Gaze And Shoot: Examining the Effects of Player Height and Attacker-Defender Interpersonal Distances on Gaze Behavior and Shooting Accuracy of Elite Basketball Players

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Abstract
The current study seeks to investigate the effects of player height and attacker-defender interpersonal distances on gaze behaviour and shooting performance of elite basketball players. To this end, ten male professional basketball players were evaluated during a shooting task involving five experimental conditions: defender positioned at 0.5m, 1m, 1.5m and 2m of distance to the attacker and an additional control condition with no defender. A wireless SMI eye-tracking glasses system was worn by each attacker for the purpose of monitoring their gaze behaviour in view of the experimental conditions. Shot efficacy and attackers' height was also evaluated. Results indicate an effect of the presence of the opponent and their body height on gaze behaviour when attempting to shoot at the basket. A greater number of fixations was found on the body of the defender, and less on the rim, for close interpersonal distances between the shooting attacker and the immediate defender (0.5m). No differences were found in fixation duration. It was also found that attackers with greater body height exhibited superior shot efficacy than those with smaller body height. In conclusion, these results suggest that when aiming at the scoring target in basketball, both performance and gaze behaviours of the attackers are sensitive to the impending constraints related to the presence of the opponent as well as to their own body size properties. Accordingly, the design of representative shooting tasks in basketball should consider the manipulation of individual and task constraints such as the interpersonal distance between shooting attacker and immediate opponent as well as body height differential.
Keywords: Visual strategies, team sports, tasks constraints; basketball

Introduction

In multiple sports, athletes are required to visually aim towards a scoring target for the purpose of performing successfully in the game. With regard to basketball in particular, shooting ability is consistently associated with game outcome, either at the youth (Lorenzo, Gómez, Ortega, Ibáñez, & Sampaio, 2010) or at the professional level (Zhang et al., 2017). In most of the literature, the training process of basketball shooting has frequently centered on developing aspects of movement (e.g. feet and hand position) (Krause, Meyer, & Meyer, 2008), while the perceptual (gaze control) focus has often been underemphasized (for a notable exception, see Vickers, 2007). Even so, most existing literature suggests that players must fixate the target early and have a narrow attentional focus on a specific location, such as the center of the back of the rim (Krause et al., 2008). However, this training principle, when considered in dynamic situations other than the free-throw, appears to ignore the possibility that there may be other sources of information (for example, position of the opponents, distance and angle to the basket, etc.) that can impact on gaze control.

One of the main factors influencing the efficacy of basketball shooting is visual control (Steciuk & Zwierko, 2015). In order to understand the role of visual perception in basketball shooting, eye-tracking technology has been widely used both in laboratory-based and field tasks, the effectiveness of which has been scientifically supported (Marques, Martins, Mendes, Coelho de Silva, & Dias, 2018). The main findings resulting from this line of research indicate that gaze behavior, when performing a basketball shot, appears to be influenced by multiple constraints such as the distance from the backboard (Steciuk & Zwierko, 2015), movement initiation (R Ferraz de Oliveira, Huys, Oudejans, Van De Langenberg, & Beek, 2007), physical exertion,(Zwierko, Popowczak, Woźniak, & Rokita, 2017) expertise (Vickers, 1996), anxiety (Wilson, Vine, & Wood, 2009), technical style (Rita Ferraz De Oliveira,

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Oudejans, & Beek, 2006) or the intervention of a defender (Van Maarseveen & Oudejans, 2018; Vickers, Causer, & Vanhooren, 2019). In particular, the seminal work by Vickers and collaborators highlighted the beneficial role of Quiet Eye, which is the duration of the final fixation on a specific location prior to final movement onset, for performing aiming tasks such as shooting in basketball (Rienhoff, Tirp, Strauss, Baker, & Schorer, 2016; Vickers, 2016). There is recent evidence indicating that at the moment of the shoot there is high pressure on the ball handler,(Csataljay, James, Hughes, & Dancs, 2013) which, in turn, requires the attackers to better explore shooting opportunities to convert a shoot. In this sense, there is a need to gain a broader understanding about shooting at the target in basketball while facing the influence of direct opponents.

