VISUAL TRACKING SPEED IS RELATED TO BASKETBALL BASKETBALL-
SPECIFIC MEASURES OF PERFORMANCE IN NBA PLAYERS

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**ABSTRACT**

The purpose of this study was to determine the relationship between visual tracking speed (VTS) and reaction time (RT) on basketball specific measures of performance. Twelve professional basketball players were tested prior to the 2012–2013 season. VTS was obtained from one core session (20 Trials) of the multiple object tracking test, while RT was measured via fixed- and variable-region choice-reaction tests, using a light-based testing device. Performance in VTS and RT, were compared to basketball specific measures of performance (assists [AST]; turnovers [TO]; assist-to-turnover ratio [AST/TO]; steals [STL]) during the regular basketball season. All performance measures were reported per 100 min played. Performance differences between backcourt (guards; n=5) and frontcourt (forwards/centers; n=7) positions were also examined. Relationships were most likely present between VTS and AST ($r=0.78$; $p<0.003$), STL ($r=0.77$; $p<0.003$), and AST/TO ($r=0.78$; $p<0.003$), while a likely relationship was also observed with TO ($r=0.49$; $p<0.109$). RT was not related to any of the basketball specific performance measures. Back-court players were most likely to outperform frontcourt players in AST and very likely to do so for VTS, TO, and AST/TO. In conclusion, VTS appears to be related to a basketball player’s ability to see and respond to various stimuli on the basketball court that results in more positive plays as reflected by greater number of assists and steals, and lower turnovers.

**KEYWORDS:** Visual Tracking Speed, Visual Perception, Reaction Time Methods, Decision Making, Sport Science, Fitness Assessment
INTRODUCTION

In professional basketball, each position has a pre-defined strategic role where aptitude is measured by game related statistics of productivity (31, 36). The ability of a specific player to meet the demands of their role is considered to be a function of several physiological, visual-motor reaction speed, and perceptual-cognitive capability measures (7, 15, 21, 28, 32). To date however, only one study has related player-specific characteristics to game-related performance measures in professional basketball players (25). McGill and colleagues (2012) reported that stability, agility, and flexibility were associated with minutes played, assists, rebounds, blocked shots, and steals per game. However, the specific roles of visual-motor reaction speed and perceptual-cognitive capability to game-related measures of performance in professional basketball players are unknown.

Though conceptually unique, a clear distinction of how visual-motor reaction speed and perceptual-cognitive capability affect athletic performance does not exist. Visual-Motor reaction speed is a measure of the length of time encompassing the onset of a stimulus, an individual’s recognition of the stimulus, and the length of time necessary to complete their response to the stimulus (15, 26, 33). Presumably, athletes who are capable of recognizing and responding (to a stimulus) within a shorter amount of time would possess a competitive advantage. To date however, research demonstrating a positive relationship with athletic performance is equivocal (7, 15, 21, 26, 29, 34). On the other hand, perceptual-cognitive capability may be related to an athlete’s ability to efficiently devote attentive resources in response to the movement patterns of several key components within a dynamic environment (10). In this case, timely and positive decisions made by athletes with superior perceptual-cognitive ability might be possible because
of additional time for a response created by their more rapid assessment of the given scenario. Nevertheless, evidence supporting this notion in professional athletes is quite limited.

Pylyshyn and Storm (1988) first introduced the multiple object tracking (MOT) task as a measure of perceptual-cognitive capability, by determining the individual’s capability to maintain their focus on a sub-group of identical objects within a dynamic environment where all elements are in constant interaction (30). Evidence suggests this ability is a function of the objects’ speed and proximity. When objects are in close proximity, fewer objects are tracked as the speed of the objects increase. Conversely, the ability to track more fast-moving objects is improved when greater distance separates these objects (2). Therefore, the ability to track multiple objects will be dependent upon the movement speed of those objects when they are confined to a constant arena, where the ability to create space between objects is limited. As such, perceptual-cognitive capability might be assessed by controlling either the speed of the object or the quantity of objects, and measuring the alternative. However, these two variables exist on different continuums. While the number of objects is limited to only positive integers, the speed in which multiple objects may be visually tracked (visual tracking speed; VTS) exists among an infinitely larger scale of numerical possibilities. As such, VTS has been suggested as the preferred dependent variable used to precisely distinguish athletic ability since it may vary significantly among several observers with a similarly established ability to track a specific number of objects (10).

