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Visual Patterns of U16 Athletes and Professional Basketball Players

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Abstract: This work aimed to compare the visual patterns of under 16 (U16) athletes and professional basketball players. The sample was composed of 10 U16 (aged 15.2 ± 0.4 years; 7.1 ± 2.5 years of experience) and 10 professional (aged 27.6 ± 3.7 years; 18.4 ± 4.6 years of experience) basketball players. All athletes were males and right-handed. Each participant performed 50 jump shots from 10 different positions and 5 different angle shots (0°, 45°, 90°, 135° and 180°). Number of fixations, time of first and last fixation, total fixation duration and Quiet Eye (QE) time of all shots were analysed. Overall, results indicated that the U16 group showed greater within-group differences regarding shot positions, last fixation times, shot angles, and first and last fixation times. Additionally, the U16 group presented different visual strategies than those of professional players, with significant differences found for shooting positions and shot angles, particularly for shots performed on the left side of the field, and for QE times. In conclusion, our results add to the understanding that longer fixation times and longer QE time are associated with better jump-shot efficacy, and this relation is evident when comparing players of different age groups.

Keywords: basketball; jump shots; visual information; eye tracking; quiet eye

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1. Introduction

Coupling between visual information and motor behaviour is a well-established research field in basketball, with studies about eye–head stabilization in relation to the target [1]; location, number and duration of fixations in the free shot [2,3]; Quiet Eye (QE) time [4] and the visual behaviour of players under conditions of anxiety [5,6]; or different conditions of attentional focus [7,8]. In this sense, we may consider that visual information is crucial for the control of movements that require greater precision, such as the basketball jump shot [9,10].

Precision skills require the control of the eye in relation to the target, to allocate the final visual fixation on the target for long enough to ensure success in the task. For example, Zwierko [11] explains that before the basketball free shot, players fixate their gaze on the rim for long enough to succeed, and that shot efficacy depends on the duration and frequency of those fixations. For the jump shot, however, there is some uncertainty regarding the influence of vision in task efficacy. In this regard, Steciuk and Zwierko [12] stated that visual behaviour only has a partial influence, as no relationships were found between fixation frequency and efficacy in the jump shot. Conversely, Oudejans et al. [13] showed that jump-shot efficacy depends on the duration and frequency of fixations on the rim, as occurs in free shots.

The visual information relevant to perform a task or motor skill is detected before the last phase of the shot [14,15]. Vickers [4] defined that relevant visual information as the QE, that is, the part of the final fixation that begins during the preparation phase and is offset when the QE falls off a location for more than 100 ms. The QE can, therefore, carry through arm flexion and extension phases. The fixation has to be at least 100 ms long and it should not move more than 3°, representing the minimum amount of time needed for a concrete action of motor control. According to this definition, QE is regarded as an important perceptive characteristic [16], as it may be considered a perception–action variable, with its start depending on the beginning of a motor action [17]. Therefore, QE is the period that starts during the preparation phase and ends when the fixation falls off of that location for more than 100 ms. The QE can therefore carry through arm flexion and extension phases. The fact that QE precedes the beginning of the movement indicates that this last fixation is used to process and define the action parameters [18]. The QE process is implicit to the performance of experts in a vast range of shot actions [19]. Longer QE periods are associated with better performance levels, and also with faster skill acquisition [20,21], as they provide the time needed for the brain to organize the neural structures that underly action planning and control [22]. Therefore, QE may be considered as an integral part of specialized motor activities [23,24].

The QE of experienced players is significantly longer than that of novice players [8]. Experienced players are able to fixate on objects in advance and for longer periods than less experienced ones, regardless task conditions [8,16]. This fixation duration is even longer for converted shots than for failed ones [25]. During the QE period, the brain has time to process the visual information enabling the experienced player to have more time to program the motor skill, allowing a better performance or better decision-making [26,27]. However, de Oliveira et al. [28] highlighted that despite longer fixations being associated with better motor programming, they only occur in conditions where both player and target are stationary. This is refuted by Klostermann et al. [29], when claiming that the QE concept also expands to the motor performance in dynamic game situations. Broadly, a recent review of studies underlined the importance of isolating which QE period contributes more to performance in the three-point shot [21]. High-level motor task success is dependent on a long fixation of a specific location before a specific phase of the movement. This location, however, is not consensual across the literature [21].

