Test Transferability of 3D-MOT Training on Soccer Specific Parameters

Micaela Dusseault
University of Mississippi

Test Transferability of 3D-MOT Training on Soccer Specific Parameters

By
Micaela Dusseault

A thesis submitted to the faculty of The University of Mississippi in partial fulfillment of the requirements of the Sally McDonnell Barksdale Honors College.

Oxford, MS
December 2021

Approved By

____
Advisor: Dr. Thomas Andre

____
Reader: Dr. Corbit Franks

____
Reader: Dr. Paul Loprinzi

DEDICATION

First, I would like to sincerely thank my research advisor Dr. Thomas Andre for his continual help and guidance throughout this entire process. Without his support, none of this would have been possible. It was a pleasure getting to work with you, and I greatly appreciate all that you have done for me.

Secondly, I would like to thank the Sally McDonnell Barksdale Honors College for supplying myself with an incredible environment to grow both as a student and an individual. I am appreciative of all the support Dr. Samonds has given me throughout the past three years.

Lastly, I would like to extend an enormous thank you to my family who has provided me with support every step of the way. I do not know what I would do without your continual presence in my life pushing me to be the best individual I can be. Thank you for your belief in my aspirations. It is in large part because of you that I am where I am today.

To all who have supported me, thank you.

ABSTRACT

MICAELA DUSSEAULT: Test Transferability of 3D-MOT Training on Soccer Specific Parameters

Objective: The benefits of perceptual-cognitive training in elite level athletes has recently been investigated in multiple sports such as basketball, soccer, and archery, but conclusive evidence proving test transferability of 3D-MOT training is lacking. The purpose of this research is to examine the transferability of perceptual-cognitive training to on-field soccer performance parameters. **Participants:** NCAA Division I women's soccer players (n=22) between the ages of 18-25 who were placed into either the experimental group (n=10) or control group (n=12). After baseline testing for both groups to determine visual tracking speed (VTS), the experimental group completed 10 3D-MOT training sessions with NeuroTracker™ over four-weeks. Game performance data, successful action, passing percentage, and short and medium range passing percentage, was collected utilizing Wyscout video analysis software during the 2021 season. **Results:** Analysis utilized an ANCOVA and observed no statistical significance ($p > 0.05$) 0.304 significance value. However, the mean VTS for the NeuroTracker™ training group increased by 0.88 from pre-3D-MOT training to post-3D-MOT training, and the control group increased by 0.15 ($p = 0.002$). The average passing-accuracy for the experimental group increased by 13.45% vs. 5.71% for the control group (mean and SD). The 3D-MOT VTS measurement increased for eight out of 10 participants in experimental group throughout the 10 sessions. **Conclusion:** The effect of test transferability of 3D-MOT training on soccer specific parameters may be present, but causation of test transferability is not present within the current study potentially due to small sample size. Further research is needed in order to investigate the cause-and-effect relationship of

3D-MOT training on soccer specific parameters. Multi-site data collection will be needed to increase sample sizes for similar investigations.

TABLE OF CONTENTS

LIST OF TABLES	vii
LIST OF ABBREVIATIONS	viii
INTRODUCTION	1
METHODS	5
RESULTS	9
DISCUSSION	14
CONCLUSION	19
REFERENCES	20

LIST OF TABLES AND FIGURES

Table 1: Subject Classification Characteristics 6

Table 2: Subject Position Characteristics 6

Table 3: Experimental Group Consistency, % Correct, and VTS Difference 10

Table 4: Experimental Group VTS Net Improvement 13

Table 5: Successful Actions Performance Statistics 13

Table 6: Passing Percentage Performance Statistics 14

Table 7: Short and Medium Passing Percentage Performance Statistics 15

Figure 1: Comparison of Pre-Training and Post-Training VTS Between Experimental and Control Group 10

Figure 2: Experimental Group Average VTS 11

Figure 3: Experimental Group Average Fastest VTS 12

Figure 4: Experimental Group Average Slowest VTS 12

LIST OF ABBREVIATIONS

3D-MOT	3 Dimensional-Multiple Object Tracking
NT	NeuroTracker^{TM}
SD	Standard Deviation
VTS	Visual Tracking Speed

INTRODUCTION

Neuroplasticity is the brain's ability to alter synaptic connections throughout one's lifetime (Wei et al., 2011). Experiences and specific training provide the basis for the brain's development, leading to the claim that the development of the brain is epigenetic or not based on genetics alone (Moen, Hrozanova, Stiles, 2018). Neural tissue reorganization is ongoing and particularly present when learning new tasks (Faubert & Sidebottom, 2012). Alterations to synaptic connections can occur very shortly following perceptual-cognitive training causing significant functional gains (Faubert & Sidebottom, 2012). Perceptual-cognitive training aims to improve an athlete's anticipation, decision-making, and on-field performance ability through the use of sport-specific visual training (Hadlow et al., 2018). Evidence shows that within five days following perceptual-cognitive training, neuroanatomical changes can occur (Faubert & Sidebottom, 2012). Because of these observed changes, perceptual-cognitive training programs have sparked great interest as evidence suggests training programs lead to increased processing speeds and visitation attention.

There are various interventions used to try to influence perceptual-cognitive functioning: pencil-and-paper type tasks, advanced computer or video game type programs, brain-computer interfaces, nutritional supplements, and pharmacological drugs (Parsons et al., 2016). The brain-computer interface cognitive intervention showed robust effects for transferability to specific tasks; while other methods such as pencil-and-paper, showed inconsistent effects of transferability and no reports of lasting effects (Parsons et al., 2016). The use of multiple object tracking training software has been shown by neurological evidence to improve attention, visual information processing speed and working memory (Romeas et al., 2016).