Previous research shows that players attempting to shoot at the basket when facing an opponent tend to alter their movement patterns by increasing speed and release height of the ball along with a shorter execution time and a longer jump time and ball flight time (Gorman & Maloney, 2016; Van Maarseveen & Oudejans, 2018) (Rojas et al., 2000). Subsequent research has gone beyond this, focusing solely on a kinematic analysis of the shooting attacker by attending to shooting efficacy and monitoring gaze behavior through the use of portable eye-tracking systems. By manipulating the defensive intervention on basketball shooting (Van Maarseveen & Oudejans, 2018; Vickers et al., 2019) two key experimental conditions have been considered: i) contested (i.e. defender at a short interpersonal distance with hand(s) up), and ii) uncontested (i.e. defender at long interpersonal distance without defensive action) situations. The effects on shot efficacy are somewhat unclear. While Gorman and Maloney (2016) found a detrimental effect of shooting accuracy of over 20%, for the defended condition Van Maarseveen and Oudejans (2018) did not. Importantly, in this later study, a distinctive pattern of shooting efficacy was disclosed between participants (i.e., six participants showed higher shooting efficacy while other six participants presented lower efficacy), suggesting a differential effect between participants when shooting against a defender. With regard to gaze behavior, in contested situations, the final fixation was shorter (especially for the participants with worse shooting performance) and the final fixation onset was delayed. In addition, there appears to be a greater foveation on the defender (i.e., longer fixation duration) in the contested condition (Van Maarseveen & Oudejans, 2018). Thus, the presence of an opponent requires the attacker to adapt her or his visuo-motor behaviours by decreasing execution time and picking-up relevant information from the nearest defender as a means to prevent shot interception.

More studies are needed to evaluate the impact of shooting while facing an opponent at a different range of interpersonal distances. Considering the fact that the scoring target in basketball is positioned at 3.05m above the floor, it may be reasonable to accept that individual constraints related to player's height may also be influenced by the interaction between the attacker and the defender in a one-vs-one sub-phase. However, to the best of our knowledge, previous research has not attended to the impact of the height of the attacker in basketball shooting task.

Building on previous scientific evidence, further insights are needed to understand how the distance between the attacker and the nearest defender, along with the height of the defender, affects gaze behavior and shooting performance. In this way, notable implications can be drawn to the design of training tasks and to the promotion of adaptive behavior tendencies that may better improve players performance. The aims of this study are twofold: (i) to analyze the effects of defensive opposition and interpersonal distance on the visual fixation patterns of expert basketball players attempting to shoot at the scoring target within an immersive sport setting; and (ii) to examine how the body height of an attacker influences gaze behavior during shooting attempt. The present study hypothesizes an impairment of shooting efficacy at a close range of interpersonal distances and for attackers with smaller body height, due to the greater interference effects of the defender on the shooting action. In addition, this study predicts that the gaze behavior of the shooting attackers will be affected both by the positioning of the opponent. Possibly, at close interpersonal distances, the point of gaze will be more attracted to the body of the defender in order to utilize information to prevent shot interception.

Methods

Participants

Ten male professional basketball players (age: 24.80 ± 4.52 years; playing experience: 12.75 ± 2.60 years; height: 193.11 ± 6.41 cm; body mass: 90.56 ± 11.26 kg) from a Portuguese National League team were selected to participate in this study. The criteria for selecting the subjects to participate in the study was related to their role in the team (i.e., guards, point guards, small forward, power forward). Moreover, participants were divided into two different height groups, Taller group (> 195 cm, n = 5) or Smaller group (< 195 cm, n = 5) for further analysis. Prior to participation, players were screened for injuries and visual-related issues and they were also informed of the content and purpose of the investigation. Written informed consent was obtained from all participants before the beginning of this investigation. The present study was approved by the institutional research ethics committee and conforms to the recommendations of the Declaration of Helsinki.

Procedures

Data collection took place during a regular training practice of a microcycle (i.e., a week of training) from the competitive period. Initially participants were subjected to a general activation involving a set of tasks monitored by the coaching staff that lasted 15 minutes. Afterwards, a wireless SMI eye-tracking glasses (v2.0) system (frequency = 60 Hz) was coupled to the head of the participant, that would act as shooting attacker, for the purpose of monitoring their gaze behaviour for further analysis. This procedure was followed by a calibration process of the eye-tracking using three points as reference, according to the system requirements. Experimental task consisted of a basketball shooting task that took place on a half-court according to the official rules of basketball. Participants were required to shoot from a predetermined position in front of the basket (at 5.6m to the basket) (Figure 1). In addition, one video camera positioned on the lateral side of the basketball court (capturing at 25 frames per second) allowed to record shooting performance and evaluate its efficacy.

Figure 1. Experimental set-up on a basketball half-court.

