



VISUAL FIXATION IN NBA FREE-THROWS AND THE RELATIONSHIP TO ON-COURT PERFORMANCE

Daniel M. Laby, MD
Private Practice, New York, NY.

Corresponding Author: drlaby@sportsvision.nyc

Submitted: October 13, 2019. Accepted: December 17, 2019. Published: January 6, 2019.

ABSTRACT

Purpose

Although hitting a baseball is often described as the most difficult task in all of sports, shooting baskets during a game likely ranks a close second. Previous studies have described the role of vision in basketball and more specifically a concept termed the “quiet eye” is related to basketball performance. How a shooter visualizes the target, how consistent their visual fixation is, and how long they maintain that fixation has been correlated to shooting success. Although the majority of previous reports have included non-professional basketball shooters, we evaluated NBA (National Basketball Association) players to determine if this skill was significant at the professional level.

Materials and Methods

We evaluated 16 professional NBA players before to the 2018-2019 NBA season. All players shot 30 consecutive free-throws while wearing Tobii Pro eye-tracking glasses. Following the completion of the task, several metrics were calculated including shooting success rate, as well as four measures of the position and duration of ocular fixation just prior to, during, and immediately after ball release for each shot of each player. Additionally, player performance statistics from the 2018-2019 season were recorded and compared to the visual fixation data. Descriptive statistics, as well as correlations between the visual fixation metrics and on-court performance metrics, were calculated.

Results

NBA shooters averaged a 79% success rate in free throw (FT%) shooting (SD = 14%, min = 56%, max=100%) during the study. Moderate statistically significant correlations were found between the percentage of successful free throws and the four measures of visual fixation ($r=0.539$ to 0.687). In addition, visual fixation measures were found to be correlated with on-court metrics suggesting that shooters who had more frequent, as well as longer, fixations on the rim were more likely to have lower Usage Percentage

(USG%), and Offensive Rebound Percentage (ORB%) as well as higher Three-Point Field Goal Percentage (FG3%). The percentage of successful shots in the study was compared to the on-court FT% and found to be moderately correlated ($r=0.536$).

Conclusions

The need to maintain ocular fixation on the rim while shooting seems elementary, but varies greatly among NBA players, as noted in these results. Our data suggest that players who visually fixate longer and more frequently on the rim are more likely to be successful in free throws, as well as more successful in 3-point goals, but less successful in offensive rebounds. The reduced offensive rebound percentage is possibly related to their being more distant from the basket when attempting 3-point goals. This data set appears to describe basketball guards in contrast to forwards/centers and supports previous research on non-professional basketball players.

Almost 25 years ago, Prof. Joan Vickers described the differences between basketball free-throw success and the length of time, as well as when, the shooter visually fixated on the target.¹ This work, as well as many subsequent publications, have termed this ability the *quiet eye* (technically the length of the final fixation just before the task's motor final movement) and have highlighted the importance of visual fixation in sporting success.

Subsequent research has further described the intricate relationship between stationary shooting (i.e., free throws) and dynamic shooting (i.e. jump shots) as well as shooting style. For example, Oudejans et al.² differentiated jump shots from other static shooting tasks. In their report they describe different shooting styles (high vs low) and at what point during the task visual information is critical. Using ocular occlusion, they created four different shooting scenarios. The scenarios provided the shooter full vision while taking the shot, no vision while taking the shot, the initial vision (up to 350 ms before taking the shot), and late vision (the final 350 ms of vision before taking the shot). The authors found that for shooters with a high shooting style, vision in the final 350 ms before the shot was critical to success. The authors further concluded that "shooting style and visual control develop in close correspondence."

More recently, Zwierko et al³ noted similar differences as reported by Oudejans et al in free throw vs jump shots. In their study, the shooters performed a shooting task following a 60-second fatigue protocol. They found more frequent fixations and longer fixations in free throws as compared to jump shots as well more frequent fixations in free throws and more

variable fixations in jump shots following exertion and fatigue. Wilson et al⁴ found similar results with a 19% decrease in performance and a 45% decrease in quiet eye following acute, severe intensity exercise (cycling).

Additionally, not only are there differences in visual fixation between static and dynamic tasks, as well as with exertion, but other factors such as contested shots, and age also play a role in the quiet eye and shooting success. In a 2018 report, Klostermann et al⁵ described the effect of shooting in a defended vs non-defended scenario for intermediate and highly skilled basketball shooters. Their report describes the beneficial effect of longer quiet eye durations in defended, but not in the undefended, the scenario on shooting performance. They also noted that the onset of the quiet eye as well as the offset of the quiet eye was related to shooting success. They conclude that not only is the quiet eye duration important, but its timing relative to the task is important as well.