One such perceptual-cognitive training platform NeuroTracker™ utilizes a 3D-MOT system to stimulate a high number of brain networks including complex motion integration, dynamic, sustained and distributed attention processing and working memory (Faubert & Allard, 2013). 3D-MOT utilizes a three-dimensional representation of moving objects which requires active processing and the simulation of the perceptual component of decision-making (Romeas et al., 2016). The multiple object tracking training stimulates the parietal and frontal regions of the cortex which are primarily responsible for the attention shifts and eye movement during the training session (Culham et al., 1998). The stimulation of the middle temporal complex is primarily due to motion perception (Culhamn et al., 1998). 3D-MOT training sessions actively stimulate multiple brain pathways in the dorsal and ventral tracts involved in decision-making which allude to its effectiveness in enhancing cognitive functioning in athletes (Goodale & Milner, 1992).

Expertise in sport has been shown to relate to high levels of performance on measures of processing speed and visual attention (Voss et al., 2010). An increase in processing speed and visual attention capability might lead to increased expertise in sport and an increase in performance measures such as passing percentage. In support of this, elite athletes have been found to perform faster and more accurately than novice or lesser skilled athletes on decision-making tasks (Moen, Hrozanova, Stiles, 2018). This ability to perform faster and more accurately on decision-making tasks is likely due to increased cortical thickness in brain regions associated with perceptual-cognitive functioning. Evidence suggests that the level of athletic performance corresponds to mental capacity for learning dynamic tasks (Faubert, 2013). The superior temporal sulcus which plays a role in motion perception has been shown to be an area of the brain that differs in cortical thickness between athletes and non-athlete controls (Faubert, 2013).

In relation to the context of sport with 3D MOT training, studies have been conducted with NBA players (Magine et al., 2014), elite level soccer players (Scharfen & Memmert, 2020), and archery athletes (Komarudin, 2020) to test transferability of perceptual-cognitive training to specific sports measurements. Gerald Mangine and his colleagues (2014) conducted research examining a professional basketball team, and observed a potential positive association between visual tracking speed and assists and steals throughout the season. In addition, the authors suggested there were most likely positive associations between visual tracking speed and assists, steals, and assists to turnover measurements, and a likely positive association between visual tracking speed and turnovers measured (Magine et al., 2014). Interestingly, the relationship between reaction time measures and visual tracking speed showed no significant relationship (Magine et al., 2014). Mangine et al. (2014) suggested a potential role for visual tracking speed performance to indicate and predict playmaking ability through analysis of sports parameters, but additional research in this space is needed. Komarudin et al. (2020A) utilized university basketball players and also demonstrated a positive correlation between visual tracking speed training and concentration, but the study lacked conclusive evidence in proving that visual tracking speed training directly affects game performance of basketball athletes because both the control and experimental group within the study showed similar playing performance measures of assists, steals, turnovers, and assists-to-turnover ratios. Additional investigations looking at perceptual-cognitive training effect in elite soccer players concluded that 3D-MOT evokes task-specific effects on training and test transferability is not likely due to the difference in the perceptual training tasks and the specific sport (Scharfen & Memmert, 2020). In order to see an effect of 3D-MOT training on task specific measures, the executive function influence on sensory information processing needs to be targeted specifically along with using 3D-MOT training in order to potentially see test transferability (Scharfen & Memmert, 2020). Research conducted with archery athletes showed an improvement in concentration following 3D-MOT training (Komarudin, 2020). With an increase in perceptual-cognitive processing speeds and concentration, an athlete can adapt and respond to high-pressure demands more effectively in a competitive environment (Komarudin, 2020B).

Soccer requires high levels of dynamic movement and cognitive intuition, forcing athletes to make decisions rapidly in order to maintain a high-level of performance. There is clearly defined positive correlation between 3D-MOT training and visual tracking speed increases, but research showing test transferability of 3D-MOT training to sports specific measures is lacking. With lack of conclusive evidence to demonstrate a positive effect of 3D-MOT training on sport specific measures, the justification for additional research within this paradigm within soccer is required to examine the effect of 3D-MOT training over the course of a Division I Women's Team Fall season on soccer specific parameters. Therefore, the purpose of this research is to examine the transferability of perceptual-cognitive training to on-field soccer performance. With 10 sessions of perceptual-cognitive training, I hypothesize that there will be a correlation between visual tracking speed and soccer specific performance measures, successful action, passing percentage, and short and medium range passing percentage.

METHODS

Ethics Statement

Approval from the University Institutional Review Board was obtained. All participants were 18 years of age or older and current members of a NCAA Division I women's soccer team. All participants were given written and verbal information about the study procedures and gave their written and verbal consent to participate.

Participants

The study utilized all eligible players (n=22) on a NCAA Division I women's soccer team (Table 1 and 2) during the Fall 2021 season (22 games). The team was divided into two groups based on position: Experimental (n=10) and Control (n=12). Each group contain roughly an even number of forwards, midfielders, defenders, and goalies. The experimental group performed 10 NeuroTracker^{TM} training sessions in the first four-weeks of the season, and the second group was the control group not performing any sessions. All players that sustained injuries, played fewer than 10 minutes within a game, or were goalkeepers (n=9) were excluded from the statistical game data collected. Over half of the subjects (n=16) had taken part in a previous 3D-MOT training session in the spring of 2021 consisting of just one baseline assessment, and this was not problematic as it relates to the results of the study; all other subjects had never taken part in a 3D-MOT training session previously.

