South African Journal for Research in Sport, Physical Education and Recreation, 2021, 43(1): 85 - 95.
Suid-Afrikaanse Joernaal vir Navorsing in Sport, Liggaamlike Opvoedkunde en Ontspanning, 2021, 43(1): 85 - 95.
ISBN: 0379-9069

GAZE BEHAVIOUR IN BASKETBALL JUMP SHOT: DIFFERENCES BETWEEN EXPERT AND NON-EXPERT ATHLETES

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ABSTRACT

The aim of this study was to compare the visual patterns of basketball players of two different levels (Under-16 vs. Senior). Twenty athletes, 10 U16 (15.2±0.4 years and 7.1±2.5 years of practice) and 10 Senior (27.6±3.7 years and 18. 4±4.6 years of practice) made a total of 50 jump shots in ten different positions (shooting angles of 0º, 45º, 90º, 135º and 180º and at distances of 6.80m and 4.23m, in each of the shooting angles). Measures of unpredictability or irregularity in biological time series were analysed through the Coefficient of Variation (CV%) values of Shannon's Entropy. Results show that gaze behaviour of both age groups is characterised by an average dispersion (CV% values between 18 and 27). However, senior players presented greater jump shot efficacy compared to U16 (64.0% vs. 41.8%) and global mean values slightly lower than the U16 in the Shannon's Entropy results. The visual patterns did not differ neither between the two groups nor between the shooting distances of the jump shots.

***Keywords*:** Variability; Eye-tracking glasses; Shannon's Entropy; Jump shot; Basketball.

INTRODUCTION

According to De Oliveira and Oudejans (2005), players do not need to be able to explain how they pitch, they just need to filter information that correctly distinguishes movement. Therefore, a temporal coordination between the stimulus, the individual motor action and the way in which the player collects relevant information throughout the performance of the task is fundamental (Afonso *et al*., 2010).

Several researchers consider the jump shot the most widely used and effective shooting technique, regardless of the player's role within the team (Knudson, 1993; Okazaki *et al*., 2006; Okazaki *et al*., 2013). Research in jump shot technique shows that the main features that distinguish the shot of experienced players from less experienced ones are: (a) the initial position of the ball; (b) the alignment of the joints responsible for the impulse generation; (c) a greater range of motion; and (d) a continuous shooting action (Okazaki *et al*., 2006). In this context, Button *et al*. (2003) and Okazaki *et al*. (2006) point out that this differentiation leads to the existence of inter-variability in movement patterns between players. In less experienced players, higher levels of variability than those of experienced players also lead to a greater inter-variability in movement patterns between players.

Okazaki *et al*. (2013) showed that due to the change of movement control parameters, the increase in jump shot distance implied a decrease in its accuracy, that is, fewer hits. In youth basketball competition levels (U14 and U16) the average jump shot distance is shorter than that of seniors (Erčulj & Štrumbelj, 2015). This is due to the fact that, in throws near the basket, the ball is released closer to the maximum jump height, allowing for greater stability, shorter flight distance of the ball and lesser need to generate large amounts of momentum at the moment the ball is released (Okazaki & Rodacki, 2012). At these youth levels, especially in U14, there are some uncategorised shot types (Erčulj & Štrumbelj, 2015). These are throws that do not fit into any biomechanical pattern that characterises the basketball shot types (jump shot, hook, lay-up).

Players at youth competition levels have distinct and less efficient coordinating strategies (Okazaki *et al*., 2013), which suggests a greater instability in the performance of the jump shot when compared to more experienced athletes (Okazaki *et al*., 2015). Thus, experience is a factor that influences jump shot variability, that is, an experienced player can be associated with lower movement variability, a situation that leads to greater jump shot consistency and precision (Okazaki *et al*., 2013).

In real contexts of practice, Okazaki *et al*. (2013) suggest that the outcome of the release movement depends on constraints of the involvement (presence of an opponent, free throw), of the task (type of throw, distance to the basket) and player (physical and motor aspects) (cf. Newel, 1986). The same happens in visual tracking. De Oliveira *et al*. (2007) advocate that there is an overall decrease in inter-articular coordination strength and stability as a function of the visual condition. However, Czyż *et al*. (2019) claim that variable and constant practice conditions may lead to the development of similar gaze behaviour. The use of Eye Tracking Glasses (ETG) allows the study of eye movements and positions, identifying a certain point in space and time that is being visualised by the observer (Holmqvist *et al*., 2011).

