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Visual Fixations in Basketball Shooting: Differences between Shooting Conditions

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Abstract: Basketball is a sport where shooting is one of the most important factors that determines the success or failure of the teams. Therefore, basketball players need to shoot the ball accurately. The present study aimed to evaluate whether different shooting conditions influence the visual behavior of athletes. For this, the Tobbi Pro Glasses 3 equipment was used to evaluate the time of the first fixation, the number of fixations, and the total time of fixations in the basket, during the shooting movement. Different distances to the basket, simulated gym audience noise, and shooting with opposition were considered. A group of 18 athletes with an average age of 22 ± 3.72 years and an average basketball practice experience of 12.5 ± 4.52 years performed 10 valid shots from different distances and different shooting angles, with different restrictions, namely, shooting with simulated opposition and gym audience noise. Statistically significant differences between shooting with opposition and baseline, in terms of the number of fixations and the total time of fixation, were found. Regarding shooting with gym audience noise, differences only occur for the total time of fixations in one position. Despite this, in all variables and positions, the values were lower in shooting with constraints compared to the baseline.

Keywords: gaze behavior; environmental constraints; shooting opposition; task constraints; ocular fixation

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1. Introduction

In basketball, among the countless technical elements, we can highlight shooting, as it is through this that points are scored during the game [1], with a direct influence on the game outcome [2]. Winning teams, when compared with losing ones, shot successfully significantly more often [3], which represents a highly successful game outcome for the ones with optimal shooting performance [4]. The combination of some factors, such as corporal balance, strength, technique [5], and visual information, is crucial in order to achieve efficient and correct basketball shooting [6]. Regarding the jump shot's effectiveness, its reliance on vision remains ambiguous. A study has suggested that visual behavior impacts the task only to a limited extent, showing no correlation between the frequency of fixations and jump shot success [7]. On the other hand, Oudejans et al. [8] demonstrated that the efficacy of jump shots is influenced by both the duration and frequency of fixations on the rim.

Newel's constraint model (1986) posits that movement emerges from the interaction of several constraints, which include the individual, the task, and the environment. Newel further argues that altering any one of these factors modifies the task's difficulty level, necessitating an adaptation [9]. This interaction facilitates the emergence of an ideal movement co-ordination pattern, with the author asserting that a modification in any constraint likely leads to a change in response or, possibly, the generation of a new response. While the tactical significance of the three-point shot in basketball is undeniable, its successful execution during gameplay necessitates navigating numerous challenges, among them being external distractions [10]. Adding constraints during shooting tasks in practice that are close/similar to the constraints that occur in a basketball game can lead the athlete to exercise behaviors and be more prepared to give a more effective response during game shooting situations.

Visual behavior appears as an interconnection between visual information and motor behavior, and, in basketball, it is studied particularly at the level of shooting. Thus, the research focuses on the fixation of the look concerning the basket [11], and the location, the number, and the duration of these fixations during the free throw [6,12]. Long durations of visual fixations on the target are necessary for the brain to process enough information to be able to shoot correctly, giving the body enough time to program the direction, strength, velocity, and co-ordination of movement [13]. Visual control is one of the most important factors that influence the efficiency of basketball shooting [7].

This evaluation of the fixation of the gaze emerges as a determining factor for the success of the shooting. This variable assists in explaining the athletes' motor performance, namely, in precision tasks [14]. Players need to process all the important information to carry out the movement [15]. In this context, vision is considered an individual constraint important in the process of basketball shooting. Rienhoff et al. [16] argue that, for tasks that require precision and aim, the quiet eye fixation system, when combined with Newell's constraints model, provides useful knowledge for this area of study.

Okazaki and colleagues [17] propose that, in actual practice scenarios, the act of shooting is influenced by the task (such as the shooting type, the distance from the basket, etc.), constraints related to the environment (like gym noise, defense by opponents, etc.), and the athlete's characteristics (including morphological and functional variables, as well as physical and motor aspects). When the athlete is subjected to external pressure, it tends to worsen the performance of his movement [18]. The same occurs in visual tracking, as considered by de Oliveira et al. [19] who emphasize a global decrease in interarticular co-ordination strength and stability as a function of visual condition. Moreover, anxiety reflects less efficient visual search strategies and gaze orientation [20,21].

Involvement constraints are directly related to conditions external to the individual and the task, such as atmospheric and pavement conditions, which directly influence the athlete's performance [9]. Multiple involvement constraints, such as opposition or background noise, can cause changes in the athlete's release mechanism and, consequently, in the athlete's effectiveness [22,23].

The effectiveness percentage diminishes when there is an active opponent present during the shooting moment [24]. In visual behavior, the shooter tends to fix his gaze later the basket, spending more time looking at the opponent (personal defender) and analyzing his body position [25]. In the absence of a defender, the time spent focusing on the ball is reduced, whereas, for positions nearer to the defender, the focus on the target increases and the attention to the ball lessens [26]. Engaging in drills that incorporate an opponent's active presence during training sessions, mimicking real-game conditions, can enhance an athlete's performance [27].