Table 1: Subject Classification Characteristics

Classification	n	Percentage (%)
Freshman	5	22.73
Sophomore	5	22.73
Junior	4	18.18
Senior	3	13.64
Graduate	5	22.73

Table 1: University grade classification characteristics for experimental and control group participants (n=22).

Table 2: Subject Position Characteristics

Position	n	Percentage (%)
Forward	8	36.36
Midfielder	5	22.73
Defender	7	31.82
Goalkeeper	2	9.10

Table 2: Soccer specific position characteristics for experimental and control group participants (n=22).

3D-MOT Testing

NeuroTracker™ is a 3D-MOT Testing software used to conduct the baseline and 10 core research sessions for all players in the experimental group. Participants in the control group performed two training sessions: a baseline training session (pre-four-week training period for experimental group) and a concluding training session (post-four-week training period for experimental group). Again, each player within the study performed a baseline assessment using NeuroTracker™ at the beginning of the study to familiarize the individual with the process.

Participants were familiarized with NeuroTracker™ with 3 practice trials prior to conducting the baseline. The baseline consisted of 1 core session with 20 individual trials within the session. The starting speed for baseline assessment was 0.68 m/sec for all participants. During the session, participants sat upright in a dark and quiet room 8 feet away from an 8-foot-wide screen and were asked to wear 3D glasses. The baseline session lasted between six to ten minutes.

At the beginning of the baseline session, eight spheres appeared on the projector screen. Four of the spheres were illuminated briefly. The participant was asked to track the four previously illuminated spheres as they moved about the screen in relation to the other four spheres. After moving for eight seconds, the eight spheres froze, and the participant was asked to identify with numbers which of the eight spheres were previously illuminated. The numbers the participant recalled were repeated back to ensure that correct sphere numbers were being collected and clicked on the software system. Depending on if the participant correctly identified the spheres, the speed of sphere movement would increase with correct answers or decrease with incorrect answers in subsequent trials during the core session.

After baseline testing was complete, participants placed in the first group were asked to perform two to four training sessions a week for four weeks to gather a total 10 core 3D-MOT training sessions over four-weeks. Each 3D-MOT training session was conducted in an identical fashion to the baseline training in a video room located next to the soccer field. At the end of each training session, 20 individual trials, visual tracking speed, fastest trial speed, consistency (%), slowest trial speed, and percentage of spheres identified correctly were recorded. VTS is defined as the level at which all four targets initially illuminated are correctly identified 50% of the time. VTS additionally represents the upper limit of a participant's ability to visual track the moving objects. Based on participant performance, starting speed would be automatically adjusted for the next training session. If a participant saw improvement in VTS during a session, the starting speed would increase for the next session; if a participant saw a decline in VTS score during a session, the starting speed would decrease for the next session. Consistency refers to participants' ability to repeatedly pick the correct four spheres at a specific VTS. Percent correct represents the number of correctly identified spheres out of the 20 trials within one session.

Sport Specific Measures - Wyscout

Wyscout is a performance analysis system utilized to collect player performance measures (e.g. passing accuracy, shots, goals, and etc.) over the course of the competition season. The games are recorded using the Spiideo platform and then uploaded to Wyscout for player performance analysis. Performance data obtained from the Wyscout analysis program was de-identified in order to sustain player confidentially. Successful actions is defined by the Wyscout software as the total number of successful actions including passing, heading, defending, etc. within a game. Short and medium length passes defined by the Wyscout software are passes 40 meters long or less.

Statistical Analysis

Pre and Post game data were averaged between the two matches preceding the four-week training and two matches post four-week training. An analysis of covariance (ANCOVA) tests, $p > 0.05$, were conducted on successful action, passing percentage, and medium and short passing percentage percent change. Statistical analyses for VTS were performed by utilizing a 2 x 2 Group x Time factorial ANOVA with repeated measures. Significant group and time differences were determined using Fisher's Least Significant Difference post-hoc test. Paired samples T-test for consistency scores in VTS baseline to post four-week training was utilized with the experimental group. Data were analyzed with IBM SPSS statistics 27.

RESULTS

The ANCOVA test showed no statistically significant change for passing percentage between pre-passing percentage and post-passing percentage ($p = 0.304$), for short and medium range passing between pre-passing percentage and post-passing percentage ($p = 0.847$), or in successful actions between pre-successful action percentage and post-successful action percentage ($p = 0.453$). There was a statistically significant interaction between group and time ($p = 0.002$; partial $\eta 2 = .386$]), for the main effect of group ($p = .006$; partial $\eta 2 = .324$), and main effect of time ($p < 0.001$: partial $\eta 2 = .573$) for VTS (Figure 1). No significant difference was observed between consistency scores in VTS over time ($p = 0.855$). The average percent correct ranged for all ten sessions are presented in Table 3. Experimental Group VTS across each session are presented in Table 4. Successful Actions Performance Statistics for the pre- and post-game means are presented in Table 5. Short and Medium Passing Percentage Performance Statistics are presented in Table 6. Passing Percentage Performance Statistics are presented in Table 7.

Table 3: Experimental Group Consistency, % Correct, and VTS Difference

	Consistency	% Correct	VTS Difference
Session 1	55.00 ± 9.67	84.42 ± 3.21	0.69
Session 2	56.15 ± 7.58	82.98 ± 3.80	0.5
Session 3	51.92 ± 12.76	82.81 ± 2.62	0.56
Session 4	56.00 ±12.24	83.88 ± 2.91	0.47
Session 5	54.75 ± 11.89	83.33 ± 2.89	0.6
Session 6	52.83 ± 11.94	82.71 ± 2.49	0.51
Session 7	49.82 ± 9.77	84.23 ± 3.99	0.84
Session 8	52.56 ± 10.79	82.50 ± 3.86	0.66
Session 9	53.90 ± 9.28	83.28 ± 5.69	0.65
Session 10	53.20 ± 8.74	83.63 ± 4.51	0.71

Table 3: NT average measurements for VTS difference, consistency, and percent correct for the experimental group (n=10). Values for consistency and % correct represent percentages for mean ± standard deviation. No significant difference was observed between consistency scores in VTS session 1 vs. session 10 ($p = 0.855$).