Interestingly, Fischer et al⁶ compared free throw shooting ability and quiet eye duration in younger vs. older shooters. As might be expected, they found a reduction in shooting accuracy in the older cohort. But somewhat surprisingly, they found that the quiet eye duration remained unchanged in the older population as compared to the younger population. They concluded that although motor performance is reduced with age, perceptual motor skills appear to be maintained with advanced age.

Fortunately, the quiet eye can be trained with resulting in improved basketball shooting ability and success. Several reports⁷⁻⁹ comparing trained, untrained, as well as

sham quiet eye training groups suggest that at least in an uncontested situation, quiet eye trained shooters are more successful than non-quiet eye trained subjects. In some reports, this increased ability does not seem to transfer to situations involving contested shots and defensive pressure. The consensus though, does suggest a benefit to specific quiet eye training in basketball shooting.

This project is intended to further describe the quiet eye, in a cohort of professional NBA (National Basketball Association) athletes, and its relationship to on-court performance metrics. Many previous reports have described the quiet eye in novice, near expert and expert athletes at many levels; this report describes the phenomenon, and its relationship to on-court performance, in high elite professional NBA athletes who would be expected to be the most expert in this ability.

MATERIALS AND METHODS

Participants

Sixteen professional basketball players were included in this report. Athletes were evaluated during routine evaluation in the 2018 pre-season training camp of a single NBA (National Basketball Association) team. Thirteen of the 16 players were available for analysis as two players did not have 2018 on-court season performance data and one player's data was removed after reporting that he purposely did not try to make the free throw shots during the testing session. All the players were male. This retrospective review was conducted in accordance with the US Department of Health and Human Services "Regulatory consideration regarding classification of projects involving real-world data" and was exempt from regulation per 45 CFR §46.104(d)(4). All data was utilized without the inclusion of any protected health information and informed consent as it is classified as secondary research.

Testing was conducted with the Tobii Pro 2 eye tracking system (Tobii Technology, Inc, Falls Church, VA). Once testing was completed, raw data were analyzed with the Tobii Pro Lab software on a Microsoft Windows Surface Pro computer.

Testing Procedure

Each player was instructed to take 30 consecutive free-throw shots following a player determined number

of "warm-up" shots. Testing was conducted on the team's practice court using NBA regulation distances and rim/backboard dimensions. While taking the 30 free throws, the Tobii Pro 2 glasses were worn, and each shot was recorded using the built-in software. Following the completion of shooting for all of the subjects, the data files were transferred to the Tobii Pro Lab software and analyzed. The data analysis software allows the calculation of several visual fixation metrics resulting from the thirty free-throws. After specifying an area of interest, in this case, the rim and surrounding backboard (Figure 1), it was possible to calculate the number of times the shooter visually fixated on a location within the area of interest (fixation count), the number of times his fixation left and re-entered the area of interest (visit count), and the total amount of time his fixation remained within the area of interest (total duration). The "% shots made" defined as a percentage of the fraction of shots successfully made divided by the total number of shots (in this case 30) was calculated for each player.

FIG. 1 Area of basketball rim, and backboard, used to determine optimal visual fixation during free-throw shots.



Basketball Performance Metrics

There are many metrics of on-court performance calculated for each NBA player each season, based on their performance on the court. We chose several which appeared to likely be related to visual fixation.

We chose four on-court measures from the 2018–2019 season to include in this analysis.

On-Court Performance Metrics:

1. Free throw percentage (FT%) – percentage of the total number of free throws made divided by the total number of attempts.
2. Three-point field goal percentage (FG3%) - percentage of the total number of 3-point shots made divided by the total number of attempts.
3. Offensive rebound percentage (ORB%) – percentage of the available offensive rebounds a player achieves while he is on-court.
4. Usage percentage (USG%) – percentage of team plays a specific player was involved in while on the court.

Statistical Method

The results were tabulated on a Microsoft Excel spreadsheet. 2018-2019 season on-court performance statistics, for each athlete, were combined with their eye fixation data. Descriptive statistics, scatterplots, and Spearman correlation statistics were calculated (Minitab statistical analysis program for Mac OS, version 19 by Minitab, LLC State College, PA). Statistical significance was set at the 95% confidence level ($p \leq 0.05$).