Shooting attacker was positioned in front of the basket (at 5.6m to the basket) facing the defender. One member of the research staff located near the basket signaled the experimental condition for the defender while an additional experimenter, located near the half-court line, supervised the task. There was an additional experimenter, positioned near the lateral line, who was in charge of passing the ball to the attacker.

Four experimental conditions involved the presence of a defender at different values of distance to the attacker: (i) 0.5m, (ii) 1m, (iii) 1.5m and (iv) 2m. An additional control condition was prescribed with (vi) no defender. Before the beginning of experimental task, the attacker was instructed to shoot at the basket according to the prescribed condition, without dribbling. Following previous research (Van Maarseveen & Oudejans, 2018), the defender was instructed to intercept the shot by jumping and moving their arms in the frontal plane of movement without making actual contact with the attacker. Before each shooting attempt, defender was verbally instructed by one member of the research staff, indicating the experimental condition to be implemented. Each attacker performed two blocks of 25 shots for a total of 50 trials, interspersed by a break of 3 minutes to prevent fatigue effects on shooting performance. The experimental conditions were randomised and the total number of trials per experimental condition counterbalanced. For the purpose of data analysis, the value of 1.90m was considered as a threshold for dividing the sample according to the height of the attackers: i) taller group; ii) smaller group. The definition of this criteria was supported by previous research in basketball that depicted players' anthropometric profiles according to their playing position (e.g., Vaquera, Santos, Villa, Morante, & García-Tormo, 2015)

Trial initiation was considered as the moment when the participant received the ball passed by one experimenter and ended when the player released the ball. Visual patterns of fixation were analyzed using SMI BeGaze software that allowed to match foveal vision with the correspondent area of interest, according to a frame-by-frame analysis. The default criteria of BeGaze software were used to calculate fixation data. A fixation was defined as gaze superimposed on a location within the targeting environment for a period equal or greater than 100ms (Van Maarseveen & Oudejans, 2018; Vickers et al., 2019). Inspired by previous research on basketball shooting (Vickers, 1996) and by the results of a pilot study (i.e., involving a similar experimental task design) the following areas of interest from the visual scenario were defined: i) ball, ii) rim, iii) backboard, iv) space between attacker and defender, v) body of defender, vi) others. The analysis of the video stream data from the lateral camera allowed us to code shot outcome as either a "converted" or a "miss".

Statistical analysis

A one-way analysis of variance (ANOVA) was used to examine potential differences on *shot accuracy* across between experimental conditions (0.5m, 1m, 1.5m, 2m, no defender). In addition, a two-way analysis of variance

(ANOVA) was utilized to analyze potential effects of experimental condition (0.5m, 1m, 1.5m, 2m, no defender) and group (taller vs smaller) on *shot accuracy*. Inspired by the procedures of Van Maarseveen and Oudejans (2018), *a posteriori* analyses on shot efficacy were computed by creating two sub-groups: higher accuracy and low accuracy. Then, a two-way analysis of variance (ANOVA) was applied to explore potential effects of experimental condition (0.5m, 1m, 1.5m, 2m, no defender) and group (higher accuracy vs low accuracy) on *shot accuracy*.

With regard to gaze behaviour, a Mann-Whitney U test was used to assess whether *fixation duration* was equivalent between converted and missed shots. Subsequently, a one-way analysis of variance (ANOVA) was computed to examine potential differences in *fixation duration* across experimental conditions. Finally, a Chi-Square test of independence was applied to identify associations between experimental conditions (0.5m, 1m, 1.5m, 2m, no defender) and group (taller vs smaller) on the *number of fixations per areas of interest*. Standardized residuals (e) were computed to ascertain which variable(s) in each category contributed most to the value of χ^2. Cells which contained values of standardized residual higher than 1.96 (e> 1.96), were considered influential for the model (Agresti, 2017). Effect size (ES) was estimated by calculating Cramer's V (V) correlation coefficients, considering 0.10 as small effect, 0.30 as medium effect and 0.50 as large effect (Fritz, Morris, & Richler, 2012). Confidence interval was set at 95% and statistical significance at 0.05. All statistical analyses were performed using SPSS software (*version 24 for Windows; SPSS Inc., Chicago, IL, USA*).

Results

Shooting accuracy

Results show no significant differences between *experimental conditions* (0.5m, 1m, 1.5m, 2m, no defender) with respect to *shot accuracy* (F (1,45) = 0.47; p = 0.76). The mean shooting accuracy ranged from 73% (SD =17.67), with the *defender at 0.5m of interpersonal distance*, to 73% (SD =17.29), with *no defender*.