Figure 1: Comparison of Pre-Training and Post-Training VTS Between Experimental and Control Group

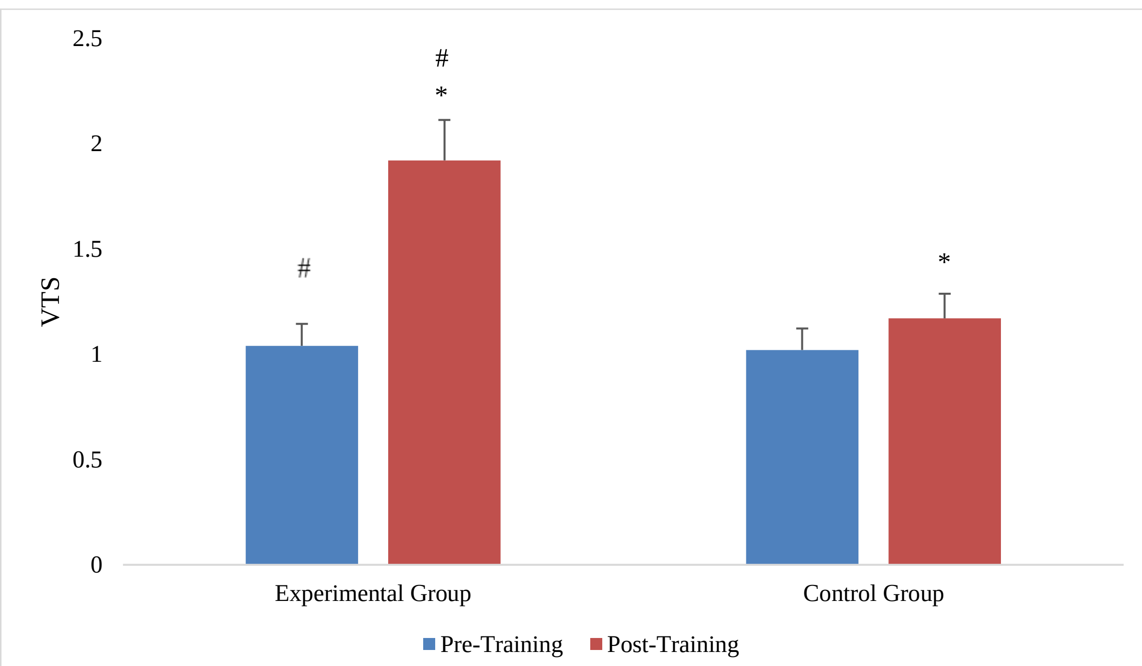

Figure 1: Average VTS pre-training and post-training for experimental group (n=10) and control group (n=12). * = significantly different between groups; # = significantly different between time

Figure 1 shows the comparison between pre-training average VTS scores for both groups and post-training average VTS scores for both groups. The experimental group saw a greater increase in post-training average VTS score than the control group. The control group saw very minimal change in average VTS score from pre-training measurement to post-training measurement.

Figure 2: Experimental Group Average VTS

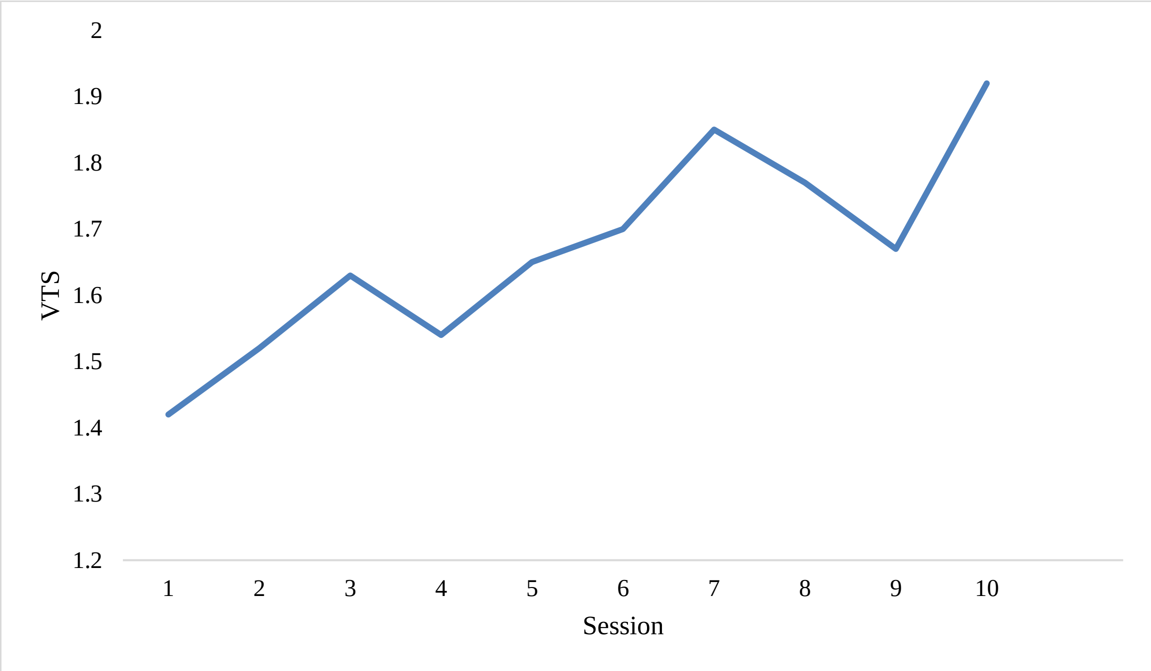

Figure 2: Experimental group average VTS (n=10).

