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ORIGINAL

INFLUENCE OF VISUAL BEHAVIOUR ON DECISION MAKING IN VOLLEYBALL BLOCKING

INFLUENCIA DEL COMPORTAMIENTO VISUAL EN LAS DECISIONES EN EL BLOQUEO DE VOLEIBOL

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ABSTRACT

The purpose of this study was to determine the influence of visual behaviour (visual fixation location, number and duration) on decision making in volleyball blocking. The visual behaviour of 38 female volleyball players (23.9 ± 4.2 years) who took part in official competition was analysed using an eye tracking system (*Mobile Eye*) during the visualisation of real-size video sequences. Regression models showed that higher success rates were obtained with shorter fixation duration on the SE and HD areas, as well as with a higher number of fixations on the BW area and a lower number on the HD area.

KEY WORDS: decision making, visual behaviour, blocking, volleyball.

RESUMEN

El objetivo del presente estudio fue conocer la influencia del comportamiento visual (localización, número y duración de las fijaciones visuales) sobre la toma de decisiones en la acción del bloqueo en voleibol. Se analizó el comportamiento visual de 38 jugadoras de voleibol (23.9 ± 4.2 años), que competían de manera federada, mediante el sistema de registro de movimientos oculares (*Mobile Eye*) durante la visualización de secuencias de video proyectadas a tamaño real. Los modelos de regresión obtenidos muestran que se obtienen mayores porcentajes de acierto cuando la duración de las fijaciones es reducida en las zonas HC y CB, y cuando aumenta el número de fijaciones en la zona BM y disminuye en la zona CB.

PALABRAS CLAVE: toma de decisiones, comportamiento visual, bloqueo, voleibol.

INTRODUCTION

The visual channel is the most frequently used one for information processing during open skills. Consequently, it is the prevailing channel for sport performance optimisation through the use of information (Damas, Moreno, Reina & Del Campo, 2004; Del Campo, Reina, Sanz, Fuentes & Moreno, 2003; Moreno, Ávila & Damas, 2001; Ruiz & Sánchez, 1997). The relationship between visual perception and decision making is clear: attention processes are determined by the visual strategies used to analyse the environment and to gather information for later processing (Tenebaum, 2003). This relationship is enhanced in a changing environment where moving objects reach high speeds and follow complex trajectories. Given the lack of time in this type of sport, the speed of decision making is crucial for an action’s successful outcome, and appropriate visual perception is essential in this process (Abernethy, 1988).

The visual searching process is characterised by a first detection of an object within the peripheral vision, which provides the athlete with information about “where it is”. This information is quickly processed in order to facilitate the detection of movement and other events within the visual environment (Knudson & Kluka, 1997). It is assumed that the detection of this stimulus in the peripheral area is not conscious. Nevertheless, peripheral vision may also be used consciously during the visual searching process (Palmi, 2007). After detecting the stimulus, the most informative areas are taken to the foveal region (Quevedo & Solé, 2007), where visual fixation takes place. Its duration seems to reveal the relative importance of that area of the image for the athlete. Fixation occurs when the gaze is focused on an object or point within the angle of vision during at least 100 ms (Vickers, 2007). Some researchers have suggested that the information from the environment is processed during visual fixation so, the longer the fixation duration, the larger the amount of information processed (Just & Carpenter, 1976). The duration and number of fixations varies depending on the type of task performed and the environment perceived. Thus, when the difficulty of the observed task increases, so does the number of visual fixations. Saccadic eye movements occur between fixations; these are fast eye movements used to go from one point to another within the visual field, setting another object from the environment in the central retinal area.

Therefore, it is important to gain knowledge on eye fixation, since what is being fixated by the eyes indicates what is being processed in the mind (Scheiter & Van Gog, 2009). Players must focus their vision only on the most informative areas of the game in order to act effectively in uncertain sport environments (Moreno, Del Campo, Reina, Ávila & Sabido, 2003).