Previously, professional soccer, hockey, and rugby players have been demonstrated to possess an ability to track multiple objects at greater speeds in comparison to amateur athletes and non-athletic control subjects (8). Though superior VTS skills have not been investigated in elite basketball populations, it is reasonable to assume that VTS plays a comparable role, given
the similarities among these sports. In general, team sports value effective ball control, which essentially depends upon the speed in which players can integrate and process multiple information sources within a dynamic 3-dimensional environment and react in a timely manner (9, 26, 34, 39, 41). In basketball, a player may use this ability to simultaneously monitor the movements and positions of several players (teammates and opponents), as well as the basketball, all in relation to themselves, each other, and the basket. Individuals who excel in this ability allot themselves more time to make a positive play and avoid costly mistakes. From a performance standpoint, this ability may be quantified by the number of assists, turnovers, and steals accumulated by the player, as these have been shown to be predictive of a winning outcome (5, 13, 14, 17, 19). Positive statistics (assists and steals) would indicate the player’s ability to observe and correctly respond to various stimuli occurring simultaneously on the court, in a timely fashion, whereas a negative statistic (turnovers) may indicate an environmental misconception or an incorrect (or untimely) response that results in the loss of ball control. Furthermore, the ratio of assists to turnovers would provide additional insight into how efficiently a player distributes the ball to his teammates and gains assists without turning the ball over. Consequently, demonstrating the relationship between tracking ability and measures of ball control would be beneficial from recruitment and needs analysis standpoints. Therefore, the main purpose of the present investigation was to determine the relationships between visual tracking speed and reaction time on game-related measures of ball control in professional basketball players. It is hypothesized that players who produce more assists, steals, and have a greater assist-to-turnover ratio, would also possess greater visual tracking speed and faster visual-motor reaction time. However, superior ball handling, which is considered to be an important aspect of successful basketball performance (5, 14, 19), may not be paramount for all
positions. Passing skills, as well as gaining and maintaining ball control appear to be of greater importance for backcourt players (guards) than frontcourt players (forwards and centers) (36).

Thus, a secondary purpose of this study was to compare visual tracking speed and visual-motor reaction speed between backcourt and frontcourt players.

METHODS

Experimental Approach to the Problem

Visual tracking speed and reaction time were examined in professional basketball players on a National Basketball Association (NBA) team prior to the commencement of the 2012 – 2013 regular season. Players reported to the Human Performance Laboratory during the week immediately prior to the start of the regular season. All testing sessions occurred approximately 60 – 90 minutes following a morning shoot-around practice and breakfast at the team’s training facility. Relationships were examined between these measures and accumulated basketball specific measures (e.g., assists, turnovers, steals and the assist-to-turnover ratio) over the course of the entire regular season (82 games), normalized to account for individual differences in playing time.

Participants

De-identified data from a convenience sample of backcourt (n = 5; 26.8 ± 2.9 y) and frontcourt (n = 7; 23.2 ± 2.6 y; Range: 19.4 – 30.7 y) players under contract to play for the NBA franchise Orlando Magic completed testing at the beginning of the season. Players gave their informed consent as part of their sport requirements. This study was considered to be exempt in accordance with our university’s institutional review board policies for use of human participants in research.
Visual Tracking Speed