Figure 2 shows in the mean VTS score across each training session. An overall increase in VTS over a 10 session training period is present.

Figure 3: Experimental Group Average Fastest VTS

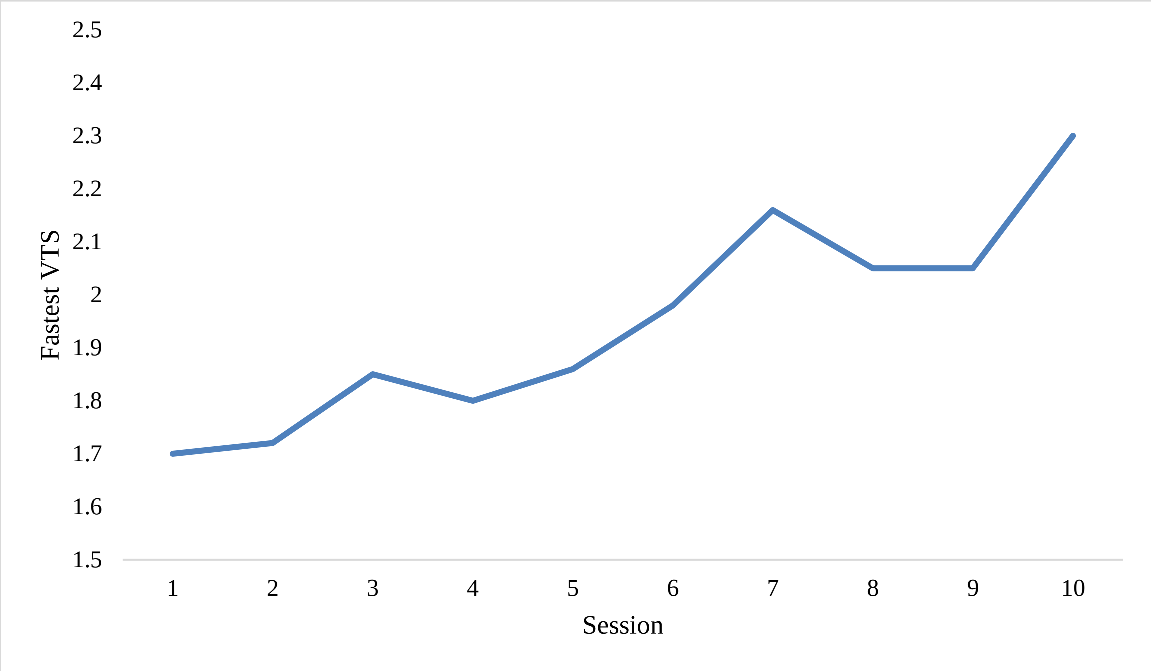

Figure 3: Experimental group average fastest VTS (n=10).

Figure 3 shows the fastest VTS score across each training session.

Figure 4: Experimental Group Average Slowest VTS

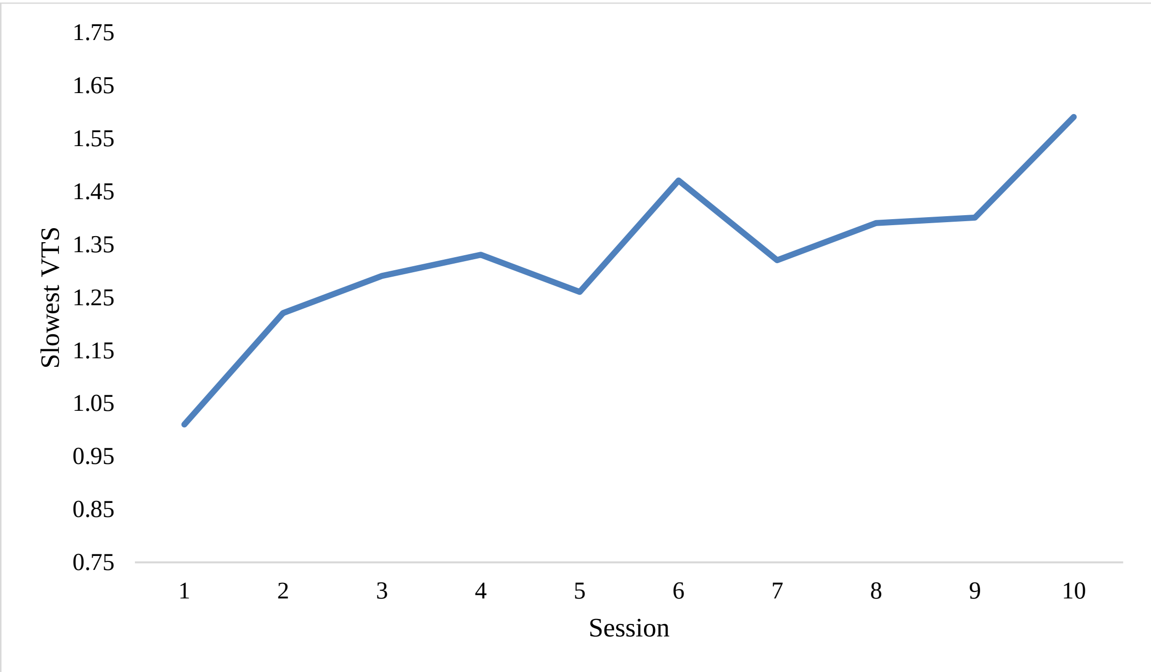

Figure 4: Experimental group average slowest VTS (n=10).

