency and offensive win rate (r = 0.767, 95% CI: 0.033, 0.964, p = 0.044) and a nonsignificant strong correlation with consistency and passing accuracy (r = 0.730 95% CI: -0.052, 0.957, p = 0.063).

**Table 3.** VTS and decision-making performance variable (n = 13)

| | **Avg ± SD** | **Range** | **95% CI** |
|---|---|---|---|
| **VTS (cm/s)** | 75.3 ± 23.7 | 33.3 – 121.7 | [60.9, 89.6] |
| **Consistency (%)** | 53.1 ± 7.0 | 42 – 63 | [48.8, 57.3] |
| **Fastest Trial (cm/s)** | 99.9 ± 21.3 | 70.7 – 129.2 | [85.1, 112.0] |
| **Passing accuracy (%)** | 60.2 ± 8.1 | 48.8 – 70.9 | [55.3, 65.1] |
| **Packing/min** | 0.43 ± 0.16 | 0.22– 0.76 | [0.34, 0.53] |
| **TO per 90** | 15.6 ± 3.2 | 9.5 – 20.4 | [13.6, 17.5] |

***Note:* Table depicts each player's VTS and an average of the 9 game performance metrics. Consistency is the accuracy at which a player correctly identified the 4 balls during the 20 trails, Visual tracking speed (VTS) is fastest speed where a player could correctly identify the 4 balls 50% of the time. Fastest Trial is the fastest trial at which a player could successfully identify all 4 balls.**

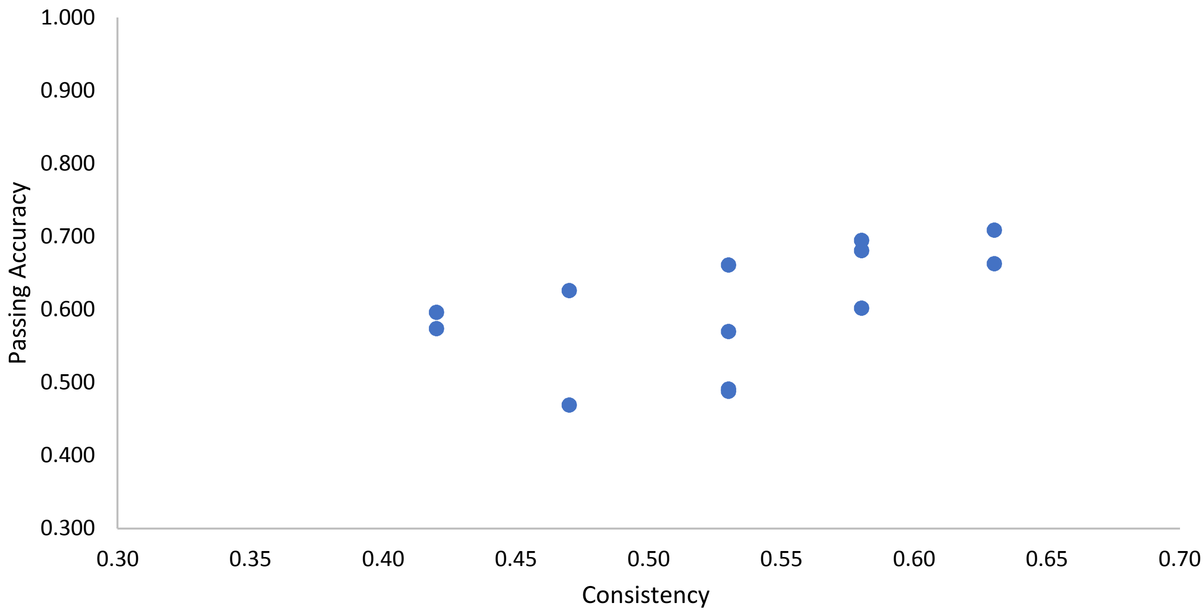
**Table 4.** Positional VTS scores and averages

| | **VTS (cm/s)** | **Fastest Trial (cm/s)** | **Consistency (%)** |
|---|---|---|---|
| **Defenders (n=5)** | 79.0 ± 23.9 | 101.9 ± 21.8 | 51.2 ± 7.9 |
| **Midfielders (n=6)** | 64.9 ± 23.8 | 96.4 ± 22.2 | 57.2 ± 3.8 |

| | | | |
|---|---|---|---|
| **Forwards (n=2)** | 96.9 ± 3.4 | 118.3 ± 1.0 | 44.5 ± 3.5 |