Visual tracking speed (VTS) was assessed by the completion of one core session on the Neurotracker (NT; CogniSens Athletic Inc., Montreal, Quebec, Canada) 3-dimensional (3D) multiple object tracking (MOT) device by each player. As previously recommended, a core session consisted of twenty individual trials used to quantify spatial awareness by determining the player’s threshold speed for effective perception and processing of visual information sources (9). For each trial, players were instructed to sit upright on a stool placed seven feet in front of a projection screen (8x8 ft) with the size of the 3D volume space being 46 degrees of visual angle at the level of the screen. All players wore specialized glasses to make the objects appear 3D in the simulator (Figure 1). Prior to each trial, a 3D transparent cube containing eight identical yellow balls, measuring 5.5 inches in diameter, was presented on the screen (Figure 2A). Four of these balls were randomly illuminated for two seconds before returning to the baseline yellow color (Figure 2B). The player was instructed to track these four balls for the duration of the individual trial. During the trial, all eight yellow balls moved simultaneously and individually throughout all regions of the cube for eight seconds (Figure 2C). The random, continuous movement patterns of each ball were only affected by collisions (impact and bounce) with the wall of the cube and the other balls. At the conclusion of eight seconds, the balls were frozen in place and were each assigned a display number, one through eight, by the computer (Figure 2D). The player was instructed to identify, by number, the four balls that were originally illuminated at the start of the trial (Figure 2E). The speed at which the balls moved on the next trial was dependent upon the correct identification of the illuminated balls and was adjusted between trials in a staircase (1 up 1 down) fashion, which has been previously demonstrated to be an efficient and reliable psychometric estimator (greater than maximum likelihood) in small experiments.
(less than 30 trials) (22, 38). If the player correctly selected all four balls, the speed of the balls was increased. Otherwise, the speed of the balls was reduced for the next trial. At the end of the twenty trials, VTS was determined to be the fastest speed (cm·s⁻¹) at which the player could correctly identify, with 100% accuracy, all four illuminated balls. For the first trial, the speed in which the balls moved was standardized to be 68 cm·s⁻¹. To avoid a training effect confound (8), all players began their core session completely unfamiliar to the NT device.

[INSERT FIGURES 1 and 2 HERE]

**Visual-Motor Reaction Time**

Visual-Motor reaction time (RT) to a visual stimulus was assessed using the light-training reaction device, Dynavision™ D2 (Dynavision International LLC, West Chester, OH, USA), in a manner consistent with what has been previously described (16, 37). Briefly, the D2 is a vertically adjustable board (4 ft × 4 ft) that consists of 64 target buttons, arranged into 5 concentric circles, which can be illuminated to serve as a stimulus for the player. In the present investigation, the D2 was adjusted so that its digital screen, located slightly higher than the center of the board, was at the player’s eye level. At a standing distance of two feet (eyes to screen) and focus being placed upon the digital screen, peripheral vision angle was 34° to the uppermost button, 43° to the furthest buttons laterally, and 45° to the lowest button. For each test, the player stood in an athletic stance, in front of the board, with the outermost buttons within arm’s reach. Lighting conditions were standardized for all D2 measures. Two separate choice reaction assessments were conducted.

The first choice reaction assessment measured the player’s visual, motor, and physical reaction in seconds to a 4-choice stimulus with the dominant hand within a controlled region. The player initiated the test by placing his hand on an illuminated “home” button. Subsequently,
the D2 would initiate the visual stimulus by lighting a single button in 1 of 4 locations adjacent
to the “home” button on the same horizontal plane. Visual (VIS) reaction time was measured by
how quickly the player recognized the stimulus and removed his hand from the “home” button.
The motor (MTR) reaction time recorded how quickly the player reached the lit button, while
physical (PHY) reaction time measured as the length of time between the initiation of the
stimulus and the player’s return back to the “home” button. This was repeated 9 times per
assessment.

The second choice reaction assessment utilized all 64 buttons to provide stimuli that
randomly occurred within the player’s center of gaze, as well as throughout their peripheral
vision. During this variable region choice reaction test (VR-CRT), the players began in an
athletic stance with their hands raised (approximately shoulder height) and ready to strike any
button on the D2 device. An initial stimulus would present on the D2 in a random location. The
stimulus remained lit until it was struck by the player. Another stimulus would then appear at
another random location. The player was instructed to successfully identify and strike as many
stimuli as possible within 60 seconds. The number of hits per minute was recorded for each
player.

