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Effects of Different Basketball Shooting Positions and Distances on Gaze Behavior and Shooting Accuracy

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Abstract: Basketball is a sport where in order to obtain points, it is necessary to put the ball in the basket. Therefore, basketball players need to shoot the ball accurately. This study aimed to evaluate if there are differences between shooting positions and angles concerning athlete visual behavior. Tobii Pro Glasses 3 was used to measure the number and duration of fixations in the target during shooting movement. The sample included 18 basketball players (10 female and 8 males; 22 ± 3.72 years; 12.5 ± 4.52 years of federated basketball practice) who performed a total of 60 shots in all shooting conditions and positions. Two distances (free throw and 3 points line) and three angles (45°, 90°, and 135°) in the 3 points shot were considered in all three shooting conditions (baseline, simulated opposition, and gym audience noise). Between distances, statistically significant differences occurred in the number and total duration of fixations and shooting accuracy. At a greater distance from the basket, the athlete tended to have less accuracy, as well as a lower number and duration of fixations. Between angles, there was no statistically significant differences, neither a tendency towards lower or higher values between them. Moreover, the shooting accuracy was better when the athlete focused for more time on the target, which occurred in the free throw condition.

Keywords: fixations; shooting angles; shooting distances; task constraints; visual behavior

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1. Introduction

Basketball, since its invention in 1891, has been gaining popularity and is one of the most popular sports in the world. The number of basketball players continues to grow, either as federated athletes or just for leisure. In our day-to-day life, we often see baskets and fields in the most varied spaces, from parks to gyms. In basketball, the only way to gain points is to put the ball in the basket through shooting. Thus, to improve athletes' performance, identifying the best shooting technique is probably the most important aspect to be studied, which is consensual for all basketball players and coaches [1–3].

According to Okazaki et al. [4] several factors influence shooting performance under a variety of conditions, such as, for example, shooting distance, vision, the proximity to one or more opponents, and the release angle of the ball. Miller and Bartlett [5] verified that the angle and velocity of entry of the ball into the basket depend on the distance of the shot. The angle of entry of the ball concerning the shot increases with distance, being greater in the case of three-point shots, corresponding to a major shoulder angle during the shot, which means that the basketball player needs more time to perform the shot after receiving the ball [6]. As basketball players have different shooting techniques, which makes the entry angle of the ball in the basket different, Wang et al. developed a network model with video recognition to observe the shooting angle during a basketball game, considering different conditions such as, for example, shooting distance [7]. To have good precision, the ball must approach the basket vertically to ensure shooting accuracy [8,9].

Kambič et al. [10] carried out a study to assess the need for biomechanical adjustments to the shot in the presence of an opponent and found that the success of the shot depends on the height of the opponent, as it can alter the visual control of the basket [11]. Moreover, Oudejans et al. [12] observed that the shot accuracy is greatly influenced by full vision throughout the jump shot execution. In fact, according to several authors [13–17], in the case of dynamic sports, such as soccer, basketball, volleyball, and others, visual skills have a direct influence on the performance of athletes, due to the necessity of them constantly making ocular movements. As basketball is, as mentioned before, a dynamic sport, with quick movements and decisions, it is very important that the visual skills, which are directly connected with the vestibular and somatosensory systems, are adequate to focus on the target [16]. For example, Agostini et al. [15] analyzed the influence of visual control in volleyball athletes, having carried out tests with the athletes with their eyes open and closed, finding that the visual system influences athletes' posture and performance. Some authors promote studies to understand the influence of the athlete's vision on the accuracy of the shot, taking into account the complete view of the basket [18,19]. A study performed by Oliveira et al. [20] analyzed the influence of visual information on basketball shooting using two sensor units to capture players' movements and two digital cameras to identify the trajectory of the ball, finding that better accuracy was obtained when players had a complete view of the basket, instead of when they only saw the basket after shooting.