Although background noise has not been studied much in basketball to date, it is common to assume that the influence of background noise on concentration when performing a given task is real [28]. Constant noise may be easier to adapt to or ignore, while noises that are sudden or fluctuate are more likely to grab attention and hinder performance [29]. Galanis et al., in their study, found that athletes experienced a notable decrease in shooting accuracy when exposed to noise distractions, compared to their baseline performance in environments without such distractions [30]. This factor was also studied at the level of decision making by the referees [31,32]. Some studies concluded that the effect of background noise on students' school performance shows noisy outdoor environments affect performance on different tasks [33–36], being relevant in the concentration component [37]. Moreover, external noise has a negative impact on human health, influencing physiological, psychological, and behavior processes [38]. Therefore, this highlights the essential need for basketball players to cultivate strong psychological skills, in addition to physical training, to mitigate the adverse impacts of noise distractions [39], and to be able to adopt a visual behavior that makes the shooting movement equally effective in situations with and without external constraints.

This study aims to analyze whether there are differences in the athlete's visual behavior when shooting with different constraints. In this way, a series of 10 shots were performed, in different positions and distances from the basket, without any constraint, and were considered baseline. Afterwards, gym audience noise and opposition constraints were added in the same positions. It is hypothesized that shooting with constraints drives the athlete to adopt a visual strategy different from those considered at baseline, especially when shooting with opposition, in which the vision of the target may not be complete.

2. Materials and Methods

The sample was formed by 18 athletes (10 females and 8 males), all players from senior teams, playing in national championships (22 $\pm$ 3.72 years; 172.15 $\pm$ 9.79 cm; 69.6 $\pm$ 13.12 kg). Each participant had a minimum of 4 years of experience in organized basketball play, averaging 12.5 $\pm$ 4.52 years, with no injuries reported in the three months leading up to the study.

Prior to taking part in the research, all athletes were thoroughly briefed about the study's purpose and provided their written informed consent. The study was approved by the ethical committee of the Polytechnic of Coimbra and performed according to the Declaration of Helsinki (CEIPC 83/2021). The data from all participants have been recorded and maintained in an anonymous manner.

All athletes performed 10 shots from different distances (free throw—4.60 m; 3 points line—6.75 m), angles (45°, 90°, and 135°) (Figure 1), and with different constraints (gym audience noise (N) and opposition (O)), totaling 1980 valid data points. These positions were chosen because, during basketball games, they are the ones where athletes made the most shots, based on Euroleague statistics data. Statistical analysis from the 2019 Basketball World Cup revealed that there was a positive correlation between the number of three-point shots made in the final and the likelihood of winning the game [40]. Environmental (gym audience noise) and task (opposition) constraints were used to assess their influence on the visual behavior during shooting. The opposition was made by adjustable equipment with different heights, depending on the athlete's height (1.20 * shooter's height), but always at a 1 m distance [41], Figure 2. The simulated gym audience noise of 105 dBA [42] starts before the athlete receives the ball in the first shot of this condition and was made by external speakers, constant during all 10 shots, and simulated hostile spectators. The same audio was used for all players and shots in this condition.

The shooting conditions were: B—baseline in 4 positions; N—gym audience noise in 4 positions; O—opposition in 3 positions.

The protocol started with a 10 min warm-up, including shooting drills and functional exercises. After that, the athlete was instrumented, and the glasses were placed and adjusted according to the athlete's comfort, as well as the signal detection box (Figure 3). The system was calibrated by fixing one point at 50 cm of distance for, at least, 3 s. The sequence of procedures carried out is shown in Figure 4.

Figure 5 shows the shot sequence, starting at one of the shooting positions (1 to 4, Figure 1), randomized for each athlete. Ten shots were made in each condition (X1, X2, and X3 with respect to B, O, or N), also in a random sequence, always in the same position, which was only changed after the 2 min rest period. This sequence of shots was made in the 4 shooting positions shown in Figure 1, with the position order being random for each athlete.

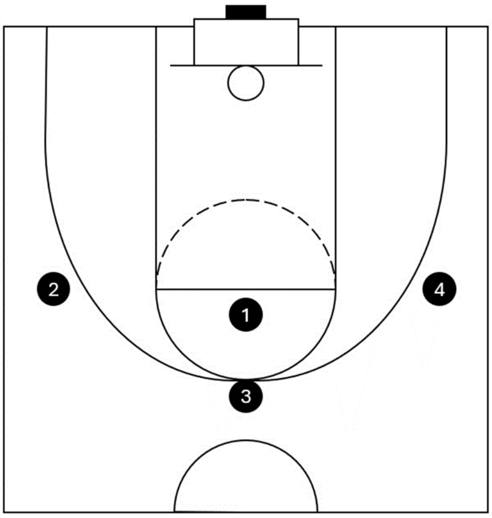

Figure 1. Tested shooting positions. 1—free throw (4.60 m); 2-3 points line (6.75 m) 45° angle; 3-3 points line (6.75 m) 90° angle; 4-3 points line (6.75 m) 135° angle.

Figure 2. Opposition equipment.

