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The Effect of Visual Stimuli on Free Throw Dynamics in Basketball

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Abstract: *The present study aims to examine the influence of visual stimuli on the dynamics of free throws in basketball. The sample consisted of 25 athletes, comprising 16 junior athletes and 9 senior athletes, who practice basketball with two teams in the city of Braşov, Romania.*
The experiment was applied to two samples of female subjects. The first sample consisted of 16 basketball players from CSM Corona Braşov, in the Under 16 category, aged between 14 and 16, with an average of 5 years of basketball experience. The second sample included 9 senior basketball players.
Data was collected from two types of tests. The first test was conducted during training sessions in the pre-competitive phase and involved performing 10 free throws, recording the number of successful attempts. The second type of test focused on collecting the percentage of successful free throws from both friendly games in the pre-season and official games.
The results generated from the analysis of the collected data (training sessions vs. friendly & official games) under the presence of technical equipment during the training process are surprising, as they invalidate the working hypothesis in the case of senior athletes.

Keywords: *basketball free throw; visual stimuli; free throw efficiency; tehnical equipment.*

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Introduction

Enhancing human beings through sports and achieving sports excellence are strategic objectives of high-performance sports. The design and implementation of innovative technologies in the sports training process and the conduct of advanced scientific research based on identifying the impact and efficiency of these technologies are major concerns for sports professionals (Lavrin, 2017; Benson et al., 2020). The implementation of specialized technologies in sports facilitates the learning and correction of technical executions in near-real-time through corrective feedback, which leads to the optimization of sports performance capacity (Lavrin, 2017; Benson et al., 2020; Berg et al., 2023). The revolutionary contributions of innovative technology in sports are multiple and significant, targeting the capacity to monitor and analyze performance through advanced sensors, software, and specialized wearable devices in basketball (Chen et al., 2021; Cheng et al., 2022).

Providing accurate data and real-time video analysis through the contribution of specialized innovative technologies facilitates the improvement of sports performance by modeling training methodologies, examining and correcting technical executions, and establishing training and competition strategies (Chen et al., 2021; Cheng et al., 2022).

Specialized sports technologies facilitate the analysis of kinematic parameters of movements, ball trajectories, etc., enabling fine-tuning of movements based on data and video images (Berg et al., 2023; Chen et al., 2021; Cheng et al., 2022).

The implementation of innovative technologies in basketball training leads to the optimization of motor learning (based on feedback) and motor control of technical skills through the formation of reflexive, automated movements adaptable to varying conditions (Kos et al., 2018; Milley & Ouellette, 2021).

The efficiency of free throws in basketball, which represents one of the most important technical finishing skills, seems to be influenced by biomechanics and the accuracy of the technical execution (Giancamilli et al., 2022; Slegers et al., 2021). The accuracy of the free throw depends on the anthropometric characteristics and posture of the player, the biomechanics of the execution, and the value of the angles of the joints involved in the movement, trajectory, force, and speed of the throw (Pakosz et al., 2021; Kurano et al., 2015). Recent studies have shown that free throws have a series of kinematic parameters that

influence their efficiency: the height and speed of the launch, the maximum height of the ball in the air, the angle at which the ball enters the basket, etc. (Ammar et al., 2016). The free throw accounts for 20% of the total points scored in the NCAA championship (USA), becoming even more important in the game's economy in the last 5 minutes of the match, sometimes determining the game tactics adopted, significantly influencing the final outcome of the game (Kozar et al., 1994).

The ideal execution involves the ideal angle of ball launch for free throws to be between 52 and 53°, with the ball's peak trajectory being 4 cm below the top edge of the backboard, complemented by the existence of 3 backspin movements of the ball per second to reach the point located 7 cm behind the center of the basket (Tran & Silverberg, 2008). The success of a free throw is ensured by the coordination of specific movements in relation to the anthropometric aspects of the players, the posture during the throw, and the different levels of consistency between the angles of the joints involved in the movement and the speed of the throw (Pakosz et al., 2021). The ball's path toward the basketball hoop is analyzed in terms of its physical components in numerous specialized studies, with complex mathematical models of the free throw in basketball being developed through angles, forces, distances, heights of the players, and specific deviations, considering that taller players are advantaged in this case (Gablonsky & Lang, 2005).