The development of specific training to improve accuracy during basketball shooting has been the subject of study by several authors in order to optimize the accuracy of distance basketball shooting [1,2,21–23]. Other studies evaluated the effect of the shooting distance on the transfer of energy from the lower limbs to the arms, an important factor for shooting effectiveness [3,24]. Some studies confirmed that shooting distance plays an important role in basketball player performance, with free throws being more accurate than longer shots [25,26].

Attentional focus is very important to expand shooting performance in collective sports such as basketball [27,28]. Thus, studying the influence of external constraints on the athlete's performance, such as gym noise, is important to help the coach develop strategies that aid athletes in focusing their attention on the shot. If the athlete is distracted by external factors, he looks away from the basket, and thus the accuracy of the shot decreases. According to Gröpel and Mesagno, external distractions, such as distracting fans or noise, alter the athlete's attention, generate anxiety, and decrease performance, requiring the definition of strategies to alleviate them, such as pre-performance routines and quiet eye training [29]. For example, Vickers et al. [30] demonstrated in their study that training techniques can be used to help basketball players to keep their concentration during the game. Some authors argue that professional basketball players develop the so-called quiet eye, which means that the final fixation is located on a specific place or object within at least 3 degrees of visual angle for a minimum of 100 ms [31–33]. Rienhoff et al. [34] evaluated the influence of the quiet eye on the shooting accuracy of basketball players and found that the longer the duration of the quiet eye, the better the performance of the athletes. In addition, they found that more experienced athletes have a longer duration of a quiet eye and, consequently, better accuracy in throwing, which was also observed by Jin et al. [35].

Defining a specific point on the basket to aim for, during the shot, influences the certainty of the shot, and the experience of the athletes helps to define this point. For example, the more experienced athletes normally choose a point in the front of the hoop, and the less experienced choose the back edge of the hoop or the center of the basket [17].

According to Mann et al. [36], it is complicated to capture and analyze the players' gaze behavior in the case of dynamics sports such as basketball. However, since visual skills are important for shooting during the basketball game, and keeping attention, Güldenpenning et al. tried through laboratory studies to develop strategies to obtain success of one's gaze during the game [37]. Williams et al. [38] observed in their study that, with perceptual experience, the use of vision increases the recognition of the relevant action. The influence of external constraints such as limited time, anxiety, attention, and performance during free throw shooting was investigated by Kostrna [39], who found that if athletes manage to maintain a goal-oriented focus, performance is somewhat influenced.

Although several studies address the influence of vision on the certainty of the shot, most of them concerning free throws, according to the authors' knowledge, few studies use specific glasses to evaluate the time and the number of target fixations.

The goal of this study was to analyze the effect of basketball shooting in different positions and distances, under the interference of environmental constraints of simulated opposition and gym audience noise, on gaze behavior and performance shooting accuracy. It was hypothesized that there would be an impairment of shooting accuracy and an alteration in gaze behavior patterns of the players when shooting at a longer distance to the basket.

2. Materials and Methods

This section describes all materials and methods present in this study.

2.1. Participants

For this study, a group formed of 18 athletes of both genders (10 females and 8 males), of two different nationalities (Cape Verdean and Portuguese), and all players from senior teams playing in the national championship, were the participants, for which relevant characteristics are presented in Table 1. All of them had at least 4 years of federated basketball practice, as well as no injuries in the 3 months before the acquisition.

Table 1. Volunteers' relevant characteristics (n = 18).

	Age (years)	Height (cm)	Mass (kg)	Practice Years
Mean ± SD	22 ± 3.72	172.15 ± 9.79	69.6 ± 13.1	12.5 ± 4.5

This study was approved by the ethical committee of the Polytechnic of Coimbra and performed according to the Declaration of Helsinki (CEIPC 83/2021). In order to participate in this study, all the athletes were fully informed of the nature of the investigation and provided written informed consent. All the participants' data were registered and stored anonymously.

2.2. Study Design

In each shooting position, all athletes performed 10 shots in each condition (baseline, gym audience noise, and opposition), totalizing 1980 valid data points. The simulated opposition was made by an adjustable equipment, always at 1 m distance and different heights depending on the athlete's height (1.20 $*$ athlete's height). Different shooting distances (4.60 m (free throw); 6.75 m (3 points line)) and angles to the 6.75 m shots (45°, 90°, 135°) (Figure 1) were used to evaluate differences between angles and distances.