***Note:*** **The table depicts the positional averages on the data from the baseline trials. Consistency score is the accuracy at which a player correctly identified the 4 balls during the 20 trails, Visual tracking speed (VTS) is fastest speed where a player could correctly identify the 4 balls 50% of the time. Fastest Trial is the fastest trial at which a player could successfully identify all 4 balls.**

**Figure 3.** Scatterplot of passing accuracy and consistency



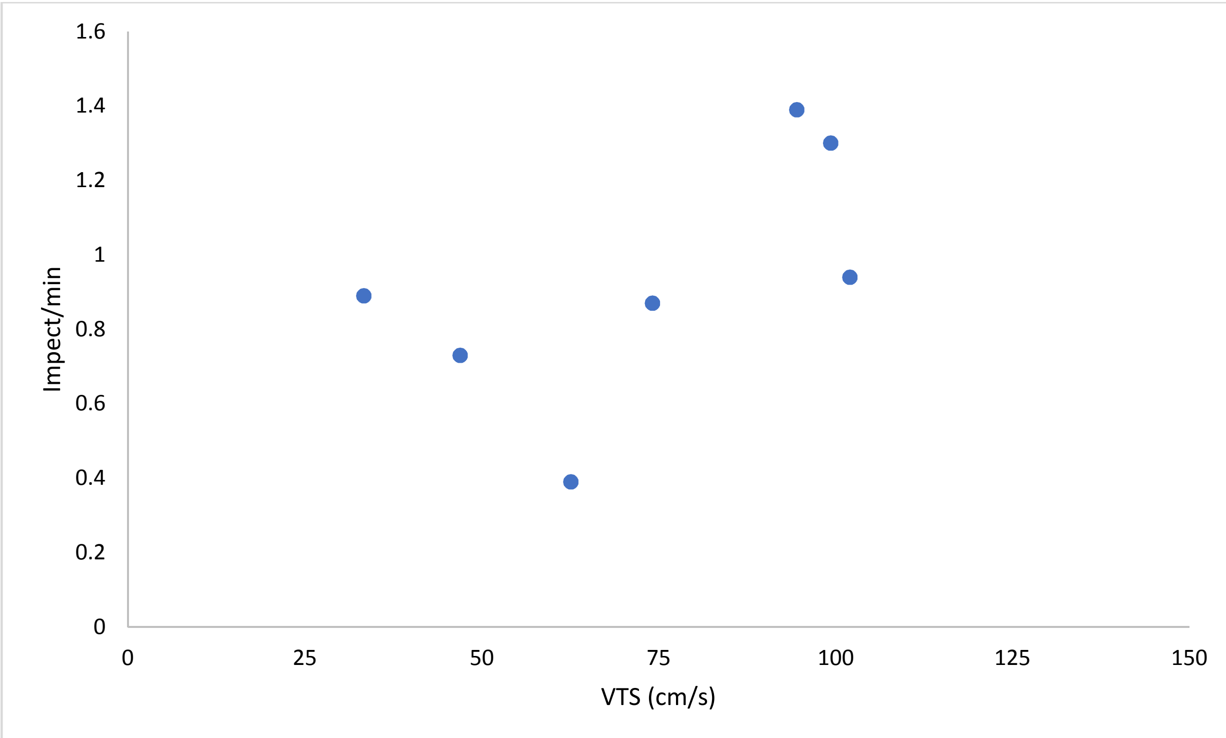

***Note:*** **Consistency score is the accuracy at which a player correctly identified the 4 balls during the 20 trails Passing accuracy is the average completion rate of passes over the 9 games. A positive correlation was seen examining passing accuracy and consistency score (r=0.650; p=0.016).**