**Game-Related Performance Statistics**

Ball control performance was determined from accumulated assists (AST), turnovers
(TO), and steals (STL), as well as minutes played over the course of regular season basketball
play. Assists are awarded to a player who passes the ball to a teammate in a way that leads to a
scored basket (not by foul shot). Turnovers are counted when the player loses possession of the
ball due to a mistake, which may include having the ball stolen, an errant pass, or committing an
offensive violation (travelling or stepping off-sides/out of bounds). Steals are earned when a
defensive player gains possession of the ball either by intercepting a pass or opponent’s dribble, without making contact with the offensive player’s hands. These statistics were obtained from a published statistics resource (27) for professional basketball players. To normalize the data for individual differences in playing time, these measures of ball control were analyzed per 100 minutes played. Additionally, the ratio of assists to turnovers (AST/TO), calculated by dividing total assists by total turnovers, was included in the analysis.

**Statistical Analyses**

To account for the small sample (n=12), the relationships between visual tracking speed, visual-motor reaction time, and game-related measures of ball control were interpreted through the analysis of the magnitude of their relationships (3, 6). Statistical Software (SPSS; V. 20.0, SPSS Inc., Chicago, IL) was used to calculate Pearson product-moment correlation coefficients and the p-value of the relationship, which along with the sample size, were input into the correlation coefficient statistic on a published spreadsheet (3) to determine the magnitude of the effect. The threshold values for positive or negative correlations were set at 0.1, which was previously reported to be the smallest clinically important correlation (6).

Similarly, inferences were made upon the magnitude of the differences between backcourt (guards) and frontcourt (forwards/centers) players in game-related measures of performance, visual tracking speed, and visual-motor reaction time. Microsoft Excel (Excel; 2007; Microsoft Corp, Redmond, WA) was used to calculate a p-value from an independent t-test. This value, along with the minimal difference threshold value (20% of the Grand Mean) and the degrees of freedom, was entered into the Raw Difference between Means and other t-Distributed Effect Statistics calculator of a published spreadsheet for interpretation (3). All data are expressed as a mean ± SD.
Qualitative inferences on correlations and group differences were determined as positive, trivial, or negative according to methods previously described (3) and were based on the confidence interval range relative to the smallest clinically meaningful effect to be positive, trivial, or negative. The percent chances of a positive or negative outcome was evaluated with the following scale: <1%, almost certainly not; 1–5%, very unlikely; 5–25%, unlikely; 25–75%, possible; 75–95%, likely; 95–99% very likely; and >99% almost certain. If the likely range substantially overlapped both positive and negative values, it was inferred that the outcome was unclear (18). In the event of a positive or negative result, correlations were re-examined at 0.3 and 0.5 threshold values to determine if the low correlation was in fact, a moderate or high correlation respectively (6).

RESULTS

Prior to regular season competition, the players’ VTS averaged $78.9 \pm 29.1 \text{ cm}\cdot\text{s}^{-1}$, while VIS-RT averaged $0.41 \pm 0.08 \text{ s}$, MTR-RT averaged $0.27 \pm 0.06 \text{ s}$, PHY-RT averaged $0.69 \pm 0.10 \text{ s}$, and CRT performance resulted in an average of $82.5 \pm 8.5 \text{ hits} \cdot \text{min}^{-1}$. Over the course of the entire regular season, the players averaged $1,518.2 \pm 732.5 \text{ minutes played}, 143.0 \pm 118.8 \text{ AST}, 86.6 \pm 46.1 \text{ TO}, \text{ and } 39.7 \pm 23.7 \text{ STL}, \text{ which equated to } 9.37 \pm 5.69 \text{ AST} \cdot 100 \text{ min}^{-1}, 5.77 \pm 1.34 \text{ TO} \cdot 100 \text{ min}^{-1}, 2.68 \pm 0.97 \text{ STL} \cdot 100 \text{ min}^{-1}, \text{ and a } 1.53 \pm 0.71 \text{ AST/TO ratio.}