Before shooting, the protocol included a 10 min warm-up with shooting and functional exercises. Then, the athlete was instrumented, and the system was calibrated to start acquisitions. Between positions, the athlete had 2 min rest, and between shooting conditions, 30 s. The sequence was randomized for each athlete to minimize the influence of external factors.

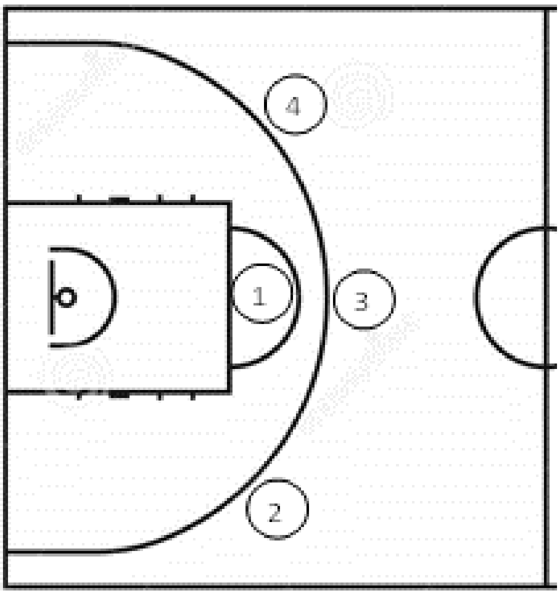

Figure 1. Shooting positions. Legend: 1—free throw line; 2—3 points line 45°; 3—3 points line 90°; 4—3 points line 135°.

Data were acquired, for all athletes, in the same gym and using the recommended ball (different sizes between males and females) with 0.62 bar of pressure. The athletes used their normal basketball shoes and practice uniforms. All shots were after breast pass, always made by the same person, and without dribble. The acquisition lasted approximately 60 min for each athlete.

Tobii Pro Glasses 3 was used to measure visual behavior, collected with a sampling frequency of 50 Hz. The equipment was tested before the acquisitions, in the same shooting tasks, in order to verify problems that may occur in the data acquisition and thus reduce the possibility of error.

Fixation duration (first and total) and the number of fixations at the moment before the shooting (from the first moment the athlete looks at the backboard until the moment the ball leaves the fingertips) were analyzed using the proper Lab program of Tobii Pro Glasses 3. Interest areas (backboard and ring) were defined before data analyses. To analyze the number and duration of the fixations, we defined an area of interest (ring and table) and a mask of a minimum of 100 ms to be considered fixation; those lower than that were considered saccades and blinked, and they were excluded for this study [37]. The precision of the basketball shooting accuracy was measured by a point system with values between 0 and 4 points [40].

2.3. Statistical Analysis

Data were statistically processed with IBM SPSS Statistics 26.0 (IBM Corporation, New York, NY, USA). Descriptive statistics for the total sample are presented with mean ± standard error and 95% CI.

The assumptions of normality were tested with Shapiro–Wilk tests. The non-parametric Friedman test was performed to understand the significance of different distances and shooting angles. Pairwise comparisons between distances (free throw and 3 points 90°) and shooting angles in 3 points shots (45–90°, 90–135°, and 45–135°) to all shooting conditions (baseline, simulated opposition, and gym audience noise) were performed with the non-parametric Wilcoxon test. The significance level was set at $p < 0.05$.

3. Results

Descriptive statistical analysis for all variables (duration of the first fixation, number of fixations, and total time of fixations) and the comparison of different distances and shooting angles is depicted in Table 2. Underlined values indicate that there are statistically significant differences.

Table 3 shows the descriptive statistics in terms of accuracy to all shooting conditions in the different positions and angles of shooting.

Non-parametric analysis was performed using the Wilcoxon test for the two variables with statistically significant differences in the Friedman test (number and total time of fixations) in order to verify the existence of statistically significant differences between shooting distances (free throw and three points 90°) and angles (45°, 90°, and 135°) (Table 4).