The reviewed studies regarding athletes' visual strategies reveal that experts use fewer fixations of longer duration, as well as prolonged quiet eye periods (Mann, Williams, Ward & Janelle, 2007). They are also able to interpret the information available in their usual sport environment more efficiently. These differences appear in environments and actions that are related to a specific sport, but not when visual capacities are examined from a general point of view (Abernethy, Neal & Koning, 1994; Kioumourtzoglou, Derri, Tzetzis & Therodorakis, 1998; Kioumourtzoglou, Michalopoulou, Tzetzis & Kourtessis, 2000). Hence, we can conclude that an effective visual strategy comprises fewer visual fixations of longer duration and few saccadic eye movements (Bard & Fleury, 1976; Vickers, 1988; Abernethy, 1990; Savelsbergh, Williams, Van der Kamp & Ward, 2002; Williams, Singer & Frehlich, 2002; Vaeyens, Lenoir, Williams, Mazyn & Philippaerts, 2007; Vaeyens, Lenoir, Williams & Philippaerts, 2007; Reina, Moreno & Sanz, 2007; Mann et al., 2007), players having, thus, longer time to process the information. Nevertheless, the visual search rate may vary based on aspects such as the sport modality (Williams, Davids, Burwitz & Williams, 1993; Williams & Davids, 1995), the role played (offensive or defensive) (Williams, 2000; Vaeyens, Lenoir, Williams, Mazyn et al, 2007; Afonso, Garganta, McRobert, Williams & Mesquita, 2012), the degree of scene uncertainty (Bard & Fleury, 1976) or the proximity to the target (Roca, Ford, McRobert & Williams, 2013).

Thus, if we aim to gain knowledge on a particular sport, it is necessary to conduct research using a specific approach, studying specific modalities and situations. According to Hayhoe (2004), the type and duration of visual fixations depend on various factors, including but not limited to the type of task and the time available to pick up relevant cues. This is the reason why the results obtained in a specific action may not be generalised to all sport actions. Consequently, we should learn how experts use their eye movements to pick up important visual cues in specific sport actions in order to determine a visual search strategy for every action. These strategies could then be used to train visual behaviour of less experienced athletes (Liebermann et al., 2002).

In volleyball, authors such as Sellinger and Ackerman (1985) stated that the relationship between the ball and the setter lets the blocker know the intention of the former regarding the area where s/he will pass the ball, as well as the setting tempo. This allows the blocker to anticipate and reach that area on time to counter the attacking action. Therefore, as regards the blocking action, it is especially important to focus on the setter as the main source of information.

The present research concentrates on gaining knowledge on the visual cues where the setter focuses her attention on, complementing the study by Vila-Maldonado, Sáez-Gallego, Abellán and García-López (2014), where decision making during the blocking action was analysed in order to determine the relationship between successful decisions and visual behaviour. The aim of this study is hence to determine whether the number and duration of visual fixations have any effect on decision-making success or failure. In doing so, our purpose is to provide coaches with useful data to train young volleyball talents, and to improve the performance of male and female volleyball players.

MATERIAL AND METHODS

PARTICIPANTS

An intentional sample of 38 female volleyball players (23.9±4.2 years) who participated in official competition was used. All players included in the study usually performed the blocking action during games. Twenty-nine played in first and second division clubs, while the other nine belonged to the Spanish national team.

The study was approved by the Royal Spanish Volleyball Federation, the national head coach and the coaches of the participating clubs.

The collaboration of experienced setters from a playing level similar to the participants' was needed in order to perform the setting sequences. Two setters from the Spanish national team (10 and 17 international games, respectively) and two setters from first division (8 and 12 years playing volleyball, respectively) helped for this purpose.

STUDY VARIABLES

INDEPENDENT VARIABLE

The independent variable is decision-making success rate. This variable derives from the results of a previous study conducted by Vila-Maldonado et al. (2014) and corresponds to the rate of successful responses that players perform when they predict and decide to which area the setter will pass the ball.

This variable is divided into success rate in zone 3 (SR3), success rate in zone 4 (SR4) and total success rate (TSR).

