The influence of basketball players' tracking speed ability on sports decision performance (#114856)

First revision

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The article must be written in English and must use clear, unambiguous, technically correct text. The article must conform to professional standards of courtesy and expression.

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Conclusions are well stated, linked to original research question & limited to supporting results.

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Comment on strengths (as well as weaknesses) of the manuscript	*I commend the authors for their extensive data set, compiled over many years of detailed fieldwork. In addition, the manuscript is clearly written in professional, unambiguous language. If there is a weakness, it is in the statistical analysis (as I have noted above) which should be improved upon before Acceptance.*

The influence of basketball players' tracking speed ability on sports decision performance

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Background : The running speed of basketball players plays a critical role in shaping the complexity and dynamics of game situations. This study aims to examine the relationship between players' tracking speed capabilities and the quality of their decision-making during gameplay.

Method s : Employing an expert-novice paradigm, Experiment 1 assessed tracking accuracy in a multiple object tracking (MOT) task at three angular velocities: 5°/s, 10°/s, and 15°/s. Experiment 2 evaluated decision-making accuracy under three distinct running speed conditions: low speed (0.67–3.98 m/s), medium speed (3.99–7.97 m/s), and high speed (7.98–12.62 m/s).

Results : In Experiment 1, expert players demonstrated significantly higher tracking accuracy (60.42 ± 13.98%) than novice players (41.25 ± 13.93%) at 10°/s ($P < 0.001$). No significant group differences were found at 5°/s or 15°/s ($Ps > 0.05$). In Experiment 2, the expert group exhibited significantly higher decision accuracy than the novice group across all three speed conditions ($Ps < 0.001$). Moreover, at high speeds (7.98–12.62 m/s), shooting decisions were significantly less accurate than passing and breakthrough decisions ($Ps < 0.001$), while no significant differences were observed between passing and breakthrough decisions ($Ps > 0.05$). Conclusion : This study demonstrates that expert basketball players exhibit superior visual attention and perceptual-cognitive decision-making abilities compared to novices. Their enhanced tracking performance and higher decision accuracy - particularly in complex, high-speed scenarios - underscore the role of domain-specific attentional allocation and strategic adaptation. These findings contribute to the theoretical understanding of expertise in dynamic sports environments and suggest practical implications for perceptual training in athletic development.

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Abstract

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Methods: Employing an expert-novice paradigm, Experiment 1 assessed tracking accuracy in a multiple object tracking (MOT) task at three angular velocities: 5°/s, 10°/s, and 15°/s. Experiment 2 evaluated decision-making accuracy under three distinct running speed conditions: low speed (0.67–3.98 m/s), medium speed (3.99–7.97 m/s), and high speed (7.98–12.62 m/s).

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Conclusion: This study demonstrates that expert basketball players exhibit superior visual attention and perceptual-cognitive decision-making abilities compared to novices. Their enhanced tracking performance and higher decision accuracy-particularly in complex, high-speed scenarios-underscore the role of domain-specific attentional allocation and strategic adaptation. These findings contribute to the theoretical understanding of expertise in dynamic sports environments and suggest practical implications for perceptual training in athletic development.

Introduction

In sports, decision-making abilities play a crucial role in players' actions, especially in complex, high-speed situations. The performance of athletes, particularly in team sports like basketball, depends on the successful integration of decision-making and technical skills (Marasso et al. 2014). The cognitive abilities involved in decision-making are critical in high-strategy sports such as basketball (Thomas 1994), where players must assess the game situation and respond rapidly by choosing the optimal course of action. In basketball, these decisions are often based on visual cues, making the role of visual attention and memory crucial for successful decision execution (Wang et al. 2018). Perception, the first step in decision-making, relies heavily on visual information, with over 80% of brain data coming from visual stimulus (Sui et al. 2018).

One of the key cognitive functions in basketball is Multiple Object Tracking (MOT), a skill that allows players to simultaneously monitor the positions of multiple teammates and opponents in dynamic scenarios (Faubert & Sidebottom 2012). MOT is essential in fast-paced environments, such as basketball, where rapid shifts between offensive and defensive roles demand continuous and accurate tracking of multiple moving objects (Faubert 2013). As basketball has become increasingly fast-paced, coaches and researchers have focused more on improving players' visual attention to enhance their decision-making accuracy (Jin 2020).

While the importance of visual attention in basketball decision-making is well-established, existing research has focused primarily on third-person perspective visual materials (Li et al., 2006), which have limited ecological validity. The first-person perspective, by contrast, provides a closer and more direct view of target objects, offering clearer insights into their physical properties. This can improve the accuracy of subsequent behavioral evaluations (Mao, 2010). Despite the growing interest in visual attention in sports decision-making, there is still a lack of research that explicitly investigates the role of tracking speed and running speed in decision accuracy (Liao 2013), particularly in dynamic team sports like basketball.