No clear relationships were observed between minutes played, VTS, or any measure of RT. Within the measures of RT, PHY-RT was a most likely related (99.8% positive) to VIS-RT ($r = 0.83; p = 0.002$) and likely related (92.5% positive) to MTR-RT ($r = 0.54; p = 0.084$). VIS-RT and MTR-RT were not related. Inferences based upon the magnitude of the relationships between visual tracking speed, visual-motor reaction time, and game-related measures of ball control are displayed in Table 1. In relation to measures of ball control, the analyses revealed
that the observed relationship between VTS and AST ($r = 0.78; p = 0.003$), VTS and STL ($r = 0.77; p = 0.003$), and VTS and AST/TO ($r = 0.78; p = 0.003$) were most likely positive, while a likely positive relationship was also observed between VTS and TO ($r = 0.486; p = 0.109$). These relationships are graphically represented in Figure 3. No significant relationships were observed between any of the RT measures and these basketball specific performance measures.

Comparisons between backcourt and frontcourt players revealed that backcourt players ($98.7 \pm 20.5 \text{ cm}\cdot\text{s}^{-1}$) possessed significantly ($p = 0.032$) faster VTS in comparison to frontcourt players ($64.8 \pm 26.7 \text{ cm}\cdot\text{s}^{-1}$). Significant differences were also observed between backcourt and frontcourt players in AST ($p = 0.004$), TO ($p = 0.043$), and AST/TO ($p = 0.010$). No differences were found for STL ($p = 0.724$) or in the reaction time measures: VIS-RT ($p = 0.829$), MTR-RT ($p = 0.747$), PHY-RT ($p = 0.716$), and CRT ($p = 0.234$) (Table 2).

**DISCUSSION**

The results of our investigation indicate that visual tracking speed is *most likely* related to the athletes’ ability to see and respond to various stimuli on the basketball court. In consequence, possessing greater VTS may result in more positive plays as reflected by greater rate for accumulating assists and steals, and assists in relation to turnovers across an entire regular season. Furthermore, backcourt players (both point guards and shooting guards) appear to possess a faster speed threshold for tracking multiple objects throughout a wide 3D space along with greater productivity in game related measures of ball control. These findings appear to be the first to demonstrate the assessment of visual tracking speed in NBA players and relate them to game-related measures of productivity. Previously, professional soccer, hockey, and
rugby players were shown to have greater speed threshold values than amateur athletes and non-
athletic control subjects (8). These results were the first to suggest that enhanced tracking
capability is a discerning measure for predicting or evaluating athletic performance. Our data
supports the work of Faubert (2013) and also suggests that visual tracking speed may be able to
differentiate between positions among athletes as our results showed that the basketball players
who are most responsible for ball control and passing (e.g. backcourt players) possessed
significantly faster speed threshold scores and a greater AST/TO than the other players. Though
our data also showed a *likely* positive relationship between VTS and TO, it was not as strong as
the relationships between VTS and AST; and between VTS and AST/TO. Potentially, the
increase in TO rate is the consequence of more attempts being made to make positive plays.
Alternatively, the VTS capability of the opposition may also play a contributing role. As such,
future exploration into these hypotheses is warranted.