The angle of shooting also has a significant influence in terms of accuracy (Table 4). We observed differences in effectiveness between free throw and 3 pts 90° (position 3) at baseline and gym audience noise. It was verified that there were higher values in 3 pts 90° (position 3) compared to the 3 pts 45° (baseline), greater values in the 3 pts 90° and 3 pts 135° with gym audience noise and baseline, and higher values in the 3 pts 45° compared to the 3 pts 135° with gym audience noise. In terms of fixation number, significant differences in baseline condition between the free-throw and 3 pts 90° were found ($p = 0.000$), and 3 pts 90° and 135° ($p = 0.023$). In the case of simulated gym audience noise, significant differences were only observed between the free-throw and 3 pts 90° ($p = 0.000$). Considering the total fixation duration, significant differences in baseline condition between the free-throw and 3 pts 90° were found ($p = 0.000$), and 3 pts 45° and 90° ($p = 0.022$). Lastly, in terms of accuracy, at baseline condition, significant differences between the free throw and 3 pts 90° were found ($p = 0.004$), between 3 pts 45º and 3 pts 90° ($p = 0.021$), and 3 pts 90° and 3 pts 135° ($p = 0.013$); in the case of simulated gym audience noise, we evaluated significant differences between free throw and 3 pts 90° ($p = 0.001$), between 3 pts 45° and 3 pts 135° ($p = 0.028$), and 3 pts 90° and 3 pts 135° ($p = 0.038$). The qualitative magnitude was identified according to [41].

Table 2. Descriptive statistics (mean ± standard deviation, median, Q1 and Q3) and Friedman test values for all variables (time of first fixations, number of fixations, and total time of fixations) for the sample (n = 18).

Variables	Conditions	Mean ± SD	Median	Percentiles		Friedman Test
				Q1	Q3	p
Duration of first fixation (ms)	B1	393.14 ± 332.83	240.00	140.00	571.00	0.455
	B2	337.03 ± 242.50	260.00	140.00	461.00	
	B3	383.43 ± 292.64	281.00	160.00	481.00	
	B4	348.33 ± 260.28	260.00	140.00	481.00	
	N1	409.27 ± 324.06	281.00	140.00	541.00	
	N2	325.38 ± 264.60	260.00	120.00	411.00	
	N3	371.57 ± 279.16	281.00	140.00	561.00	
	N4	325.31 ± 230.98	240.00	140.00	461.00	
	O2	341.46 ± 237.51	260.00	160.00	461.00	
	O3	343.85 ± 255.01	260.00	140.00	501.00	
	O4	327.77 ± 231.68	260.00	140.00	406.00	

Table 2. *Cont.*

Variables	Conditions	Mean ± SD	Median	Percentiles		Friedman Test
				Q1	Q3	*p*
Number of fixations	B1	2.08 ± 1.08	2.00	1.00	3.00	0.000
	B2	1.70 ± 0.86	2.00	1.00	2.00	
	B3	1.66 ± 0.84	2.00	1.00	2.00	
	B4	1.76 ± 0.82	2.00	1.00	2.00	
	N1	2.22 ± 1.15	2.00	1.00	3.00	
	N2	1.75 ± 0.91	2.00	1.00	2.00	
	N3	1.63 ± 0.83	1.00	1.00	2.00	
	N4	1.65 ± 0.82	2.00	1.00	2.00	
	O2	1.52 ± 0.72	1.00	1.00	2.00	
	O3	1.60 ± 0.80	1.00	1.00	2.00	
	O4	1.52 ± 0.78	1.00	1.00	2.00	
Total duration of fixations (ms)	B1	707.41 ± 345.45	701.00	480.00	941.75	0.000
	B2	532.64 ± 322.164	480.00	340.00	681.00	
	B3	568.98 ± 302.932	520.00	330.50	761.00	
	B4	550.79 ± 302.73	501.00	335.25	681.00	
	N1	763.44 ± 418.70	741.00	460.00	680.50	
	N2	519.83 ± 307.19	461.00	301.00	680.50	
	N3	546.09 ± 305.52	481.00	320.00	721.00	
	N4	488.55 ± 250.44	461.00	320.00	641.00	
	O2	498.51 ± 323.81	421.00	300.00	661.00	
	O3	506.61 ± 268.73	491.00	281.00	666.00	
	O4	481.70 ± 265.11	420.50	301.00	641.00	