In basketball official games, the only type of throw where all variables are constant is the free throw, which is executed from the same spot, without dynamic movement (stationary), with the same certified ball (weight, material, size), and the distances to the target (basketball hoop) being constant both vertically (4,224 mm, the distance between the free-throw line and the projection of the hoop's center on the ground) and horizontally (3,050 mm). The target has an inner edge diameter between 450 and 459 mm, and the size 7 ball used in men's competition has a diameter between 238 and 245 mm, while the size 6 ball used in women's competitions has a diameter between 227 and 232 mm (FR Basket, 2024)

Typically, all basketball players execute this type of throw by positioning themselves at the middle of the foul line, perpendicular to the basketball backboard. The throw trajectory is determined by the angle of the ball's launch and the release point (distance from the ground and distance from the hoop). Mathematically, the ball's trajectory toward the hoop has an ascending and a descending part, where mechanical work is expended. The stability of the ball in flight is ensured by its backspin

movement (Gablonsky & Lang, 2005). The ball's trajectory can be flat, medium, or high, with the launch angle and release point influencing the angle of entry into the hoop. It should be noted that most basketball players do not use the backboard as an aid for this type of throw, executing the technical procedure directly at the basketball hoop.

The aspiration to identify a solution for successful free throws in basketball is materialized through a multitude of studies and research. In this context, the optimal conditions for successful free throws, the influence of independent variables, disturbing factors, and consequently the external environment, methodologies, and training methods applied, the introduction of information technology in the specific training process, and more recently, even applications for mobile computing devices have been analyzed (Tran & Silverberg, 2008; Price, 2008; Mascret et al., 2022; Cheng et al., 2022; App Store, 2024). In terms of the ball's trajectory, complex mathematical models have been developed but without practical applicability in the specific training process (Tran & Silverberg, 2008; Gablonsky & Lang, 2005; Olteanu et al., 2023).

The Noah Shooting System (NSS), developed in the USA, aimed at analyzing the angle of the ball's entry into the hoop following a successful free throw and specifying it audibly in the form of a number (Noah Basketball, n.d.). Another scientific research shows the efficiency of correcting the ball's trajectory with the help of modern technology. Thus, the subjects were introduced during training to a device that, in near-real-time during a free throw in a basketball game, projects the ball's trajectory onto a projection surface indicating the ideal trajectory for the performer. This ideal trajectory of the ball generated by the athlete is established and determined through video kinematic analysis, with the purpose of the ball's trajectory projection in the air on the optimal path being to influence the neuromuscular adjustment of the execution based on the ball's path. In the mentioned study, the innovative device was implemented for 360 subjects from 3 age categories, resulting in a notable increase in the percentage of successful throws for each category (Olteanu et al., 2023).

From a technical perspective, current technology can accurately study and analyze the trajectory of the ball during the flight phase following the execution of a free throw (Przednowek et al., 2018), provided that the distance from the ground of the key points is known, as well as specific deviations (the ratio of competitive ball sizes (size 7 – male, size 6 – female) to the basketball hoop size).

The importance of free throws in basketball has been highlighted in numerous previous studies (Oancea & Ionescu, 2015; Oancea, 2016a; Oancea & Bondoc-Ionescu, 2015), and their efficiency can be a criterion for a model of improving secondary selection strategy (Oancea, 2016b). The positive intervention of technology in the sports training process can also be applied to the development of motor qualities, providing valuable information that can be used to adjust, adapt, or modify the content of specialized training (Petre et al., 2022), as well as to improve peripheral vision and reaction time in various athletes (Badau et al., 2023; Gorgan et al., 2023; Badau et al., 2023). Through the implementation of technology or specific equipment in sports training, basketball can become a tool for evaluating both specific interventions (Lakotos et al., 2024) and for motor qualities development (Gorgan et al., 2024), leading to increased confidence or self-esteem in athletes (Ababei et al., 2019).

Study methodology

The study methodology required the use of technical and IT equipment to mark successful free throws with a visual signal. This was achieved by placing an infrared sensor at the lower part of the backboard using two clamps for fixation. The sensor was positioned so that when the basketball passed through the hoop and was guided by the net, it interrupted the laser beam from the sensor. The signal sent by the sensor, when the ball crossed its path, was translated by a device into a visual signal – a red LED strip placed along the edges of the backboard's inner side. The visual signal would be visible for one second when a free throw was successful.