While our data may indicate a potential role for visual tracking speed in the playmaking
ability of professional basketball players, it does not indicate such a role for visual-motor
reaction time. These findings support previous reports of elite basketball players from Greece
possessing significantly greater predictive and selective attention skills in comparison to amateur
athletes, but only possessing comparable visual-motor reaction time capability (21). Though
possibly aided by faster oculomotor reactions to visual stimuli (34), elite athletes appear to be
more capable of correctly assessing and responding to a dynamic environment (8, 26). This
ability may be the consequence of being able to correctly identify key indicators, within a
dynamic environment, that will allow an individual to deduce future occurrences (1, 23). To
perform this task, a person will typically centralize their gaze direction to a localized region,
which would enable them to accumulate the greatest amount of critical information from the
surrounding regions (24, 40). Being able to efficiently assess the relevant information from this scene will determine the time and opportunity the individual will have to respond appropriately to the demands of the given scenario (20, 42). Similarly, the NT device presents useful information (ball position, ball trajectories, ball collisions and non-collisions) from several points across the visual field, which may allow the individual to deduce future ball positions, enabling them to maintain their attention on the items of interest. In basketball for example, as the ball handler monitors the movements (planned and unplanned) of his teammates, he may also analyze the positioning of the defenders as movement progresses. From this information, the ball handler may determine if one or more of his teammates will reach an advantageous (in relation to his defender and the basket) position. As such, our data indicates that players who can make this determination faster are most likely to make an assist. Conversely, a defending player who quickly makes this determination is most likely to recognize the future position of the basketball in time to make an interception. However, not all of the variance in performance can be explained by the current methodology for determining VTS. It is important to account for the effect of personal movements that occur while the player assesses the dynamic scene, as well as his ability to maintain track of relevant items with momentary shifts in focus. Such movement and shifts in focus have been demonstrated to impair tracking ability (11, 35), though the current VTS assessment required the player to maintain constant focus from a fixed position. Consequently, the MOT task on the NT device appears to be able to distinguish the elite cognitive processing employed by elite competitors (12, 24), though not completely in a manner that distinguishes elite play in basketball.

In contrast, RT measured via two simple choice reaction tests was not related to measures of ball control, nor were significant differences observed between position types. Previously,
using a similar choice reaction test, no differences were observed between elite rugby, netball, or hockey players in comparison to normative samples (29). It is possible that the methodological design (e.g. randomly flashing lights) may not effectively distinguish between quick reflexes and the anticipatory capability of elite athletes. Though a simple luminance-based RT test may be able to identify faster reflexes in professional athletes compared to non-athletes (15), anticipatory capability cannot be discerned when performance is solely deterred by random pattern complexity (4). Likewise, in basketball, the most appropriate response to a given scenario cannot be determined by simply reacting to any random stimulus on the court; the stimulus must have meaning. In concordance with this notion, RT has been demonstrated to be predictive of athletic ability when the task involved a complex component, thus allowing the athlete to predict or anticipate the stimulus and respond accordingly (26). However, the RT tasks of the present investigation did not provide such indicators. In the second test (VR-CRT), the athlete would have to continuously change his focus to cover all possible board regions because all possibilities were always equal in likelihood. During competitive play, this strategy would not be efficient for deducing the appropriate course of action. With so many possible focal points performing such a search has been reported to result in a very high ratio of perceptual blur (40), ultimately leaving the athlete largely uninformed. Even when the region was fixed and choices were limited, as they were in the first test, the athlete was still incapable of deducing which light would be next to illuminate; they simply had to react. Although evidence does suggest that the ability to react quickly to visual stimuli is important in team sports (7, 34), the results of the present investigation do not indicate a relationship between RT, measured by the D2 device, and measures of ball control in basketball. It is possible, however, that our small sample may have inhibited our power to see an effect, while greater familiarity with the D2 device, as recently
recommended by Wells et al. 2014, may have generated a more exact reaction times for statistical analysis (37). Therefore, future designs, seeking to examine the effect of training (on the NT and D2 devices) on game-related performance measures, should consider these possibilities.

