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Section IV – Psychological and Sociological Aspects of Sport and Exercise

Visual Search Strategies and Decision-Making in Highly Trained Female Youth Basketball Players: A Quasi-Experimental in Situ Study of Gaze Behavior during Pick-and-Roll Plays

by
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This study explored how U16 female basketball players direct their visual attention and make decisions during side pick-and-roll situations under realistic game conditions. Twelve experienced players participated in 4v4 scenarios, where defensive strategies were systematically varied to reflect authentic tactical challenges. Using Pupil Core eye-tracking glasses operating at 120 Hz, we recorded gaze behavior without restricting natural movement on the court. Gaze data were synchronized with nine predefined tactical areas of interest using the surface tracker plugin, enabling detailed analysis of visual search behavior in dynamic environments. Time-series, entropy, and gaze transition analyses revealed that offensive decisions were closely shaped by defensive constraints. "Pass to Roller" and "Pass to Corner" were the most frequent responses, depending on the defensive strategy in place. Players' gaze patterns evolved throughout each trial, with final fixations on decision targets occurring mainly in the last phase of action preparation. Focused visual strategies were more common in shooting and passing decisions, whereas broader search behavior's characterized driving actions. These findings show that young players adapt their visual attention on a moment-to-moment basis in response to tactical demands, and support the relevance of in situ eye-tracking as a tool for understanding perception and decision-making in youth basketball.

Keywords: *adolescence; visual perception; team sports; tactical behavior; invasion sports*

Introduction

Basketball is one of the most widely played sports globally, with over 450 million participants, predominantly youth (The International Basketball Federation, n.d.). In addition to its intense physical demands, basketball presents substantial cognitive and perceptual challenges, requiring athletes to make rapid, context-sensitive decisions in fast-paced and unpredictable environments (Esteves et al., 2011). Players must continuously adapt to evolving game dynamics, such as opponent movements, teammate positioning, and ball trajectories under severe time-pressured scenarios (Esteves et al., 2011). Consequently, decision-making is recognized as a cornerstone of basketball performance, prompting a growing emphasis on training methods that integrate perceptual and cognitive components alongside motor skill development.

Recent investigations into long-term athlete development highlight how tactical and perceptual demands are increasingly prioritized, particularly during intermediate stages of training (Cañadas et al., 2018). Offensive training tasks tend

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to dominate youth basketball sessions, especially among female teams, while as players progress in age and skill, a shift is observed from simplified individual formats toward more complex and game-representative activities (Cañadas et al., 2018). Notably, this shift in pedagogical approaches aligns with the increasing emphasis on perceptual-cognitive demands designed to improve decision-making in game-representative environments. Related evidence suggests that increasing visuomotor task complexity by expanding the number and direction of response options places greater demands on visual search, stimulus discrimination, and rapid perception-action mapping (Zhang et al., 2026). In youth basketball games, there is a strong correlation between visual perception and assists, game efficiency, and total points scored (Zemková et al., 2025). Within this context, developing a deeper understanding of visual perception, particularly on how players identify and utilize task-relevant information, becomes essential for informing evidence-based practices in youth basketball training.

A critical tool in assessing visual perception is gaze behavior analysis, which allows researchers and coaches to examine where and for how long athletes focus their visual attention in performance contexts (Brams et al., 2019). Expert athletes, for instance, have been shown to deploy more efficient and targeted gaze strategies than novices, relying on longer fixations and reduced search dispersion as a mean to selectively make use of actionable information (Kredel et al., 2017; Mann et al., 2009). Technological advances, such as wearable eye-trackers, have further enabled the study of gaze behavior in ecologically valid sport settings, overcoming earlier limitations of laboratory-bound methodologies (Orquin and Holmqvist, 2018; Popowczak and Zwierko, 2025; Vater et al., 2020).

Despite these developments, significant methodological and demographic gaps persist in basketball gaze behavior research. Most studies to date have focused on isolated shooting tasks in static, controlled environments, often excluding dynamic defensive scenarios (Han et al., 2025). Furthermore, the majority of participants have been senior male players, with far fewer studies involving youth athletes or female populations (24%) (Han et al., 2025). This uneven distribution limits the generalizability of findings and neglects key stages of player development. Moreover, the exclusion of dynamic, in-game experimental settings restricts our potential of understanding how gaze behavior operates under real-time tactical pressures. For example, Esteves et al. (2021) found that when the distance between the shooting attacker and the defender decreased, the former exhibited longer fixations and a narrower attentional focus. Meyer et al. (2022a) further noted that fixating on lower-body cues (such as hips and legs) could enhance anticipation accuracy, while focusing on deceptive upper-body cues (such as head or ball movements) tended to impair judgment, particularly among novice players.

Other studies have also highlighted the importance of gaze strategies in contested shooting scenarios. For instance, the presence of a defender led to more dispersed visual attention and a decline in shooting accuracy, indicating the necessity of training perceptual resilience under pressure (Van Maarseveen and Oudejans, 2018). Hernández-Peña et al. (2025) demonstrated that expert players displayed longer and more focused fixations when executing motor actions against complex defensive formations. In video-based simulations of deceptive plays, expert players, compared to novices, employed fewer but more targeted fixations and achieved higher decision accuracy (Meyer et al., 2022b).

Collectively, these findings underscore the importance of developing efficient visual strategies in dynamic competitive contexts. However, they also point to a clear gap in current research on gaze behavior during complex tactical actions, such as the pick and roll. This is especially relevant given that the pick and roll is one of the most frequently used offensive plays in professional basketball, accounting for 29.1% of late-game NBA possessions (Christmann et al., 2018), and over half of the offensive plays during the 2020 Olympic Men's Basketball Tournament (Bismpos and Karamousalidis, 2022). It is typically executed in central court areas and by perimeter players, particularly during high-pressure or decisive moments (Amatria et al., 2025; Stavropoulos and Stavropoulos, 2020). Common outcomes include ball-handler shots, passes to the roller, and pick-and-pop actions, with passes to the roller and layups being the most effective solutions (Koutsouridis et al., 2018; Marmarinos et al., 2016).