In a systematic review, Marques *et al*. (2018) demonstrated that research in ocular movements is mainly centred in the analysis of fixations (gaze pauses over areas of interest) and saccades (quick movements between fixations), allowing also the verification of the amount of variability existing in them, while Czyż *et al*. (2015), secure that blurring vision affected the accuracy of the basketball shot. In this sense, the visual tracking strategy used by athletes is closely linked to attention (Discombe & Cotterill, 2015; Grobelny & Michalski, 2017) and reflects the way in which the eyes move relative to the stimulus to extract relevant information (Williams *et al*., 2004), preceding an effective motor behaviour (Afonso *et al*., 2010). Since basketball players are constantly changing their visual field in an attempt to obtain visual information that allows them to achieve the best performance (Ripoll *et al*., 1986; Afonso *et al*., 2010), and taking into account that there are no known studies that take a non-linear approach to the analysis of basketball jump shot (quality analysis of gaze variability), this study aims to verify if the visual patterns of U16 basketball players diverge from senior basketball players.

The Dynamic Systems Theory (DST) suggests that all biological systems self-organise according to environmental, biomechanical and morphological constraints, in order to find the most stable solution to produce a given response (Kamm *et al*., 1990; Harbourne & Stergiou, 2009), with minimum variability. Variability is inherent to biological systems and can be described as normal changes occurring in human performance after repetition of the same movement (Stergiou, 2016). Statistically, it corresponds to the variance of data relative to the mean and is usually quantified by the size of the standard deviation (Button *et al*., 2003).

Shelhamer (1998) defines a dynamic system as one in which its behaviour can be described by a set of mathematical rules as a temporal function. In this sense, the data necessary for this type of interpretation can arise both from the fixations of the athlete and from the ocular movements in relation to a given reference, represented by the *x* and *y* coordinates of the position of the eyes on a target along the time series. In this perspective, one could consider the players' visual patterns as a dynamic process that combines the set of fixations and saccades inherent to the process of extracting the maximum information from the environment (Boccignone & Ferraro, 2004). Hence, in a basketball match, different patterns of actions occur with high variability where players go through alternations of states of stability and instability, that is, order and disorder (Coelho e Silva *et al*., 2008; Figueiredo *et al*., 2009).

Accordingly, DST introduces the notions of non-linearity and stability to explain variability. The concept of Entropy is based on the observation of a time series and the state in which the phenomenon under analysis occurs. If a system has very low entropy, the next state of the system will be very predictable. However, high entropy values indicate a very high level of uncertainty relative to the next state of the system (Harbourne & Stergiou, 2009; Stergiou, 2016).

PURPOSE OF RESEARCH

Visual entropy can be considered as the analysis of Shannon's entropy based on heat maps. Representing the spatial distribution of ocular movements for a given stimulus, considering the frequency distribution (histogram) of the coordinates of each ocular movement (Couceiro *et al*., 2014). High values of entropy are indicators of a greater distribution of ocular movements along the visual field, thus suggesting greater gaze dispersion (Di Stasi *et al*., 2016). In this context and for a better understanding of emerging properties in complex systems, the analysis of data continued, considering measures of unpredictability or irregularity of biological time series (Shannon's Entropy values). This analysis was elaborated considering intra-individual and inter-individual variation.

METHODOLOGY

Participants

Twenty athletes (10 U16 players and 10 senior players) participated in this study. U16 players (15.2±0.4 years; 7.1±2.5 years of practice) belonged to two district level teams in Portugal (Coimbra and Leiria). Senior players were League 1 and 2 professional (27.6±.7 years; 18.4±4.6 years of practice).

Ethical clearance

Written and informed consent was obtained from athletes and caregivers and this study followed the code of ethics of the University of Coimbra and the assumptions of the Declaration of Helsinki in human research.

Measures

The participants performed the jump shots, after receiving the ball (Argiriou *et al.*, 2014) from their dominant side (Oudejans *et al.*, 2012), at 4.23m and 6.80m from the basket.