In basketball, the shot is the most important technical element of the game. The jump shot is a specialized dynamic motor skill that is the result of a combination of balance, strength, technique [30] and visual information [2]. This type of shot involves a motor pattern that is different from the set shot [31], presenting some advantages such as: (i) greater execution speed, (ii) better ball protection and (iii) greater precision at different distances [30]. Hence, changes in the players' visual field may also interfere with how the player gathers relevant information during task performance [7]. This assumption partially supports this research. It is important to consider that the neural efficiency hypothesis states that the brains of experienced players are faster and more efficient in the execution of the task [8,32,33]. In this perspective, the visual patterns of experts will be more efficient and research that fits in the expert vs. non-expert paradigm may be useful. In terms of visual tracking during the basketball jump shot, some studies use this approach [4,11,29].

In basketball, when comparing players of different experience levels performing the jump shot, research also points to experienced players having fewer and longer fixations than novice players [2,8,34]. Maarseveen and Oudejans [35] analysed the motor and gaze behaviours of youth basketball players with and without opposition, and found that shooting accuracy was affected by the duration of the last fixations in both conditions, especially in the contested shots. Considering the set of variables in the present research, Erčulj and Štrumbelj [36] found that there were no differences between U14 and U16 in shooting performance, despite the latter group showing behaviours closer to that of senior players than their U14 counterparts. According to the authors [36], the fact that young players shoot from distances closer to the basket is a situational variable that might have contributed to this lack of differences. Therefore, a systematic revision of Marques et al. [37] highlighted the importance of using Eye Tracking Glasses for the assessment and intervention in visual attention training to increase shot efficiency in basketball. The coupling between visual information and motor behaviour is important in selecting the relevant stimuli for task success.

Given the above, the literature in this field has not studied the differences in visual strategies between these two age groups. Therefore, the aim of this work is to compare the visual patterns of U16 athletes and professional basketball players. Considering that young players show greater motor instability in jump-shot execution than experienced players [38], it is important to assess if that instability is also present in their visual patterns. Therefore, we hypothesized that the visual search strategies in the jump shot, expressed in the total number of fixations, fixation duration, time of first fixation and time of last fixation of expert players would have statistically significant differences with that of U16 players. Additionally, we hypothesized that expert players would show longer QE times, when compared with U16 players. Finally, we expected that shooting position would influence the visual strategies of players during the jump shot.

2. Materials and Methods

2.1. Participants

A total of 20 male athletes (10 U16 athletes and 10 professional basketball players), all right-handed, participated in this study. The dominant hand was identified as the shooting hand. The U16 group was composed of district-selected players from two regional areas of Portugal (Coimbra and Leiria; 15.2 ± 0.4 years old; 7.1 ± 2.5 years of practice; stature: 179.4 ± 2.4 cm; playing position: 4 guards, 6 forwards). Professional (Pro) players played in teams from the 1st and 2nd national division (Liga Placard and Proliga, respectively; 27.6 ± 3.7 years of age; 18.4 ± 4.6 years of practice; stature: 193.2 ± 9.8 cm; playing position: 4 guards, 6 forwards). The research protocol was approved prior to data collection by the scientific committee of the Faculty of Sport Sciences and Physical Education of the University of Coimbra, and all participants gave consent according to the Helsinki Declaration and Oviedo Convention. The research protocol was approved by the Ethics Committee in the Institute Polytechnic of Coimbra (83_CEIPC/2021) and the scientific committee of the Faculty of Sport Sciences and Physical Education of the University of Coimbra. All procedures were in accordance with the ethical standards.

2.2. Instruments

QE times were determined with an additional camera (Casio Exilim Pro Ex-F1; Shibuya, Tokyo, Japan) recording the motor action. The camera was positioned laterally, 3 metres away, at a 90° angle from the shooting hand. Eye movements were captured with the SMI ETG 2W Eye Tracking Glasses (SMI ETG 2W; SensoMotoric Instruments, Teltow, German). This system records eye movements at 60 Hz, and automatically compensates parallax errors with accuracy rates of 0.5° for all distances (iViewETG User Guide, V2.0, of 2013). All data was coded and analysed with BeGaze V3.7 software.