The accumulation of positive statistics that measure ball control (assists & steals), while avoiding turnovers, is a valued quality for all basketball positions (5, 14, 19). Generally, certain players and positions are granted more opportunities for such plays (positive and negative) because of team strategy or individual skill. In the present investigation, backcourt players (point guards and shooting guards) were most likely to accumulate assists at a faster rate than frontcourt players. This may have been the consequence of these players being very likely to also possess greater VTS, though greater VTS may have also been the consequence of accumulated experience at positions that necessitate this ability for success. Ironically, these players were also very likely to possess a greater rate of turnovers. However, this rate was still very likely to be slower than their rate of assists (AST/TO) and possibly the consequence of their role as ball handlers. It is typical for these players to maintain possession of the ball, and be defended by similar players, while they attempt to make passes to teammates who try to secure strategically advantageous positions (36). Thus, more ball handling opportunities may lead to both a greater amount of positive and negative plays, though the lack of a clear difference in steals was surprising. However, this finding may be related to equal stealing opportunities arising at both the passing and receiving ends of a pass attempt. Given the small sample size, and the general nature in which positions were examined, these results may not be reflective of the entirety of the National Basketball Association. Future studies may build upon this investigation by examining these phenomena across several teams and by individual position.
To the best of our knowledge, only one other investigation has reported relationships between game-related ball control statistics and measures of physical performance. In collegiate athletes, McGill and colleagues (2012) demonstrated relationships between core stability and assists ($r = 0.60$) agility ($r = –0.74$) and steals ($r = 0.54$). Those investigators also reported a significant correlation between agility and steals ($r = –0.69$) (25). Though the authors did not provide any explanation of these relationships, it is likely that core stability and agility would have some relevance to assists and steals as they are both measures of body control. Comparatively however, the present investigation found similar, if not stronger relationships between VTS and assists ($r = 0.78$) and steals ($r = 0.77$). Though these relationships are population dependent, it is possible that the variance in steals and assists cannot be completely explained by a single variable (i.e. VTS, agility, core stability). Rather, a multivariate approach may be necessary to understand how these measures contribute to a basketball player’s ability to produce more positive plays, while avoiding costly turnovers.

**PRACTICAL APPLICATIONS**

Considering the observed relationships between visual tracking speed and game-related measures of ball control, the findings of this investigation indicate a potentially important role in basketball player evaluation. Visual tracking speed is a measure of a player’s ability to track multiple objects (i.e., teammates and opponents movements on the court) within a fast-paced, dynamic setting, which would allow the player more time to appropriately respond to the demands of the given situation. Though preliminary, the data from our investigation suggests that greater visual tracking speed is related to game-related measures of ball control (assists, turnovers, AST/TO, and steals). Thus, the ability to evaluate a player’s capability to perform in
measures that are related to team success would prove beneficial for player recruitment and needs analysis.
### References


FIGURE LEGEND

Figure 1. Neurotracker 3D Multiple-Object Tracking
For testing, the participant sits upright on a stool placed seven feet in front of a projection screen (8x8 ft) while wearing specialized 3D glasses.

Figure 2. Neurotracker 3D Multiple-Object Tracking Assessment Protocol
A) Eight spheres are presented within a 3 dimensional cube; B) Four spheres are randomly highlighted by the computer for 2 seconds; C) All eight identical spheres randomly move throughout the cube for 8 seconds; D) Spheres are randomly assigned a number (1 – 8); and E) the correct four spheres are highlighted after participant makes selections.

Figure 3. Bivariate relationships between Visual Tracking Speed and Game-Related Measures of Performance in Professional Basketball Backcourt (n = 5) and Frontcourt (n = 7) players.
A) Assists (100 min⁻¹); B) Steals (100 min⁻¹); C) Assists-to-Turnovers Ratio; and D) Turnovers (100 min⁻¹).

#Open Spheres = Back Court Players; Closed Spheres = Front Court Players; Solid Black Line = Line of Best Fit
Table 1. Qualitative inferences on the magnitude of the relationship between game-related measures of performance, perceptual-cognitive function, and visual-motor reaction time (n=12).

<table>
<thead>
<tr>
<th></th>
<th>r</th>
<th>Positive</th>
<th>Trivial</th>
<th>Negative</th>
<th>Qualitative Inference&lt;sup&gt;a&lt;/sup&gt;</th>
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<tr>
<td>AST</td>
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<td>0.3</td>
<td>0.0</td>
<td>Most Likely Positive</td>
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<td>AST/TO</td>
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<td>99.8</td>
<td>0.2</td>
<td>0.0</td>
<td>Most Likely Positive</td>
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<td><strong>Variable Region Choice-Reaction</strong></td>
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<sup>a</sup>Threshold set to 0.1 for all relationships.
#AST = Assists; TO = Turnovers; STL = Steals; AST/TO = Assists-to-Turnovers Ratio
Table 2. Positional differences in perceptual-cognitive function, visual-motor reaction time, and statistical performance measures of ball control in NBA players.