Legend: B1—baseline in position 1; B2—baseline in position 2; B3—baseline in position 3; B4—baseline in position 4; N1—simulated gym audience noise in position 1; N2—simulated gym audience noise in position 2; N3—simulated gym audience noise in position 3; N4—simulated gym audience noise in position 4; O2—opposition in position 2; O3—opposition in position 3; O4—opposition in position 4.

Table 3. Descriptive statistics in points (mean ± standard deviation, median, Q1 and Q3) in terms of accuracy for the sample (n = 18).

Variables	Conditions	Mean ± SD	Median	Percentiles	
				Q1	Q3
Accuracy	B1	2.57 ± 1.39	3.00	1.00	4.00
	B2	1.78 ± 1.37	1.00	1.00	3.00
	B3	2.12 ± 1.46	1.00	1.00	4.00
	B4	1.84 ± 1.40	1.00	1.00	4.00
	N1	2.62 ± 1.44	3.00	1.00	4.00
	N2	2.10 ± 1.47	1.00	1.00	4.00
	N3	2.11 ± 1.49	1.00	1.00	4.00
	N4	1.82 ± 1.44	1.00	1.00	4.00
	O2	1.55 ± 1.33	1.00	1.00	1.00
	O3	1.76 ± 1.40	1.00	1.00	4.00
	O4	1.70 ± 1.43	1.00	1.00	3.00

Legend: B1—baseline in position 1; B2—baseline in position 2; B3—baseline in position 3; B4—baseline in position 4; N1—simulated gym audience noise in position 1; N2—simulated gym audience noise in position 2; N3—simulated gym audience noise in position 3; N4—simulated gym audience noise in position 4; O2—opposition in position 2; O3—opposition in position 3; O4—opposition in position 4.

Table 4. Results of the Wilcoxon test and effect sizes [41] for all variables with statistical significance (number of fixations and total time of fixations) for the sample (n = 18).

Dependent Variable	Independent Variables		Wilcoxon Test		Magnitude	
	Shooting Conditions	Positions	*Value*	*p*	*d*	(Qualitative)
Fixation number	B	1–3	−4.437	0.000	0.434	(small)
		2–3	−0.142	0.887	0.047	(trivial)
		2–4	−1.394	0.163	0.071	(trivial)
		3–4	−2.276	0.023	0.120	(trivial)
	N	1–3	−5.316	0.000	0.588	(medium)
		2–3	−1.504	0.132	0.138	(trivial)
		2–4	−0.549	0.583	0.115	(trivial)
		3–4	−0.962	0.336	0.024	(trivial)
	O	2–3	−1.219	0.223	0.105	(trivial)
		2–4	−0.356	0.722	0.000	(trivial)
		3–4	−0.123	0.722	0.101	(trivial)
Total fixation duration (ms)	B	1–3	−4.702	0.000	0.426	(small)
		2–3	−2.290	0.022	0.116	(trivial)
		2–4	−1.421	0.155	0.058	(trivial)
		3–4	−0.160	0.873	0.060	(trivial)
	N	1–3	−6.288	0.000	0.590	(medium)
		2–3	−0.839	0.402	0.086	(trivial)
		2–4	−0.587	0.557	0.111	(trivial)
		3–4	−1.856	0.064	0.206	(small)
	O	2–3	−1.181	0.237	0.027	(trivial)
		2–4	−0.368	0.713	0.056	(trivial)
		3–4	−0.319	0.750	0.093	(trivial)
Accuracy	B	1–3	−2.920	0.004	0.316	(small)
		2–3	−2.305	0.021	0.240	(small)
		2–4	−0.355	0.723	0.043	(trivial)
		3–4	−2.485	0.013	0.196	(small)
	N	1–3	−3.404	0.001	0.348	(small)
		2–3	−0.055	0.956	0.007	(trivial)
		2–4	−2.193	0.028	0.192	(small)
		3–4	−2.073	0.038	0.198	(small)
	O	2–3	−1.516	0.130	0.154	(trivial)
		2–4	−1.306	0.192	0.109	(trivial)
		3–4	−0.341	0.733	0.042	(trivial)

Legend: B—baseline; N—simulated gym audience noise; O—opposition.