2.3. Task and Protocol

Participants executed the jump shot after receiving the ball [39] from their dominant side [13], at 4.23 m and 6.80 m from the basket, from ten positions previously marked on the floor, with angles of 0°, 45°, 90°, 135° and 180°, in relation to the rim (5 shots at 6.80 m and 5 shots at 4.23 m in each of the shooting angles) (Figure 1).

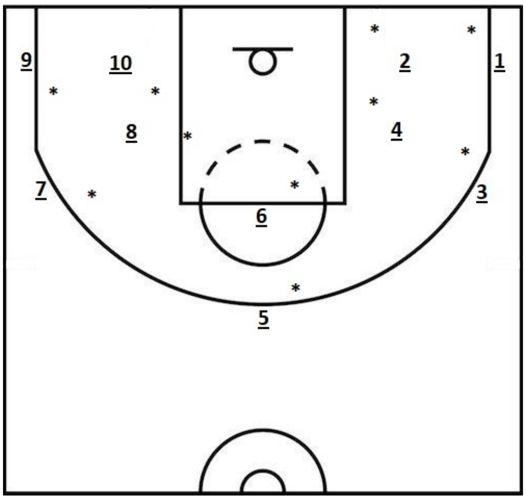

Figure 1. Shot positions (1–10); shot angles: 0° (positions 1 and 2), 45° (positions 3 and 4), 90° (positions 5 and 6), 135° (positions 7 and 8) and 180° (positions 9 and 10). * Location of the passer.

2.4. Procedures

Participants performed the shots following a non-randomized sequence, chosen freely and individually. The shots were taken sequentially from positions 1 to 10, or following the inverse order. Regarding shooting style, athletes performed the jump shots without making any step prior to the take-off. Regarding ball release technique (high or low), players chose the technique they felt more comfortable with. A 60 s recovery period was given between each set of 10 shots. A rebounder and a highly skilled passer were used, placed on the side of the shooting hand. The task was done on an indoor basketball pitch and each athlete performed the task alone, to avoid any distraction. After a brief 15 min warm-up routine that ended with a shooting routine without the ETG, participants fitted the eye tracker and performed a few practice trials until they felt comfortable wearing the equipment. After this, a 3-point calibration of the ETG was made at the beginning of the task, and an offset calibration was made every 10 shots, to reduce calibration errors. Data collection comprised a total of 1000 jump shots.

2.5. Data Coding of Variables

The coding process used the ETG proprietary software BeGaze V3.7. Data coding started when the player fixated on the ball before receiving a pass, and ended when the player's gaze deviated off the target for more than 100 ms. The videos were analysed in the software using a frame-by-frame methodology, as described by Holmqvist et al. [40]. The tracking ratio of senior players was between 99.4% and 93.3% and the U16 players between 99.6% and 92.4%. Based in Marques et al. [37], the following dependent variables were selected: (i) shot efficacy, expressed in the quantification of the results obtained by the participants' converted (1 point) or unconverted (0 points) shots; (ii) number of fixations; (iii) fixation duration; (iv) duration of first fixation; (v) duration of last fixation and (vi) QE time.

The software was calibrated to detect a fixation when the participant's gaze dwelled on a location for a minimum of 100 ms. The end of each fixation was determined when the participant produced a saccade, by moving rapidly between locations in two or more consecutive frames [40]. Additionally, data from blinks was removed [40,41]. Total fixation durations were determined as the difference between the onset and the ending of each fixation. The first fixation duration is the duration of the first fixation. Similarly, last fixation duration is the duration of the last fixation. Lastly, the number of fixations is the sum of all fixations each participant made.

QE time is defined as the part of the final fixation between the beginning of the fixation and the first observable movement of the shooting hand, within a minimum of 3° of the visual angle and a minimum of 100 milliseconds [4]. To determine QE times, gaze data was synchronised with the lateral camera, and then manually determined by one trained researcher. Finally, efficacy was measured by the total number of converted shots, where a successful attempt was valued with 1 point, and a non-successful one 0 points.