Defensive strategies such as switches and hedges often reduce success rates by disrupting timing and spacing (Amatria et al., 2025; Koutsouridis et al., 2018). Furthermore, a positive relationship has been established between pick and roll efficiency and team performance across different levels of competition (Alonso-Pérez-Chao et al., 2025; Bismpos and Karamousalidis, 2022; Marmarinos et al., 2016).

Despite the prevalence and tactical relevance of the pick and roll in basketball, research on gaze behavior during such actions remains relatively limited. One of the few studies in this area implemented an in situ 3 vs. 3 pick and roll task to examine how decision-making and gaze behavior varied under different defensive strategies, including "under", "over" , and "hedge" (Van Maarseveen et al., 2018). The results showed that while defensive strategies did not significantly affect players' decision accuracy, they did influence visually-guided behavior. Gaze data further revealed that in shooting and driving scenarios, final fixations were typically aligned with the selected option (Van Maarseveen et al., 2018). Moreover, fixations were most frequently directed toward the screener or the roller, the screen defender, and the space between them, highlighting these as critical areas for decision-making (Van Maarseveen et al., 2018). Notably, only 21.4% of incorrect decisions involved a fixation on the optimal option, indicating that an optimized visual search may be a key factor contributing to poor decision-making.

Thus, the present study aimed to address these limitations and advance understanding of gaze behavior in dynamic and tactically complex scenarios. Specifically, it had two main objectives: first, to characterize the gaze behavior of the ball handler during a side pick-and-roll task and to examine how visual attention patterns would vary according to the task outcome and different defensive conditions; second, to analyze the gaze strategies associated with different offensive choices, aiming to reveal potential connections between perception and action during tactical decision-making. We hypothesized that different types of offensive decisions would be accompanied by distinct gaze behavior patterns, particularly in terms of the distribution and sequence of fixations on key tactical cues.

Methods

Participants

Twelve right-handed U16 highly trained female basketball players (age: 14.73 ± 0.85 years) participated in the study. All players had at least three years of competitive experience and were familiar with pick-and-roll offensive strategies. Informed consent was obtained from both the participants and their legal guardians before the study commencement.

This study was conducted following the principles of the Declaration of Helsinki, and approved by the Bioethics Committee of the Research Center in Sports Sciences, Health Sciences, and Human Development, Vila Real, Portugal (Resolution UID/04045; approval date: 08 April 2025).

Measures

To analyze gaze behavior in real-game situations, this study utilized the Surface Tracker plugin in Pupil Player to match gaze data with nine predefined areas of interest (AOIs): Ball Handler Defender (BHD), Screener/Roller (SR), Screen Defender (SD), Corner Player (CP), Corner Defender (CD), Ball, Basket, Free Space In-between Players (FSI), and Free Space Outside Players (FSO). AOIs were annotated using a combination of key frame positioning and interpolation to account for dynamic scene changes.

Fixations (≥125 ms) were automatically synchronized and spatially mapped to the corresponding video frames, with each gaze point assigned to a specific AOI (Savelsbergh et al., 2002; Vaeyens et al., 2007). All matches were manually reviewed by two trained researchers to ensure accuracy.

This method, combining dynamic AOI annotation with gaze overlay techniques, is suitable for analyzing gaze behavior in dynamic, naturalistic environments and provides strong ecological validity (Kredel et al., 2023)

The offensive decision made by the ball-handler in each trial was coded into one of the following five categories: shoot, drive, pass to roller, pass to corner player, and no decision (Figure 1).

Each trial concluded with either a successful shot or an unsuccessful shot, or a turnover. The decision outcomes were recorded.

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Trials were independently video-coded by two trained analysts. In the situation of disagreement, a consensus was reached through discussion. No evaluation of decision accuracy (i.e., whether the decision was tactically correct or incorrect) was included in the current analysis.

Design and Procedures

All testing was conducted on an indoor basketball court that met the official standards set by the International Basketball Federation (FIBA), using regulation-sized hoops and size 6 basketballs for women. Two high-definition cameras were positioned at a height of 5 m to record the entire trial from multiple angles.

Each trial simulated a 4-on-4 pick-and-roll offensive scenario, initiated from the 45-degree wing. The offensive sequence began when the ball-handler received a pass from the researcher and made the first dribble. Before each trial, the main researcher instructed the defensive strategies, which were systematically varied across trials and categorized into the following four types: under, over, over and double team, over and hedge team (Figure 2).

Players' gaze behavior was recorded using the Pupil Core eye-tracking glasses (Pupil Labs, Germany), operating at a sampling rate of 120 Hz. The system comprises lightweight eye-tracking glasses connected via cable to a mobile recording unit housed in a waist pouch, allowing participants to move freely in a natural sports environment. A standard three-point calibration procedure was performed before each trial. Calibration accuracy was checked regularly and adjusted as needed to ensure data quality.

Statistical Analysis

A series of quantitative procedures were employed to investigate the relationships between defensive strategies, offensive decisions, and gaze behavior. All statistical analyses were performed using the Python programming environment. A significance level of $\alpha = 0.05$ was adopted for all inferential tests, which were two-tailed. The analytical approach was designed to capture both statistical associations and meaningful behavioral adaptations within the task constraints.

To examine the association between defensive strategies and offensive decisions, a chi-square test of independence was conducted. Cramér's V was calculated to estimate effect size. To facilitate interpretation of specific deviations from expected frequencies, the results were visualized using a frequency heatmap and a standardized residuals plot.

The influence of defensive strategy and offensive decision on action execution time was assessed using the Kruskal-Wallis H test, as the Shapiro-Wilk test indicated a significant departure from normality. When significant effects were identified, Dunn's post hoc tests with Bonferroni correction were applied to adjust for multiple comparisons. Epsilon squared (ε^2) was reported as a measure of effect size.

Descriptive statistics of gaze behavior were computed for each offensive decision category, including the fixation count, whether the decision target was fixated, and whether the final fixation landed on the chosen AOI. Differences in fixation-decision consistency were assessed using a chi-square test, with Cramér's V indicating the strength of association.

To investigate the temporal distribution of gaze allocation, a time-series analysis was conducted following the method proposed by Mann et al. (2009). Each trial was divided into 20 equal temporal segments (5% intervals), and the proportion of trials in which the selected AOI was being fixated was calculated for each segment. Only valid trials in which the final fixation aligned with the decision target were included in this analysis.