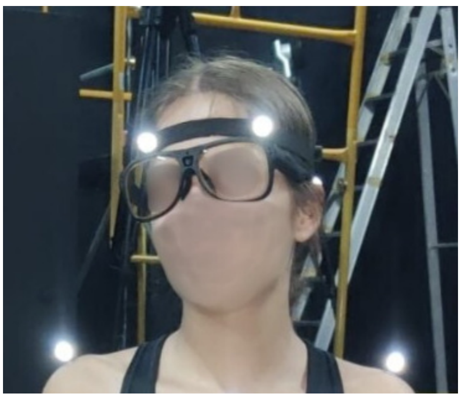

Figure 3. Example of an athlete instrumented with the Tobii glasses before data acquisition.

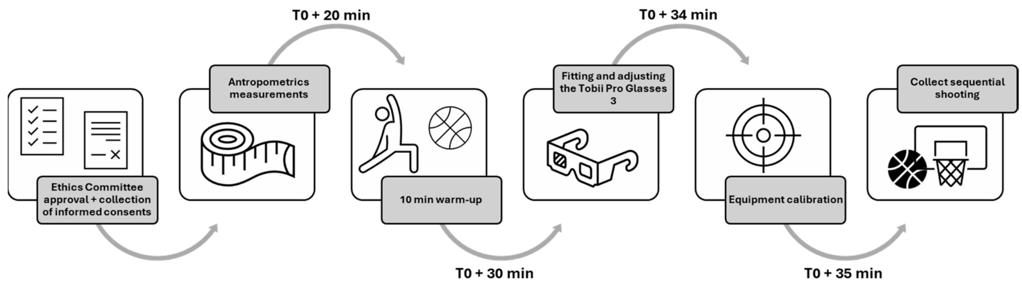

Figure 4. Sequence of methodological procedures.

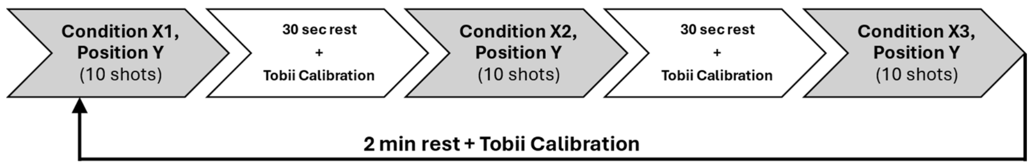

Figure 5. Sequence of shooting to a randomized position (1 to 4), in all shooting conditions (X1, X2, and X3—B, O, or N), also randomized, which was repeated in all shooting positions.

The sequence of shooting was randomized to reduce the influence of factors such as exercise learning on the task and fatigue. Between conditions in the same position, the athletes had 30 s to rest, and, between positions, they had a 2 min rest.

Each athlete received the ball through a chest pass, consistently executed by the same individual, specialized in basketball coaching, and performed a three-point shot immediately, which means catch and shoot. In the free throw, the athlete had a maximum of 5 seconds, the regulated time in basketball games, to carry out his or her routine and shoot.

Data collection occurred in the same gym, using a game ball inflated to the recommended pressure of 0.62 bar. The size of the ball varied between female and male players in line with official guidelines. All participants wore their regular basketball footwear and practice uniforms. Each collection lasted approximately 60 min.

Visual behavior was assessed using Tobii Pro Glasses 3, capturing data at a rate of 50 Hz and outfitted with numerous sensors and cameras to enable eye tracking while allowing the head to move freely. The glasses transmit sensor output to a recording unit via an HDMI cable, where video-based eye tracking takes place. By analyzing the corneal reflection caused by infrared illuminators positioned on the glasses (eight per eye), the system determines the direction of the eye's gaze with an accuracy of 0.6 degrees, recording both eyes at the same time. Tobii presents eye-tracking data within a gaze data structure, encompassing the gaze position (gaze2D) within the scene video frame, 3D gaze locations for both eyes, and pupil sizes and gaze directions for either the right or left eye. The gaze2D variable indicates whether the subject is looking at the scene video frames. Equipped with rechargeable batteries, Tobii Pro Glasses 3 can record for up to 105 minutes per charge. The glasses wirelessly send multiple digital media packets [43]. This equipment measures durations and numbers of fixations, saccades, and eye movement, among other variables. Prior to data collection, the equipment underwent thorough testing, to identify and mitigate any potential issues that could affect data integrity.

Analysis of fixation durations (both initial and total) and the frequency of fixations leading up to the moment of shooting (starts when the athlete first gazes at the backboard when the ball is received and ends in the last fixation before the ball is released) was conducted using Tobii Pro Glasses 3's Lab software. Specific regions of interest, namely, the backboard and hoop, were predefined prior to data examination. For fixation analysis, regions of interest (such as the hoop and court) were designated, and a minimum fixation duration of 100 ms was applied; fixations shorter than this duration were categorized as saccades or blinks and excluded from the study [44].

Efficiency was measured using a system that varies between values from 0 to 4, depending on whether or not the ball is converted and whether or not it touches the hoop [45]. The athlete was not aware of the quantification of each value before collection; they only knew that the effectiveness would be calculated with a scale with values between 0 and 4.