In modern basketball, players face highly dynamic and complex visual stimuli, where they must rapidly assess positions, trajectories, and potential actions to make quick decisions—such as whether to shoot, pass, or break through (Vickers, 2007). The speed of movement, both of players and objects on the court, significantly increases the complexity of decision-making (Williams et al. 2013). Existing research indicates that the ability to track moving objects at varying speeds can reflect differences in visual attention and cognitive load between expert and novice players (Pylyshyn & Annan, 2006; Sungur & Boduroglu, 2012). However, there is still a gap in the literature regarding how different tracking speeds and running speeds influence decision-making in basketball, particularly in terms of how these factors interact to affect cognitive processing and decision accuracy.

This study seeks to address this gap by investigating the relationship between tracking speed, running speed, and decision-making accuracy in basketball players. In Experiment 1, the accuracy of expert and novice players in MOT tasks was compared across different tracking speeds. Experiment 2 focused on decision-making accuracy under three different speed ranges to explore how speed influences decision quality. The goal is to analyze the advantages of expert players in tracking and decision-making, providing insights into how visual attention impacts sports decision-making.

The central hypothesis of this study is that expert basketball players have superior visual attention and decision-making abilities compared to novices. It is expected that as target speed increases, expert players will demonstrate higher tracking accuracy and decision-making accuracy than their novice counterparts, within certain speed ranges.

Materials & Methods

Participants

The study used G∗Power 3.1.9.7 software to estimate the sample size, setting the effect size to be biased by η^2= 0.03 (Lakens 2014), α = 0.05. The calculation indicated that a statistical test power of 0.80 could be achieved with 40 participants (20 in each group). Considering the potential for participant withdrawal during the experiment, 48 participants were ultimately selected, with 24 participants in each group (Jin 2020). The participants were divided into two groups: an expert group and a novice group, based on their basketball experience and skill level. The expert group consisted of female players from the Northeast Division of the Chinese University Basketball League First Division (Pylyshyn & Annan 2006), with an average playing time of over 15 minutes per game, a minimum sports level of Level 1 (including Level 1), an average age of (21.20 ± 2.12) years, an average training period of (9.10 ± 2.14) years, and a weekly training time of (27.64 ± 7.16) hours in the past year. The novice group included female students from the basketball elective course at Northwest Normal University, with an average age of (19.83 ± 0.89) years, an average training period of (1.60 ± 0.49) years, a weekly training time of (1.20 ± 0.15) hours, and no formal sports level. All participants have no previous experience in MOT, were right-handed, with normal or corrected vision, and maintained stable emotions and a good mental state before the experiment. They played electronic games for no more than 4 hours per week and experienced no fatigue. The experiment was approved by the ethics committee of Northwest Normal University (No. NWNU-20230301). Prior to the experiment, participants were thoroughly informed of the purpose and procedures of the study and were required to sign an informed consent form.

Design

Experiment 1 used a multiple object tracking task to assess tracking performance at different target speeds. A mixed experimental design was employed: 2 (group: experts, novices) × 3 (target speed: 5 °/s, 10 °/s, 15 °/s), where the group was the between-subjects variable, the target speed was the within-subjects variable, and the dependent variable was tracking accuracy. The accuracy calculation was based on the proportion of correctly selected targets in each participant's trials.

Experiment 2 followed a 2 (group: experts, novices) × 2 (decision type: intuition, cognition) × 3 (attack method: passing, shooting, breakthrough) × 3 (speed: low speed 0.67-3.98 m/s, medium speed 3.99-7.97 m/s, high speed 7.98-12.62 m/s) design. The group was the between-subjects variable, the target speed was the within-subjects variable, and the dependent variable was decision accuracy. During the experiment, a principal investigator was present to accompany and ensure the smooth progression of the procedure.

Apparatus

The experiment was conducted using a Lenovo E15 laptop, with an operating system of Windows 10, a 15.6-inch display screen, a screen resolution of 1920 × 1080 pixels, and a refresh rate of 60 Hz. At the beginning of Experiment 1, a "+" symbol lasting 500 ms was displayed at the center of the screen, followed by 12 white spheres. Three of the spheres turned blue and flashed three times, marking them as target objects, while the remaining spheres remained white as non-target objects. Subsequently, all spheres turned white and moved randomly at speeds of 5 °/s, 10 °/s, and 15 °/s. After 8 seconds, the spheres stopped moving, and the target objects turned red. Participants were required to determine how many of the red spheres contained target objects, press the corresponding number keys, and proceed to the next trial.

Stimuli

The offensive video sequences used in Experiment 2 were selected from Women's Chinese Basketball Association (CBA) games, specifically focusing on the forward position. These clips were drawn from the final matches of the 2020-2021 and 2021-2022 seasons, which were temporally close to the experiment. A total of 129 segments were included, each representing actions such as passing, breakthrough, and shooting (Jin et al. 2023). Ten high-level female basketball players recreated these scenes on-site, with each team wearing black and white jerseys and identified by their numbers. A tall player with short hair wore a sports camera (model: Insta360 One X) to capture footage from the player's first-person perspective (Ping 2019).

(1) Determination of content validity: Five CUBA basketball coaches and CBA players reviewed and validated the 129 selected WCBA league offensive position attack videos, as well as the final first-person perspective videos (Spitz et al. 2018).