Statistical Analysis

The independent variables were the age group, the shot angles and the shooting positions. The dependent variables were shot efficacy, the number of fixations, fixation duration, duration of first fixation, duration of last fixation and the QE time. In this sense, statistical analysis of interactions between age group and shooting position, age group and shooting angles and its efficacy, number of fixations, fixation duration, time of first fixation, time of last fixation and QE time was made with a two-way ANOVA after checking the normality and homogeneity assumptions [42]. When the interaction between the ANOVA two-way factors was statistically significant, a new variable was created that resulted from the crossing of the factors for each dependent variable. After this, the one-way ANOVA, after checking the normality and homogeneity assumptions [42] with a post hoc Tukey HSD test, was used for the newly created factor, based on the interaction of the first factors. When no statistically significant interaction was identified, an individual study of each independent variable was made. Accordingly, to compare the age groups and shooting places for efficacy, number of fixations, fixation times, time of first fixation, time of last fixation and QE time, Student's t-test was applied, after checking the normality assumption [42]. Additionally, to compare shooting positions and shooting angles for efficacy, number of fixations, fixation times, time of first fixation, time of last fixation and QE time, the one-way ANOVA was applied with a post hoc Tukey HSD test [42].

The variable efficacy was transformed into a quantitative variable, based on the order of data [43] (pp. 340–341). In this case, the statistical interaction between the factors (age group and shot positions and age group and shot angles) was made with the two-way ANOVA, after validation of the assumptions mentioned above. In case of no statistically significant interaction between factors, the previously mentioned calculations were applied. Effect size (ES), presented as η2 and η_p^2 for the one-way ANOVA and two-way ANOVA (respectively), was interpreted according to the following criteria: no effect (ES < 0.04), minimal effect (0.04 ≤ ES < 0.25), moderate effect (0.25 ≤ ES < 0.64), and strong effect (ES ≥ 0.64) [40]. Apart from the effect size, the power (π) of the corresponding test was also presented [43]. Cohen's d was used for the t test for independent samples, with the following criteria: small effect ($d < 0.20$), moderate effect ($0.20 \leq d < 0.80$) and large effect ($d \geq 0.80$) [42,44]. The data analysis was conducted using IBM SPSS (V25, IBM, USA) software and a statistical significance of 5% ($p < 0.05$).

3. Results

Since there were no statistically significant interactions found between the ANOVA two-way factors, an individual study of each independent variable was made.

3.1. Efficacy (According to Positions, Location and Angle)

Regarding efficacy, within-group analysis revealed that positions affected efficacy for the U16 group, with statistically significant differences ($F_{(9:490)} = 3.366$; $p = 0.001$; $\eta^2 = 0.058$; minimal effect size, $\pi = 0.986$). We found better efficacy when comparing between position 1 and position 6 ($p = 0.001$), position 1 and position 10 ($p = 0.001$), position 3 and position 6 ($p = 0.035$), position 5 and position 6 ($p = 0.009$) and between position 6 and position 7 ($p = 0.035$) (Table 1).

Table 1. Between-group comparison for shot efficacy, according to position and angle.

		$\bar{x} \pm$ SD U16	Pro	t	p	d
positions	1	363.50 ± 221.54 [a,b]	483.50 ± 252.54	−2.526	0.013 *	0.505
	2	463.50 ± 251.73	553.50 ± 242.44	−1.821	0.072	0.364
	3	413.50 ± 242.44 [c]	523.50 ± 249.26	−2.237	0.028 *	0.447
	4	473.50 ± 252.34	613.50 ± 215.71	−2.982	0.004 *	0.596
	5	393.50 ± 235.61 [d]	583.50 ± 231.46	−4.068	0.001 *	0.814
	6	573.50 ± 235.61 [a,c,d,e]	593.50 ± 226.78	−0.432	0.666	0.087
	7	413.50 ± 242.44 [e]	523.50 ± 249.29	−2.237	0.028 *	0.447
	8	433.50 ± 247.44	593.50 ± 226.78	−3.371	0.001 *	0.674
	9	423.50 ± 245.16	523.50 ± 249.29	−2.022	0.046 *	0.404
	10	523.50 ± 249.29 [b]	543.50 ± 245.16	−0.404	0.687	0.081
angles	0°	413.50 ± 241.21	518.50 ± 248.79	−3.030	0.003 *	0.429
	45°	443.50 ± 248.02	568.50 ± 236.29	−3.649	0.001 *	0.516
	90°	483.50 ± 251.26	588.50 ± 228.02	−3.095	0.002 *	0.437
	135°	423.50 ± 243.92	558.50 ± 239.69	−3.948	0.001 *	0.558
	180°	473.50 ± 251.06	533.50 ± 246.18	−1.706	0.090	0.241

* Statistically significant differences ($p < 0.05$). ([a]) Position 1 vs. position 6. ([b]) Position 1 vs. position 10. ([c]) Position 3 vs. position 6. ([d]) Position 5 vs. position 6. ([e]) Position 6 vs. position 7.