DEPENDENT VARIABLES

The dependent variable was visual behaviour and, more specifically, visual fixations (Vickers, 2007). Following movements have also been recorded as fixations in this study. These are the movements that keep an object image stable in the retina during an eye movement. Fixation location, number and duration (in seconds) have been analysed. Regarding location, eight areas of the scene and the setter have been used, as shown in figure 1, as well as other areas on the background or with no relevant information. Mean and percentage number and duration of fixations have been calculated for every participant and location.

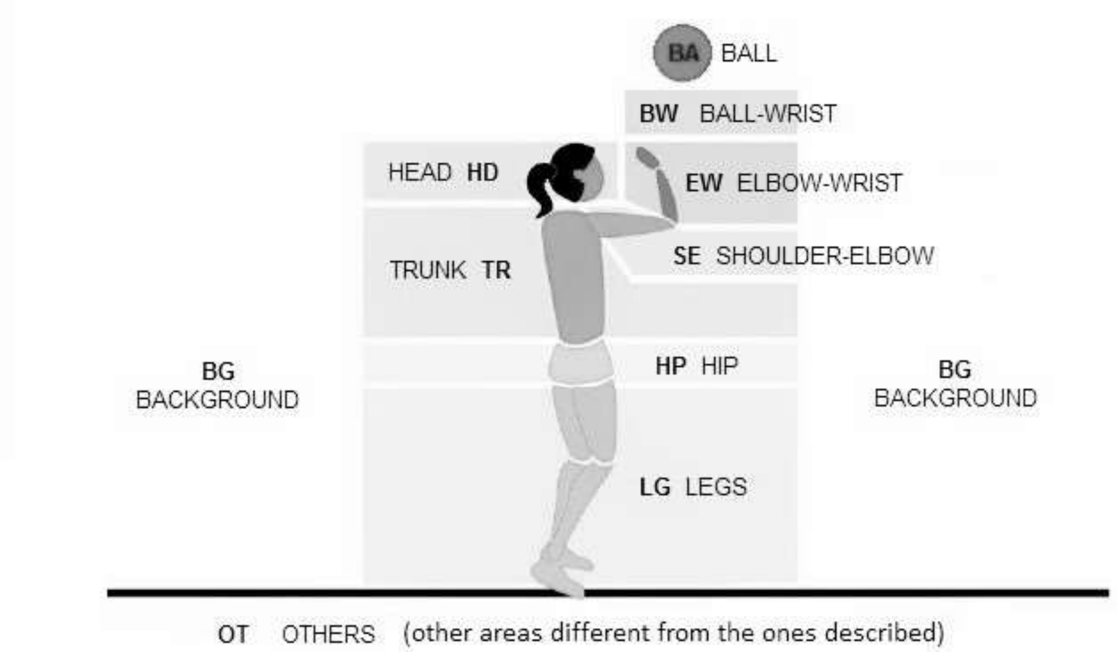

Figure 1. Fixation location diagram (adapted from Vila-Maldonado, Sáez-Gallego, Abellán & Contreras, 2012).

INSTRUMENTS

The study was conducted on the volleyball courts where the different teams usually trained. The following material was set up (see figure 2): official poles and net, a 5x3-m screen 0.5 m from the net and a DLP projector (model BENQ PB2250, 2200 ANSI lumens – XGA, 1024 x 768), behind the screen. A laptop (HP Compaq 6710b) was used to show the video sequences, and a digital video camera (miniDV format, SONY DCR – TRV15E PAL) and a tripod (HAMA STAR 62) were used to record the experiment.