(2) Determination of structural validity: The study also selected 6 high-level basketball players and 6 college students enrolled in the basketball elective course for validity testing. This step aimed to eliminate the "ceiling effect" and "floor effect," ensuring that each video could effectively distinguish decision-making efficiency among players at different skill levels. For videos with low discriminative power, the video durations were adjusted by either extending or shortening the clips until each video clearly differentiated the decision-making speed and accuracy between high-level players and elective course students. As expected, high-level players demonstrated higher decision-making speed and accuracy (Dai et al. 2011), thus forming the experimental materials for this study (Wang 2010). The final video duration for each clip was 3000 ms.

Video analysis

In the statistical analysis of 60 basketball game videos from Experiment 2, it was noted that there were 10 players in 59 videos, while only one video featured 9 players. Due to this fixed number characteristic, analysis of the number of players did not provide effective insights into the results of sports decision-making. Therefore, following consultations with experts, Experiment 2 focused on analyzing the average speed of the ball handler.

Notes: ■pass, ●shoot.

Figure 1 Example of positioning calibration for ball bearers

Video analysis technology is a critical tool in modern sports science research, providing detailed data on player performance. By recording the time and location (x and y-axis coordinates) of movements during competitions, it is possible to describe the behavior of players through ordinary video footage (Kamble et al. 2019). The analysis tracks location changes over a specified time period, which are determined by the nature of the event. Based on the standard dimensions of a basketball court (28 meters in length and 15 meters in width), the court is set within a Cartesian coordinate system with an x-axis of 28 meters and a y-axis of 15 meters, with a stride value of 1 meter. Each time the step size increases by 1 meter, this serves as a reference for the grid covering the field, where mapping the event onto the grid results in corresponding x and y values (Cullinane et al. 2024). See Figure 1.

Storm player software (version 5.81) is employed to play the video material and calculate the ball handler's speed using the following steps:

The time interval is set to Δt (0.5 s), and the position changes of the ball handler are checked within each 0.5-second interval. If there is no change in the player's position, the location is recorded at 0.5-second intervals. If a change in position occurs, the location is recalibrated based on the time of the change, and the time interval is recalculated. This algorithm enables real-time detection and tracking of the ball handler's position and movement.

By recording the position changes over a continuous period, the player's running speed is calculated using the following formula. If the player moves from position P1 (x_1, y_1) to position P2 (x_2, y_2) within time Δ t, the velocity v can be expressed as: $v = \frac{P2 - P1}{\Delta t} = \frac{\sqrt{(x2 - x1)^2 + (y2 - y1)^2}}{\Delta t}$

By calculating the average speed of the ball handler in each video and combining it with the speed settings of the multiple object tracking task in Experiment 1, the decision video material was divided into three speed ranges: 0.67-3.98 m/s, 3.99-7.97 m/s, and 7.98-12.62 m/s. The results showed that, within the range of 0.67-3.98 m/s, there were a total of 28 videos (including 6 passes, 13 shots, and 9 breakthroughs). In the range of 3.99-7.97 m/s, there were a total of 27 videos (including 11 passes, 7 shots, and 9 breakthroughs). In the range of 7.98-12.62 m/s, there were only 5 videos (including 3 passes and 2 breakthroughs), with no shooting decisions made by the ball handler while running at high speed.

Procedure

Experiment 1: A multiple object tracking experimental program was developed using Matlab R2020b software. The distance between the participant and the screen was approximately 60 cm, and the stimulus presentation area covered the entire screen. To familiarize the participants with the experimental process, five practice trials were conducted before the formal experiment. The experiment consisted of 10 blocks, each containing 3 trials corresponding to the three target speeds: 5 °/s, 10 °/s, and 15 °/s, for a total of 30 trials. A 10-second white screen was displayed between each block to alleviate eye fatigue. The experimental sequence was counterbalanced within subjects. The entire experiment lasted approximately 11 minutes.

Figure 2 Basic process of sports decision-making task

Experiment 2 was programmed using Experiment Builder 2.3 software. Referring to previous research, the presentation time for intuitive decisions was set at 600 ms, while the presentation time for cognitive decisions was set at 1200 ms (Lu 2018). Intuitive decision-making task instructions: "The '+' sign is first displayed in the center of the screen, followed by a blank screen and a first-person perspective game video, prompting: 'Please make a decision.' Carefully observe and judge the attacking style of the ball handler within 0.6 seconds. The situation on the court is urgent; please make a quick decision. Press 1 for passing, press 2 for shooting, and press 3 for a breakthrough." Cognitive decision-making task instructions: "The '+' sign is first displayed in the center of the screen, followed by a blank screen and a first-person perspective game video, prompting: 'Please make a decision.' Carefully observe and judge the attacking style of the ball handler within 1.2 seconds. Please make accurate and prompt decisions. Press 1 for passing, press 2 for shooting, and press 3 for a breakthrough." After the practice trials are completed, the screen will display "Start formal experiment," and the button operation will remain consistent with the preparation stage. The video will be played in full screen, and participants will alternate between cognitive and intuitive decision-making tasks using an ABBA design to balance task order (Liu 2012), with a 30-second break between tasks. Three types of attack videos for each decision-making task will be randomly presented, and the entire experimental process will take approximately 27 minutes. See Figure 2.