**Table 5.** Comparison of attacking vs defensive players and NT

| | **VTS (cm/s)** | **Fastest Trial (cm/s)** | **Consistency %** | **Passing accuracy (%)** | **Turnovers per 90 minutes** |
|---|---|---|---|---|---|
| **Defenders (n=6)** | 77.6 ± 21.6 | 96.7 ± 23.3 | 53.5 ± 0.08 | 60.5 ± 0.08% | 13.1 ± 2.26 |
| **Attackers (n=7)** | 73.2 ± 27.0 | 102.7 ± 20.8 | 52.7 ± 0.06 | 60.0 ± 0.09% | 17.7 ± 2.22 |

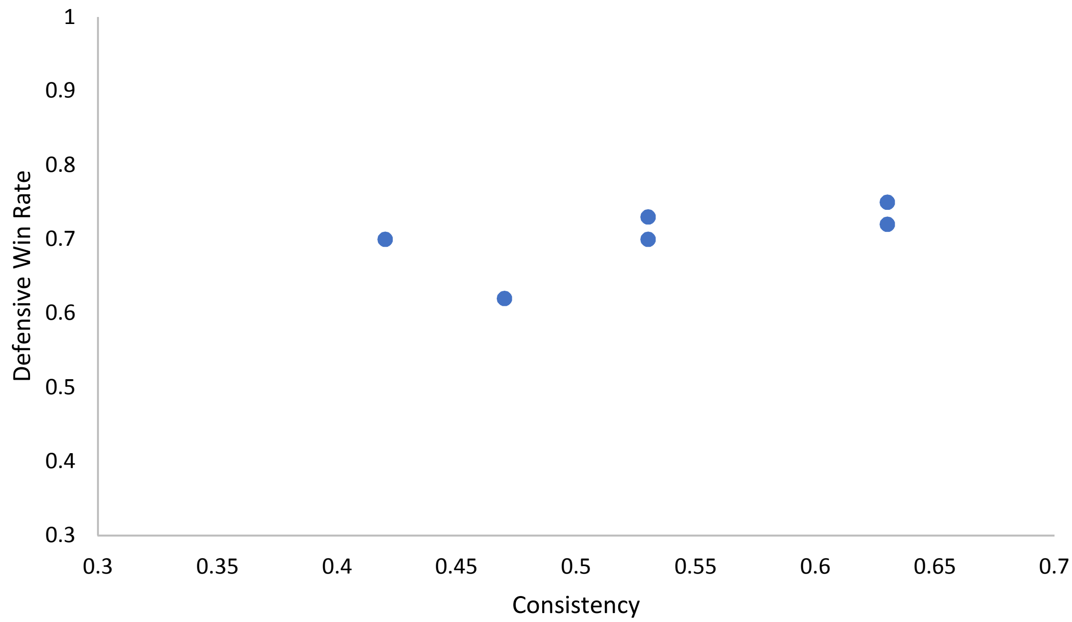
***Note:*** **Defenders (n=6) included centerbacks, outside backs and holding midfielder. Attackers (n=7) include attacking midfielders, wide midfielders, and forwards.**

**Figure 4.** Scatterplot of VTS and average impect rate per minutes played for attacking players




***Note:*** **A nonsignificant moderate correlation between VTS and average impect rate per minute (r = 0.607; p = 0.148). This graph only depicts attacking players (n = 7). Average impect rate per minute are points awarded to receiving for positioning themselves in a place to advance the ball past oppositions.**

