



Visual tracking speed threshold in NCAA Division I women's soccer predicting match performance: A preliminary study

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ABSTRACT

Correlations between sport performance and visual training have been previously demonstrated. However, it remains unclear if these relationships exist between visual tracking thresholds and in-competition decision-making metrics. Therefore, the purpose of this study was to investigate the relationship between visual tracking speed (VTS) and soccer-specific performance measures. 19 NCAA Division I soccer players VTS was measured from 1-core session on a 3-dimensional multiple object tracking (3D-MOT) software NeuroTracker (NT) and soccer performance metrics were obtained from WyScout. Spearman's rank order correlation coefficient was utilized to examine potential correlations between criterion variables. There was nonsignificant correlation between VTS score and passing accuracy ($r = -0.380$). However, there was a strong correlation found between consistency score and passing accuracy ($r = 0.650$). When examining players based on their positional role, for attacking players there were nonsignificant strong correlation with consistency and passing accuracy ($r = 0.730$). For defenders, consistency and defensive win rate had a strong correlation ($r = 0.731$). Although there was no significant correlation seen between VTS and decision-making variables when examining the entire team, there was a significant strong positive relationship between consistency scores and passing accuracy. Future research should seek to include multiple teams for improved sample size.

Keywords: Performance analysis of sport, Physical conditioning, Perceptual-cognitive processing, Executive function, Task transfer, Soccer performance.

Cite this article as:

Phillips, J., & Andre, T.L. (2022). Visual tracking speed threshold in NCAA Division I women's soccer predicting match performance: A preliminary study. *Scientific Journal of Sport and Performance*, 2(1), 94-104. <https://doi.org/10.55860/REVS9403>

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Submitted for publication October 31, 2022.

Accepted for publication November 29, 2022.

Published December 22, 2022.

[Scientific Journal of Sport and Performance](#). ISSN 2794-0586.

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doi: <https://doi.org/10.55860/REVS9403>

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 (Moen et al., 2018). 3-dimensional multiple object tracking (3D-MOT) has previously been utilized to improve processing speed (Parsons et al., 2016) and peripheral vision (Nyquist et al., 2016). Cognitive training has 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 analysing 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). The theoretical concept behind 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 currently two primary theories to potentially explain this. The first is Edelman's theory of "*neural group selection*" which claims learning and development are caused by specific neural brain development in which 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., 2018). 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 (Moen et al., 2018). These two theories are used to explain the potential transfer of cognitive training and executive function to real world experience and sports performance benefits.

Sports performance at the highest level requires attention, decision making and working memory to function 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 has been observed in higher level professional soccer in males and females (mean score: 15.52AU) comparatively to lower professional division male and female players (mean score: 13.18AU). They both however 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) (Homack et al., 2005; Vestberg et al., 2012). Furthermore, investigations comparing cognitive training modalities have examined VTS and light board reaction time's 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; $p = .829$, motor reaction time; $p = .747$, physical reaction time; $p = .716$) (Mangine et al., 2014). However, VTS was determined as having a "*most likely positive*" relationship with magnitude-based inferences between VTS and assists ($r = 0.78$; $p = .003$), steals ($r = 0.77$; $p = .003$, and assist-to-turnover ratio ($r = 0.78$; $p = .003$) throughout the NBA season (Mangine et al., 2014). 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.

MATERIAL AND METHODS

Participants

The participants for this study consisted of 19 NCAA Division I soccer athletes. All participants were 18-22 years old and were members of the team during the 2021 spring season. Players were excluded if they were a goalkeeper or players who averaged less than 10-minutes per game. This time criteria was decided to avoid the influence of those who play a few minutes with only 1 or 2 actions that would influence the averages of the group. After exclusion criteria only 13 players were utilized for analysis. All participants signed an informed consent form prior to the start of the study and approval from the University of Mississippi's Institutional Review Board was obtained.

Measures and procedures

The player's NT baseline measures were the players' VTS and were assessed by completing 1-core session on the NT (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 team film room in the team 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 colour. 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 as the average of the last 4 reversals of the staircase speed (meter per second). Consistency was also used which is a measure of performance consistency across all 20 trials. 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.