To characterize gaze distribution before the final fixation, fixation percentages for each AOI were calculated for the time window preceding the final gaze. A Friedman test for repeated measures was used to assess within-subject differences in visual allocation. Gaze dispersion was quantified using Shannon entropy, and a Kruskal-Wallis test was used to compare entropy values across offensive decision types.

Finally, gaze transition behavior was analyzed by constructing first-order Markov transition matrices based on sequential AOI fixations in each trial. Refixations were excluded to isolate meaningful transitions between AOIs. Binomial tests ($p < 0.05$) were used to identify statistically significant transitions, which were then visualized through gaze transition network diagrams to illustrate the structural properties of visual search patterns across task conditions.

Results

A chi-square test of independence revealed a significant association between defensive strategies and offensive choices ($\chi^2 = 486.46$, $df = 12$, $p < 0.001$, Cramér's $V = 0.382$) (Figure 1). Under the "Under" defense, the most common offensive actions were "pass to corner" and "drive". In the "over" condition, "pass to corner" remained the most frequent choice (Figure 1). During the "show" strategy, both "drive" and "pass to corner" were prevalent. Under the "over and double team" condition, "pass to roller" was the most frequent response (Figure 3).

In the "under" defensive strategy, the "shoot" action occurred more often than expected (Figure 3). Under the "over and double team" condition, "pass to roller" was the offensive choice that exceeded expectations the most. Similarly, in the "show" strategy, "drive" occurred significantly more frequently than anticipated (Figure 4).

The Shapiro-Wilk test showed that execution times were not normally distributed ($W = 0.956$, $p < 0.001$), thus non-parametric tests were applied. The Kruskal-Wallis test found significant effects of defensive strategies ($H = 68.04$, $p < 0.05$, $\eta^2 = 0.059$) and offensive decisions ($H = 188.76$, $p < 0.001$, $\eta^2 = 0.167$) on execution time. Post hoc analysis revealed a significant difference only between "show" and "over and double team" defenses ($p = 0.018$). For offensive decisions, execution times differed significantly between "drive" and "shoot" ($p = 0.006$), "drive" and "pass to roller" ($p < 0.001$), and "drive" and "pass to corner" ($p = 0.003$); all other comparisons were not significant.

Figure 6 illustrates the time-series distribution of fixations on the ultimately selected area of interest (AOI) under different offensive decision types. Overall, the proportion of fixations on the target AOI increased markedly during the final phase of each trial (between 80% and 100% of the trial duration).

Further analysis showed that for the "pass to roller" decision, fixations on the target AOI tended to occur during the early phase of the trial. In contrast, the proportion of fixations on the target AOI for "shoot" and "drive" decisions gradually increased during the middle to late stages. For "pass to corner", fixations on the target AOI were predominantly located at the end of the trial.

Of the 126 valid trials, 114 (90.5%) showed a final fixation on the AOI matching the chosen offensive decision. Consistency varied by the action type, with the highest alignment for "drive" and the lowest for "pass to roller". A chi-square test confirmed a significant association between decision type and fixation consistency ($\chi^2(3) = 7.99$, $p = 0.046$, Cramér's $V = 0.236$). Friedman tests revealed significant differences within each decision type ($\chi^2 = 55.46–159.42$, all $p < 0.001$), indicating that gaze patterns varied with tactical demands (Figure 7).

The SR was the most frequently fixated AOI overall, especially during "pass to roller" decisions, where fixation time on SR exceeded that of other AOIs. For "drive" actions, players focused more on FSI and FSO, suggesting a visual search for open space. In passing actions, gaze was concentrated on the CP or SR, reflecting a receiver-oriented focus. Kruskal-Wallis tests showed significant differences in gaze dispersion across decision types ($\chi^2(3) = 10.893$, $p = 0.0123$). "Shoot" and "pass" actions had lower entropy, indicating more focused gaze, while "drive" showed higher entropy, reflecting broader visual scanning. SR emerged as a central AOI, particularly in "pass to roller", where both fixation time and transition frequency were highest (Figure 8). "Shoot" transitions were more concentrated toward the basket, while "pass to corner" showed broader, more distributed gaze patterns, suggesting that visual complexity increased with tactical demands (Figure 8).

The SR consistently received the most fixation time, particularly under "over and double team" (52.7%) (Figure 7). Defensive strategies shaped the structure of gaze behavior: in the "show" strategy, transitions were fewer and more focused (Figure 9). In contrast, "under" and "over" prompted more dispersed transitions, indicating broader information search. Under the "over and double team" condition, players' attention was strongly concentrated on SR, with reduced fixations on other AOIs, reflecting a narrowed focus under pressure (Figure 9).

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Table 1. Target fixation and decision-making consistency across offensive decision types.

Decision Type	Total	Fixated	Final Hit	No fixated	Match Rate
Shoot-basket	15	15	14	93.3%	84.6%
Drive-basket	29	25	25	100%	90.3%
Pass to Roller	24	24	19	79.2%	8.7%
Pass to Corner	79	62	56	90.3%	10.3%