4. Discussion

This study aimed to analyze the gaze behavior and shooting accuracy in different shooting positions and distances under the interference of environmental constraints of simulated opposition and gym audience noise. The hypothesis that differences exist when shooting at a greater distance was confirmed.

All shooting conditions showed that the shooting distance had an important role in the duration time of fixation. Shooting distance played an important role in how long the fixation lasts. When the athlete was closer to the basket, in the case of the free throw, the fixation time values and the number of fixations were greater when compared to the three-point shot. These results were in accordance, in terms of visual information, with the work of de Oliveira et al. [18], who affirmed that visual sensory information has a very important role in basketball shots. Breslin et al. [26] verified that the ability to visualize the basket without alteration, which occurs in the free throw in which the athlete is completely focused on the basket, allows for greater concentration of the athlete, and thus the number of fixations can be higher. The athlete has no external factors to distract him, causing him to divert the focus of attention to other targets. Even considering the character of the free throw in which, during the game, it is an unopposed task, in order to obtain good accuracy, athletes must be concentrated and focused. For example, [32,34] verified in their study that the athlete's performance is influenced by the quiet eye time, which means that the athletes must remain completely focused on the target during a significant time interval.

In the case of accuracy (Table 4), it was observed that the lowest value was obtained for the three-point shot, wherein the lowest number and time of fixations were observed. Thus, it is possible to conclude that the performance of athletes is greatly influenced by basket visual information, which follows Kostrna et al. [39].

These external constraints, such as opposition and gym audience noise, influence shooting accuracy. Environmental constraints can alter the athletes' attention—the number of fixations is smaller, and the fixation time is as well. In this case, the athletes' performance decreases, confirmed by the lower observed accuracy.

Several authors [17,20,32,34,35] tried to match visual ability, such as staring, with the performance of basketball players, the vast majority assessing free-throw accuracy. However, none of these studies used the gaze behavior obtained directly by glasses placed on the athlete. The great advantage of using glasses is that the number of fixations and fixation time can be properly evaluated for each athlete. Since the number and time of fixation are directly linked with the throwing distance and effectiveness, having a correct value for these parameters is essential to define training strategies.

One of the limitations of this study was that it only carried out shooting at two different distances (free throw and 3 points line) and at three different angles (45°, 90°, and 135°). Adding, in future studies, closer distances and the angles of 0° and 180° will certainly provide interesting values to be evaluated. Moreover, using a sample consisting of a larger number of players of different genders and age groups in a future study may provide data that allow a comparison between genders and ages, which is an added value for the study.

5. Conclusions

In this study, only in the number of fixations and total fixation duration had statistical differences between shooting distances and angles for the three shooting conditions. Comparing shooting distances (free throw and 3 points 90°), statistically significant differences occurred in the two shooting conditions for the variables. For the closer distance, the values of fixation duration and the total number of fixations were higher. This means that the athlete focused longer on the target when he was at a shorter distance. In the comparisons between shooting angles (45°, 90°, and 135°), statistically significant differences were only verified in one of each of the studied variables (fixation duration and total number of fixations). It was also observed that greater focus, which corresponded to a greater number and longer fixation time, improved the performance of athletes, and accuracy was better.

These results are very important for coaches and athletes because by identifying which type of shooting there is less focus on, strategies can be developed to improve attention and focus during the shooting, depending on the throw distance, particularly in novice participants who can be trained from the beginning of the sports practice to develop strategies that allow them to keep their focus on the basket for a longer time. Likewise, the influence that the shooting angles have on the athlete's focus on the basket can be corrected in training.

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