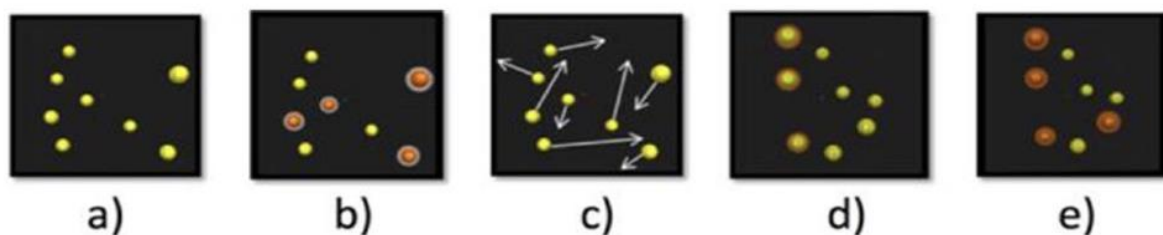


Figure 1. NeuroTracker single trial stages (Romeas, 2016).

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 impact 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 1) 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 1. Packing and Impact 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.

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

Points breakdown

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 impact).

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 midfielder, the passer will get 8 points for packing, while the player receiving the pass will get 8 points for impact).

Note. The table outlines the measure of packing and impact used to quantify player decision making and field awareness to advance the ball to a player in better position and players ability to find space to receive the ball.

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 analysed 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 $p < .05$ as a statistical significance criterion.

RESULTS

From the 19 participants, 6 participants were excluded from analysis from not meeting minutes played criteria. Shown in Table 2, Visual tracking speeds ranged from 33.3 to 121.7 cm/s (avg.: 75.3 ± 23.7 cm/s) for the 13 participants. There was weak nonsignificant correlation between VTS and passing accuracy ($r = -0.380$, 95% CI: -0.770, 0.216, $p = .20$), moderate nonsignificant correlation between VTS and packing rate ($r = -0.466$, 95% CI: -0.809, 0.114, $p = .108$) and a very weak nonsignificant correlation between VTS and average turnovers per 90-minute game ($r = -0.030$, 95% CI: -0.572, 0.530, $p = .922$). Similarly, there was a negative nonsignificant moderate correlation between participants fastest trial and passing accuracy ($r = -0.491$, 95% CI: -0.786, 0.176, $p = .088$) and fastest trial and packing rate ($r = -0.489$, 95% CI: -0.801, 0.136, $p = .090$) 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, $p = .681$). A weak nonsignificant correlation was observed for consistency and packing rate ($r = 0.296$, 95% CI: -0.305, 0.728, $p = .326$) 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, $p = .016$). 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, $p = .099$). For attackers, VTS and impact rate per minute ($r = 0.607$, 95% CI: -0.269, 0.933, $p = .148$) had a moderate nonsignificant correlation. There was a strong correlation between consistency and offensive win rate ($r = 0.767$, 95% CI: 0.033, 0.964, $p = .044$) and a nonsignificant strong correlation with consistency and passing accuracy ($r = 0.730$, 95% CI: -0.052, 0.957, $p = .063$).

Table 2. VTS and decision-making performance variable ($n = 13$).

	Avg \pm 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 3. 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	$60.5 \pm 0.08\%$	13.1 ± 2.26
Attackers ($n = 7$)	73.2 ± 27.0	102.7 ± 20.8	52.7 ± 0.06	$60.0 \pm 0.09\%$	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.