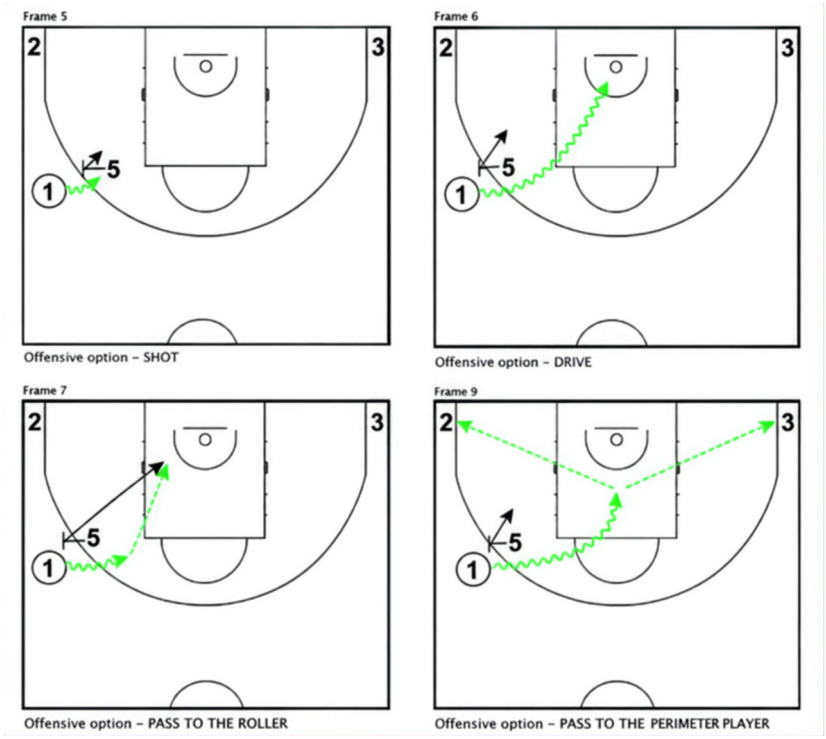


Figure 1. Categories of the offensive decision.

Five categories of offensive decisions made by the ball handler were coded: Shoot, Drive, Pass to Roller, Pass to Perimeter Player, and No Decision. Only one primary offensive decision was coded for each trial

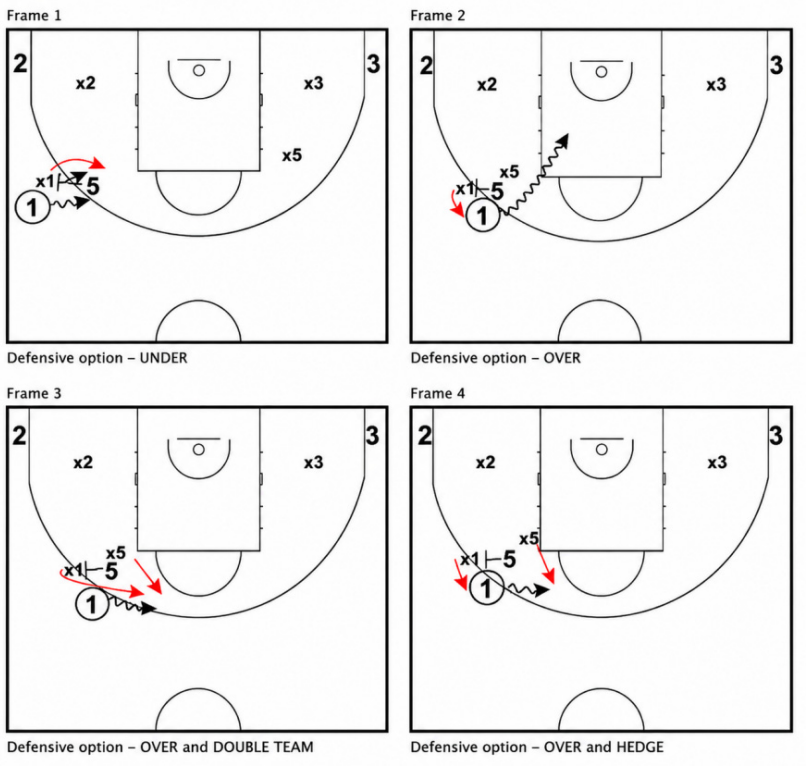


Figure 2. Types of defensive strategies.

Four defensive strategies were implemented: Under, Over, Over and Double Team, and Over and Hedge Team. All trials were initiated from the 45-degree wing, and the defensive strategy was instructed by the researcher prior to the start of each trial

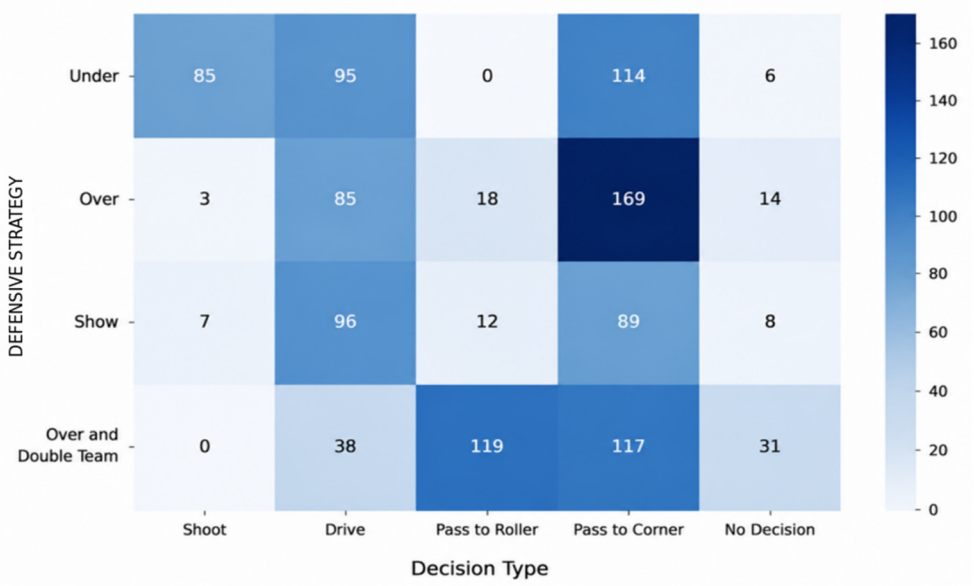


Figure 3. Heatmap of offensive action frequencies across defensive strategies.