Between-group comparisons indicated that professional players obtained better overall results than the U16 group in almost all shooting positions ($t_{(998)} = -6.870$; $p = 0.001$; $d = 0.862$; large effect size) and angles with the exception of positions 2, 6 and 10, and angle 180°.

3.2. Between-Group Comparison for QE Time

Average QE times were longer for professional players when compared to U16 (587.1 ms vs. 546.3 ms). They were also longer in both age groups when converted vs. non-converted shots were compared (U16: 563.21 ms vs. 536.18 ms; Pro: 594.27 vs. 574.17 ms).

Between-group analysis only showed statistically significant differences for positions 8 and 9 and at shot angles 135° and 180° (Table 2).

Table 2. Between-group comparison for QE time, according to position and angle (times in milliseconds—ms).

		$\bar{x} \pm$ SD U16	Pro	t	p	d
positions	1	547.26 ± 258.52	532.14 ± 263.70	0.290	0.773	0.058
	2	507.24 ± 273.82	591.84 ± 263.09	−1.575	0.118	0.315
	3	524.94 ± 248.91	616.32 ± 283.38	−1.713	0.090	0.343
	4	502.92 ± 235.00	547.80 ± 271.90	−0.883	0.379	0.177
	5	602.62 ± 231.93	636.20 ± 239.19	−0.713	0.478	0.143
	6	529.86 ± 219.81	579.32 ± 204.38	−1.165	0.247	0.233
	7	559.28 ± 195.35	602.60 ± 239.97	−0.990	0.325	0.198
	8	500.80 ± 249.34	629.00 ± 196.17	−2.857	0.005 *	0.572
	9	519.30 ± 209.03	614.72 ± 206.47	−2.296	0.024 *	0.459
	10	476.66 ± 213.79	512.62 ± 210.87	−0.847	0.399	0.169
angles	0°	527.25 ± 265.69	561.99 ± 263.78	−0.928	0.355	0.131
	45°	513.93 ± 241.09	582.06 ± 278.43	−1.850	0.066	0.262
	90°	566.24 ± 227.76	607.76 ± 223.18	−1.302	0.194	0.184
	135°	530.04 ± 224.77	615.80 ± 218.46	−2.736	0.007 *	0.387
	180°	497.98 ± 211.44	563.67 ± 214.67	−2.184	0.030 *	0.309

* Statistically significant differences ($p < 0.05$).

3.3. Total Fixation Duration before Jump-Shot

Regarding fixation duration before the jump shot, they were longer for the professional group in the global (663.25 ms vs. 347.72 ms), first (366.94 ms vs. 332.97 ms) and last (371.79 ms vs. 284.21 ms) fixation durations.

Between groups, significant differences in shooting positions 2, 3, 4, 8 and 9 and in shooting angles 0°, 45°, 135° and 180° were found (Table 3).

Table 3. Between-group comparison for total fixation duration before shot, according to position and angle (times in milliseconds—ms).

		$\bar{x} \pm$ SD		t	*p*	d
		U16	**Pro**			
positions	1	586.34 ± 219.92	604.40 ± 255.47	−0.379	0.706	0.076
	2	560.18 ± 269.83	703.64 ± 277.11	−2.623	0.010 *	0.525
	3	590.44 ± 222.71	695.53 ± 266.37	−2.140	0.035 *	0.043
	4	527.70 ± 224.32	671.78 ± 224.66	−3.209	0.002 *	0.095
	5	649.95 ± 162.85	683.65 ± 258.53	−0.780	0.437	0.156
	6	598.69 ± 187.68	632.62 ± 221.78	−0.826	0.411	0.165
	7	613.74 ± 183.13	669.37 ± 228.42	−1.343	0.182	0.269
	8	588.76 ± 242.08	690.69 ± 217.90	−2.213	0.029 *	0.048
	9	587.14 ± 177.19	663.09 ± 197.74	−2.023	0.046 *	0.405
	10	543.40 ± 165.79	617.73 ± 276.49	−1.630	0.106	0.326
angles	0°	573.26 ± 245.25	654.02 ± 269.81	−2.215	0.028 *	0.313
	45°	559.07 ± 224.61	683.65 ± 245.44	−3.744	0.001 *	0.530
	90°	624.32 ± 176.70	658.14 ± 241.01	−1.132	0.259	0.160
	135°	601.25 ± 213.92	680.03 ± 222.35	−2.553	0.011 *	0.361
	180°	565.27 ± 172.12	640.41 ± 240.23	−2.542	0.012 *	0.360