The experiment was applied to two samples of female subjects. The first sample consisted of 16 basketball players from CSM Corona Braşov, in the Under 16 category, aged between 14 and 16, with an average of 5 years of basketball experience. The second sample included 9 senior basketball players from CSU Braşov, aged between 24 and 40, most with extensive competitive experience.

For the junior category, over a 4-week training period prior to the start of the competitive season, totaling 18 indoor training sessions, and the technical system was used every time free throws were practiced. Its setup was easy, as the sensor and LED strip remained attached to the backboards, requiring only connection to a power source to operate.

For the senior players, data collection was done in the same way as for the juniors but over a shorter period of just 2 weeks. This intervention

aimed to engage the athletes more actively and provide additional satisfaction for successful free throws through the visual stimulus.

Following this intervention period, a standard test of 10 free throws (Test 10) was conducted with all 25 subjects. The percentage of successful free throws during training sessions was then compared with the results from two official games and five pre-season practice games for the senior sample, and four official games and four friendly matches for the junior athletes. We must acknowledge that during official games, we had a significant advantage in data collection since free throws are part of the official statistics compiled for each game, as required by the Romanian Basketball Federation.

Ethics approval and consent from the participants were obtained. After being informed about the objectives and procedures of the study, the participants' representatives provided informed consent for participation (including information about the possibility of withdrawing without any impact on their status), which adhered to internationally accepted ethical standards.

Results

After collecting the data, it was compiled into tables, as follows:

Table 1. Results of Test 10 – Training Session

Junior athletes	Test 10 (FT made)	Percentage (%)	Senior athletes	Test 10 (FT made)	Percentage (%)
Subject 1	6	60	Subject 1	8	80
Subject 2	5	50	Subject 2	7	70
Subject 3	6	60	Subject 3	7	70
Subject 4	5	50	Subject 4	8	80
Subject 5	6	60	Subject 5	7	70
Subject 6	5	50	Subject 6	6	60
Subject 7	4	40	Subject 7	7	70
Subject 8	6	60	Subject 8	7	70
Subject 9	5	50	Subject 9	7	70
Subject 10	4	40			
Subject 11	4	40			
Subject 12	5	50			
Subject 13	4	40			
Subject 14	6	60			
Subject 15	5	50			
Subject 16	6	60			
$\bar{x}$	**5,13**	**51,3**		**7,11**	**71,11**
σ	**0,81**	**8,1**		**0,61**	**6,1**
V	**15,73**	**15,73**		**8,45**	**8,45**

From the analysis of the presented data, it is observed that junior athletes achieve an average success rate of 51.3% for free throws, which is significantly lower than the 71.1% recorded by senior athletes.

It is worth noting the value of the standard deviation and, consequently, the coefficient of variation, which provide stability and relevant statistical significance for this research, both for the junior sample and the senior sample.

Table 2. Results of Friendly & Official Games - Free Throw Percentage

Junior athletes	FT total	FT made	Percentage (%)	Senior athletes	FT total	FT made	Percentage (%)
Subject 1	12	6	50	Subject 1	18	14	77,78
Subject 2	8	3	37,5	Subject 2	24	18	75
Subject 3	6	3	50	Subject 3	16	11	68,75
Subject 4	2	1	50	Subject 4	11	9	81,82
Subject 5	5	2	40	Subject 5	22	16	72,73
Subject 6	7	3	42,86	Subject 6	15	9	60
Subject 7	14	5	35,71	Subject 7	18	12	66,67
Subject 8	17	7	41,18	Subject 8	8	6	75
Subject 9	11	4	36,36	Subject 9	6	5	83,33
Subject 10	20	7	35				
Subject 11	14	4	28,57				
Subject 12	11	4	36,36				
Subject 13	18	6	33,33				
Subject 14	6	2	33,33				
Subject 15	2	1	50				
Subject 16	16	6	37,5				
$\bar{x}$	10,56	4	39,86		15,33	42,28	73,45
σ	5,66	2	6,88		6,06	32,61	7,42
V	53,55	50	17,27		39,54	77,14	10,11

Following the collection of data from friendly and official games, we can state that the junior athletes achieve an average success rate of 39.86% for free throws, while the senior sample records a success rate of 73.45%. This indicates a significant difference between the two values, attributed to competitive experience as well as the level of specific basketball training.

