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# Gaze behavior in basketball shooting: Preliminary investigations

HANNA STECIUK, TERESA ZWIERKO

## Abstract

Introduction. **One of the main factors influencing the efficiency of basketball shooting is visual control. Proper visual fixation toward the hoop and backboard during shooting is necessary for preprogramming various movement parameters, e.g. direction, force, velocity, timing and limb coordination.** Aim of Study. **The aim of the study was to examine the relationship between gaze behavior and shooting efficiency in basketball.** Material and Methods. **Six collegiate basketball players performed jump shots off the dribble at six various positions around the goal (perimeter and distance, beyond the three-point line). A mobile binocular Eye Tracking System (SMI ETG 2w, Germany) was used to record the numbers of fixation points, gaze-stabilizing fixation points (quiet-eye) and total fixation time during dynamic shot tasks. SMI BeGaze software and SMI Semantic Gaze Mapping technology were used for data analysis. Differences between the variables related to shot accuracy and distance from the backboard were calculated.** Results. **The results showed that the average total fixation time for accurate shots was 916 ms, with an average two points of fixation. There was a significant difference in the number of fixation points related to perimeter and distance shots. Distance shots were characterized by a greater number of fixation points than close shots (3.3 vs 2.5, $p < 0.05$). In contrast, there were no significant differences in the number of fixation points, number of gaze-stabilizing fixation points and total fixation time in relation to shot accuracy.** Conclusion. **It was concluded that gaze behavior had a partial impact on shooting efficiency. Moreover, the distance from the backboard had a significant influence on the gaze behavior of basketball players during the execution of jump shots.**

**KEYWORDS: Eye tracking, quiet eye, shooting accuracy, gaze behavior.**

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Corresponding author: hannasteciuk@gmail.com

*University of Szczecin, Department of Physical Culture and Health Promotion, Szczecin, Poland*

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**What is already known on this topic?**
Long durations of visual fixation are necessary to allow detailed parameterization of required shooting movement. Proper visual fixation toward the hoop and backboard during shooting is necessary for preprogramming various movement parameters.

## Introduction

The main element of a basketball player's skill is shooting. This ability is crucial in the game and can be described as a complex targeting skill that requires the integration of visual information, gained through overt shifts of gaze, with effectors movements that execute the aiming movement [1]. Several kinds of shots can be distinguished, e.g. shots from a stable position, jump shots and free throws – characterized by the absence of any interrupting opponents. Researchers also divide the basketball shooting techniques into low and high shooting styles, as determined by seeing or not seeing the target after the ball and hands enter the line of sight [1, 2]. In the low shooting style, the ball and hands remain below the eye level before the final extension of the elbow, after which they move in front of the face. In contrast, in the high style the ball is first carried to a position above the head followed by an extension of the elbow until it is released [3].

Experimental observations show that players use a range of shooting techniques. For example, Vickers [1] noticed the predominance of a low (hand) shooting style among the players, while De Oliveira et al. [3], using visual occlusion methods, found that a late pick up of visual information in both low and high style shooters characterized expert performance of a jump shot. In their study, long fixations were denied by virtue of intermittent occlusions. Gaze behavior was not recorded. The same researchers in 2008 [2] reported that with a more dynamic shot task (i.e. a jump shot), the low-style shooters looked at the target for half the time of a free shot (0.5s vs. 1.0s), without any consequence for their shooting performance. Those findings corroborate the view that basketball shooting is largely controlled moment-to-moment by vision, in the sense that visual information is picked up and used during movement execution. The specifics of the timing of the pick-up of optical information depend on both the prevailing shot type and the shooting style. This distinction of technique demonstrates how the arm kinematics in basketball shooting determines whether or not the basket is visible during the last elbow extension.

Shooting style is also defined as an observable characteristic in shooting distances within (at least) the 3-point line [4]. Miller and Bartlett [5] indicate that when the entry angle between the ball and the hoop is more acute, the vertical virtual target area is smaller and produces a smaller entrance area. For instance, when the ball approaches the basket from above, the passage area is given by the difference between the ball and relative basket areas. Thus, shots performed from greater distances require a higher release angle and higher accuracy.

Shooting efficiency is a combination of many factors such as proper technique, style, strength and kinematics, but visual control is one of the most significant ones. Proper visual fixation toward the hoop and backboard during shooting is necessary for preprogramming various movement parameters, e.g. direction, force, velocity, timing, and limb coordination [2].

When a player orients their gaze toward a distant target such as a basketball hoop, the most common movement of the eyes is a sequence of events in which the eyes move prior to the head [6]. There is a saccade to about 40° horizontal, which is a neural limitation for saccades from the central fixed position. The same authors explain that the eyes localize the target first, and the head follows because of its greater inertia. Visual discrimination begins immediately and is maintained on the target even though the head is moving. This movement is normally smooth, with the processing of information occurring as soon as the eyes stabilize on the target.