Statistical analysis

The data for Experiment 1 were recorded and collected using Matlab R2020b software, while the data for Experiment 2 were recorded and collected using Experiment Builder 2.3 software and analyzed using SPSS 29.0 software. Experiment 1 uses tracking accuracy as the dependent variable and employs a repeated measures analysis of variance (ANOVA) with 2 (groups) × 3 (target velocity). Experiment 2 uses decision accuracy as the dependent variable and employs a repeated measures ANOVA with 2 (group) × 2 (decision type) × 3 (attack style) × 3 (speed). If the interaction effect is significant, further simple effects analysis will be performed. The Bonferroni method will then be used for pairwise comparisons. P <0.05 will be used as the threshold for statistically significant differences.

Results

Tracking accuracy of experts and novice MOT at different speeds

Note

**P<0.01

Figure 3 Tracking accuracy of MOT at different speeds for experts and novices

A repeated measures ANOVA was performed with target speed (5 °/s, 10 °/s, 15 °/s) as the within-subjects variable, group (expert group, novice group) as the between-subjects variable, and tracking accuracy as the dependent variable. The results showed that the main effect of the group was significant, with the accuracy of the expert group (56.81 ± 13.11%) being significantly higher than that of the novice group (46.95 ± 12.70%, $P < 0.001$). The main effect of target speed was significant, $F(2, 92) = 196.722$, $P < 0.001$, $\eta^2 = 0.810$. Post-hoc analysis revealed that as target speed increased, accuracy significantly decreased (*Ps* < 0.01). The interaction effect between target speed and group was also significant, $F(2, 92) = 5.891$, $P = 0.006$, $\eta^2 = 0.114$. Simple effects analysis showed that at 10 °/s, the accuracy of the expert group (60.42 ± 13.98%) was significantly higher than that of the novice group (41.25 ± 13.93%, $P < 0.001$); at other speeds, no significant differences in accuracy were found (*Ps* > 0.05). See Figure 3.

Decision accuracy of expert and novice video materials at different speeds

A repeated measures ANOVA was conducted using group (expert group, novice group) as the between-subjects variable, decision type (intuition, cognition), attack method (passing, shooting, breakthrough), and speed (low speed: 0.67-3.98 m/s, medium speed: 3.99-7.97 m/s, high speed: 7.98-12.62 m/s) as within-subjects variables, with accuracy as the dependent variable. The results are shown in Table 1.

The analysis revealed a significant main effect of group, with the decision accuracy of the expert group (0.66 ± 0.11) being significantly higher than that of the novice group (0.32 ± 0.10), $F(1, 46) = 1069.644$, $P < 0.001$, $\eta^2 = 0.959$. The main effect of decision type was also significant, with the accuracy of intuitive decisions (0.47 ± 0.11) being significantly lower than that of cognitive decisions (0.52 ± 0.10), $F(1, 46) = 45.818$, $P < 0.001$, $\eta^2 = 0.499$. The main effect of attack method was significant, $F(2, 92) = 171.733$, $P < 0.001$, $\eta^2 = 0.789$. Post-hoc analysis revealed that the accuracy of shooting decisions (0.40 ± 0.10) was significantly lower than that of passing (0.55 ± 0.11) and breakthrough (0.53 ± 0.12), *Ps* < 0.001; there was no significant difference in the accuracy of passing and breakthrough decisions ($P = 0.05$). The main effect of speed was significant, $F(2, 92) = 729.000$, $P < 0.001$, $\eta^2 = 0.941$. Post-hoc analysis showed that as speed increased, decision accuracy significantly decreased (*Ps* < 0.001).

The interaction effect between group and decision type was significant, $F(1, 46) = 7.050$, $P = 0.011$, $\eta^2 = 0.133$. The interaction effect between group and attack method was significant, $F(2, 92) = 38.394$, $P < 0.001$, $\eta^2 = 0.455$. The interaction effect between group and speed was significant, $F(2, 92) = 41.583$, $P < 0.001$, $\eta^2 = 0.475$. The interaction effect between decision type and attack method was significant, $F(2, 92) = 5.243$, $P = 0.007$, $\eta^2 = 0.102$. The interaction effect of group, decision type, and attack method was significant, $F(2, 92) = 3.923$, $P = 0.023$, $\eta^2 = 0.079$. The interaction effect between decision type and speed was significant, $F(2, 92) = 7.254$, $P = 0.001$, $\eta^2 = 0.136$. The interaction effect between attack method and speed was significant, $F(4, 184) = 177.963$, $P < 0.001$, $\eta^2 = 0.795$. The interaction effect of group, attack method, and speed was significant, $F(4, 184) = 31.753$, $P < 0.001$, $\eta^2 = 0.408$. The interaction effect of decision type, attack method, and speed was significant, $F(4, 184) = 5.054$, $P < 0.001$, $\eta^2 = 0.099$. No other significant interaction effects were found (*Ps* > 0.05).

To further explore the interaction effect between groups and decision types, a simple effects analysis was conducted, which revealed that the decision accuracy of the expert group was significantly higher than that of the novice group in both intuitive and cognitive decision-making tasks ($Ps < 0.001$). In both groups, the accuracy of cognitive decision-making was significantly higher than that of intuitive decision-making ($Ps < 0.01$).