* Statistically significant differences ($p < 0.05$).

3.4. Between-Group Comparison for Number of Fixations

For any of the groups analysed, no within-group differences were found that would show any statistically significant interaction between shooting positions and the number of fixations.

The between-group analysis of this variable showed statistically significant differences for position 7 ($t_{(98)} = 3.176$; $p = 0.002$; $d = 1.257$; large effect size) and for angle 135° ($t_{(198)} = 2.364$; $p = 0.019$; $d = 0.334$, moderate effect size) (Table 4).

Table 4. Between-group comparison for number of fixations, according to position and angle.

		$\bar{x} \pm$ SD		t	*p*	d
		U16	**Pro**			
positions	1	1.96 ± 0.86	1.84 ± 0.74	0.750	0.455	0.150
	2	2.00 ± 0.90	2.04 ± 0.78	−0.237	0.813	0.047
	3	2.22 ± 0.95	1.92 ± 0.75	1.747	0.084	0.349
	4	1.86 ± 0.83	2.06 ± 0.74	−1.269	0.207	0.254
	5	1.96 ± 0.86	1.84 ± 0.65	0.789	0.432	0.157
	6	1.76 ± 0.74	1.86 ± 0.81	−0.644	0.521	0.129
	7	2.28 ± 1.01	1.72 ± 0.73	3.176	0.002 *	0.635
	8	1.82 ± 0.92	1.80 ± 0.73	0.121	0.904	0.024
	9	2.14 ± 0.95	2.04 ± 0.81	0.568	0.571	0.114
	10	1.98 ± 0.87	1.96 ± 0.70	0.127	0.899	0.025
angles	0°	1.98 ± 0.88	1.94 ± 0.76	0.344	0.731	0.049
	45°	2.04 ± 0.91	1.99 ± 0.75	0.425	0.671	0.060
	90°	1.86 ± 0.80	1.85 ± 0.73	0.092	0.927	0.013
	135°	2.05 ± 0.99	1.76 ± 0.73	2.364	0.019 *	0.334
	180°	2.06 ± 0.91	2.00 ± 0.75	0.509	0.611	0.072

* Statistically significant differences ($p < 0.05$).

3.5. Between-Group Comparison for First Fixation Duration

Regarding the first fixation duration, statistically significant differences were found for the shooting angles within the U16 group ($F_{(4;495)}$ = 2.911; p = 0.021; η^2 = 0.023; no effect size, π = 0.784) and we found longer times of first fixation when comparing between angle 0° and angle 90° (p = 0.013). This situation did not occur with the professional players (Table 5).

Comparing the two age groups, statistically significant differences were found for the first fixation duration ($t_{(998)}$ = −2.387; p = 0.017; d = 0.151; small effect size). Position 7 ($t_{(98)}$ = 7.066; p = 0.009; d = 0.532; large effect size) and angle 135° ($t_{(198)}$ = 4.906; p = 0.028; d = 0.397; moderate effect size) also showed significant differences between the groups.

Table 5. Between-group comparison for first fixation duration, according to position and angle (times in milliseconds—ms).