The data were analyzed using IBM SPSS Statistics 26.0 (IBM Corporation, New York, NY, USA) [46]. Descriptive statistics for the entire sample were reported as mean ± standard error with a 95% confidence interval, median, and percentiles. In statistical analysis, the first (Q1) and third quartiles (Q3) are critical measures that segment a dataset into four equal parts. Q1, the lower quartile, delineates the bottom 25% of data when ordered from lowest to highest, serving as a threshold below which a quarter of the data falls. Conversely, Q3, the upper quartile, marks the threshold below which 75% of the data lies, effectively separating the top 25% of values from the rest. These quartiles are instrumental in assessing data distribution, identifying outliers—using the interquartile range (IQR) between Q1 and Q3—and providing a foundation for comparative analysis. The IQR is a robust measure for variability that helps in pinpointing outliers, defined as data points lying more than 1.5 times the IQR from the quartiles. Together, Q1 and Q3 offer a comprehensive overview of a dataset's spread, central tendency, and skewness, crucial for detailed statistical examination and interpretation [47]. Normality assumptions were assessed using the Shapiro–Wilk test. Pairwise comparisons between baseline and the different conditions, for duration of first fixation, total duration of fixations, number of fixations, and efficiency, were conducted using the non-parametric Wilcoxon test. The significance level was set at $p < 0.05$.

3. Results

A descriptive statistical analysis was conducted on three variables, all related with fixations (total duration, first fixation duration, and number) (Table 1).

Concerning the duration of the first fixation, the higher value occurs with the constraint of gym audience noise at the position of free throw (409.27), while the lower value occurs, also, with the constraint of gym audience noise at the position of 135° (325.31). With regard to the number of fixations, the values fluctuate between 1.52 and 2.22, with the higher value at the position of the free throw line with the constraint of gym audience noise, and the lower value at the positions of 45° and 135° with opposition. At least, in the variable of the duration of fixations, the values go between 763.44 (N1) and 481.70 (O4). In all three variables, the higher value occurs at the free throw line with the constraint of gym audience noise.

Table 2 presents the descriptive statistics related to shooting efficiency, under the different shooting conditions in the analysis.

A tendency for higher effectiveness values can be observed in baseline shooting, in relation to shooting with constraints, in five of the seven conditions, with only a difference in shooting with gym audience noise at 45° and 90°, where the values are quite similar between themselves with a slight superiority in the gym audience noise condition.

Table 3 shows the two-by-two comparisons made for each of the parameters under study and effect sizes. The qualitative magnitude was identified according to McLeod [48].

For the number of fixations, statistically significant differences were observed only in the comparison between baseline and shooting with opposition for the positions of 45° ($p = 0.011$) and 135° ($p = 0.024$), observing a tendency for higher values at baseline compared to shooting with opposition, while, in the gym audience noise condition, there was no common trend across the four comparisons, following the trend observed regarding accuracy.

Regarding the first fixation duration, no statistically significant differences were found between any of the comparisons made, while, for the total fixation duration, there were differences between opposition and baseline in the three positions under study, namely, 45° ($p = 0.004$), 90° ($p = 0.001$) and 135° ($p = 0.003$), as well as between simulated gym audience noise and baseline at the 135° position ($p = 0.003$). For this variable, total fixation duration, there was a tendency for higher values in the baseline in relation to shooting with constraints for the seven comparisons.

Table 1. Descriptive statistics (mean ± standard deviation, median, Q1, and Q3) for all variables (duration of the first fixations, number of fixations, and total time of fixations) for the sample (n = 18).

Variables	Conditions	Mean ± SD	Median	Percentiles	
				Q1	Q3
Duration of First Fixation [ms]	B1	393.14 ± 332.83	240.00	140.00	571.00
	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
Number of Fixations	B1	2.08 ± 1.08	2.00	1.00	3.00
	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
	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—Position 1, Baseline condition; B2—Position 2, Baseline condition; B3—Position 3, Baseline condition; B4—Position 4, Baseline condition; N1—Position 1, Simulated gym audience noise condition; N2—Position 2, Simulated gym audience noise condition; N3—Position 3, Simulated gym audience noise condition; N4—Position 4, Simulated gym audience noise condition; O2—Position 2, Opposition condition; O3—Position 3, Opposition condition; O4—Position 4, Opposition condition.

Table 2. Descriptive statistics (mean ± standard deviation, median, Q1, and Q3) for efficiency (n = 18).

Variable	Conditions	Mean ± SD	Median	Percentiles	
				Q1	Q3
Efficiency	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—Position 1, Baseline condition; B2—Position 2, Baseline condition; B3—Position 3, Baseline condition; B4—Position 4, Baseline condition; N1—Position 1, Simulated gym audience noise condition; N2—Position 2, Simulated gym audience noise condition; N3—Position 3, Simulated gym audience noise condition; N4—Position 4, Simulated gym audience noise condition; O2—Position 2, Opposition condition; O3—Position 3, Opposition condition; O4—Position 4, Opposition condition.

Table 3. Results of Wilcoxon test and effect sizes for the variables with statistical differences (n = 18).