Color intensity represents the frequency of each defensive strategy-offensive decision combination, illustrating the relationship between defensive conditions and offensive choices

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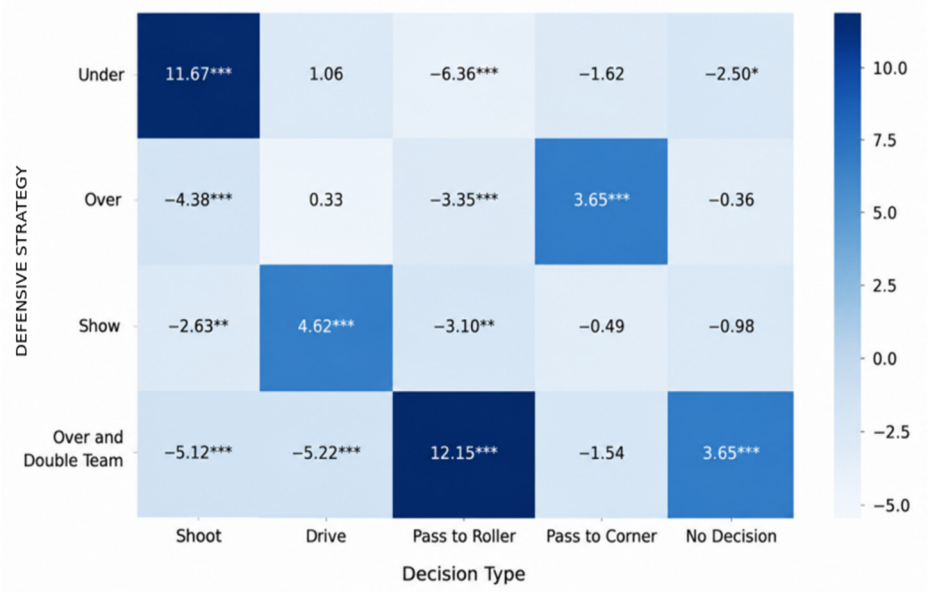


Figure 4. Heatmap of standardized residuals between defensive strategies and offensive actions.

*Positive values indicate that the offensive decision occurred more frequently than expected in the corresponding defensive strategy, whereas negative values indicate lower-than-expected frequencies. Color intensity reflects the magnitude of deviation from expected values; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$*

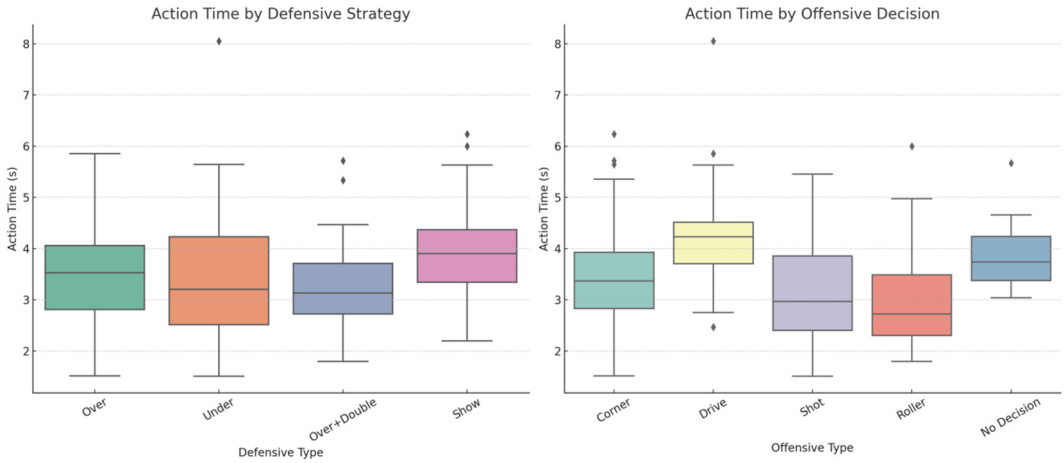


Figure 5. Boxplot of action execution time across defensive strategies.

The left panel shows the distribution of action execution times in the four defensive strategies, and the right panel shows execution times across different offensive decision types. Boxplots depict differences in execution time across task conditions, where boxes represent the interquartile range, the central line indicates the median, whiskers represent the data range, and dots denote outliers

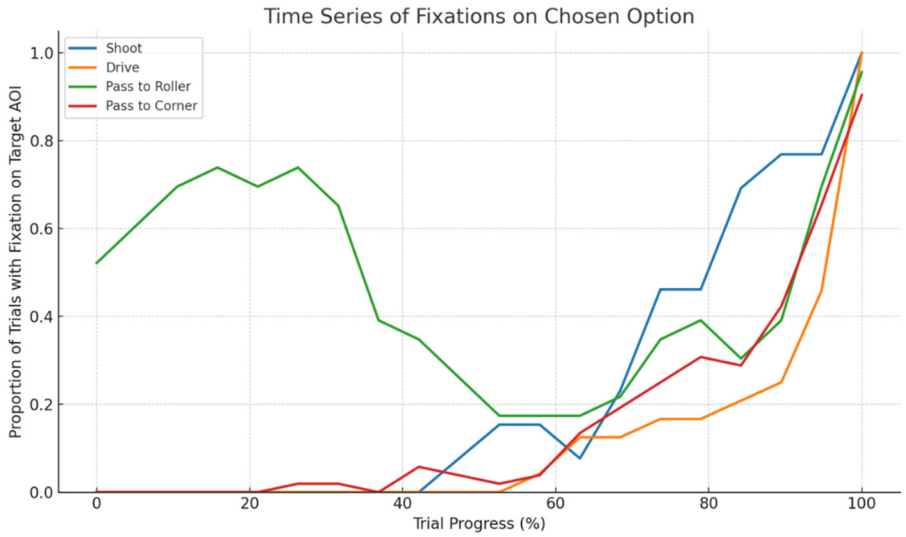


Figure 6. Time series of fixations on target AOI across offensive decisions illustrating the temporal dynamics of gaze behavior throughout the trial.