To test the interaction effect between groups and attack methods, a simple effects analysis was conducted, showing that, across all attack methods, the decision accuracy of the expert group was significantly higher than that of the novice group ($Ps < 0.001$). In the expert group, the accuracy of shooting decisions (0.52 ± 0.10) was significantly lower than that of passing (0.74 ± 0.12) and breakthrough (0.72 ± 0.13) ($Ps < 0.001$), with no significant difference between passing and breakthrough decisions ($P = 0.139$). In the novice group, the accuracy of shooting decisions (0.27 ± 0.10) was significantly lower than that of passing (0.35 ± 0.10) and breakthrough (0.34 ± 0.11) ($Ps < 0.001$), with no significant difference between passing and breakthrough decisions ($P = 0.139$).

Table 1 Decision accuracy of experts and novices at different video speeds

In order to test the interaction effect between group and speed, a simple effects analysis was conducted, and it was found that the decision accuracy of the expert group was significantly higher than that of the novice group at all three speeds ($Ps < 0.001$). In both the expert and novice groups, as the ball handler's speed increased, decision accuracy significantly decreased ($Ps < 0.001$).

In order to test the interaction effect between decision types and attack methods, a simple effects analysis was conducted, and it was found that among the three attack methods, the accuracy of cognitive decision-making was significantly higher than that of intuitive decision-making ($Ps < 0.05$). In both intuitive and cognitive decision-making, the accuracy of shooting decisions was significantly lower than that of passing and breakthrough ($Ps < 0.001$), while there was no significant difference in the accuracy of passing and breakthrough decisions ($Ps > 0.05$).

In order to test the interaction effect between decision type and speed, a simple effects analysis was conducted, and it was found that there was no significant difference ($P = 0.108$) between intuitive decision accuracy (0.62 ± 0.09) and cognitive decision accuracy (0.65 ± 0.10) at 0.67-3.98 m/s. At speeds of 3.99-7.97 m/s and 7.98-12.62 m/s, the accuracy of cognitive decision-making was significantly higher than that of intuitive decision-making ($Ps < 0.001$). In both intuitive and cognitive decision-making, the accuracy of passing decisions was significantly higher than that of shooting and breakthrough ($Ps < 0.001$), and the accuracy of shooting decisions was significantly higher than that of breakthrough ($Ps < 0.001$).

In order to test the interaction effect between attack mode and speed, a simple effects analysis was conducted, and it was found that there was no significant difference in decision accuracy among the three attack modes at 0.67-3.98 m/s and 3.99-7.97 m/s ($Ps > 0.05$). At 7.98-12.62 m/s, the decision-making accuracy for shooting was significantly lower than that for passing and breakthrough ($Ps < 0.001$), and there was no significant difference in decision-making accuracy between passing and breakthrough ($Ps > 0.05$). Among the three offensive methods, the accuracy of passing decisions was greater than that of shooting and breakthrough ($Ps < 0.001$), and the accuracy of shooting decisions was greater than that of breakthrough ($Ps < 0.001$).

In order to test the interaction effects between groups, decision types, and attack methods, a simple effects analysis was conducted, and it was found that the expert group had significantly higher decision accuracy than the novice group in both intuitive and cognitive decision-making tasks across all three attack methods ($Ps < 0.001$). In the expert group, the accuracy of cognitive decision-making for passing and breakthrough was significantly higher than that of intuitive decision-making ($Ps < 0.001$). In the novice group, the accuracy of cognitive decision-making during passing (0.38 ± 0.11) was significantly higher than that of intuitive decision-making (0.33 ± 0.09, $P < 0.01$). There was no significant difference in the accuracy of other decisions ($Ps > 0.05$). In the expert group's intuitive decision-making, the accuracy of shooting decisions was significantly lower than that of passing and breakthrough ($Ps < 0.001$), while the accuracy of passing decisions (0.70 ± 0.11) was significantly higher than that of breakthrough decisions (0.67 ± 0.14, $P = 0.024$). In the expert group's cognitive decision-making, the accuracy of shooting decisions was significantly lower than that of passing and breakthrough ($Ps < 0.001$), while there was no significant difference in the accuracy of passing decisions (0.78 ± 0.12) and breakthrough decisions (0.77 ± 0.11) ($P = 0.981$). In both intuitive and cognitive decision-making in the novice group, the accuracy of shooting decisions was significantly lower than that of passing and breakthrough ($Ps < 0.01$), while there was no significant difference in the accuracy of passing and breakthrough decisions ($Ps > 0.05$).

In order to test the interaction effects between groups, decision type, and speed, a simple effects analysis was conducted, and it was found that in both intuitive and cognitive decision-making, the decision accuracy of the expert group was significantly higher than that of the novice group at all three video speeds ($Ps < 0.001$). In both the expert and novice groups, the accuracy of cognitive decision-making was significantly higher than that of intuitive decision-making when the ball handler's speed was between 3.99-7.97 m/s and 7.98-12.62 m/s ($Ps < 0.05$), while there was no significant difference in the accuracy of other decisions ($Ps > 0.05$). In the cognitive decision-making of the expert group, there was no significant difference in decision accuracy between 0.67-3.98 m/s (0.84 ± 0.10) and 3.99-7.97 m/s (0.80 ± 0.11) ($P = 0.104$), while the accuracy of other decisions decreased significantly with increasing speed ($Ps < 0.01$). At different speeds for the three attack methods, the decision accuracy of the expert group was significantly higher than that of the novice group ($Ps < 0.001$).