Dependent Variable	Independent Variables		Wilcoxon Test		Magnitude	
	Positions	Shooting Conditions	Value	*p*	d	(Qualitative)
First Fixation Duration [ms]	1	N—B	−0.830	0.406	0.049	(trivial)
	2	N—B	−0.780	0.436	0.046	(trivial)
		O—B	−0.898	0.369	0.019	(trivial)
	3	N—B	−0.889	0.374	0.042	(trivial)
		O—B	−1.737	0.082	0.144	(trivial)
	4	N—B	−1.175	0.240	0.093	(trivial)
		O—B	−0.993	0.321	0.083	(trivial)
Fixations Number	1	N—B	−1.331	0.183	0.126	(trivial)
	2	N—B	−0.576	0.565	0.056	(trivial)
		O—B	−2.553	<u>0.011</u>	0.227	(small)
	3	N—B	−0.004	0.997	0.036	(trivial)
		O—B	−0.517	0.605	0.073	(trivial)
	4	N—B	−1.442	0.149	0.135	(trivial)
		O—B	−2.183	<u>0.029</u>	0.300	(small)
Total Fixations Duration [ms]	1	N—B	−1.040	0.298	0.146	(trivial)
	2	N—B	−0.489	0.625	0.041	(trivial)
		O—B	−2.862	<u>0.004</u>	0.106	(trivial)
	3	N—B	−1.571	0.116	0.075	(trivial)
		O—B	−3.390	<u>0.001</u>	0.218	(small)
	4	N—B	−3.009	<u>0.003</u>	0.224	(small)
		O—B	−2.772	<u>0.003</u>	0.241	(small)

Table 3. *Cont.*

Dependent Variable	Independent Variables		Wilcoxon Test		Magnitude	
	Positions	Shooting Conditions	Value	*p*	d	(Qualitative)
Efficiency	1	N—B	−0.259	0.795	0.035	(trivial)
	2	N—B	−2.274	0.023	0.225	(trivial)
		O—B	−1.509	0.131	0.170	(trivial)
	3	N—B	−0.065	0.948	0.007	(trivial)
		O—B	−2.352	0.019	0.252	(trivial)
	4	N—B	−0.146	0.884	0.014	(trivial)
		O—B	−0.568	0.570	0.099	(trivial)

Legend: B1—Position 1, Baseline condition; B2—Position 2, Baseline condition; B3—Position 3, Baseline condition; B4—Position 4, Baseline condition; N1—Position 1, Simulated gym audience noise condition; N2—Position 2, Simulated gym audience noise condition; N3—Position 3, Simulated gym audience noise condition; N4—Position 4, Simulated gym audience noise condition; O2—Position 2, Opposition condition; O3—Position 3, Opposition condition; O4—Position 4, Opposition condition. Underline *p* values are values with statistically significant differences.

For the effectiveness values, there were only statistically significant differences in the comparisons between baseline and gym audience noise for the position of 45° ($p = 0.023$) and between baseline and opposition for the position of 90° ($p = 0.019$).

4. Discussion

The goal of this research was to examine the gaze behavior under various shooting conditions, namely, in the context of environmental constraints such as simulated opposition and gym audience noise. The hypothesis that shooting with constraints drives the athlete to adopt a different visual strategy was confirmed, particularly in shooting with opposition.

Some shooting conditions showed statistically significant differences in the fixation number and total fixation duration, while. in the first fixation duration, this has not occurred (Table 2). This may happen because the first look at the target may be earlier or later in time, which was not measured in this study, and it does not differentiate between conditions.

Regarding shooting with simulated gym audience noise, differences only occur for total fixation duration in N4. This difference can be justified by the fact that external noise affects the concentration on the task of the athletes [28]. But, since this difference only happens in one shooting position (N4), the results do not follow the previous study by Wilson et al. [18], who stated that factors that provoke anxiety led the athlete to increase the number of fixations and reduce their duration. The fact that the noise was simulating the audience in a basketball game and that it was not a real situation probably could not produce the natural anxiety of a game. Galanis et al. [30] also concluded that effectiveness decreases when the athlete is subject to background noise, which was not concluded in the present study. On the other hand, these conclusions are in line with studies that found that, when noise is constant, the athlete can ignore the background noise, thus becoming more focused on the task [29]. Although this only presents statistically significant differences for one of the positions, the values, when compared with the baseline, are lower. This may be because concentration on the task decreases with the interference of an external factor [37]. But, from the moment the shooting mechanism is automated, by practice, experience, and high skills, the effect of gym audience noise on it decreases, leading the athlete's brain to seek information that is already automated and reducing the concern with external factors such as gym audience noise [49,50].

For shooting with opposition, it is possible to verify that the number of fixations is statistically significantly different between O2 and O4 when compared with the baseline (B) of the respective positions, and for the total duration of fixations, between all three positions. These differences can be verified by the fact that the athlete has long fixation times on the defender and in his position, which was not measured in this study, reducing the fixation time on the target [25].

All of them have a lower total duration of fixation values for the conditions with constraints when compared to the baseline. For the total number of fixations, shooting with opposition has a lower average than the baseline ones (Table 2). This may be because the athlete does not focus only on the target but also on the opponent, or even because the vision of the target is reduced, in line with previous studies [25]. In addition, the lower duration and number of fixations when shooting with opposition may be because concentration on the target decreases with the presence of an external constraint [51].

In terms of efficiency, there are higher values in unopposed shots (the baseline condition) when compared to shots with opposition, which is in line with previous studies that state that external factors and pressures lead to a decrease in effectiveness [18,22,23]. In the comparisons carried out on shots with gym audience noise, there is no common trend, in line with what was found by Bell et al. for constant background noise [29].