RESULTS

Descriptive Statistics

Descriptive statistics for the vision as well as on-court metrics are presented in Table 1. A review of the table reveals that the player cohort played in an average of approximately 48 games (SD 34.14). The average percentage of successful free throws (of the 30 each athlete attempted) was 79.29 % with a range of 56.67% to 100%. The average visit count was 45.93 \pm 16.68, the average fixation count was 56.65 \pm 23.52, and the average total duration was 48.95 \pm 34.50. On-court performance metrics for the 2018-19 NBA basketball season for this group revealed an average FT% of 74.75% \pm 13.19% ranging from a minimum of

48.10% to a maximum of 100%. The FG3% mean was 32.26% \pm 10.08%, the average ORB% was 4.64% \pm 2.87%, and the average USG% was 17.71% \pm 5.48%.

METRICS

Relationship Between Shots Made and Visual Fixation Metrics

If the visual fixation metrics are indeed related to a professional basketball player’s ability to successfully shoot free-throws, we would expect statistically significant correlations between the fixation metrics and free throw ability. Table 2 as well as Figure 2, describe the relationship between the three visual fixation metrics and free throw success in our study sample.

TABLE 1 Descriptive Statistics for the Vision as Well As On-Court

	Mean	Std	Min	Max
% shots made	79.29	14.45	56.67	100.00
visit count	45.93	16.68	19.00	67.00
Total duration	48.95	34.50	7.68	117.77
fixation count	56.64	23.52	23.00	88.00
G	48.38	34.14	7.52	116.87
FT%	74.75	13.19	48.10	100.00
FG3%	32.26	10.08	0.00	42.00
ORB%	4.64	2.87	0.90	9.70
USG%	17.71	5.48	11.20	33.90

TABLE 2 The Relationship between the Three Visual Fixation Metrics and Free Throw Success

	% Shots Made	Visit Count	Total Duration	Fixation Count
% shots made		0.011	0.047	0.007
visit made	0.653		0.001	<0.001
Total duration	0.539	0.802		0.001
fixation count	0.687	0.970	0.801	

FIG. 2 Scatterplot of visual fixation metrics by percentage of shots made during study. Note the positive relationship of each metric to shooting success.

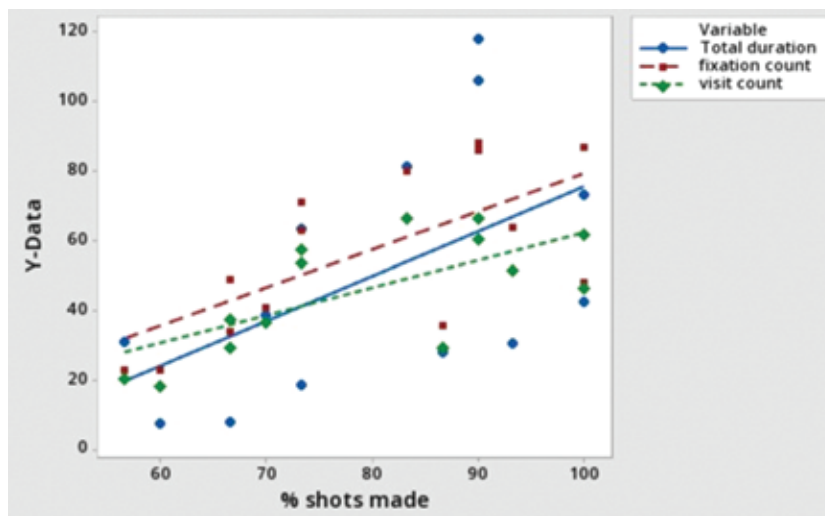
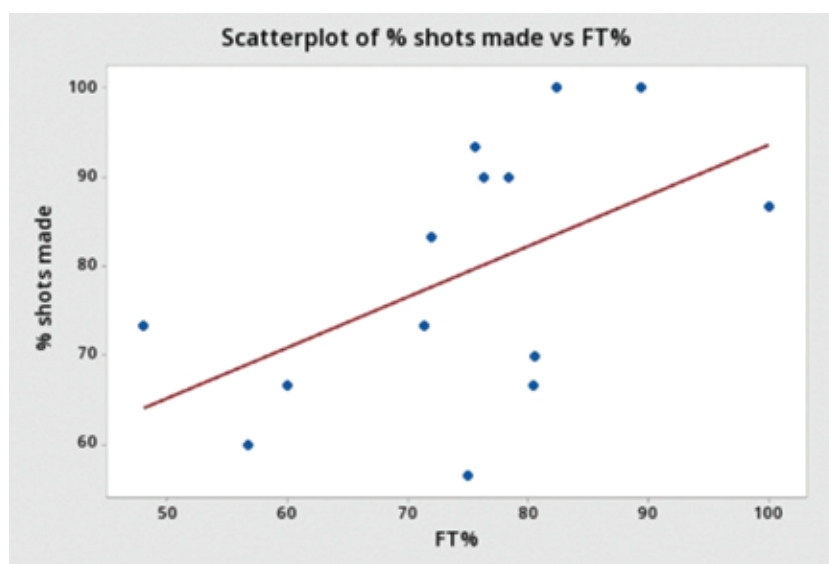