Exercises description

Five jump shots were performed from each position previously marked on the ground, with angles of 0º, 45º, 90º, 135º and 180º relative to the basket (5 jump shots at 6.80m and 5 jump shots at 4.23m at each throwing angle) (Figure 1). A standard basketball backboard and rim were set up inside a sports hall where the throwing positions were marked. All athletes used Wilson Solution balls. In order to capture the eye movements, the visual tracking system - SMI ETG 2W - was used.

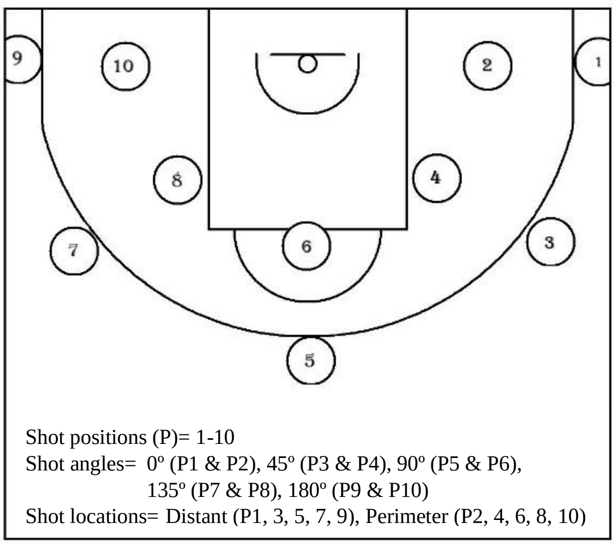

Figure 1. **SHOT POSITIONS, SHOT ANGLES AND SHOT LOCATIONS**

Design and procedures

The experimental procedures adopted were as follows: *i)* after a brief explanation of the objective of the task, athletes had 10 minutes to carry out warm-up jump shots; *ii)* the athletes wore the visual tracking system - SMI ETG 2w, at 60 Hz to determine the horizontal and vertical coordinates of their gaze towards the basket; *iii)* a three point calibration was performed before the start of the task; *iv)* a 60s break was made between each set of 10 jump shots; *v)* an offset calibration was performed before each set of 10 jump shots; *vi)* the task was performed in an indoor space and each participant was analysed individually; *vii)* a two-values score was defined to quantify the jump shots efficacy by allotting "0" points for each unconverted jump shot and "1" point for each converted jump shot.

Visual patterns analysis

Data recording started when the player fixed the ball, before receiving a pass, and ended when the player' gaze deviated off the target for more than 100ms. The tracking ratio of the players were as follows: senior players - between 99.4% and 93.3%; U16 players - between 99.6% and 92.4%.

To analyse the visual patterns, eye blinks (situations where there is no gaze information) were identified and removed from the raw data (Holmqvist *et al*., 2011; Di Stasi *et al*., 2016). Shannon's Entropy was used in data analysis *(ShEntropy)* (Stergiou, 2016). The uPATO programme (Martins *et al*., 2018) was utilised to compute the time series adopted in nonlinear data analysis.

Analysis of data

The coefficient of variation (CV%) was employed to analyse the variability of the dispersion relative to the mean value. As the CV% analyses the dispersion in relative terms, it is presented in % (CV %= $\frac{SD}{\mu}$*100). The lower the CV% value, the more homogeneous the data will be, that is there will be less dispersion around the mean. A classification based on Vaz *et al*. (2017) was used as follows: CV%≤ $\overline{X}_{CV}$–S_{CV} rated as a low dispersion (homogeneous data); $\overline{X}_{CV}$–S_{CV} < CV% ≤ $\overline{X}_{CV}$ + S_{CV} rated as a medium dispersion; CV%> $\overline{X}_{CV}$+S_{CV} rated as a high dispersion (heterogeneous data), were $\overline{X}_{CV}$ is the sampling mean of the coefficient of variation and the S_{CV} is the sampling standard deviation of the coefficient of variation. If the CV% value is ≤18%, there is homogeneous data; between 18% and 27%, there is an intermediate dispersion; and >7%, there is heterogeneous data.

RESULTS

Jump shot efficacy

Table 1 presents mean and standard deviation (%) values for the efficacy of both age groups (U16 and senior) in all jump shot conditions.