In order to test the interaction effects between groups, attack methods, and speed, a simple effects analysis was conducted, and it was found that the decision accuracy of the expert group was significantly higher than that of the novice group across different speeds for the three attack methods ($Ps < 0.001$). The accuracy of shooting decisions for both the expert and novice groups was significantly lower than that of passing and breakthrough at 7.98-12.62 m/s ($Ps < 0.001$), while there was no significant difference in the accuracy of other decisions ($Ps > 0.05$). In the expert group's shooting decision, there was no significant difference in the accuracy of decisions between 0.67-3.98 m/s (0.80 ± 0.09) and 3.99-7.97 m/s (0.76 ± 0.11) ($P = 0.076$), while the accuracy of other decisions decreased significantly with increasing speed ($Ps < 0.05$).

In order to test the interaction effects between decision types, offensive styles, and speed, a simple effects analysis was conducted, and it was found that the accuracy of cognitive decisions was significantly higher than that of intuitive decisions at 7.98–12.62 m/s for passing, 3.99-7.97 m/s for shooting, and 3.99-7.97 m/s and 7.98–12.62 m/s for breakthrough ($Ps < 0.05$), while there was no significant difference in the accuracy of other decisions ($Ps > 0.05$). At a speed of 7.98-12.62 m/s for both intuitive and cognitive decision-making, the accuracy of shooting decisions was significantly lower than that of passing and breakthrough ($Ps < 0.001$), while there was no significant difference in the accuracy of other decisions ($Ps > 0.05$). In breakthrough cognitive decision-making, there was no significant difference in decision accuracy between 0.67-3.98 m/s (0.64 ± 0.11) and 3.99-7.97 m/s (0.59 ± 0.12) ($P = 0.067$), while the accuracy of other decisions decreased significantly with increasing speed ($Ps < 0.05$).

Discussion

Experiment 1 aimed to explore the visual attention differences between expert and novice players in multiple object tracking tasks under different target speed conditions. As the target speed increased, the tracking accuracy of both groups showed a decreasing trend. However, at a target speed of 10 °/s, the accuracy of the expert group was significantly higher than that of the novice group ($P < 0.001$), reflecting the visual attention advantage of expert players in tracking speed, thereby supporting our hypothesis.

This result aligns with the findings of Jingwen Song (Song 2012), but differs from those of Jin Peng et al. on the differences in target velocity tracking accuracy, which may be attributed to gender differences among the subjects (Jin 2020). There was no significant difference in tracking accuracy between the two groups at target speeds of 5 °/s and 15 °/s. The attention resources consumed by the target speed task are limited, and the difficulty of the task increases with the target speed. Due to the lower difficulty of the 5 °/s task, players can manage it easily; the 15 °/s task, however, is too difficult and exceeds the visual capability of both groups of players. Thus, at a target speed of 10 °/s, expert players demonstrated higher accuracy based on their ability to quickly process visual information acquired through long-term training and competition. Zhang Xuemin's research also shows that players outperform control groups in tracking tasks (Zhang et al. 2005).

Experiment 2 examined the performance of expert and novice groups in motion decision-making tasks across different speed ranges and decision types. The results showed that the decision-making accuracy of the expert group was significantly higher than that of the novice group across all three speed ranges ($Ps < 0.001$), confirming the advantage of expert players in decision-making ability. As speed increased, decision accuracy significantly decreased ($Ps < 0.001$), indicating that players' decision flexibility and accuracy are affected by targets of different speeds. The faster the target movement speed, the greater the cognitive load on players, which impacts decision-making accuracy. Specifically, when the ball handler moves at high speed, the player must quickly assess the relative position of the ball handler to other players in order to respond quickly to the rapidly changing game environment. This rapid response ability is a core characteristic of high-level players, which can significantly improve their decision-making efficiency in complex environments (Mann et al. 2007).

Moreover, fast-paced basketball games may make players more inclined to rely on intuitive decision-making rather than thoughtful analysis, thereby increasing the diversity and flexibility of decision-making. Due to long-term training and competition, expert players have accumulated a wealth of knowledge, which makes their decision-making abilities significantly better than those of novice players. Wu Yin’s research further suggests that long-term exercise training can alter brain structure and help players process complex visual information more efficiently during sports (Wu et al. 2015). Ericsson and Lehmann argue that long-term exercise can increase the excitability of players' nervous systems, making them more flexible in visual attention regulation (Ericsson & Lehmann 1996). Elite male basketball players, as compared to amateur basketball players, are able to preserve their cognitive performance in tests probing visuospatial attention and decision-making even after an exhaustive bout of acute physical exercises (Mancı et al. 2023). Although the analysis of the number of players did not provide meaningful results, the relationship between the ball handler’s movement speed and motion decisions is significant.