From a statistical perspective, we can assert that the indicators are irrelevant regarding the number of free throws attempted and made, as the numerical values vary considerably. It was noted that some players were fouled more than others due to their positions, the tactical style of play, and the dynamics of modern basketball.

Nevertheless, the values of the coefficient of variation provide the study with a solid basis for statistical relevance for both samples.

Table 3. Comparison of Free Throw Percentage: Training Session vs. Official Games

Junior athlets		Senior athlets	
Training session	Official games	Training session	Official games
51,3	39,86	71,1	73,45

We chose to present the values recorded during the training sessions (Test 10) as well as the percentage of successful free throws from the practice and official games.

Thus, we observe that among senior athletes, there is a difference between the two sessions testing free throw efficiency, a difference we did not anticipate at the beginning of the study. Specifically, it is noted that a higher percentage is achieved during basketball games compared to training sessions. This can be explained by the fact that the athletes have reached an optimal level of physical condition, as well as by the significant competitive experience of the senior athletes.

In contrast, within the junior athletes' sample, we see that the success rate for free throws in official games is approximately 40%, while the success rate during training sessions exceeds 50%. This difference can be attributed to game conditions, a lack of competitive experience, and the positive influence of the equipment used in this research.

This assertion is also supported by the interest shown by junior athletes in making successful free throws during training sessions to trigger the visual stimulus of the technical system introduced. To this end, a satisfaction questionnaire was created for both samples, with the main conclusion being that for junior athletes, this technology played a role in enhancing and promoting technical execution. In contrast, the enthusiasm of the senior athletes was not as anticipated; they paid attention to the visual stimulus only during the initial attempts. The satisfaction questionnaire revealed that the technical equipment introduced in the training process also aimed to train under visually disruptive conditions, yielding results opposite to those expected at the beginning of the research.

Limits and discussions

In this study, it is important to mention the limitations related to executing free throws under game conditions (physical effort, psychological demands, adversarial conditions, or the influence of disruptive factors).

Another limitation of the research is the small sample size for the senior athletes, just nine female athletes. It should be noted that 4 additional subjects were part of the study, but they were not retained in the team roster once the championship began. Therefore, we did not present the data collected for these individuals.

The frequency of participation in training sessions among junior athletes, as well as the number of minutes played in official and friendly games, is additional limitations of the study.

At the beginning of our research, we aimed to ensure a larger numerical sample in the case of senior athletes, but we did not receive approval for this from the two sports teams near our locality with which we wanted to expand the intervention. Unfortunately, the relatively short time that the clubs have available from the moment the teams are formed for the new championship edition does not allow for long-term interventions during the 3-5 week pre-season period. For this reason, the period during which we implemented the technical equipment in the sports training process is limited, but it seems that its effect has positive connotations, providing us with the premises for a future research study that is quantitatively superior to the present one. At the same time, we mention that we had only one technical device available, which led to the study being conducted only in the locality of Braşov.

The novelty of the research lies in the innovative and original approach to the issue of free-throw efficiency in basketball, through the introduction of a technical device during training sessions. The presence of this device, which emits a visual signal when free throws are successful, is believed to strongly influence the initial success rate of the technical execution by activating the participants, as demonstrated in this study. Later, we strongly belive that it will stabilize this movement and transforms it into a dynamic stereotype by developing muscle memory specific to the free throw.

This approach can be part of efforts aimed at increasing the free-throw percentage in basketball, an aspect that has been analyzed in numerous studies.

Conclusions

After analyzing the collected data, we reached the main conclusion that the presence of information technology in the sports training process has significant effects. However, as previously mentioned, the effects differ between junior athletes and senior athletes.

In this context, it's important to highlight that, at the senior athlete level, there is a difference between the two sessions testing free throw efficiency—a difference we didn't anticipate at the start of the study. Specifically, during basketball games, a higher success rate is achieved compared to training sessions. This can be attributed to the athletes reaching peak physical condition and the significant competitive experience of senior players.

Conversely, in the sample of junior athletes, we observe that in official games, around 40% of free throws are successful, while during training sessions, the success rate exceeds 50%. This difference can be explained by game conditions, a lack of competitive experience, and the positive impact of the equipment used in this study.

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