A further analysis of individual shooting patterns permitted to identify two sub- groups composed of 5 athletes each: i) *higher shot accuracy* (M= 84%; SD=4.47) and ii) *low shooting accuracy* (M= 66.40%; SD=6.22). A significant *condition* x *group* interaction effect on shooting accuracy was also found F (4,40) = 2.83; p = 0.04, η2 = .221. There was a significant main effect of *group*, F (1, 40) = 26.68, p = .000, η2 = .418) but no main effect of *condition*, F (4, 40) =0.83, p = .51. The group of *higher shot accuracy* presents greater values for all of the experimental conditions than the *low shooting accuracy* with the exception of *defender at 2m* (Figure 1).

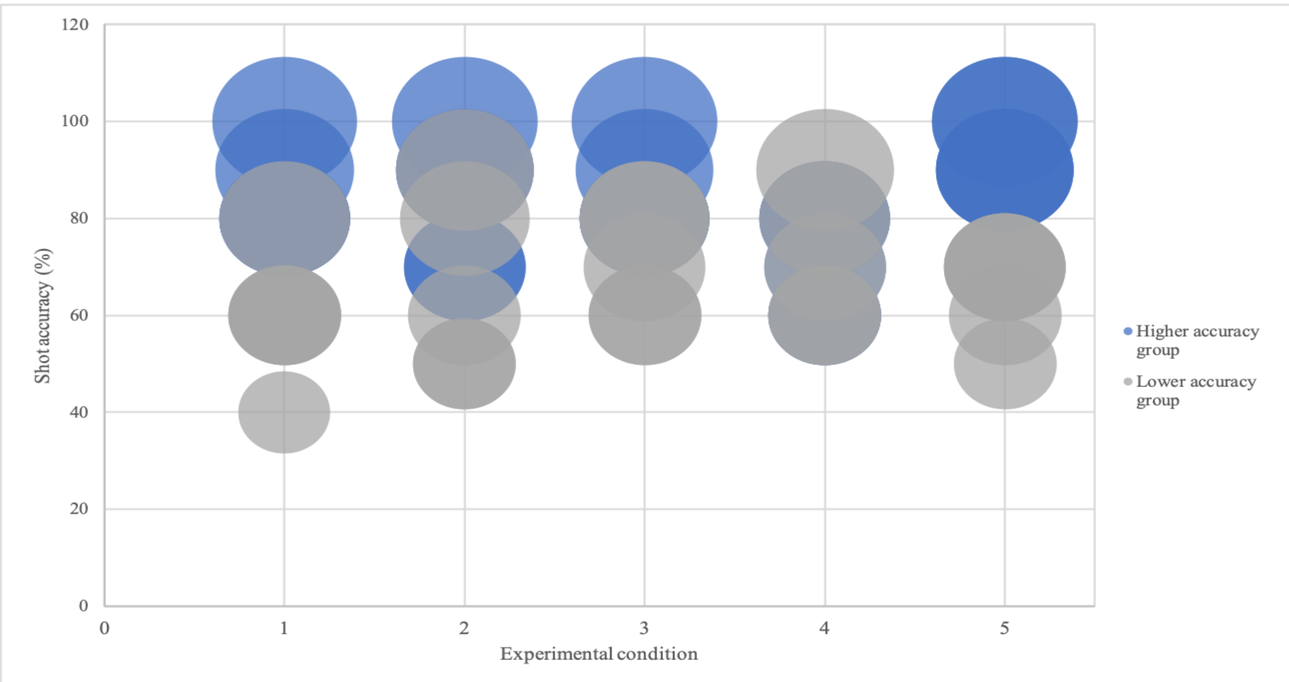

Figure 1. Distribution of shot accuracy across experimental conditions (1 to 5) and accuracy sub-groups (higher and lower).

With respect to the players' height, the study also considered two sub-groups composed of 5 athletes each: i) *taller* and ii) *shorter*. We found a significant main effect of *group*, F (1, 40) = 1.71, p = .000, η2 = .282. The number of converted shots made by the *taller* group (M= 81.33%; SD=13.58) was larger than the *shorter* group (M= 66%;

SD=12.73). In contrast, there was no main effect of *condition*, F (4, 40) =0.46, p = .51 and *condition* x *group* interaction effects on shooting accuracy, F (4,40) = 1.11; p = 0.367.