Figure 4 shows slowest VTS score across each training session. 7.

Table 4: Experimental Group VTS Net Improvement (First Three Session to Last Three Sessions)

	VTS 1	VTS 2	VTS 3	Mean	VTS 8	VTS 9	VTS 10	Mean	Net Improvement
Participant 1	1.43	1.42	1.45	1.43	1.56	1.35	1.93	1.61	12.56%
Participant 2	1.25	1.19	1.13	1.19	1.33	1.15	1.08	1.19	0.00%
Participant 3	1.38	1.71	1.65	1.58	1.71	1.85	2.07	1.88	18.78%
Participant 4	1.69	1.5	2.14	1.78	2.03	1.94	1.14	1.70	-4.13%
Participant 5	1.33	1.47	1.76	1.52	1.6	1.27	2.1	1.66	8.99%
Participant 6	1.82	1.81	1.53	1.72	2.1	1.47	2.2	1.92	11.82%
Participant 7	1.28	1.37	1.49	1.38	2.02	2.32	2.07	2.14	54.83%
Participant 8	1.42	1.19	1.47	1.36	1.95	1.42	1.76	1.71	25.74%
Participant 9	1.75	1.89	2.1	1.91	1.64	1.7	2.55	1.96	2.61%
Participant 10	1.15	1.67	1.6	1.47	1.76	2.2	2.28	2.08	41.18%
Group Mean	1.45	1.52	1.63	1.53	1.77	1.67	1.92	1.79	17.24%
Standard Deviation	0.23	0.24	0.3	0.26	0.25	0.4	0.47	0.28	18.70%

Table 4: VTS measurements (m/sec) for first three sessions, beginning average, last three sessions, and ending average for experimental group participants (n=10). Average experimental group VTS measurements for the first three sessions, beginning average, last three sessions, and ending average.

Table 5: Successful Actions Performance Statistics

	Game 1	Game 2	Pre-Average	Game 3	Game 4	Post-Average	% Change
Experimental Group	51.65 ± 17.36	51.40 ± 10.78	51.5 ± 13.4	53.60 ± 18.02	58.00 ± 8.20	55.8 ± 12.0	4.3%
Control Group	46.1 ± 8.84	54.60 ± 9.49	50.3 ± 7.8	46.87 ± 13.99	62.38 ± 8.32	55.3 ± 9.5	5.0%

Table 5: Successful action percentage averages for the experimental group (n=6) and control group (n=7). Values represent percentages for mean ± standard deviation.

DISCUSSION

The aim of this study was to examine test transferability of 3D-MOT training to soccer specific parameters during a Division I Women's Soccer season. The results of the current investigation did not see a statistically significant difference between the experimental and control groups regarding in-game performance metrics. These results differ from Mangine et al. (2014) who observed a positive association between VTS and decision metrics in professional basketball. However, the previous study utilized a single baseline session so it is unclear what impact training would have. Although, these results are in agreement with previous research using university basketball players that did not demonstrate VTS training directly affects game performance in basketball (Komarudin et al., 2020A). Similar to the current investigation a limited sample size was utilized given the unique population with university athletes. Given the limitations, there may be practical applications given as there was an increase in general passing-accuracy but a smaller increase in short and medium range passing-accuracy with 10 sessions of 3D-MOT training (Table 6). Similar increases were observed for short and medium passes in the control group as well. This may be due to the simplicity and increase likelihood of completed accurate passes across shorter distances.

Table 6: Short and Medium Passing Percentage Performance Statistics

	Game 1	Game 2	Pre-Average	Game 3	Game 4	Post-Average	% Change
Experimental Group	67.83 ± 10.57	75.30 ± 6.07	70.7 ± 8.70	78.17 ± 11.86	76.33 ± 15.47	77.1 ± 12.00	6.4%
Control Group	65.00 ± 12.61	70.6 ± 12.30	67.9 ± 11.10	72.0 ± 11.86	82.0 ± 15.47	78.1 ± 12.00	10.2%

Table 7: Passing percentage averages for short and medium length passes (40m or less) for the participants in the experimental group (n=6) and control group (n=7). Values represent percentages for mean ± standard deviation.

The positive increase in passing-accuracy aligns with previous research conducted showing that there was a 15% improvement in passing-accuracy in soccer players in the experimental 3D-MOT training group in comparison to the control group (Romeas et al., 2016). However, the previous study utilized standard drills instead of competitive match play during a season. Increased passing ability and accuracy has been proven to be a better predictor of success than age in soccer (Wilson et al., 2020). Interestingly there was a 13.45% change value between pre-passing percentage averages and post-passing percentage averages, but no statistical significance was observed (Table 7). Increasing passing-accuracy can inadvertently lead to increased time of possession of the ball. In the Euro 2000 competition, successful teams had longer bouts of possession within a game than unsuccessful teams (Penas et al., 2011). In the English Premier League, teams with more success were found to have longer possessions than unsuccessful teams (Jones et Al., 2004). Further, in the analysis of 288 matches in the UEFA Champions League from 2007-2010, winners had the highest percentage of successful passes compared to teams that lost or tied, and winners had the highest amount of ball possession compared to teams that lost or tied (Penas et al., 2011).