The x-axis represents the percentage of trial progression, and the y-axis represents the proportion of trials in which the target AOI was fixated within each time segment

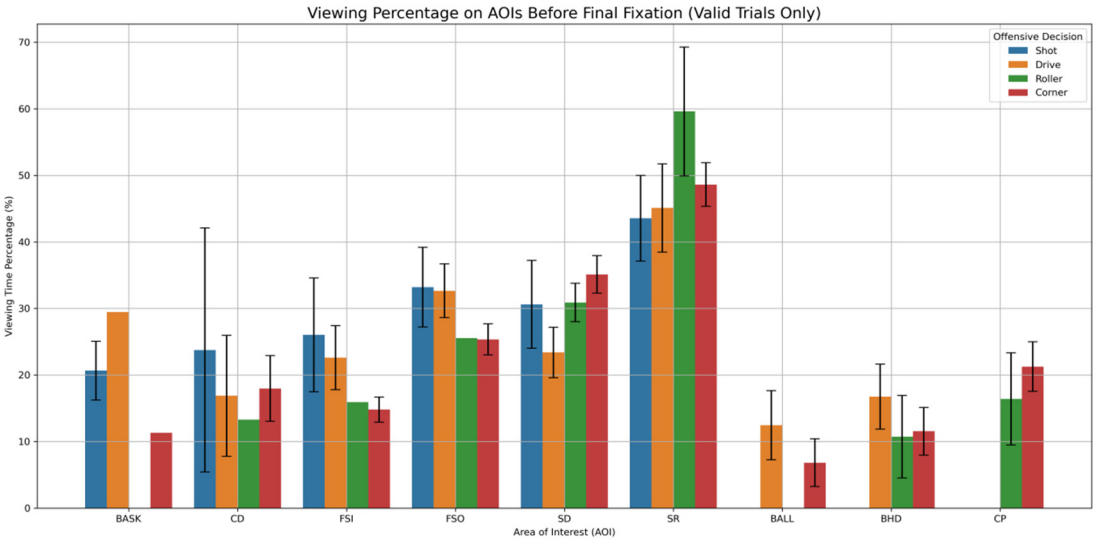


Figure 7. Viewing time percentage on AOIs before final fixation by offensive decision, which illustrates patterns of visual information allocation before the final fixation in different decision contexts.

The figure displays the proportion of viewing time allocated to each area of interest (AOI) prior to the final fixation, across different offensive decision types, based on valid trials. Bars represent mean fixation time proportions, and error bars indicate standard errors

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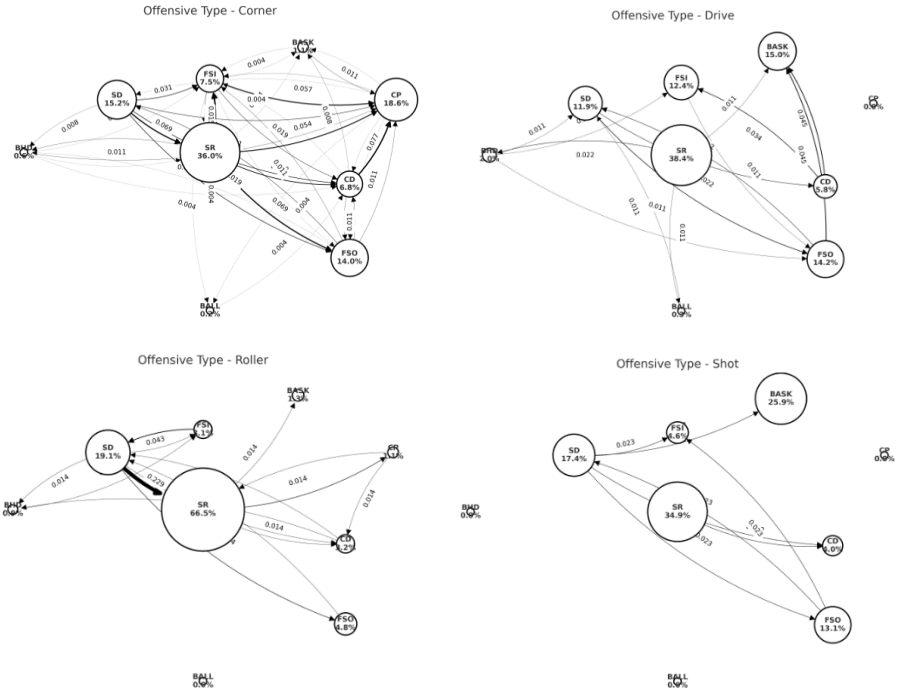


Figure 8. Gaze transition paths across offensive decision types.
Circles represent the AOIs. Circle size indicates the overall proportion of fixations on each AOI, with percentage values shown below the AOI labels. Arrows represent gaze transitions between AOIs; arrow thickness reflects transition probability, and numerical values adjacent to the arrows indicate the corresponding transition probabilities

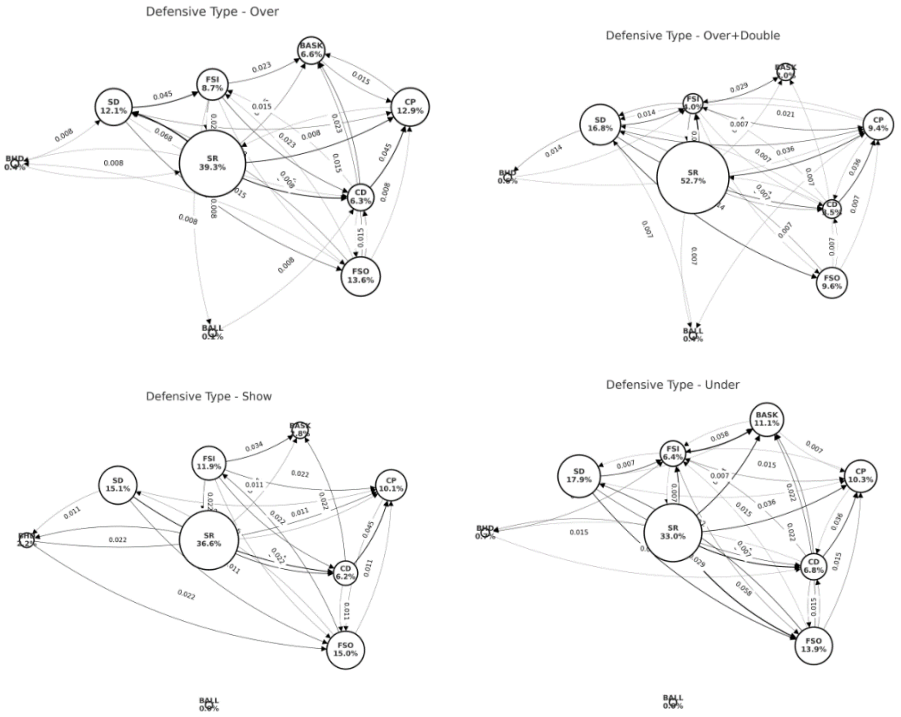


Figure 9. Gaze transition paths under different defensive strategies.