FIG. 3 Scatterplot of % shots made vs Free Throw percentage (FT%). Note the positive relationship indicating a better FT% in those players who made a greater percentage of the 30 free throws in the study.



Spearman correlation coefficients (r) are noted in the lower-left portion of Table 2, and corresponding p-values are noted in the upper-right portion of the table for each parameter combination. Correlations ranged from 0.970 for visit count and fixation count to 0.539 for Total duration and % shots made. All correlations were statistically significant, although for Total duration vs % shots made the p-value was 0.047. Figure 2 demonstrates the relationship between

% shots made and the other three visual fixation metrics. The figure graphically demonstrates the positive relationship between these parameters as noted by the Spearman r values.

Relationship between Visual Fixation Metrics and On-Court Performance Metrics

A positive correlation between FT% during the season and % shots made during the study was anticipated and found. Figure 3 graphically demonstrates

the relationship, while statistically, a correlation of 0.536 ($p=0.048$) was found.

Also, each of the visual fixation metrics were compared to the remaining on-court metrics as described in Table 3. None of the on-court metrics were correlated to the fixation count metric, while all three on-court metrics demonstrated correlation to the total duration metric ($r= -0.565$ to $+0.604$), and visit count was correlated to USG%. All correlations were statistically significant (p 0.022 to 0.035).

Figure 4 graphically demonstrates these relationships, specifically as total duration increases an increase in 3-point field goals is noted as well as a decrease in ORB% and USG%.

DISCUSSION

These results confirm, and highlight, the importance of visual fixation for successful basketball shooting. Precisely where and for how long a shooter fixes on

TABLE 3 Visual Fixation Metrics Were Compared to the Remaining On-Court Metrics

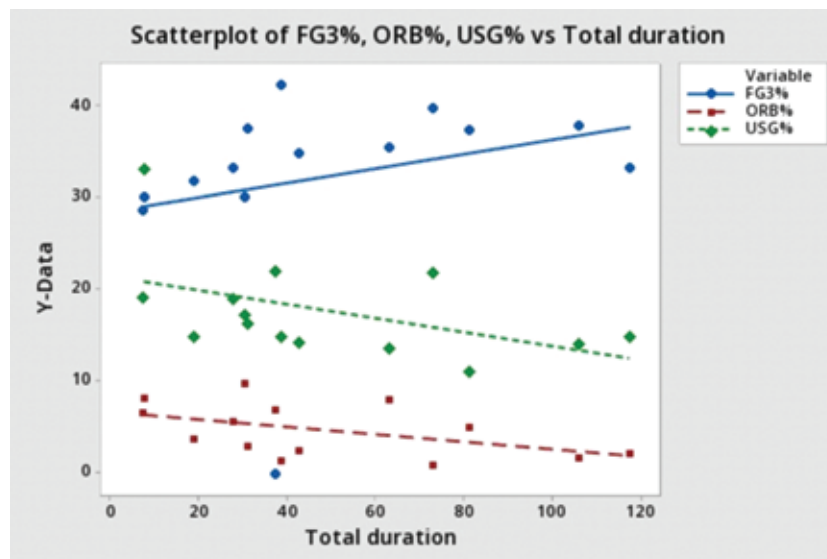
	USG%	FG3%	ORB%
visit made	-0.577		
Total duration	-0.598	0.604	-0.565

the target is correlated to both free-throw as well as 3-point field goal success. Additionally, it appears that the NBA players in this cohort with better visual fixation tended to gain fewer offensive rebounds as well as be involved in fewer plays while they were on the court. This could be a reflection of the fact that they are more confident shooters, more successful 3-point shooters, and thus a greater distance from the basket precluding their ability to rebound offensively.