Table 7: Passing Percentage Performance Statistics

	Game 1	Game 2	Pre-Average	Game 3	Game 4	Post-Average	% Change
Experimental Group	62.33 ± 8.89	66.60 ± 8.41	63.2 ± 8.00	73.17 ± 13.64	69.14 ± 14.35	71.7 ± 12.00	8.5%
Control Group	58.14 ± 13.30	62.63 ± 14.91	60.0 ± 11.00	58.29 ± 17.09	71.71 ± 9.52	64.8 ± 10.00	4.8%

Table 6: Passing percentage averages for the ten participants in the experimental group (n=6) and control group (n=7). Values represent percentages for mean ± standard deviation.

The control group for the four-week experiment showed improvement in passing-accuracy, short and medium range passing, and successful actions between pre- and post-average measurements (Table 5, 6, 7). The cause for the improvement in the control group is unknown but could likely be due to a confounding factor influencing the experimental group improvement percentage difference between pre- and post-average measurements for the four-week period, as well. The improvement could have been influenced by the level of competition across the games that were utilized. In addition, the improvement could be due to the increased number of games played at the end of the four weeks. As the season progresses, teams could plausibly improve from practice which could influence the passing-accuracy, passing-accuracy for medium and short-range passes, and successful actions percentage.

Komarudin et al. (2020A) conducted a study with university-aged basketball players and additionally found that the control group saw similar playing performance measure improvements compared to the experimental group. While improvement in control group playing performance measures is prevalent, the percent change for the control group for all sports specific parameters was not as large as the percent change for the experimental group (Successful Actions - 15.6% vs. 2.86%, Passing Percentage - 13.45% vs. 5.71%, and Short and Medium Range Passing Percentage - 13.22 vs. 11.42%). Similar to Komarudin et al. (2020A), statistical significance within this study for all sports specific parameters was not present, but an effect between perceptual-cognitive training and sports specific parameters is evident and indicative of a need for further research.

Interestingly, eight out of the ten participants in experimental group saw a net improvement in VTS score from the first three 3D-MOT training session average to the last three 3D-MOT training session average (Table 4). The cause for increase in visual tracking speed can be due to neural tissue reorganization. Alterations to the neuronal pathways can occur as quickly has five days following perceptual-cognitive training (Faubert & Sidebottom, 2012). The study was conducted over a four-week period, and participants were asked to perform two to four 3D-MOT training sessions each week. However, participants chose when to perform their sessions and were not assigned specific training times each week. The dips in figure 2, which graphical shows the average VTS for the experimental group, could represent VTS scores following a gap or multiple day period in which participants did not perform 3D-MOT training sessions due to traveling for competition or days of rest. The ability of the neural tissue to continue to reorganize and alter synaptic connections might have been influenced leading to a decreased VTS score.

High levels of performance on measures of processing speed and visual attention have been correlated in elite levels of sport (Voss et al., 2010). The improvement in VTS for the experimental group during the 4-week experiment could be caused by the innate ability of elite level athletes to perform faster and more accurately on decision-making tasks than their non-athletic or lesser athletic counterparts (Moen, Hrozanova, Stiles, 2018). Professional athletes have been shown to start at a higher NeuroTracker™ speed threshold than elite amateur athletes and non-athletes (Faubert, 2013). Professional athletes additionally see a steeper increase in speed threshold than elite amateur athletes and non-athletes (Faubert, 2013). Elite amateur athletes and non-athletes have been shown to start at the same initial speed threshold, but elite amateur athletes increase at a steeper rate relative to non-athletes increase in speed threshold (Faubert, 2013). The average VTS between pre-3D-MOT training and post-3D-MOT training for the experimental group increased by 0.88 while the average VTS for the control group increased by 0.15 (Figure 1). Improvement in VTS throughout the 10-session 3D-MOT training was critical to try and prove test transferability of perceptual-cognitive training on the sports specific parameters measured.

Along with competition level differences between pre- and post-training soccer specific parameter measurements, another limitation that explains the lack of statistical significance is sample size. 22 participants performed the study, 10 within the NeuroTracker™ experimental group and 12 within the control group, but only 13 participants' game data was used for successful action and passing percentage analysis due to playing time stipulations previously mentioned. A sample size of 22 participants was not enough to allude to a cause and effect relationship between 10 sessions of 3D-MOT training and an increase in passing-accuracy. Further, the sample size is reduced by the limitation of playing time. However, individual responses to 3D-MOT training should not be completely ignored as there was a net improvement for eight of the ten participants in the experimental group (Table 4). More research is needed with an expanded sample size while following the same procedural steps to show a cause-and-effect relationship between the specific modality of perceptual cognitive training, 3D-MOT, and passing-accuracy. Potentially multiple sites at comparable competition levels could be utilized to expand the sample size for future projects. Additionally, the research platform can be expanded to include other collegiate athletes during competition season. A comparison can then be made between sports on the effectiveness of the perceptual-cognitive training program within the training paradigm across the sport.

CONCLUSION

Although the 3D-MOT VTS measurement increased from eight out of ten participants in experimental group throughout the 10 sessions, and the soccer specific parameters measured had a positive percent change between pre-3D-MOT training and post-3D-MOT training, no significant changes were observed. Additional studies will need to be conducted with larger sample sizes to determine if a positive effect of 3D-MOT training on soccer specific parameter measurements is present. There are many potential directions in which research on test transferability of 3D-MOT perceptual-cognitive training could further be explored. The positive effect the results from the study show for test transferability of 3D-MOT training to on-field soccer specific parameters require further investigation and justification. A future direction for research, as previously noted, would be to increase the sample size. While the current study conducted examined soccer specific match performance parameters, a standardized practice session among the participants would potentially provide greater standardized conditions.