		$\bar{x}$ ± SD		**t**	***p***	**d**
		U16	**Pro**			
positions	1	326.22 ± 261.29	343.15 ± 224.05	−0.348	0.729	0.070
	2	253.54 ± 217.28	311.31 ± 230.08	−1.291	0.200	0.258
	3	339.16 ± 236.54	387.28 ± 291.78	−0.906	0.367	0.181
	4	304.35 ± 221.64	328.90 ± 261.12	−0.507	0.613	0.101
	5	404.28 ± 260.63	396.63 ± 320.27	0.131	0.896	0.026
	6	389.29 ± 244.26	353.14 ± 258.72	0.719	0.474	0.143
	7	296.34 ± 221.23	436.73 ± 300.87	−2.658	0.009 *	0.532
	8	347.17 ± 282.23	417.52 ± 252.34	−1.314	0.192	0.263
	9	329.90 ± 214.20	355.81 ± 254.62	−0.551	0.583	0.110
	10	292.79 ± 198.39	338.88 ± 304.72	−0.896	0.372	0.179
angles	0°	289.88 ± 241.85 [a]	327.23 ± 226.51	−1.127	0.261	0.159
	45°	321.75 ± 228.72	358.09 ± 277.03	−1.012	0.313	0.143
	90°	396.79 ± 251.41 [a]	374.88 ± 290.47	0.570	0.569	0.081
	135°	321.76 ± 253.58	427.13 ± 276.42	−2.809	0.005 *	0.397
	180°	311.34 ± 206.24	347.35 ± 279.49	−1.036	0.301	0.147

* Statistically significant differences (p < 0.05). ([a]) Angle 0° vs. angle 90°.

3.6. Between-Group Comparison for Last Fixation Duration

Finally, within-group analysis showed that the last fixation duration for the U16 group was affected by the shooting angles ($F_{(4;495)}$ = 3.207; p = 0.013; η^2 = 0.025; no effect size, π = 0.827), and we found longer times of last fixation when comparing between angle 45° and angle 90° (p = 0.017) (Table 6).

Between-group analysis showed significant differences in the last fixation duration ($t_{(998)}$ = −5.629; p = 0.001; d = 0.356; moderate effect size). Regarding the influence of shooting positions and angles in the last fixation duration, significant differences were found for positions 2, 3, 4 and 7 and in angles 0°, 45°, 135° and 180°.

Table 6. Between-group comparison for last fixation duration, according to position and angle (times in milliseconds—ms).

		$\bar{x}$ ± SD U16	$\bar{x}$ ± SD Pro	t	*p*	d
positions	1	396.57 ± 243.90	418.24 ± 224.97	−0.462	0.645	0.092
	2	339.21 ± 252.03	484.90 ± 280.54	−2.732	0.007 *	0.546
	3	303.72 ± 212.58	501.11 ± 276.53	−4.002	0.001 *	0.800
	4	332.59 ± 224.93	433.53 ± 238.68	−2.175	0.032 *	0.435
	5	423.83 ± 251.97	475.88 ± 299.90	−0.940	0.350	0.188
	6	417.89 ± 246.51	442.78 ± 222.81	−0.530	0.597	0.106
	7	355.52 ± 219.33	484.25 ± 278.22	−2.569	0.012 *	0.514
	8	433.80 ± 275.35	496.51 ± 246.36	−1.200	0.233	0.240
	9	335.55 ± 203.23	412.57 ± 238.33	−1.739	0.085	0.348
	10	336.52 ± 196.35	411.89 ± 252.55	−1.501	0.136	0.333
angles	0°	367.89 ± 248.42	451.57 ± 255.20	−2.350	0.020 *	0.332
	45°	318.15 ± 218.22 [a]	467.32 ± 259.23	−4.402	0.001 *	0.623
	90°	420.86 ± 248.01 [a]	459.34 ± 263.37	−1.064	0.289	0.150
	135°	394.66 ± 250.76	490.38 ± 261.51	−2.642	0.009 *	0.374
	180°	336.04 ± 198.81	412.23 ± 267.16	−2.288	0.023 *	0.324

* Statistically significant differences ($p < 0.05$). ([a]) Angle 45° vs. angle 90°.

4. Discussion

The aim of this work was to compare the visual patterns of U16 athletes and professional basketball players. Additionally, we also sought to understand if these variables were affected by shooting angles, shooting positions and efficacy level.

Comparisons between age groups showed that professional players had better jump-shot efficacy in the positions and shooting angles, which is in line with studies where similar comparisons were made for this type of shot in an expert vs. non-expert paradigm, e.g., [15,29,38,45]. This difference of values was expected due to the initial definition of the experimental setup and due to the variation in the jump-shot distance, as individual performance is tied to each athlete's physical and physiological capabilities.