A review of the scientific literature found only a single report comparing a visual function in professional NBA players to on-court performance. Mangine et al,¹⁰ in a 2014 report, demonstrated that athletes who were able to visually track faster-moving multiple targets were noted to have a greater ability to see and respond correctly to on-court stimuli as compared to athletes who were unable to track the targets successfully. The report notes that guards, in general, were superior to forwards/centers in their ability to track the faster targets leading to a greater number of assists and steals, as well as fewer turnovers. It might be interesting to compare the athlete’s visual tracking ability to their visual fixation ability, by on-court position, in future research.

We were both pleased as well as surprised by the only moderate correlation between free throws

FIG. 4 Scatterplot of total duration vs each of the visual fixation metrics. As total duration increases, there is a corresponding increase in 3-point field goals noted along with a decrease in ORB% and USG%.



taken during the training camp and free-throws shot during a game. As noted above, many factors can affect shooting ability, and there is likely a significant difference between shooting in a pre-season training camp without any spectators, or an opposing team, and shooting during a game that could be won or lost depending on the success of the shot. Despite these differences, we anticipated a greater degree of correlation between these otherwise similar tasks.

Of the visual fixation metrics, the total duration metric appears to be the most important to on-court performance. The total duration metric was correlated to each of the on-court performance metrics included and it was highly correlated to two other visual fixation metrics (visit count and fixation count; $r=0.801-0.802$) and moderately correlated to % shots made. This finding confirms the original premise of Dr. Vickers as well as the work of other researchers who emphasized the duration of the quiet eye as being fundamental to success. The number of fixations within the target region or the number of fixations into the target region appears to be less critical than the actual amount of time the shooter fixes on the target area.

These data appear to describe the characteristics of the basketball guard position in contrast to forwards or centers. Specifically, the shooter with longer visual fixation patterns on the basket appeared to be more successful at shooting not only free-throws but 3-point field goals as well. In addition, the athlete with longer visual fixation patterns gained fewer offensive rebounds and appears to perhaps pass the ball less (likely shooting more) all of which are very similar in many aspects to what one would expect from the basketball athlete at the guard position. Perhaps, these metrics can be used to guide a team in evaluating players in the future.

Despite the relatively small cohort, several measures were sufficient to show statistically significant correlations. Future work will hopefully expand the number of players that are included in this analysis in order to better define the relationship between these measures of visual function and on-court basketball performance.

This report highlights the importance of vision in basketball performance, specifically what and for how long a player fixes on the basket prior to,

during and just after making a shot. We hope that this work will aid athletes to be more successful in shooting and provide a pathway to improve any deficiency found.

AUTHOR CONTRIBUTIONS

DML designed and performed the study, prepared the manuscript, and performed the statistical analysis and data review.

COMPETING INTERESTS

None.

REFERENCES

1. Vickers JN. Visual control when aiming at a far target. *J Exp Psychol Hum Percept Perform* 1996; April; 22(2): 242–54.
2. Oudejans RRD, van de Langenberg RW, Hutter RI. 2002. Aiming at a far target under different viewing conditions: Visual control in basketball jump shooting. *Human Movement Sci* 2002; 21:457–80.
3. Zwierko T, Popowczak M, Wozniak J, Rokita A. Visual control in basketball shooting under exertion conditions. *J Sports Med Phys Fitness* 2018 Oct, 58(10):1544–53.
4. Wilson MR, Webb A, Wylie LJ, Vine SJ. The quiet eye is sensitive to exercise-induced physiological stress. *Prog Brain Res* 2018;240:35–52.
5. 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 May;36(9):1054–60.
6. Fischer L, Rienhoff R, Tirp J, et al. Retention of quiet eye in older skilled basketball players. *J Mot Behav* 2015;47(5):407–14.
7. Harle SK, Vickers JN. Training quiet eye improves accuracy in the basketball free throw. *Sport Psychol* 2001;15:289–305.
8. Vine SJ, Wilson MR. The influence of quiet eye training and pressure on attention and visuo-motor control. *Acta Physiologica* 2011;136(3):340–6.
9. Vickers JN, Vandervies B, Kohut C, Ryley B. Quiet eye training improves accuracy in basketball field goal shooting. *Prog Brain Res* 2017; 234:1–12.
10. Mangine GT, Hoffman JR, Wells AJ, et al. Visual tracking speed is related to basketball-specific measures of performance in NBA players. *J Strength Condit Res* 2014;28(9):2406–14.