Previous studies have shown that as the number of players on the field increases, players' cognitive load significantly increases, affecting both decision-making time and accuracy (Vaeyens et al. 2010). In this study, the complex interaction between visual attention and motion decision-making was revealed by analyzing the performance of ball handlers under different speed conditions. Specifically, the average running speed and total running distance not only provide information on players' physical condition but also offer insights into their decision-making ability at critical moments. At high speeds, players' visual attention may be disrupted, leading to neglect of the surrounding environment, thus impacting decision-making quality. Research has shown a significant correlation between visual attention and sports decision-making. During high-speed sports, players tend to rely more on intuitive decision-making, which may lead to misjudgment. The results of this study confirmed this finding, showing that the accuracy of intuitive decision-making was significantly lower than that of cognitive decision-making ($P < 0.001$). Additionally, the ball handler did not make any shooting decisions while running at high speeds (7.98-12.62 m/s), providing important insights for practical training. This suggests that other offensive methods may be more effective than shooting in high-speed situations.

Spitz et al.'s research suggests that there is no significant difference in the accuracy of football referees when reviewing plays in slow motion compared to real-time decisions, and slowing down video speed does not improve decision accuracy, possibly due to a loss of authenticity in the real-time environment (Spitz et al. 2018). In contrast to Spitz et al.’s findings, this study supports Lorains' viewpoint. Lorains' research explains why expert players make more accurate decisions at high speeds: faster speeds better align with the dynamic, time-sensitive decision-making environment in sports, meeting the cognitive processing needs of players (Lorains et al. 2013). This is reflected in the experimental data: as speed increases, decision accuracy significantly decreases, particularly for shooting decisions. This decline may be attributed to the heightened cognitive load and attentional demands imposed by faster speeds. According to cognitive load theory (Ping, 2019), excessive processing demands can overwhelm working memory, impairing decision-making efficiency.

However, the expert group still showed significant advantages over the novice group under high-speed conditions, indicating that the fast-moving competitive environment places higher demands on players' attention allocation and timely decision-making, further emphasizing the crucial role of visual attention in sports decision-making. Therefore, coaches and practitioners should consider incorporating high-speed visual tracking drills-such as dynamic target tracking, occlusion-based recognition tasks, and sport-specific decision scenarios-into training routines. These tasks should emphasize contextual realism, requiring players to respond under temporal constraints that closely mimic actual gameplay.

This study found the promoting effect of multiple object tracking training on sports decision-making ability, underscoring the close relationship between visual attention and sports decision-making. However, research on how multiple object tracking training affects the brain mechanisms of players is still insufficient. The expert group includes only players from one university-level league, the study exclusively included fmale participants, which restricts the generalizability of the findings to male players, the unbalanced number of decisions at different speeds, which reduces the diversity of expertise and limits the generalizability of the results. Future studies should integrate brain imaging technology to further explore the neural adaptive changes caused by training, providing a scientific basis for training strategies aimed at enhancing players' decision-making abilities.

Conclusions

This study demonstrates that expert basketball players exhibit superior visual attention and perceptual-cognitive decision-making abilities compared to novices. Their enhanced tracking performance and higher decision accuracy-particularly in complex, high-speed scenarios-underscore the role of domain-specific attentional allocation and strategic adaptation. These findings contribute to the theoretical understanding of expertise in dynamic sports environments and suggest practical implications for perceptual training in athletic development.

Acknowledgements

Competing Interests

The authors declare that they have no competing interests.

Author Contributions

Qi-feng Gou conceived and designed the experiments, performed the experiments, analyzed the data, prepared figures and/or tables, and approved the final draft.

Sun-nan Li conceived and designed the experiments, prepared figures and/or tables, reviewed drafts of the paper, and approved the final draft.

Data Availability

The following information was supplied regarding data availability:

The raw measurements are available in the Supplemental Files.

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Table 1(on next page)

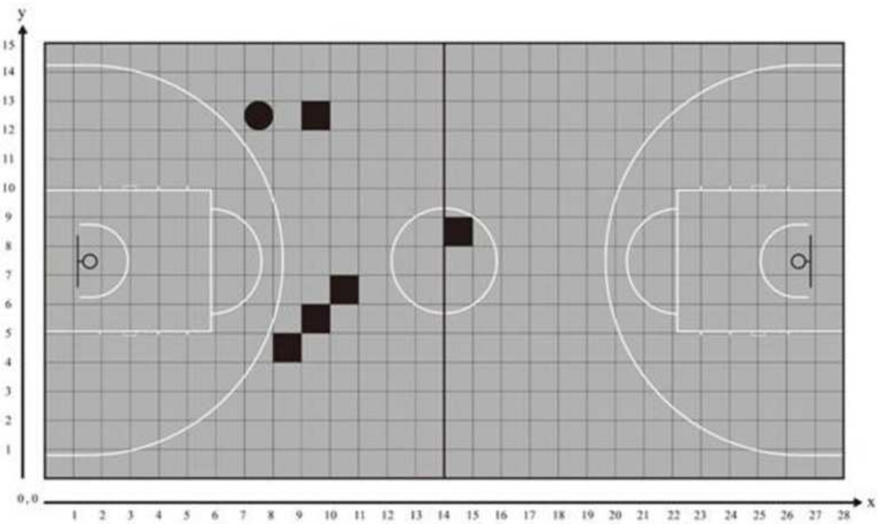
Decision accuracy of experts and novices at different video speeds