***Table 1*. COMPARISON BETWEEN GROUPS OF MEAN AND STANDARD DEVIATION OF EFFICACY IN ALL JUMP SHOT POSITIONS**

Jump Shot positions	Age group	μ of efficacy	SD
1	U16	26.00	13.49
	Sen	50.00	27.08
2	U16	46.00	23.19
	Sen	64.00	26.33
3	U16	30.00	12.64
	Sen	58.00	19.88
4	U16	48.00	30.11
	Sen	76.00	24.58
5	U16	32.00	21.60
	Sen	70.00	23.57

Continued

Table 1. **COMPARISON BETWEEN GROUPS OF MEAN AND STANDARD DEVIATION OF EFFICACY IN ALL JUMP SHOT POSITIONS** *(cont.)*

Jump Shot positions	Age group	μ of efficacy	SD
6	U16	64.00	19.32
	Sen	72.00	26.99
7	U16	36.00	22.70
	Sen	58.00	22.01
8	U16	40.00	31.26
	Sen	72.00	26.99
9	U16	38.00	25.73
	Sen	58.00	22.01
10	U16	58.00	17.51
	Sen	62.00	27.40
Total	U16	41.80	20.90
	Sen	64.00	23.42

The results of the present study indicated that senior players were better in all the shooting positions and that both age groups had better average results when shooting from perimeter positions. Senior players had a higher shooting efficacy compared to the U16 players (64.0% vs. 41.80%).

Heat maps

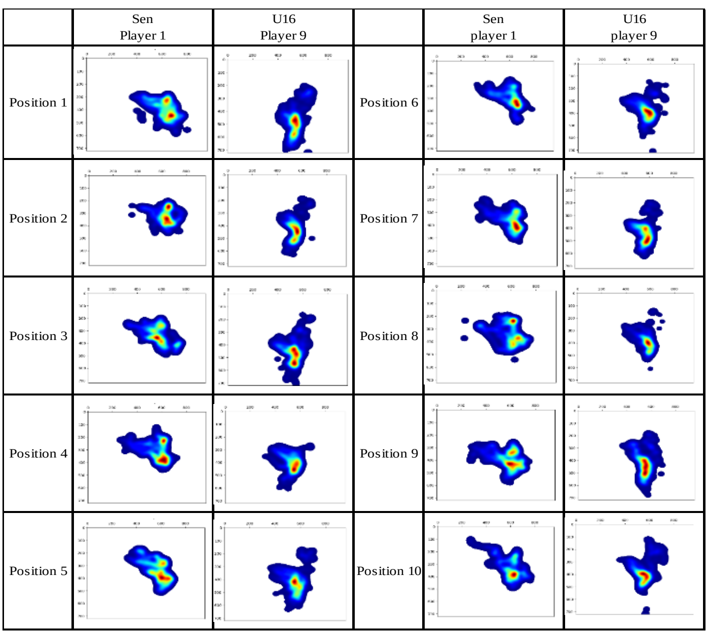

Figure 2. **HEAT MAPS OF TWO PLAYERS PER SHOOTING POSITION**

The heat map corresponds to the patterns of ocular movements of participants around the *x* and *y* axes and are considered as an egocentric frame (Lappi, 2016). The heat maps were generated using the coordinates based on the position of the eyes and not on the environment itself. This visualisation allows verification that there is not a great variability of ocular movements at intra-individual level between senior players and U16 players (Figure 2). This was used for support for the quantitative analysis (Bojko, 2009). Using heat maps, future studies can verify if there are visual signatures for each player.