Discussion

In the present study, we investigated the use of information sources by the ball handler during a typical 4v4 basketball task. We manipulated defensive strategies in a pick-and-roll task and observed how available information sources guided the ball handler's (inter) actions within the team, while attempting to convert a shot.

Importantly, our study adopted a "functional" approach to in-situ gaze behavior, embedded in a representative task of basketball performance constraints. We employed time-series analysis of gaze patterns, gaze paths and heat mapping to examine decision-making behavior. By enrolling youth basketball players, we also addressed an existing research gap concerning how early-career athletes manage the evolving information landscape to adapt to the complexity and dynamics of a typical game sub-phase task.

Our study indicates that offensive decisions were strongly associated with the defensive strategies employed. Players co-adapted to the specific task constraints, as expected, to identify the most suitable course of action to succeed. Notably, evidence of co-adaptation extended across the action timescale. Defensive strategies that imposed greater pressure on the ball handler, and offensive actions that involved dribbling actions to the basket were characterized by longer duration. Additionally, gaze behavior dynamics revealed a "last-second" adjustment in the use of information sources, for the majority of the defensive strategies, as fixations on the final visual target tended to emerge immediately prior to action execution. Gaze transition paths also underscored the central role of information pick-up by the ball handler, from the screener and roller, under interacting constraints.

We found that defensive strategies and offensive decisions were significantly associated. In basketball, coaches commonly employ different strategies (e.g., "under", "over", "show" and "over and double") to counteract the instability caused by pick-and-roll plays, protect the basket and regain ball possession. Defensive actions implying lesser pressure on the ball handler, such as "under" and "over", were associated with shooting actions. This tendency to shoot under conditions of reduced pressure was also noticed by Van Maarseveen et al. (2018) who found that the ball handler was more likely to shoot when facing an "under" defensive strategy, especially on the left side of the court. Conversely, high-pressure strategies on the ball, such as "show" and "over and double" more frequently led to a drive to the basket or a pass to the roller (i.e., the player who sets the screen, creates a line of pass by moving toward the basket). Previous research has highlighted the importance of informational variables, such as interpersonal distance and body-posture, for attacker-defender interaction and information pick-up in basketball (Esteves et al., 2011). It was demonstrated that within specific range of interpersonal distance, the ball handler was influenced by foot positioning of the closest defender, which in turn shaped the direction of the dribble penetration to the basket. Similar effects of defensive pressure on technical actions were also observed at a collective scale of analysis (Sampaio et al., 2016).

Of particular interest, defensive strategies that created additional pressure on the ball handler, such as "show" and "over and double", required longer execution times. This larger timescale was also found in the action of driving to the basket, from the attacking perspective, in comparison with the shoot and the pass (i.e., either to the corner or to the roller). These results can be explained by the fact that higher pressure on the ball demands the attacking team to thoroughly explore the informational landscape to find the most prominent solutions to shoot at the basket. In addition, the action of dribbling to the basket usually generates a defensive reorganization, to counterbalance offensive advantage, that involves the intervention of additional defenders (i.e., help defense). Within this game scenario, the attacker performing the drive must "read" resultant action possibilities and find alternative and effective options, such as passing the ball to the corner, if needed. Interestingly, the quality of the decision of the ball handler has been identified as a relevant factor influencing execution time (Van Maarseveen et al., 2018). In a 3v3 basketball sub-phase task, Van Maarseveen and colleagues (2018) reported that correct decisions were executed faster than incorrect ones. The process of navigating throughout the unfolding dynamics of a basketball game requires players to continuously detect and use relevant information across a spectrum of action possibilities, intrinsically connected over

time. The perception of multiple and temporally connected opportunities for action has also been discussed by Seifert et al. (2021) in climbing, where expert climbers were asked to use different handhold modes under conditions of varying complexity. By actualizing the state of relation with the immediate environment on a moment-to-moment basis, performers may "find their ways" to explore the opportunities that support goal achievement (Woods et al., 2020). Therefore, task constraints (i.e., defensive condition), action modes (i.e., drive) and quality of the decision reflect the distinctive nature of how basketball players negotiate emerging action opportunities across space and time.

In our study, we delved into the dynamics of gaze behavior in order to go beyond cumulative data and open a broader understanding of how youth basketball players detect visual information on a moment-to-moment basis. We analyzed normalized trial time series (in percentages) to gain a deeper understanding of gaze dynamics, specifically how fixation on the final target location progressed over time. The proportion of visual fixations on the final target location increased throughout each trial, with a marked rise in the final 20%. This pattern aligns with previous research stating that sport performers employ visually-guided behavior strategies across both individual (Casanova and Peixoto, 2020; Hildebrandt and Cañal-Bruland, 2020) and team sports (De Oliveira et al., 2008). Of note, fixations on the target area for "shoot" and "drive" options tended to occur later in the trial, whereas "pass to the roller" was characterized by early fixation patterns. Self-regulated actions, such as shooting at the basket and dribbling to the basket, that highly depend on the decision of the ball handler, can be successfully implemented via last-moment adaptation. Previous research has shown that basketball players, when shooting, pick up late optical information to fine-tune their movement patterns and update their state of relation with the environment (De Oliveira et al., 2006, 2007). In our study, task solutions involving other players, such as "pass to the roller", appeared to require earlier gaze anchoring on this area of interest to better anticipate action solutions. These results suggest that players exhibited distinct temporal fixation patterns depending on their offensive choices, underscoring a close coupling between visual attention and tactical decision-making.