**Figure 5.** Scatterplot of consistency score and defensive win rate for defensive players




***Note:*** **A strong correlation was found between consistency and defensive win rate for defensive players (n = 6) (r = 0,731; p = 0.099). Defensive win rate is the win rate out of 1 for defenders tackles against an opposition.**

# CHAPTER V

# DISCUSSION

The purpose of this study was to examine the potential relationship between visual tracking speed and efficiency measures associated with in-game sport specific decision-making variables. Although there was no significant correlation seen between visual tracking speed and decision-making performance variables when examining the team as a whole, a significant strong positive relationship between consistency scores and passing accuracy was observed (Figure 3). Research indicates there is a limit on the number of targets that can be tracked at a maximum speed (Holcombe & Chen, 2013). Potentially the fastest trials or scores could be influenced by random chance resulting in properly identifying the four balls correctly. This could potentially negatively affect consistency score as NT speed could be too fast leading to incorrect and inaccurate trials, but a higher overall score and peak tracking speed. This could potentially be one explanation to why a moderate but nonsignificant negative correlation was observed between passing accuracy and VTS. Conversely, individuals may accurately track a higher volume of targets at a slower speed increasing accuracy and consistency scoring (Alveres & Franconeri, 2007; Holcombe & Chen, 2012, Vater et al., 2021). Consistency score ranged between 42%-84% prior to exclusions suggesting a range of individual variability in baseline ability.

Interestingly, there was only one positive moderate correlation with VTS and impect rate per minute but failed to reach significance. Prior to this study, there was only one other study examining VTS and decision-making metrics throughout a competitive sport season producing differing results from the current investigation. Baseline VTS in NBA players had a strong positive correlation with VTS and performance metrics (assists: r=0.78, steals: r=0.77, assist-to-turnover: r=0.78) (Mangine et al., 2014). However, the previous studies results differed compared to the current investigation, which observed negative nonsignificant moderate correlations and very weak correlations for decision-making performance metrics and VTS with the whole team. The differences in strength of correlation could be due to the differences in statistical analysis utilized as their study utilized Pearson's product-moment analyzing the magnitude of their relationships, the different cognitive and visual demands of each sport, and performance metrics of interest of basketball compared to soccer, or the lack of interaction between VTS and sport. However, a more plausible explanation for the difference in VTS results could be due to the population employed with differences in age, gender, and expertise level.

Current literature suggests the separation between elite, amateur and novice decision makers are their pattern recognition (Gorman et al., 2012) and different visual search strategies (Klostermann et al., 2018). All the participants in the current study were amateurs, which could explain the nonsignificant weak to moderate correlations observed with VTS. Comparatively, Mangine et al. (2014) observed strong positive correlation in professional athletes with performance metrics (assists: r=0.78, steals: r=0.77, assist-to-turnover: r=0.78). Faubert (2013) demonstrated a difference exists in baseline VTS between elite athletes, amateurs, and non-athlete college students. The amateurs consisted of NCAA athletes (similar to the current investigation) and there was no difference at baseline from the non-athlete population (Faubert, 2013). Interestingly, amateur athletes saw a significantly greater increase in VTS over 15 NT sessions compared to the non-athlete group indicating a potential accelerated training effect within this population. Baseline VTS has also been moderately correlated positively with age and gender in younger adults (Tran and Poehls, 2018). Although, a recent investigation utilizing the transfer of NT to in-game basketball performance in a younger population (19.9 $\pm$ 1.1 years) produced nonsignificant results compared to the control group of conventional training (Komarudin et al., 2021). One possible explanation is the brain does not fully develop until 25 years old with the frontal lobe being one of the last areas to develop (Sowell et al., 1999). This area is responsible for higher executive function, related to perceptual-cognitive processing and level of expertise (Vestberg et al., 2012). Mangine et al. (2014) study had an average age of 23.3 $\pm$ 2.6 years for the front court players (n = 7) and 26.8 $\pm$ 2.9 years for the backcourt (n=5) with a range of 19.4 – 30.7 years old indicating nearly half their sample potentially had fully developed while the other half were still developing. The current study utilized similar aged athletes (19.8 $\pm$ 1.4 years) as Komarudin et al., (2021), which may potentially explain why there were no significant correlations seen with VTS with in-game metrics. This finding may be important for those within the same population but it does not explain why professional athletes have been observed to have faster baseline VTS compared to amateur and college students controlled for age (Faubert et al., 2013). While age can potentially be a factor, sensory, physical and psychological makeup also could be playing a role. While cortical thickness of the superior temporal sulcus, which has been linked to training experience, or some athletes could possess an innate predisposition (Faubert et al., 2013; Lahnakoski et al., 2012; Wei et al., 2011).