Normalised Shannon's Entropy

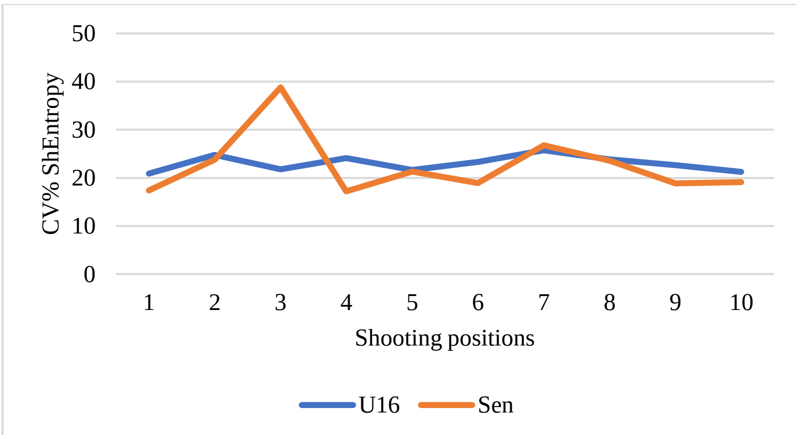

Figure 3. **COMPARISON OF CV% VALUES OF SHANNON'S ENTROPY IN TWO AGE GROUPS PER SHOOTING POSITION**

Table 2. **CV% OF SHANNON'S ENTROPY AVERAGE VALUES IN TWO AGE GROUPS PER SHOOTING POSITION**

Jump Shot positions	CV% ShEntropy U16	CV% ShEntropy Sen
1	20.886	17.362
2	24.746	23.756
3	21.788	38.788
4	24.095	17.193
5	21.638	21.292
6	23.286	18.944
7	25.732	26.733
8	23.854	23.578
9	22.650	18.843
10	21.261	19.138

Shannon's Entropy values (visual entropy) were normalised according to the maximum possible value for each participant. This normalisation consisted of dividing the entropy value obtained for each subject by the maximum entropy value that the particular time series allowed. The CV% values (Figure 3) for athletes' ocular movements, by throwing positions and by age groups are constant throughout the jump shots, but are lower for senior athletes compared to U16. However, there is a slight discrepancy of values in position 3 of the senior athletes (38.788) (Table 2).

DISCUSSION

Research on visual patterns in basketball jump shot is based on samples from adult subjects and uses linear data analysis (Marques *et al*., 2018). This study aimed to verify whether the visual patterns of basketball players during the jump shot, were affected by each player's experience. Several authors point to differences in the jump shot motor patterns between young and experienced players (Button *et al*., 2003; Okazaki *et al*., 2013, 2015; Erčulj & Štrumbelj, 2015).

The CV% values obtained for visual entropy (inferred from Shannon's Entropy values) show that, although there were slightly different values for the two groups, these were constant both in the age group and in the different shooting positions, despite the presence of a discrepancy in position 3, where senior athletes presented CV% values characteristic of a higher dispersion. Considering the actual state of the art, it cannot justify this discrepancy in position 3. Future studies should address this issue.

Regarding the jump shot throwing distance at youth level basketball, Okazaki *et al*. (2013) affirm that there is a variation in movement patterns when the distance increases, which causes the accuracy to decrease. Consequently, Erčulj and Štrumbelj (2015) state that in a match situation the average shooting distance is lower in U16 compared to the senior level.

In terms of the jump shot efficacy, the current data indicates that both age groups presented better average results in the shots made at 4.23m (perimeter area). Senior athletes achieved greater jump shot efficacy compared to the U16 (64.0% *vs*. 41.8%). This is due to, in part, the difference in weekly training volume to which each group is subjected (bi-daily training sessions for seniors *vs* three to four weekly training sessions for U16). Additionally, the number of years of deliberate practice (18.4±4.6 *vs*. 7.1±2.5) is another factor that might explain the discrepancies (Ericsson, 2008).

According to Czyż *et al*. (2019), at the level of varied practice vs constant practice, there are no changes in the gaze behaviour. Similarly, there were no differences between Shannon's Entropy values in positions at 4.23m (perimeter) and 6.80m (distant). This points to the possibility that the throwing distance is not a determining factor at a visual level, in contrast to the motor level. In short, the results obtained allow concluding that the visual patterns did not vary neither between the level of the athletes' experience (U16 *vs* seniors) nor between the distance of the jump shots. To conclude, the strength of this study is that, to the best of our knowledge, it is the first study focusing on a non-linear approach of the gaze behaviour of the basketball jump shot.

RECOMMENDATIONS

We recommend that longitudinal studies should be performed to analyse when the athlete's visual patterns stabilise. This stabilisation should be understood according to the age and/or experience of the athletes. Strategies to achieve such stabilisation can be considered in sport training when this stabilisation does not yet exist.

Acknowledgments and funding sources

This work was funded by FCT/MEC through national funds and, when applicable, co-funded by FEDER–PT2020 partnership agreement under the project UIDB/50008/2020 and partly financed by the QREN, Mais Centro – Programa Operacional Regional do Centro, FEDER (CENTRO-07-CT62-FEDER-005012; ID: 64765). Was also supported by the "uPATO"; funded project of the Telecommunications Institute, funded by UIDB/50008/2020.

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(*Subject editor: Prof. Stanislaw Czyż)*