Gaze behaviour

With regard to *fixation duration,* no differences were found between converted and missed shots, even though close to significance U ($N_{missed\ shots}$ = 542, $N_{converted\ shots}$ =1646) =1.896, p=0.058. Moreover, *fixation duration* did not significantly differ across experimental conditions (p = 0.827) (Table 1).

Significant differences were found on the *number of fixations per area of interes*t (ball, rim, backboard, space between attacker and defender, body of defender, others) with respect to *experimental conditions* (χ^2 (4, N=2188) = 58.51; $p < 0.001$, ϕ_{Cramer}= 0.08) although with a small effect. In the condition where the *defender is at 0.5m of interpersonal distance*, attackers presented significantly less fixations on the *rim* (Observed = 130; Expected = 160.3; Standardized Residuals = -2.4) and more on the *body of the defender* (Observed = 101; Expected = 66.8; Standardized Residuals = 4.2) than would be expected if experimental conditions had no effect.

Table 1

Fixation duration for experimental condition, areas of interest, and shot outcome

Variables		Mean	Standard Deviation
Experimental condition	0.5m	274.11	160.18
	1m	279.53	177.02
	1.5m	274.77	178.51
	2m	276.92	174.35
	No defender	286.97	193.04
Areas of interest	Ball	259.90	153.06
	Rim	273.55	161.96
	Backboard	282.95	190.30
	Space between attacker and defender	285.72	194.79
	Body of defender	285.27	164.53
	Others	277.45	193.22
Shot outcome	No success	267.74	170.31
	Success	281.86	178.53

Discussion

The present study aims(i) to analyze the effects of interpersonal distance between the attacker and defender on the visual fixation patterns of expert basketball players attempting to shoot at the scoring target; and (ii) to examine how body height influences gaze behavior during shooting attempt. For that purpose, an experimental setting has been designed to afford the players an immersive context of performance that represents the informational flow of a shooting action in basketball game. To the best of our knowledge, this is the first study to analyse the impact of defensive positioning at a different range of interpersonal distances on gaze behavior and shooting efficacy of elite basketball players. Results demonstrate that shooting efficacy was not affected by the experimental conditions but not between groups. In fact, attackers with greater body height exhibited superior shot efficacy than their counterparts. *A posteriori* analyses indicated that the sub-group of athletes with higher shot accuracy was consistently more accurate than the lower accuracy group, except when the defender was more distant (i.e., 2m). The study also reveals that the number of fixations per area of interest was influenced by experimental conditions. As hypothesized, at close interpersonal distance (i.e., 0.5m) attackers showed significantly less fixations on the rim and more on the body of the immediate defender. There were no observable effects of experimental conditions and shot outcome on fixation duration. Altogether, these results suggest an adaptive control of gaze of the shooting attacker in view of the individual and task constraints, namely body height of the opponent and interpersonal distance.

In this study no significant differences were found between experimental conditions with respect to the outcome of the shot. These results build on previous evidence on the effects of the presence on a defender on shooting efficacy. A recent investigation (Van Maarseveen & Oudejans, 2018) prescribed a medium-range (4.88m) shooting task performed by young athletes, while manipulating the intervention of the defender (contested vs. uncontested) and no effects were found for shot efficacy. In the aforementioned study, a subsequent analysis was made to further inspect individual differences in the performance response by considering two subgroups of different accuracy levels ("worse" and better" shooters). Results indicate that shooting accuracy of the worst and better groups was significantly different in the contested position but not in the uncontested position. The results found in the present study corroborate this previous evidence as the higher shot accuracy group was consistently more accurate than the lower accuracy group across experimental conditions, except when the defender was more distant (i.e., 2m). These results suggest that a number of participants succeeded in adapting their movement behaviors to the presence of the defender while other did not. Interestingly, shooting accuracy of both groups was relatively similar when the potential interference of defenders' actions was smaller. In this line of reasoning, Vickers et al. (2019) reported that the presence of the defender significantly affected shooting efficacy during a three-point shooting task (6.70m). From a kinematic point of view, Rojas et al (2000) and Gorman and Maloney (2016) also notice that in the contested condition the presence of the defender led to critical changes in the speed, release height, release angle, jump time and ball flight times. In this regard, studies carried out in a competitive environment demonstrate that subtle changes in the interpersonal distance between the attacker and the defender are sufficient to promote notable fluctuations in shooting accuracy (Lucey, Bialkowski, Carr, Yue, & Matthews, 2014). For example, when the defender is positioned at 2.74 meters or more away at the release point of the shot, the shooting percentage is around 43%, however within 1.83 meters, the accuracy substantially decreases to 32% (Lucey et al., 2014). Based on our findings, it can be claimed that the proximity to a defender may act as a relevant task constraint when shooting at the basket, even though with a differential impact across different participants. More research is needed to consolidate this assertion by expanding the analysis on interpersonal variability of shooting efficacy and by combining different measures (e.g., perceptual and kinematic).