Studies that compare experts and non-experts concluded that the experts have a lower number of fixations but higher times in each fixation, which means they can concentrate longer on the task, without being distracted by external factors [52]. Experts also have higher effectiveness values compared to non-experts. This is in line with the results obtained in this study, in which higher efficacy values are observed in shots with a longer total fixation duration, in this case, in baseline shots. Moreover, another study with visual behavior and basketball shooting concludes that, with higher values of accuracy, the number and total duration of fixations are also higher, which is in accordance with the results of the present study [53].

In shooting with opposition, the results are in line with the hypotheses, with statistically significant differences between shooting with and without opposition, reducing the values of the number and total duration of fixations in opposition ones. In shooting with simulated gym audience noise, the results do not agree with the hypotheses initially formulated, with no statistically significant differences being verified except for the N4 position, despite the lower values in shooting with simulated gym audience noise.

The fact that the opposition is static and always at the same height and distance from the shooter does not exactly replicate what happens in the game, in which this opposition is variable, becoming a limitation of this study. One way to improve this aspect in future studies is to create a mechanism that can move, causing uncertainty for the shooter. For the gym audience noise, which is simulated and in a situation of comfort for the athlete, the impact is not the same as it would be if it were in a situation of a game and discomfort for the athlete.

Trying to study the visual behavior of an athlete or coach in a game situation could be an interesting study to carry out in the future, in which it is possible to evaluate the real constraints that occur during the basketball game. Studies that relate, for the same variables, the number of saccades and quiet eye time, for example, can be of scientific value, as well as studying the differences between fixations on the target (table) and on the defender for shots with opposition. Furthermore, employing a sample that includes a more extensive array of players from various genders and age groups in future research could yield data facilitating comparisons across genders and ages. Moreover, more shooting positions (0 degrees on both sides) and mid-range shots (instead of just three-points shots and free throws) can be considered in further studies.

5. Conclusions

This study explored the effects of simulated opposition and gym audience noise on basketball players' gaze behavior during shooting, uncovering that environmental constraints significantly influence athletes' visual strategies. Our findings confirmed that environmental constraints indeed necessitate different visual strategies from athletes, which is particularly evident in shooting involving opposition.

While simulated audience noise had a limited impact, suggesting the artificial nature of the simulation may not fully capture real-game anxieties, the presence of opposition markedly altered gaze patterns. Shooting amidst simulated gym audience noise showed a significant difference only in the total fixation duration for one specific shooting position (135°), indicating that external noise can affect athletes' concentration, albeit not uniformly across all scenarios. This finding diverges from previous research suggesting a more generalized impact of anxiety-inducing factors on visual attention, possibly due to the simulated nature of the noise not replicating the authentic anxiety of a real game setting.

Conversely, shooting with opposition presented clear differences, particularly in the number of fixations and total fixation duration, highlighting the athlete's divided attention between the defender and the target. These results align with the hypothesis that external constraints, such as an opposing player, significantly alter an athlete's visual strategy.

The implications of these findings are manifold for coaches, athletes, and sports scientists. Understanding the impact of environmental constraints on gaze behavior can inform more targeted training regimes that simulate real-game pressures, potentially enhancing athletes' focus and performance under various conditions.

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References

1. Palao, J.; Ortega, E.; Olmedilla, A. Technical and tactical preferences among basketball players in formative years. In *Iberian Congress on Basketball Research*; Catholic University of San Antonio: Murcia, Spain, 2004; pp. 38–41.
2. Vencúrik, T.; Knjaz, D.; Rupčić, T.; Sporiš, G.; Li, F. Kinematic analysis of 2-point and 3-point jump shot of elite young male and female basketball players. *Int. J. Environ. Res. Public Health* **2021**, *18*, 934. [CrossRef]
3. Csataljay, G.; James, N.; Hughes, M.; Dancs, H. Performance differences between winning losing basketball teams during close, balanced and unbalanced quarters. *J. Hum. Sport Exerc.* **2012**, *7*, 356–364. [CrossRef]
4. Cabarkapa, D.; Fry, A.C.; Deane, M.A. Differences in Kinematic Characteristics Between 2-point and 3-point Basketball Shooting Motions–A Case Study. *J. Adv. Sports Phys. Educ.* **2021**, *4*, 19–23. [CrossRef]
5. Okazaki, V.; Okazaki, F.; Rodacki, A.L.; Lima, A. Variabilidade inter-individual na estrutura temporal do arremesso no basquetebol. *Motriz* **2009**, *15*, 831–841.
6. de Oliveira, R.; Oudejans, R.; Beek, P. Gaze Behavior in Basketball Shooting: Further Evidence for Online Visual Control. *Res. Q. Exerc. Sport* **2008**, *79*, 399–404. [CrossRef]
7. Steciuk, H.; Zwierko, T. Gaze behavior in basketball shooting: Preliminary investigations. *Trends Sport Sci.* **2015**, *2*, 89–94.
8. Oudejans, R.; Karamat, R.; Stolk, M. Effects of Actions Preceding the Jump Shot on Gaze Behavior and Shooting Performance in Elite Female Basketball Players. *Int. J. Sport Sci. Coach.* **2012**, *7*, 255–267. [CrossRef]
9. Newell, K.M. Constraints on the Development of Coordination. In *Motor Development in Children: Aspects of Coordination and Control*; Wade, M.G., Whiting, H.T.A., Eds.; Martinus Nijhoff: Dordrecht, The Netherlands, 1986; pp. 341–360.
10. Jeon, H.; Kim, J.; Ali, A.; Choi, S. Noise distraction and mental practice in closed and open motor skills. *Percept. Mot. Ski.* **2014**, *119*, 156–168. [CrossRef]
11. Ripoll, H.; Bard, C.; Paillard, J. Stabilization of the head and eyes on target as a factor in successful basketball shooting. *Hum. Mov. Sci.* **1986**, *5*, 47–58. [CrossRef]