Based on positional role difference and level of risk a player can take depending on position, the assumption was VTS and strength of correlation between diverse performance and efficiency measures would be different. Players were put into positional roles compared to positions due to only two forwards meeting the inclusion criteria. When separated into attacking and defensive players (Table 5), certain position specific metrics showed positive correlations (i.e. Attacking players consistency and offensive win rate, passing accuracy, attacking players VTS and impect rate and defensive players consistency and defensive win rate). Interestingly, Mangine et al. (2014) observed differences between groups examining score differences in frontcourt and backcourt players in professional basketball athletes providing evidence of scores based on position and role. In the current study, average scores were examined between positional grouping also noting positional differences between defenders, midfielders, and forwards (Table 4). With additional investigation, the potential to generate a positional profile may be feasible.

A positional based analysis was constructed for positional roles however when examining efficiency and performance measures specific to their position and others with similar roles, the data appears to show weak positive correlations with VTS. When examining the whole teams' VTS and performance and efficiency measures, the data presented negative nonsignificant correlations. It could be these performance variables were not accurate measures when examining the team as a whole, as players depending where they are on the field can take risks while some have to play more conservative which could have influenced performance variables. The three variables we selected for the team as a whole analysis were passing accuracy, packing rate, and turnovers. These three were selected due to their relevance to game outcome. The criterion variable of interest was passing accuracy given this metric is characteristically examined in relation to team success in soccer (Longo et al., 2019; Collet, 2013). Player's average overall passing accuracy ranged from 48.8%- 70.9% (Avg: 58.4%). Defenders passing accuracy ranged from 49.1% - 62.6% (Avg: 58.5%), midfielders were 48.8% - 70.9% (Avg: 63.9%), and forwards were 46.9% - 59.6% (Avg: 53.3%) Both holding midfielders had the two highest passing accuracies on the team, which Konefal et al. (2019) found positive match outcomes for central midfielders with higher passing accuracy resulted in wins and draws. The team average passing accuracy (2020: 67% vs 2021: 60.2%) was lower than the previous season, despite the teams record of 8-1 in the 2021 Spring season compared to the fall record of 4-5. Throughout different professional European soccer leagues more successful teams maintain higher possession (>50%) and possession advancement, passing accuracy, which is related to better decision making in order to keep the ball and retain possession (Longo et al., 2019). In the case of this team, the season average for possession was 49.8%, getting out possessed in 5 of the 9 games played ranging from 34% to 60% (Q1: 44%; Q2: 49%; Q3: 56.5%). Average turnover per 90 minutes played was also examined in this study producing conflicting results compared to Mangine et al. (2014) who observed a likely positive correlation (r = .49). Potentially this is because turnovers are more frequent in soccer and positionally bias, as forwards and attacking players can take more risks compared to defenders.