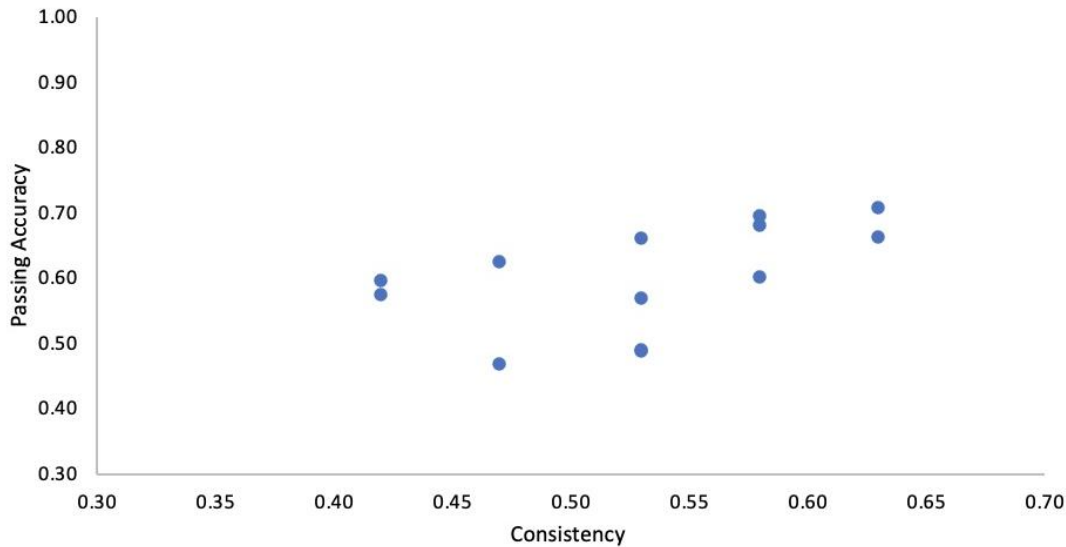


Figure 2. Scatterplot of passing accuracy and consistency. Consistency score is the accuracy at which a player correctly identified the 4 balls during the 20 trials. Passing accuracy is the average completion rate of passes over the 9 games. A positive correlation was seen examining passing accuracy and consistency score ($r = 0.650$; $p = .016$).

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. There was no significant correlation seen between visual tracking speed and decision-making performance variables when examining the team as a whole. However, there was a significant strong positive relationship between consistency scores and passing accuracy (Figure 2).

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 & 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. 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 sessions, 2 times per week for 5 weeks (Romeas et al., 2016). In another study Nimmeritichter 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 (Nimmeritichter et al., 2015). 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. 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 ($n = 12$) 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 analysing 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 (Mangine et al., 2014). Faubert (2013) demonstrated a difference exists in baseline VTS between elite athletes, amateurs, and non-athlete college students (Faubert, 2013). A recent investigation utilizing the transfer of NT to in-game basketball performance in a younger population (19.9 ± 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, which is responsible for higher executive function (Sowell et al., 1999). Mangine et al. (2014) study had an average age of 23.3 ± 2.6 years for the front court players and 26.8 ± 2.9 years for the backcourt 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 ± 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 (Komarudin et al., 2020).

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 trials and limited mental fatigue, which could indicate player's attenuation to in game mental fatigue leading to 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 (Foxy & 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 (Kurzban et al., 2013; Petruo et al., 2018). 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.

In addition, a role-based analysis was constructed for attacking and defending positional roles, the data appears to show weak positive correlations with VTS. When separated into attacking and defensive players, similar to methods in previous research (Table 3), position specific metrics showed positive correlations. Interestingly, Mangine et al. (2014) observed differences between groups examining score differences in

frontcourt (n = 7) and backcourt (n = 5) players in professional basketball athletes providing evidence of scores based on position and role. With additional investigation, the potential to generate a positional profile may be feasible.

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 criterion variable of interest was passing accuracy given this metric is characteristically examined in relation to team success in soccer (Collet, 2013; Longo et al., 2019). 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 ($r = 0.49$). Potentially this is because turnovers are more frequent in soccer and positionally bias, as attacking players take more risks compared to defenders seen in Table 3.

This study is not without limitations. The first limitation of this study was the sample size and criteria for inclusion of analysis. However, the sample size is comparable to previous research published in this space. 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 NCAA Division I institutions and the team maintained the same tactical formation during the season.

CONCLUSION

The investigation did not see any significant correlations between VTS and success rate, passing accuracy or turnover per 90 minutes. Similar nonsignificant results were seen when examining fastest trial speed and these performance metrics. These results found were not similar to those seen in the Mangine et al., paper done with professional basketball players. The relationship between consistency and success rate and turnover rate were nonsignificant as well; however, there was a strong significant correlation between consistency and passing accuracy. When examining consistency and VTS further between positional specific metrics for attackers and defenders, some metrics correlated better based on role. Future investigations should look to include multiple teams to further elucidate these relationships and the potential for implementing a visual cognitive training program.

AUTHOR CONTRIBUTIONS

Andre and Phillips came up with the study design. Phillips collected and analysed the data and drafted the manuscript. Andre critically reviewed and edited the manuscript.

SUPPORTING AGENCIES

No funding agencies were reported by the authors.

DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

ACKNOWLEDGMENTS

We would like to thank Dr. Jocelyn Faubert and Faubert Labs for donating NeuroTracker glasses and software to conduct this research.

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