The role of gaze behavior has been extensively examined to identify visual search strategies and differences between skilled and less skilled athletes [7]. Basketball players have also been examined to ascertain the orientation of the gaze toward the basket that indicates better results in expert players. Studies carried out by Ripol et al. [8] show that eye–head stabilization toward the target is even more crucial when the body is moving (as in the jump shot) than when there is more postural stability (as in the free throw). In this study, monitoring of eye and head movements during the execution of jump shots by expert, intermediate and beginner shooters was investigated. The duration of head stabilization and eye–head stabilization toward the target was longer in successful shots than in misses. The results showed that skilled basketball players oriented their gaze toward the basket sooner and maintained vision in the region of the target longer than lower-skilled players did. This analysis noted that head stabilization is a reference for subsequent movements, and that the execution phase of the experts lasted 310 ms on average.

Furthermore, Vickers [1, 9, 10] conducted examinations on elite basketball players during free throws. An eye tracking system to record the gaze behavior of the expert and near expert shooters was used. The author found that those experts fixed their gaze at the hoop for a relatively long time before initiating the final shooting movements, resulting in a long duration of what was then termed ‘quiet eye’. As the author noted, the quiet eye period is a final fixation or tracking gaze that is targeted at a specific location or object in the visual-motor workspace within a 3° visual angle (or less) for a minimum of 100 ms. Target fixation durations showed that expert shooters looked at the target area more than twice as long as near experts (972 ms vs. 357 ms, $p < 0.01$). That finding implies that long durations of visual fixation are necessary to allow detailed parameterization of the required shooting movements. Vickers [1] reported that the shooting phase lasted even 476 ms on average for expert players. Interestingly, the expert shooters suppressed their vision of the target, either by blinking or looking away, as they initiated the final shooting movement of the free throw.

Those reported studies show a close relationship between shooting efficiency and gaze behavior, but the experimental protocols were varied in terms of methodology of testing. In our studies we will be trying further to develop methodological methods by using a mobile system that approximates actual game conditions.

The current study was conducted to address the issue of visual control in basketball shooting. We examined the gaze behavior of academic basketball players who were performing jump shots off the dribble. The jump shot is a dynamic task involving a whole body movement in which the relative positions between the player and the target change continuously. A dependence was assumed between shooting efficiency and gaze behavior during jump shots.

**Material and Methods**

Six female collegiate basketball players, aged 20 to 25 years (mean age = 22), performed jump shots off the dribble. Their basketball experience was from 7 to 13 years. All participants played either in the guard or forward position on the University of Szczecin team.

The local Bioethical Committee approved the research project. All participants were informed about the testing protocol and each provided their written informed consent before the experiment.

We used official FIBA regulation-sized basketballs: a standard backboard and hoop in a sports hall. We marked spots on the floor at six specific distances from the backboard, which represented typical positions in basketball shooting [11]. Four of them were on the perimeter: defined as the area outside the free throw lane and inside the three-point line, and two beyond the three-point line, on the both sides of basket.

Figure 1 shows these court positions: two of them were at 0° relative to a backboard, at a distance of 4.5 m; two at the extension of the free throw line (60°) 4.05 m from the basket; and two outside the 3 point line at 6.75 m, 45° relative to the backboard.

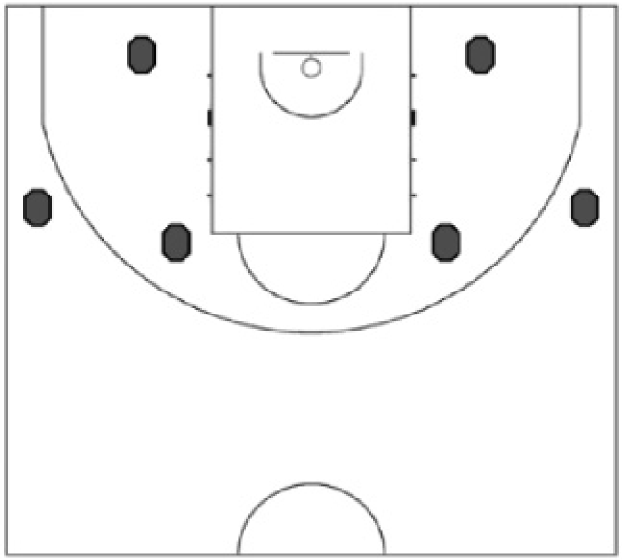

**Figure 1.** The six shooting positions used in the shooting test

Gaze behavior was registered using a mobile binocular Eye Tracking System (SMI ETG 2w, Germany) that consisted of glasses tracking the eye movements and a controller storing the video recording.