Table 1 Decision accuracy of experts and novices at different video speeds

group	type	Speed (m/s)	pass	shoot	breakthrough
			M±*SD*	*M*±*SD*	*M*±*SD*
expert	intuition	0.67-3.98	0.83±0.07	0.79±0.07	0.80±0.09
		3.99-7.97	0.78±0.11	0.75±0.08	0.72±0.13
		7.98-12.62	0.49±0.15	\	0.47±0.19
	cognition	0.67-3.98	0.86±0.10	0.82±0.10	0.85±0.11
		3.99-7.97	0.82±0.09	0.78±0.13	0.80±0.12
		7.98-12.62	0.67±0.17	\	0.67±0.13
novice	intuition	0.67-3.98	0.44±0.09	0.43±0.11	0.44±0.12
		3.99-7.97	0.35±0.10	0.35±0.08	0.35±0.11
		7.98-12.62	0.20±0.08	\	0.18±0.08
	cognition	0.67-3.98	0.47±0.10	0.45±0.10	0.44±0.11
		3.99-7.97	0.38±0.13	0.39±0.09	0.37±0.10
		7.98-12.62	0.28±0.11	\	0.24±0.11

Figure 1

Figure 1 Example of positioning calibration for ball bearers


y
15
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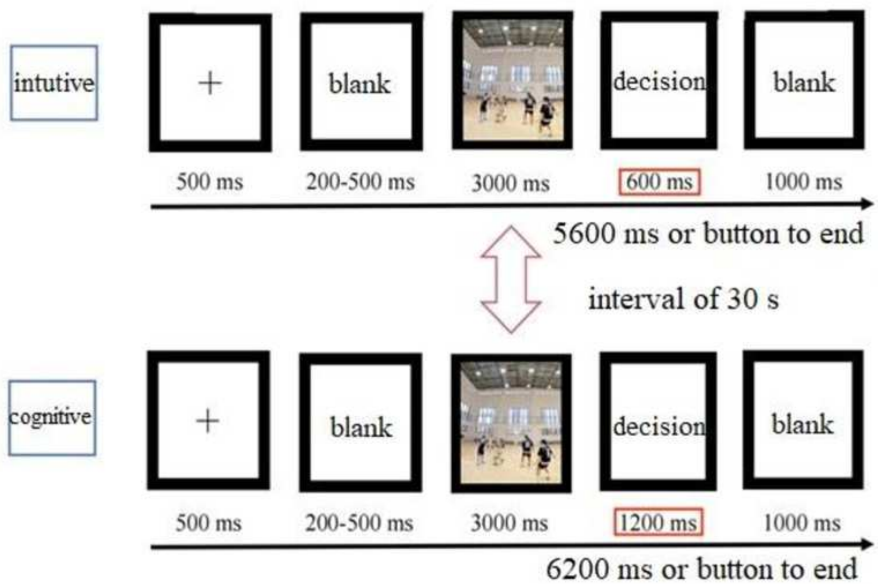
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28
x

Figure 2

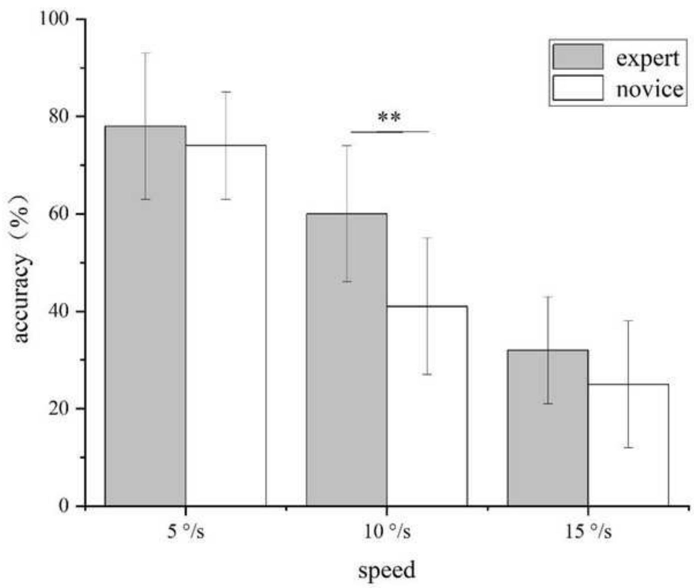
Figure 2 Basic process of sports decision-making task



intutive
+
blank
decision
blank
500 ms
200-500 ms
3000 ms
600 ms
1000 ms
5600 ms or button to end
interval of 30 s
cognitive
+
blank
decision
blank
500 ms
200-500 ms
3000 ms
1200 ms
1000 ms
6200 ms or button to end

Figure 3

Figure 3 Tracking accuracy of MOT at different speeds for experts and novices


100
80
60
40
20
0
accuracy（%）
expert
novice
**
5 °/s
10 °/s
15 °/s
speed