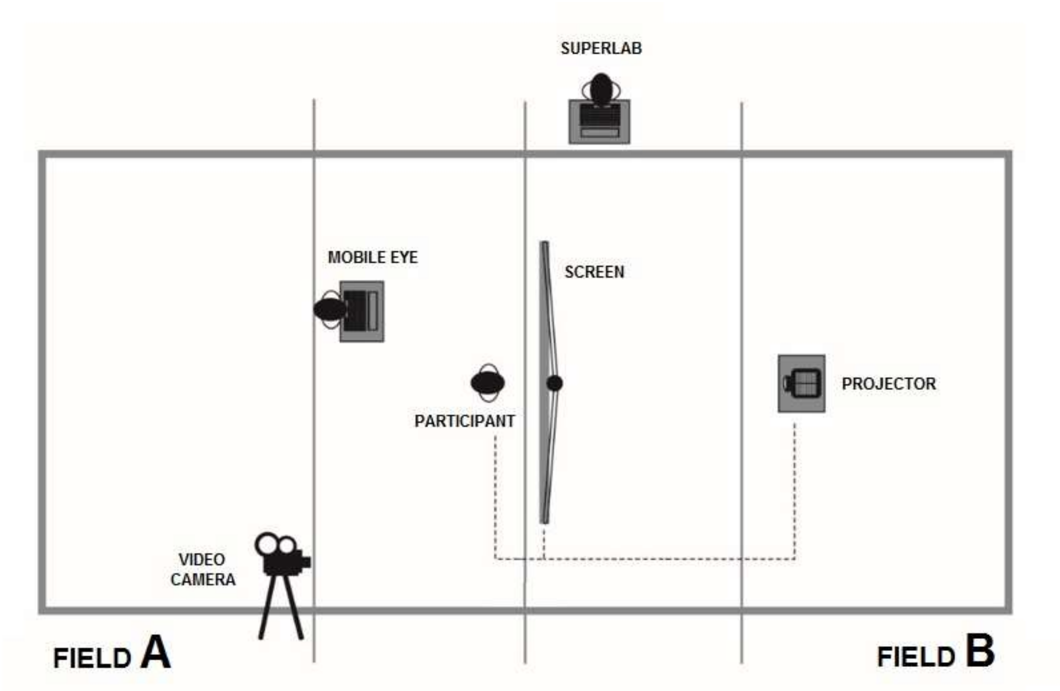

Figure 2. Material layout (taken from Vila-Maldonado et al., 2012).

The eye movement tracking system *Mobile Eye* (ASL laboratories, Bedford, USA) was used in order to assess the participants' visual behaviour.

The setting video sequences were edited with *Pinnacle Studio Plus* 9.3 software and shown to the players with *Superlab* 4.0 stimulus-presenting software*.* The videos resulting from the Mobile Eye system were analysed frame by frame with *VirtualDub*-1.9.6 software*.*

PROCEDURE

VIDEO SEQUENCES

Four setters, from the same competitive level as the participants, participated in the video sequence recording. There were requested to perform medium-height sets to zone 3 and high sets to zone 4, as they would do during a game. A total of 48 setting sequences were edited, 12 for trial attempts and 36 for assessment. The video sequences were cut after the first part of the ball flight, after the post-contact phase (see Vila-Maldonado et al., 2014).

EXPERIMENTAL SET-UP

The participant stood in zone 3, 0.5 metres from the net, in a ready position to perform a blocking action (figure 2) and wearing the eye tracking system. At the beginning of the experiment, all players were shown the same instructions about the procedure on a screen and the Mobile Eye system was calibrated. This calibration was repeated at the end of the experiment to verify that it had not been affected during the data collection.

After calibration, the trial and assessment sequences were displayed. The participant was asked to watch the images on the screen and to make a decision accordingly regarding the place where she thought the set would go to.

DATA ANALYSIS

Two setting sequences were deleted due to errors that prevented it from being analysed in at least 80% of the sample. Therefore, the final number of assessment sequences was 34.

Two researchers analysed the Mobile Eye videos independently, applying the corresponding protocol to reach an agreement regarding the differences during the data extraction. An Excel observation sheet was used for this purpose.

The data obtained was analysed with SPSS 19.0. Descriptive parameters (mean and standard deviation) regarding the number and duration of visual fixations were analysed. Regression models were applied including all variables, which were kept or dropped out of the model along the process. The t-test (coefficient quality test) result with $p<0.05$ was used as a practical criterion to keep a variable in the model. Fisher's F-test for regression was conducted.

RESULTS

Table 1 shows the descriptive parameters (M ± SD) of the number and duration of fixations, divided by location.