REFERENCES

Culham, J. C., Brandt, S. A., Cavanagh, P., Kanwisher, N. G., Dale, A. M., & Tootell, R. B. (1998). Cortical fMRI activation produced by attentive tracking of moving targets. *Journal of neurophysiology, 80*(5), 2657–2670. https://doi.org/10.1152/jn.1998.80.5.2657

Faubert, J. (2013). Professional athletes have extraordinary skills for rapidly learning complex and neutral dynamic visual scenes. *Scientific Reports (Nature Publisher Group)*, *3*(1154), 1–3. https://doi.org/10.1038/srep01154

Faubert, J., & Allard, R. (2013). Stereoscopy benefits processing of dynamic visual scenes by disambiguating object occlusions. *Journal of vision*, *13*(9), 1292-1292.

Faubert, J., & Sidebottom, L. (2012). Perceptual-cognitive training of athletes. *Journal of Clinical Sport Psychology*, *6*(1), 85–102. http://search-ebscohostcom.umiss.idm.oclc.org/login.aspx?direct=true&db=s3h&AN=74029747&site=ehostlive&scope=site

Goodale, M. A., & Milner, A. D. (1992). Separate visual pathways for perception and action. *Trends in neurosciences, 15*(1), 20–25. https://doi.org/10.1016/0166-2236(92)90344-8

Hadlow, S. M., Panchuk, D,, Mann, D.L., Portus, M. R., & Abernethy, B. (2018). Modified perceptual training in sport: a new classification framework. *Journal of Science and Medicine in Sport.* 21(9), 950-958. https://doi.org/10.1016/j.jsams.2018.01.011

Jones, P.D. & James, N., & Mellalieu, S. (2004). Possession as a performance indicator in soccer. *International Journal of Performance Analysis in Sport*. *4*. 98-102.

Karama, S., Ad-Dab'bagh, Y., Haier, R. J., Deary, I. J., Lyttelton, O. C., Lepage, C., Evans, A. C., & Brain Development Cooperative Group. (2009). Positive association between cognitive ability and cortical thickness in a representative US sample of healthy 6 to 18 year-olds. *Intelligence*, *37*(2), 145–155. https://doi.org/10.1016/j.intell.2008.09.006

Komarudin, Mulyana, Berliana, & Purnamasari, I. (2020A). NeuroTracker three-dimensional multiple object tracking (3D- MOT): a tool to improve concentration and game performance among basketball athletes. *Annals of Applied Sport Science*, *9*, 1–9.

Komarudin, K & Sagitarius, S. & Sartono, H., & Awwaludin, P. (2020B). Neurotracker training to improve the archery athlete concentration. *Jurnal Pendidikan Jasmani dan Olahraga*. *5*. 10.17509/jpjo.v5i2.27385.

Lago-Peñas, C., Lago-Ballesteros, J., & Rey, E. (2011). Differences in performance indicators between winning and losing teams in the UEFA Champions League. *Journal of Human Kinetics*, *27*(1). doi: 10.2478/v10078-011-0011-3

Legault, I., & Faubert, J. (2012). Perceptual-cognitive training improves biological motion perception: evidence for transferability of training in healthy aging. *Neuroreport*, *23*(8), 469–473. https://doi.org/10.1097/WNR.0b013e328353e48a

Mangine, G., Hoffman, J., Wells, A., Gonzalez, A., Rogowski, J., Townsend, J., Jajtner, A., Beyer, K., Bohner, J., Pruna, G., Fragala, M., & Stout, J. (2014). Visual tracking speed is related to basketball-specific measures of performance in NBA players. *Journal of Strength and Conditioning Research*, *28*(9), 2406–2414. https://doi.org/10.1519 /JSC.0000000000000550

Moen, F., Hrozanova, M., & Stiles, T. (2018). The effects of perceptual-cognitive training with Neurotracker on executive brain functions among elite athletes. *Cogent Psychology*, *5*(1), 1–13. https://doi.org/10.1080/23311908.2018.1544105

Parsons, B., Magill, T., Boucher, A., Zhang, M., Zogbo, K., Bérubé, S., Scheffer, O., Beauregard, M., & Faubert, J. (2016). Enhancing cognitive function using perceptual cognitive training. Clinical EEG and Neuroscience, *41*(7), 37–47. https://doi.org/10.1177/1550059414563746

Romeas, T., Guldner, A., & Faubert, J. (2016). 3D-multiple object tracking training task improves passing decision-making accuracy in soccer players. *Psychology of Sport and Exercise*, 22, 1–9. https://doi.org/10.1016/j.psychsport.2015.06.002.

Scharfen, H.-E., & Memmert, D. (2021). Cognitive training in elite soccer players: evidence of narrow, but not broad transfer to visual and executive function. *Ger J Exerc Sport Res*, *51*, 135–145. https://doi.org/10.1007/s12662-020-00699-y

Voss, M. W., Kramer, A. F., Basak, C., Prakash, R. S., & Roberts, B. (2010). Are expert athletes ‘expert’ in the cognitive laboratory? A meta-analytic review of cognition and sport expertise. *Applied Cognitive Psychology*, *24*(6), 812–826. https://doi.org/10.1002/acp.1588

Wei, G., Zhang, Y., Jiang, T., & Luo, J. (2011). Increased cortical thickness in sports experts: a comparison of diving players with the controls. *PloS one*, *6*(2), 1–6. https://doi.org/10.1371/journal.pone.0017112

Wilson, R.S., Sandes de Souza, A.P., Santiago, P., Ignacio, D.L., & Smith, N.M.A. (2020). Individual performance in passing tests predicts age-independent success in small-sided soccer possession games. *Transl Sports Med, 3*, 353– 363. https://doi.org/10.1002/tsm2.142