The present results also reveal that attackers with greater body height show superior shot efficacy than those with less body height. These results indicate that body height has a significant impact on shooting accuracy. It is universally recognized that the tallest players tend to play closer to the basket, and therefore spend more time in perimeter positions (i.e., near the basket) (Zhang et al., 2018). Thereby, tallest players score more short- to medium-range shots, while smaller players score higher number of 3-point shots (Zhang et al., 2018). In this study, taller players may have benefited from a greater level of correspondence with game demands, resulting in superior accuracy in the present task (shoot at 5.6m to the basket). Also, the instruction prescribed to the defender for not approaching the attacker with physical contact, may have also allowed a spatial-temporal advantage for taller players to perform with high level of shot efficacy that can be somehow connected with the exploration of relevant kinematic parameters previously identified in the literature (e.g. Gorman and Maloney, 2016). Most of these short- to medium-range shots are usually performed with reduced interpersonal distance between players (Esteves et al., 2016), and often in contact-based situations. Based on prior attunement to these information variables (e.g., interpersonal distance, body height, movement velocity, etc), tallest players may have been more proficient in anticipating their opponents' actions and prospectively adapting their shooting patterns into higher level of shot efficacy (Montagne, 2005). Conversely, attackers with less body height may have not been able to effectively explore the perception-action coupling that would have supported an enhanced basketball shooting as a result of a level of attunement to the evolving informational constraints embedded in the experimental task.

With regard to gaze behavior, attackers exhibited significantly less fixations on the rim and more on the defender for close interpersonal distances (i.e., defender positioned at 0.5 m). No differences were found in the number of fixations. There is previous evidence that corroborates our findings by showing that shooting attackers adapt their gaze behavior when facing an opponent (Van Maarseveen & Oudejans, 2018) in terms of later final fixation onset and longer fixation on the defender. These changes in gaze behavior under the effect of experimental task constraints (i.e., interpersonal distance) seem to express participants' attempts to adapt their gaze patterns to the interference of the defender. Previous research alludes to an online visual control of the basketball shot (Oudejans et al., 2002; Oliveira et al., 2008) that highlight the importance of utilizing visual information during movement execution. In the present study, elite basketball players may have directed their gaze to the body of the defender, at close interpersonal distances, to monitor the actions of the defender in order to preserve the effectiveness of their shooting actions. The results obtained on gaze behavior and shot efficacy suggest that despite differences in gaze patterns that are a function of changing distances, there is not a concomitant impact in shooting accuracy. This finding supports the suggestion that different gaze patterns can be used to obtain a similar level of shooting success highlighting the role of variability in gaze behaviour as a way to sustain performance outcomes during skilled action (Dicks, Button, Davids, Chow, & Van der Kamp, 2017).

Relevant potential implications may be further drawn from this exploratory study. Firstly, coaches could better design representative training tasks by attending to the perceptual effects associated to the manipulation of interpersonal distance between the attacker and defender. For instance, if the intention would be to design a more stable practice environment to afford greater levels of shooting efficacy, the defender should be positioned at more than 0.5m apart from the attacker. Conversely, the design of a more challenging environment for shooting training could imply prescribing interpersonal distances near 0.5m. Secondly, the relevance of physical constraints (i.e., body height) while aiming at the target should be considered in training to better improve shot efficacy by critically managing height differences between players. It would also be valuable to extend actual line of research by attending to the dynamics of coupling between gaze behaviours and motor actions, which may inform the prospective nature of movement regulation. Moreover, the possibility to consider body size measures (e.g., body height, arm length) or action capabilities (i.e., jump power) of the interacting dyad (both attacker and defender) could create an opportunity to measure the exploration of body and action-scale affordances (for an example in football see (Dicks, Davids, & Button, 2010).

Conclusions

Altogether, the results indicate an adaptive control of gaze by the attackers in view of the individual and task constraints, namely interpersonal distance and its respective body height. Despite the defensive influence at a given range of interpersonal distances, elite basketball attackers demonstrate a consistent efficacy when shooting at the scoring target. From the perspective of task design, this study underlines the importance of manipulating representative constraints related to the presence of an opponent and players' body height while aiming at the scoring target in basketball.

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