Midfielders were initially hypothesized to have the highest VTS due to the positional cognitive and visual demands for ball distribution within the sport, however, seen in Table 4, midfielders had the slowest average visual tracking speed ( forwards had the highest followed by defenders). Mangine et al. (2014) when examining an NBA team saw a significant difference in back court players compared to front court players' VTS. Back court players are comprised of those point guards and shooting guards, which are players who play on the perimeter and are the playmakers compared to the front court players of power forwards and centers, who play a more simplistic role. In soccer midfielders are the link between the defense and forwards and have to be aware what is in front and behind them which led to the belief they would have the highest VTS. It was believed they would be similar to the back court player seen in the previous study due to position encompassing both attack and defensive roles compared to forwards and defenders primarily focused on one or the other. Despite midfielders having the lowest VTS, midfielders did have the highest average consistency when compared to the forwards and defenders.

In this study, consistency, rather than VTS, showed to have strong correlations with performance measures. The strong positive correlation finding between consistency and passing accuracy could possibly be explained by those with higher consistency scores were able to sustain the same level of alpha power throughout the 20 trails and limited mental fatigue, which could indicate players attenuation to in game mental fatigue and better in game decision making. Those with faster visual tracking speed trials and scores could have had greater increases in alpha power, which is responsible for processing distracting information (Foxe and Snyder, 2011). Plausibly it could be due to the maintenance of producing the same level of alpha waves, as opposed to alpha power, however this was not measured in the current investigation so can only be inferred. Another explanation could be the gamma waves production aiding in cortical cooperation for memory and attention as well aiding in the "binding rhythm" (Jensen et al., 2007). A combination of these two factors possibly contributed to higher consistency score minimizing the effects of cognitive fatigue. There is evidence to suggest cognitive tasks that require executive control show effects on mental fatigue and the degree at which performance is affected depends on the level of which the task engages the prefrontal regions (Petruo et al., 2018; Kurzban et al., 2013) In the case of these studies, they were all repeated tasks of much longer durations and trials compared to the 8 minutes and 20 trials of NT. However, brain activity and event related potentials (ERP) were not examined within the current investigation to know if cognitive fatigue or brain wave activity levels contributed to consistency score.

There is evidence to support NT and other forms of vision training potentially have a transfer effect into improvements in sports performance or increases in game performance statistics (Causer et al., 2011; Clark et al., 2012; Deveau et al., 2014; Komarudin et al., 2020; Nyquist et al., 2016; Oudejans et al., 2005; Romeas et al., 2016; Vine and Wilson, 2010). Most vision training studies are examining the effects of different perceptual training devices across varied sports and populations, which can make comparisons difficult. Some sports are more standardized and examining a transfer effect to in-game performance are more apparent. For example, Komarudin et al. (2020) examined an archery shooting score improvement after 12 sessions which resulted in a larger net gain improvement for the NT group compared to the conventional training group. In archery, there are no moving factors like oppositions or ball, allowing for a transfer effect to be more easily examined. The research is limited for soccer and in-game improvements from vision training devices. Although, there is evidence to support improvements in a standardized soccer training session. Romeas et al. (2016) examined passing, dribbling, and shooting decision-making in a controlled training session observing passing improving by 15% after 10 training session, 2 times per week for 5 weeks. In another study Nimmeritchter et al. (2016) examined 1 v 1 success rate in a controlled training session, which improved by 34% after vision training 2 times per week for 6 weeks. There appears to be potential evidence of a training effect in a standardized setting, however it remains unclear if this will translate to competition performance improvements and may be a worthwhile exploration.

**Limitations**

This study is not without limitations. The first limitation of this study was the sample size and criteria for inclusion of analysis. There were 19 total players at baseline and only 13 total were included in analysis due to not playing in 7 of the 9 games. The sample size for the current investigation as a limitation will be a common issue for future investigations utilizing competitive athletics. Secondly, the research team had no control over competition level in the season, player tactical style, and rotation. However, all teams competed against were other division l institutions and the team maintained the same tactical formation during the season.