<table>
<thead>
<tr>
<th></th>
<th>Back Court</th>
<th>Front Court</th>
<th>Mean Difference(^a) ± 90% CI(^b)</th>
<th>Percent</th>
<th>Qualitative Inference</th>
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<tbody>
<tr>
<td><strong>Visual Tracking Speed (cm·s(^{-1}))</strong></td>
<td>98.7 ± 20.5</td>
<td>64.8 ± 26.7</td>
<td>34.0 ± 26.0</td>
<td>96.1</td>
<td>2.9</td>
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<tr>
<td><strong>Reaction Time</strong></td>
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<tr>
<td>Visual (s)</td>
<td>0.41 ± 0.13</td>
<td>0.42 ± 0.05</td>
<td>-0.01 ± 0.08</td>
<td>28.5</td>
<td>27.2</td>
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<tr>
<td>Motor (s)</td>
<td>0.27 ± 0.04</td>
<td>0.28 ± 0.07</td>
<td>-0.01 ± 0.06</td>
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<td>26.4</td>
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<td>Physical (s)</td>
<td>0.67 ± 0.14</td>
<td>0.69 ± 0.08</td>
<td>-0.02 ± 0.10</td>
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<td>26.1</td>
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<tr>
<td>CRT (Hits · Min(^{-1}))</td>
<td>86.8 ± 8.2</td>
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<tr>
<td>Assists (100 min(^{-1}))</td>
<td>14.25 ± 4.62</td>
<td>5.88 ± 3.32</td>
<td>8.40 ± 4.10</td>
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<td>Turnovers (100 min(^{-1}))</td>
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<td>Steals (100 min(^{-1}))</td>
<td>2.80 ± 1.11</td>
<td>2.59 ± 0.93</td>
<td>0.21 ± 1.00</td>
<td>51.1</td>
<td>23.8</td>
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<tr>
<td>AST/TO (100 min(^{-1}))</td>
<td>2.10 ± 0.43</td>
<td>1.12 ± 0.59</td>
<td>0.98 ± 0.56</td>
<td>98.9</td>
<td>0.9</td>
</tr>
</tbody>
</table>

\(^a\) Mean Difference refers to the first named group minus second named

\(^b\) ±90% CI: add and subtract this number to the mean effect to obtain the 90% confidence intervals for the true difference. Qualitative inference represents the likelihood that the true value will have the observed magnitude.

#CRT = Choice Reaction Time; AST/TO refers to the Assists to Turnovers ratio.
Figure 1. Neurotracker 3D Multiple-Object Tracking

For testing, the participant sits upright on a stool placed seven feet in front of a projection screen (8x8 ft) while wearing specialized 3D glasses.
Figure 2. Neurotracker 3D Multiple-Object Tracking Assessment

A) Eight spheres are presented within a 3 dimensional cube; B) Four spheres are randomly highlighted by the computer for 2 seconds; C) All eight identical spheres randomly move throughout the cube for 8 seconds; D) Spheres are randomly assigned a number (1 – 8); and E) the correct four spheres are highlighted after participant makes selections.
Figure 3. Bivariate relationships between Visual Tracking Speed and Game-Related Measures of Performance in Professional Basketball Backcourt (n = 5) and Frontcourt (n = 7) players.

A)

B)

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A) Assists (100 min^{-1}); B) Steals (100 min^{-1}); C) Assists-to-Turnovers Ratio; and D) Turnovers (100 min^{-1}).

#Open Spheres = Back Court Players; Closed Spheres = Front Court Players; Solid Black Line = Line of Best Fit