Since the seminal work of Vickers (1996), the "fixation duration" variable has attracted considerable research interest in the context of basketball. This relevance is underscored by the premise that the longer an athlete's gaze is directed toward specific areas of interest, the more information can be extracted and utilized for subsequent actions (Davids et al., 2005; Moran et al., 2018; Williams et al., 2025). Accordingly, the duration of visual fixations on areas of interest is often interpreted as an indicator of informational saliency. In our study, significant differences were found in fixation duration across different decision modes which indicated that players adapted their visual behavior's to the possibilities of action originating from the specific game conditions. In particular, the SR emerged as the area of interest with greater focus of attention, when the ball handler opted to "pass to the roller". The importance of the "screener/roller" was also noted in the study by Van Maarseveen et al. (2018), alongside the screener defender and space-related variables. In contrast to our findings, Van Maarseveen et al. (2018) did not observe an influence of players' chosen options on fixation duration across the different areas of interest. A tentative explanation for this discrepancy may lie in the differences in the experimental design. Our study employed a 4v4 pick-and-roll scenario incorporating four defensive strategies commonly used in gameplay—under, over, over with hedge, and over with double team. In comparison, Van Maarseveen and colleagues (2018) used a 3v3 pick-and-roll format with only three defensive strategies: under, over, and hedge. The fact that our experimental design incorporated a higher degree of informational resonance with actual basketball gameplay—both in terms of the number of players and the presence of defensive actions—may have enabled attacking players to more effectively couple perception and action, thereby better sustaining their visually guided behavior.

Visual search strategies can be meaningly captured through the use of gaze paths where visual fixation patterns are tracked over time in order to identify a sequence of clusters expressing how visual cues are being picked-up during a specific goal-oriented task, such as a 4v4 basketball sub-phase (Williams et al., 2025). In our study the screener/roller emerged as a prominent area of

interest across various offensive decisions (i.e., shot, drive, pass to the roller or pass to the corner). Notably, this information source was particularly important to the option of "pass to the roller". While "shooting to the basket" was linked to narrower scan paths, "driving" and "passing to the corner" were associated with more dispersed visual fixations. Taken together, these findings suggest that as offensive complexity increases (i.e., "driving" or "passing to the corner") players are required to further scan the performing environment, by searching and shifting between relevant visual cues. In contrast, more straightforward actions like "shooting", that depend more on an individual scale, involve a more centralized gaze strategy, with less visual cues being perceived. The centrality of the "screener/roller" was also evident concerning the defensive strategies, indicating this area as crucial in the information landscape at the interface between attack and defense. In this sense, the "screener/roller" can be highlighted as a "visual anchor".

Recent evidence from a dynamic dribbling dual-task showed that experienced youth soccer players exhibited fewer fixations and more saccades than amateur players while completing the task faster and with fewer errors, suggesting that visual-search organization may vary according to sporting experience and task demands (Heper et al., 2026). Typically, less experienced performers adopt a "target-control strategy", focusing their gaze on the intended target. In contrast, expert performers demonstrate a "context-control strategy", shifting between foveal and peripheral vision to adapt to the evolving constraints (Tenenbaum and Bar-Eli, 1995). Our findings suggest that youth basketball players employed a "context-control strategy", adapting their visual search behavior to task constraints. This strategy may have included directing their gaze to extract proximal visual cues (i.e., foveal spot strategy), but also to anchor their gaze in specific visual cues as a mean to detect relevant peripheral information ("gaze anchor strategy"), as well as shifting between foveal and peripheral information (i.e., visual pivot strategy) (Vater et al., 2020). In informationally rich and dynamic settings like basketball, where complex interactions unfold among players, targets, and the ball, the ability to functionally adapt visual strategies (i.e., foveal and peripheral vision) appears to sustain game performance (Klostermann et al., 2020).

In this study we adopted a functional and representative approach to investigating visually guided behavior in a 4v4 basketball task. Our in-situ experimental approach involved a representative scenario of typical performance environments. This option reflected the need of preserving the integrity of perception and action couplings that feature the ways that sport performers operate in effective game environments. Previous research has shown that gaze behavior in the in-situ experimental context significantly differs in the information pick up when compared to video simulation tasks (i.e., Dicks et al., 2009, 2010). Building on this premise, we ensured that participants were immersed in an environment to actively pick up relevant information to support respective actions. In essence, they were allowed to act to perceive and perceive to act. Moreover, we utilized a range of complementary analyses to examine the uniqueness of visually-guided behaviors, preserving both temporal structure and spatial mapping of gaze dynamics. This study highlights how youth basketball players functionally adapt their gaze behavior and decision-making while coping with dynamic constraints, underscoring the importance of representative tasks in understanding perception-action couplings in team sports and basketball in particular.

This study offers valuable insights into gaze behavior and decision-making in youth basketball; however, some limitations should be acknowledged. The sample consisted exclusively of U16 female players, which limits the generalizability of the findings to other age groups, genders, or expertise levels. Although the 4v4 side pick-and-roll scenario was designed to be representative, it cannot fully capture the complexity and situational pressure of real 5v5 competition. Only trials with valid final fixations were included in several analyses, potentially excluding cases involving hesitation or uncertainty. Furthermore, gaze data were collected from individual players, preventing the simultaneous examination of interactive visual strategies among teammates. Finally, while entropy and transition analyses provide useful indicators of gaze dynamics, they do not directly

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reflect underlying cognitive processes such as anticipation or decision confidence. Future research should consider more diverse samples, multi-player tracking, and multidimensional data streams to further explore the interplay between perception and action in dynamic sport contexts.

Conclusions

This study explored how youth basketball players detect visual information for action during a 4v4 pick-and-roll basketball task, under varying defensive strategies. By adopting a "functional" approach to in-situ gaze behavior, we were able to examine decision-making behavior as it typically takes place in effective performance settings. Our results highlight the dynamic interplay between gaze behavior and decision-making in youth basketball. Ball handlers demonstrated an adaptation of their gaze patterns to the evolving defensive conditions. Notably, players relied on last-second information pick-up to support offensive actions mostly dependent on a self-regulated scale, such as shooting and dribbling to the basket. Game situations that generated a higher level of interaction with teammates implied earlier gaze anchoring, granting higher anticipation windows of opportunity. Finally, youth players showed an adaptation of gaze strategies to the complexity of the task. While an increase in offensive complexity was associated with an extensive scan of the performing environment, centralized gaze strategies were associated with straightforward actions such as "shooting". In conclusion, this study underscores the importance of functional gaze behaviors in fast-paced game scenarios, such as basketball games, and demonstrates how young athletes co-adapt their perceptions, actions and decisions across temporal scales to achieve success.

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