In the front of the glasses a camera (60 Hz) was mounted that registered the visible image. Inside the eyepiece were binocular infrared LEDs responding to eye movement tracking and cameras registering images of the eyes. The system recorded the field of view with a superimposed marker corresponding to the gaze direction of both eyes.

SMI BeGaze software and SMI Semantic Gaze Mapping technology were used for data analysis. Times were determined using frame-by-frame analysis. For control of the recording, offset correction by reference point was activated.

Differences between the variables related to shot accuracy and distance from the backboard were calculated. During the study we recorded the number of fixation points, gaze-stabilizing fixation points (quiet-eye) and total fixation time during the dynamic shot task, in the middle of the aiming and shooting phase. In this study the quiet-eye period was determined as a final fixation of the gaze tracking, directed at a specific location or object for minimum 100 ms.

**Main task procedure**

After a brief explanation of the task, the participants undertook individual warm-ups for about 15 minutes. Then they made several warm-up shots with the eye tracking system mounted, so that it could be adjusted and calibrated and the player could become suitably adapted to the device. At the beginning of the task, players were instructed to look at the basket and commence the main task when they were ready. Participants performed two series of 6 shoots in a particular order, as quickly as they could with a 3-minute break between the two series.

The jump shot consisted of taking several steps while dribbling the ball, then stopping and jump shooting from defined place in a continuous self-paced movement, ended with the ball rebounding and a change in position to commence the next entry. Each attempt was registered as a hit or a miss. The entire experiment lasted about 30 min. We registered the moment when the player stabilized the gaze and started looking toward the basket. For each condition we calculated the average duration of the looking behavior directed at the target (i.e. basket or backboard).

The data were classified according to the distance from the basket (perimeter or distant), and shooting accuracy. Data were averaged and analyzed offline. Initially, the data sets were analyzed using descriptive statistics (mean ± standard deviations). The STATISTICA software package (version 10.0) was used to perform all statistical evaluations according to the methods proposed by Jascanien et al. [12]. Statistical significance was set at $p < 0.05$ and Student's t test for paired samples.

## Results

The analyses covered 36 jump shots with an average 47% accuracy (Table 1). The shots were separated by the distance from the basket: close – 24 shoots, perimeter – 12 shots from beyond the 3 point line. Hits and misses were distinguished from all registered shots. Distance shots were characterized by a 75% shooting accuracy and closer shots by a 33% accuracy.

Table 2 shows results of average analyzed data parameters of gaze behavior. The total fixation time of a standard shot was 859 ms with an average of 2.8 ± 1.2 fixations and 1.8 ± 0.7 quiet-eye fixations. The longest fixation time was 1,530 ms, while the shortest 460 ms. The maximum number of fixation points was 6, and for quiet-eye points it amounted to 3.

Table 3 shows the results of fixation points, total fixation time and quiet-eye parameters in relation to shooting accuracy. The number of fixation points during accurate shots was 2.5 ± 0.9, and inaccurate shots 1.9 ± 0.7. The difference was not statistically significant ($p > 0.05$). Total fixation time of accurate shots was 916 ms, and of inaccurate was 809 ms, and the difference was not significant ($p > 0.05$). On average, there were two (1.9 ± 0.7) fixations longer than 100 ms in accurate shots, and 1.7 ± 0.7 in misses, but not statistically significant ($p > 0.05$).

Table 4 shows the results of gaze behavior in relation to the shooting distance. Perimeter shots lasted longer – 862 ms, than distant shoots – 854 ms ($p > 0.05$), even though distant shots had more fixation points. There

**Table 1.** Shooting efficiency. Numbers of shots and percentage of accuracy

| Data | All shots | Perimeter | Distant |
|---|---|---|---|
| No. of shots | 36 | 24 | 12 |
| No. of accurate shots | 17 | 8 | 9 |
| No. of inaccurate shots | 19 | 16 | 3 |
| Percentage of accuracy | 47% | 33% | 75% |

**Table 2.** Average data from descriptive statistical analysis

| Average data | $\bar{x}$ ± SD | Min. | Max |
|---|---|---|---|
| Number of fixation points | 2.8 ± 1.2 | 1.0 | 6.0 |
| Total fixation time (ms) | 859 ± 266 | 460 | 1530 |
| Quiet eye fixation points (above 100 ms) | 1.8 ± 0.7 | 1.0 | 3.0 |

**Table 3.** Comparison of the results of gaze behavior parameters and the accuracy of shooting. Data distinguished by accuracy of shooting

| Shots | Number of fixation points | | Total fixation time | | Quiet-eye fixation points (above 100 ms) | |
|---|---|---|---|---|---|---|
| | $\bar{x}$ ± SD | $p$ | $\bar{x}$ ± SD | $p$ | $\bar{x}$ ± SD | $p$ |
| Accurate | 2.5 ± 0.9 | ns | 916 ± 272 | ns | 1.9 ± 0.7 | ns |
| Inaccurate | 3.1 ± 1.3 | | 809 ± 257 | | 1.7 ± 0.7 | |