12. Harle, S.; Vickers, J. Training quiet eye improves accuracy in the basketball free throw. *Sport Psychol.* **2001**, *15*, 286–305. [CrossRef]
13. Williams, A.M.; Singer, R.N.; Frehlich, S.G. Quiet eye duration, expertise, and task complexity in near and far aiming tasks. *J. Mot. Behav.* **2002**, *34*, 197–207. [CrossRef]
14. Klostermann, A.; Panchuk, D.; Farrow, D. Perception-action coupling in complex game play: Exploring the quiet eye in contested basketball jump shots. *J. Sports Sci.* **2018**, *36*, 1054–1060. [CrossRef]
15. de Oliveira, R.; Oudejans, R. A ligação entre percepção e acção no lançamento do basquetebol. In *O Contexto da Decisão–A Acção Táctica no Desporto. Visão e Contextos*; Araújo, D., Ed.; Edições Visão e Contextos: Lisboa, Portugal, 2005; pp. 355–378.
16. Rienhoff, R.; Tirp, J.; Strauss, B.; Baker, J.; Schorer, J. The 'Quiet Eye' and Motor Performance: A Systematic Review Based on Newell's Constraints-Led Model. *Sports Med.* **2016**, *46*, 589–603. [CrossRef]
17. Okazaki, V.; Lamas, L.; Okazaki, F.; Rodacki, A. Efeito da distância sobre o arremesso no basquetebol desempenhado por crianças. *Motricidade* **2013**, *9*, 61–72. [CrossRef]
18. Wilson, M.R.; Vine, S.J.; Wood, G. The influence of anxiety on visual attentional control in basketball free throw shooting. *J. Sport Exerc. Psychol.* **2009**, *31*, 152–168. [CrossRef]
19. de Oliveira, R.; Huys, R.; Oudejans, R.; van De Langenberg, R.; Beek, P. Basketball jump shooting is controlled online by vision. *Exp. Psychol.* **2007**, *54*, 180–186. [CrossRef]
20. Janelle, C.M. Anxiety, arousal and visual attention: A mechanistic account performance variability. *J. Sports Sci.* **2002**, *20*, 237–251. [CrossRef]
21. Wilson, M. From processing efficiency to attentional control: A mechanistic account of the anxiety-performance relationship. *Int. Rev. Sport Exerc. Psychol.* **2008**, *1*, 184–201. [CrossRef]
22. Gorman, A.D.; Maloney, M.A. Representative design: Does the addition of a defender change the execution of a basketball shot? *Psychol. Sport Exerc.* **2016**, *27*, 112–119. [CrossRef]
23. Nakano, N.; Inaba, Y.; Fukashiro, S.; Yoshioka, S. Basketball players minimize the effect of motor noise by using near-minimum release speed in free-throw shooting. *Hum. Mov. Sci.* **2020**, *70*, 102583. [CrossRef]
24. Csataljay, G.; James, N.; Hughes, M.; Dancs, H. Effects of defensive pressure on basketball shooting performance. *Int. J. Perform. Anal. Sport* **2017**, *13*, 594–601. [CrossRef]
25. van Maarseveen, M.; Oudejans, R. Motor and Gaze Behaviors of Youth Basketball Players Taking Contested and Uncontested Jump Shots. *Front. Psychol.* **2018**, *9*, 706. [CrossRef]
26. Esteves, P.T.; Dicks, M.; Travassos, B.; Silva, P.; Fonseca, T. Visually aiming at the scoring target in basketball: An exploratory study. In Proceedings of the Poster Session Presented at X Progress in Motor Control, Budapest, Hungary, 22–25 July 2015.
27. Rojas, F.J.; Cepero, M.; Ona, A.; Gutierrez, M. Kinematic adjustments in the basketball jump shot against an opponent. *Ergonomics* **2010**, *43*, 1651–1660. [CrossRef]
28. Shield, B.; Dockrell, J. The effect of classroom and environmental noise on children's academic performance. *J. Aucoustical Soc. Am.* **2008**, *123*, 133–144. [CrossRef]
29. Bell, R.; Mieth, L.; Röer, J.P.; Buchner, A. The metacognition of auditory distraction: Judgments about the effects of deviating and changing auditory distractors on cognitive performance. *Mem. Cognit.* **2022**, *50*, 160–173. [CrossRef]
30. Galanis, E.; Hatzigeorgiadis, A.; Comoutos, N.; Charachousi, F.; Sanchez, X. From the lab to the field: Effects of self-talk on task performance under distracting conditions. *Sport Psychol.* **2018**, *32*, 26–32. [CrossRef]
31. Aragao-Pina, J.A.; Passos, A.; Araújo, D.; Maynard, M.T. Football refereeing: An integrative review. *Psychol. Sport Exerc.* **2018**, *35*, 10–26. [CrossRef]
32. Sors, F.; Lourido, D.T.; Parisi, V.; Santoro, I.; Galmonte, A.; Agostini, T.; Murgia, M. Pressing crowd noise impairs the ability of anxious basketball referees to discriminate fouls. *Front. Psychol.* **2019**, *10*, 2380. [CrossRef]
33. Clark, C.; Martin, R.; van Kempen, E.; Alfred, T.; Head, J.; Davies, H.; Stansfeld, S. Exposure-effect relations between aircraft and road traffic noise exposure at school and reading comprehension: The ranch project. *Am. J. Epidemiol.* **2006**, *163*, 27–37. [CrossRef]
34. Haines, M.; Stansfeld, S.; Head, J.; Job, R. Multi-level modelling of aircraft noise on performance tests in schools around Heathrow Airport London. *J. Epidemiol. Commun. Health* **2002**, *56*, 139–144. [CrossRef]
35. Lundquist, P.; Holmberg, K.; Landstrom, U. Annoyance and effects on work from environmental noise at school. *Noise Health* **2000**, *2*, 39–46.
36. Maxwell, L.; Evans, G. The effects of noise on pre-school children's pre-reading skills. *J. Environ. Psychol.* **2000**, *20*, 91–97. [CrossRef]
37. Dalton, B.H.; Behm, D.G. Effects of noise and music on human and task performance: A systematic review. *Occup. Ergon.* **2007**, *7*, 143–152. [CrossRef]
38. Babisch, W. Road Traffic Noise and Cardiovascular Risk. *Noise Health* **2008**, *10*, 27. [CrossRef]
39. Yang, L.; Tian, Y.; Wang, Y. Noisy condition and three-point shot performance in skilled basketball players: The limited effect of self-talk. *Front. Sports Act. Living* **2024**, *5*, 1304911. [CrossRef]
40. Stavropoulos, N.; Kolias, P.; Papadopoulou, A.; Stavropoulou, G. Game related predictors discriminating between winning and losing teams in preliminary, second and final round of basketball world cup 2019. *Int. J. Perform. Anal. Sport* **2021**, *21*, 383–395. [CrossRef]
41. Amaro, C.M.; Gomes, B.B.; Mendes, R.; Castro, M.A. Effect of different height and distance oppositions on basketball shooting precision. *J. Phys. Educ. Sport* **2022**, *22*, 1271–1276.