Regarding QE times, several authors state that more experienced players present longer QE times than non-experts, and these longer times are associated with better performance, as they have more time to organize the neural structures responsible for the planning and control of the action [4,8,16,19,26,27]. This work corroborates these conclusions, as the QE times of professional players were longer than that of U16 players. When QE times are related with efficacy, we can verify that on average, longer times correspond to greater efficacy percentages, as stated by Vine et. al. [20].

Considering that the research regarding the expert vs. non-expert paradigm refers mainly to adult athletes, this study aimed to introduce a new variable, the players' age group. Despite the U16 group being composed of players from the U16 regional squad, we obtained similar results to those within the expert vs. non-expert paradigm [4,8,16,19,26,27], indicating that age group may be considered as an inexperience factor. Oudejans et al. [13] and Zwierko et al. [11] indicated that shot efficacy depends on the frequency and duration of fixations. Mann et al. [8] stated that experienced players have fewer and longer fixations than novices. Our results are in line with the above authors, as professional players presented fewer and longer fixations (1.92; 663.25 ms) than U16 players (2.00; 347.72 ms).

It is important to consider the findings from Ziwerko et al. [46] involving experienced adult players, wherein the average fixation duration was 420.62 ms, which is closer to our U16 values, whereas Vickers [17] reported an average fixation duration of 586.83 ms, which is closer to the values of our group of professional players. This disparity in the results might be mainly due to different methodological procedures. For example, in Vickers [17], the jump shot was made from the free-throw position. In Zwierko et al. [46], the jump shot was made from shooting position 5 after an approximation run, reception and passing. Data also showed that when comparing both age groups, the last fixation duration was not relevant for efficacy. Additionally, the same thing happened with the U16 players. Regarding the first fixation duration, longer times were associated with greater efficacy. The U16 group showed significant within-group differences regarding shot angles (first and last fixation times).

Among all between-group differences, the most significant ones were in shot position 7, for number of fixations and time of first and last fixation; and positions 8 and 9, for QE time and total fixation time, shot angle 135° and number of fixations. These positions and angles were on the left side of the basket, while all participants were right-handed. As shooting positions interfere with efficacy in U16 players, further studies should focus on this aspect, to better understand these discrepancies. Thus, based in Dias et al. [47], we can speculate that players shoot using different cycles of perception–action and different strategies to understand the environment in terms of vision in relation to the basketball.

Facing this scenario, disturbances imposed on the players when performing the task allow them to find new ways to solve motor problems. This enables us to hypothesize that the problem of individuality is not confined to ideal or standardized techniques, but contains a variety of strategies that may be implemented according to intra-individual variability. Possibly, the perceptions that the player drew from the properties of the context—"affordances" [48]—were important to perform this movement. Hence, when considering that "functional variability" is associated with the way we affect the task and the player during the performance, it is plausible that this form of "noise" may contribute to a better accommodation to the demands of the task [47].

On this basis, the manipulation of task-related constraints [49] "forced" the appearance of solutions uniquely adjusted to each player, and that may have changed variables such as shot efficacy, among others [47]. In this sense, considering that athletes can optimize their performance in basketball, we recommend the exploration of different couplings of information–movement, in different levels of complexity.

One of the main limitations of this study is the relatively low sample size. Although a total of 1000 shots were analysed (100 per position, 50 per group), they were made only by a few players. Future studies should increase the number of players. Also, future studies should separate professional players of different league levels, as the results may also be different between these groups. Finally, future studies should also control the shooting technique.

5. Conclusions

The results of this study expand the explanatory power of multiple factors, such as Quiet Eye, number of fixations, fixation duration, duration of first fixation and duration of last fixation, among others. When comparing both age groups, the last fixation duration was not relevant for efficacy.

Regarding the first fixation duration, longer times were associated with greater efficacy. The U16 group showed significant differences within the group regarding shot angles and first and last fixation times.

On the other hand, professional players had better jump-shot efficacy in positions and shooting angles when compared to the U16 group. However, the group of professional players did not show any differences within the group. We found between-group differences in shot position for the number of fixations, QE time and all fixation durations. Regarding shot angles, between-group differences were found for the number of fixations, QE time and all fixation durations.

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Informed Consent Statement: Participants older than 18 years provided informed consent. Youth participants assented to participate and their parents or legal guardians signed informed consent.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

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