**Table 4.** Data distinguished by the shooting distance

| Shots | Number of fixation points | | Total fixation time | | Quiet eye fixation points (above 100 ms) | |
|---|---|---|---|---|---|---|
| | $\bar{x}$ ± SD | $p$ | $\bar{x}$ ± SD | $p$ | $\bar{x}$ ± SD | $p$ |
| Perimeter | 2.5 ± 1,0 | * | 862 ± 269 | ns | 1.8 ± 0.7 | ns |
| Distant | 3.3 ± 1,4 | | 854 ± 272 | | 2.0 ± 0.7 | |

*$p$ < 0.05

was a significant difference ($p < 0.05$) in the number of fixation points between perimeter (2.5 ± 1.0) and distant shots (3.3 ± 1.4). The number of quiet-eye fixations was similar between perimeter (1.8 ± 0.7) and distant shots (2.0 ± 0.7).

In contrast to this, in relation to shot accuracy there were no significant differences in the number of fixation points, number of gaze-stabilizing fixation points, and total fixation time.

## Discussion

The purpose of this study was to determine gaze behavior when aiming at a distant target. We examined the relationship between gaze behavior and shooting efficiency in basketball. The study was placed within the context of a basketball jump shot as a dynamic task involving changing positions between the player and the basket. The used mobile measuring system approximated real game conditions. We supposed that there was dependence between shooting efficiency and gaze behavior during a jump shot. Our main findings show only that: (1) the average total fixation time of accurate shots was 916 ms, with an average two points of fixations; (2) there was a significant difference in the number of fixation points between perimeter and distant shots; (3) players who were performing distant shots were characterized by essentially a greater number of fixation points than when shooting from the close distance.

The distance from the backboard had a significant influence on the gaze behavior of basketball players during the jump shots with fewer fixation points for closer shots, and more for shots from a distance. Our results also suggest that perimeter shots need faster aiming and movement decision. In contrast, there were no significant differences in the number of fixation points, number of gaze-stabilizing fixation points and total fixation time in relation to shot accuracy.

Vickers [1] states that a long duration of visual fixation is necessary to allow detailed parameterization of the required shooting movements, and that blinking or looking away is a suppression of vision to reduce interference between the visual and motor systems. The same researcher found that expert shooters looked at the target area for 972 ms, which implies that long durations of visual fixation are better in allowing detailed parameterization of the required shooting movements. Our results of accurate shots (916 ms) are close to the findings of Vickers. Longer quiet eye periods gave players an extended programming duration while minimizing distractions from other environmental cues. Our results show that a greater distance allows a longer quiet-eye fixation than in the closer shooting positions.

On the other hand, Oudejans et al. [11] challenged the notion that accurate shooting should always involve extensive preprogramming of movements. In their study seeing the target for only 397 ms was sufficient for a successful jump shot. Other researchers [3] showed that in dynamic far-aiming tasks such as basketball jump shooting, late pick-up of optical information is crucial for the successful guidance of movements, although long target fixations have only been noticed in static self-paced tasks, where the positions of both the player and the target are constant. In dynamic sports games, a variety of distance aiming tasks are used very often, and, frequently, there is less time for a greater number of long fixations and elaborate movement programming. Even though our studies found that in every kind of shooting category, an average two points of quiet-eye fixation points were recorded (longer than 100 ms).

In our opinion, further research into the issue is necessary as gaze behaviors during sports still remain largely unknown. A limitation in this study is that the number of participants was relatively low and their performance was at or near expert level. Future experiments can thus determine the relative contribution of predisposition and practice. We believe the results of the present study establish a basis for future studies probing more directly into the relationships between gaze behaviors and shooting accuracy in basketball.

Despite its exploratory nature, this study makes several noteworthy contributions to training practice in basketball. We believe that the practical implications of such studies will help improve the training process of basketball players. Also, investigating the informational basis of gaze behavior in basketball shooting is an exciting path for future research.

## Conclusion

The present study reveals that gaze behavior has a partial impact on goal-shooting efficiency, characterized by a longer total fixation time and fewer fixation points in accurate shooting, but there were no significant differences in the collected data on the number of fixation points in relation to shot accuracy. Future research should attempt this.

**What this study adds?**

The used mobile eye tracking system that permitted a study in approximated real game conditions, and allowed us to prepare a dynamic shooting test that developed methodological improvements. Player gaze behavior was being examined while the players were performing a dynamic exercise of jump shots off the dribble. This is the first such data available on dynamic tasks using a mobile eye tracking system, and it has provided valuable results.

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