**Conclusion**

This study is the first to examine soccer decision-making performance metrics and NT VTS over the course of a season. In regard to VTS, there were no significant correlations observed with any of the performance or efficiency measures which were not in agreement with previous research. Although, when examining players based on their position's role, there was a strong positive significant correlation seen between attacking players and VTS, however it failed to reach significance. Finally, although midfielders were hypothesized to have higher VTS due to their positional demand, however forwards who had the highest. Neurotracker's consistency percentage was found to have a strong correlation with passing accuracy. VTS did not present evidence to suggest a significant relationship to any of the decision-making performance factors. While this could suggest those with higher consistency scores were potentially less susceptible to mental fatigue possibly aiding in greater passing accuracy, teammates and opponent awareness or possibly random chance, more research and evidence is needed. Future studies should potentially inspect the impact of NT and or other cognitive vision trainers over the duration of a season examining game performance metrics with the additional inclusion of interspersed controlled practice scrimmages. Previous research suggests a possible training effect positively affecting passing accuracy (Romeas et al., 2016) and successful decision (Nimmeritchter et al., 2016) measured in a training setting. It is not clear if this will subsequentially translate to in season competition.

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# Julia Phillips

Oxford, MS 38655

**EDUCATION**

**University of Mississippi-** Oxford, MS **2020-Present**
Master of Science in Exercise Science GPA: 3.85
**University of Mississippi-** Oxford, MS **December 2019**
Bachelor of Science in Exercise Science Overall GPA: 3.97
*Minor in Chemistry*
**Florida State University-** Tallahassee, FL **2016**
Bachelor of Science in Exercise Science

**PROFESSIONAL EXPERIENCE**

**Oxford Football Club.** **2020-Present**
*Club Soccer Coach*
- Coach youth soccer players and assist in learning fundamental techniques
- Provide instruction and plan practice to facilitate in player development
- Provide each individual an environment to succeed

**Shed Fitness** **2020-Present**
*Group Fitness Instructor*
- Lead group fitness classes
- Demonstrate and correct technique for exercises
- Aid in gym management

**University of Mississippi Soccer Team** **2020-Present**
*Student Coach*
- Review film from games and training session and provide statistics based on team and individual performances
- Plan and help with individual and team training sessions and daily operations
- Provide opponent in-game statistical scouting report

**Virginia Therapy & Fitness Center** **Summer 2019**
*Intern*
- Gained hands-on experience by assisting in the post-surgery recovery of athletes
- Utilized different devices to collect and analyze data that showed patient muscular asymmetries
- Analyzed videos of patients’ movement to correct and suggest exercises that prevent re-injury
- Learned various recovery and movement techniques, gaining valuable understanding of its purpose and its connection to specific injuries and muscles

**OrthoVirginia Orthopedics** **Summer 2016**
*Intern*
- Shadowed an OrthoVirginia Orthopedics Physician and gained exposure to various clinical examinations and medical departments
- Maintained documentation for medical diagnoses and treatment plans
- Learned how to interact with a diverse group of staff members and patients

**University of Mississippi and Florida State University Soccer Camp** **2016-2021**
*Camp Counselor*
- Organized and facilitated practice sessions
- Led drills to help build performance skills of players
- Ensured a fun, positive, and competitive environment for campers

**AWARDS AND HONORS**

- Chancellor's Honor Roll (2017, 2018, 2019)
- Dean's Honor Roll (2016)
- Atlantic Coast Conference (ACC) Academic Honor Roll (2016)
- South Eastern Conference (SEC) Academic Honor Roll (2017, 2018,2019)
- Ole Miss Scholar Athlete (2017, 2018, 2019)
- Fall 2019 Academic All-America nominee for soccer
- December Student Athlete of the Month (2019)
- Taylor Medal Award (2020)
- Banner Bearer Exercise Science (2020)

**VOLUNTEER EXPERIENCE**

- Oxford Park Commission Volunteer Soccer Coach (2018-2019)
- National Girls and Women in Sports Clinic (2016-2019)
- Bramlett Elementary Walking Wednesday (2016-2019)
- Boys and Girls Club Oxford Chapter Volunteer (2018)
- Leap Frog After-School Program (2017)