42. Kalipci, E.; Arslan, F. Determination of noise pollution knowledge in the sport centres of Konya city. *J. Int. Environ. Appl. Sci.* **2007**, *2*, 64–70.
43. Nasrabadi, H.R.; Alonso, J.M. Modular streaming pipeline of eye/head tracking data using Tobii Pro Glasses 3. *bioRxiv* **2022**, bioRxiv:2022.09.02.506255.
44. Boddington, B.J.; Cripps, A.J.; Scanlan, A.T.; Spiteri, T. The validity and reliability of the Basketball Jump Shooting Accuracy Test. *J. Sports Sci.* **2019**, *37*, 1648–1654. [CrossRef]
45. Biedert, R.; Buscher, G.; Dengel, A. The eye book. *Informatik-Spektrum* **2009**, *33*, 272–281. [CrossRef]
46. Ghasemi, A.; Zahediasl, S. Normality Tests for Statistical Analysis: A Guide for Non-Statisticians. *Int. J. Endocrinol. Metab.* **2012**, *10*, 486–489. [CrossRef]
47. Moore, D.S.; McCabe, G.P.; Craig, B.A. *Introduction to the Practice of Statistics*; W.H. Freeman and Company: New York, NY, USA, 2016.
48. McLeod, S.A. What Does Effect Size Tell You? Simply Psychology. 2009. Available online: https://www.simplypsychology.org/effect-size.html (accessed on 17 February 2024).
49. Cratty, B.J. *Psychology in Contemporary Sport*; Prentice-Hall: Englewood Cliffs, NJ, USA, 1973.
50. Singer, R.N. *Motor Learning and Human Performance: An Application to Physical Skills*, 2nd ed.; Macmillan: New York, NY, USA, 1975.
51. Zelinsky, G.J. A theory of eye movements during target acquisition. *Psychol. Rev.* **2008**, *115*, 787–835. [CrossRef]
52. Marques, R.; Dias, G.; Martins, F.; Gomes, R.; Mendes, R.; Martinho, D.; Silva, M.J.C.e.; Mendes, R. Visual Patterns of U16 Athletes and Professional Basketball Players. *Appl. Sci.* **2023**, *13*, 3783. [CrossRef]
53. Amaro, C.M.; Amaro, A.M.; Gomes, B.B.; Castro, M.A.; Mendes, R. Effects of different basketball shooting positions and distances on gaze behaviour and shooting accuracy. *Appl. Sci.* **2023**, *13*, 2911. [CrossRef]