Table 1. Descriptive statistics (M ± SD) of the number and duration of fixations by area.

Locations	**Number of fixations** (M ± SD)	**Fixation duration (s)** (M ± SD)
BALL (BA)	0.33 ± 0.3	0.349 ± 0.183
BALL-WRIST (BW)	0.19 ± 0.2	0.366 ± 0.258
ELBOW-WRIST (EW)	0.60 ± 0.3	0.491 ± 0.103
SHOULDER-ELBOW (SE)	0.39 ± 0.4	0.549 ± 0.328
HEAD (HD)	0.46 ± 0.3	0.545 ± 0.247
TRUNK (TR)	0.08 ± 0.1	0.404 ± 0.355
HIP (HP)	0.03 ± 0.1	0.147 ± 0.240
LEGS (LG)	0.07 ± 0.2	0.194 ± 0.299
BACKGROUND (BG)	1.01 ± 0.1	0.382 ± 0.125
OTHER (OT)	0.10 ± 0.3	0.261 ± 0.296

TOTAL	3.3	3.689

Figure 3 shows the distribution by area of all the fixations observed.

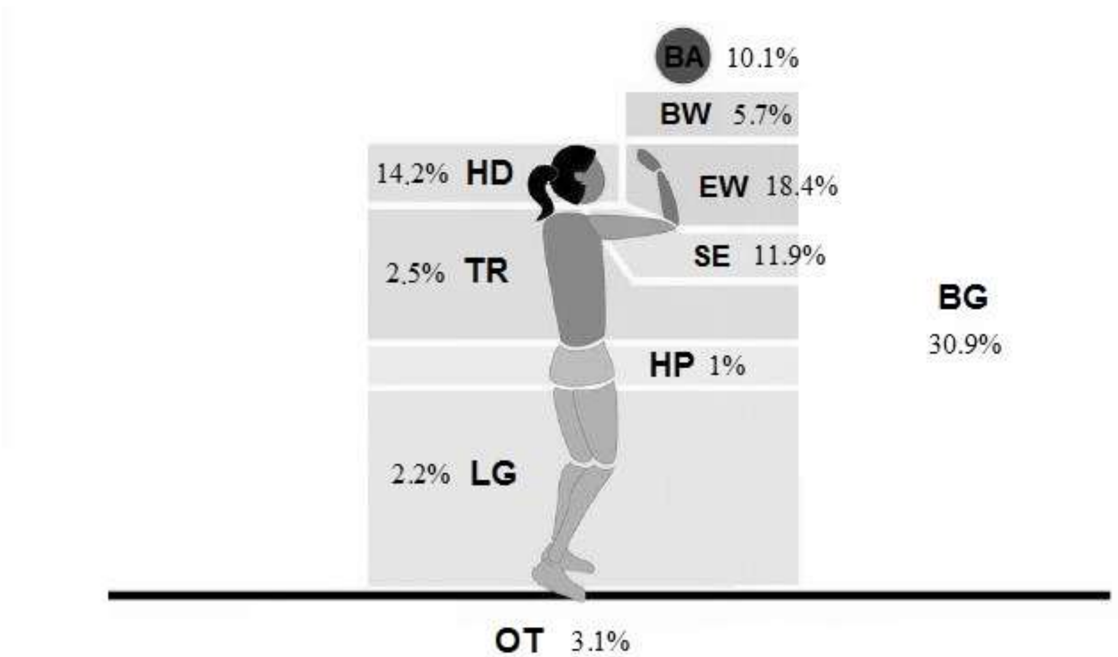

Figure 3. Fixation percentage by area (adapted from Vila-Maldonado et al., 2012).

Regression models have been conducted to determine how the mean number and duration of fixations affect the success rate (SR3, SR4, TSR) in the different visualisation areas.

The multiple regression model obtained for the total success rate based on the mean fixation duration is shown in table 2. The results reveal that the fixation duration in the SE and HD areas negatively affects total success rate in decision making during the blocking action. According to the model obtained, the best total success rates are achieved when spending the shortest possible fixation time on these areas.

Table 2. Regression model based on duration. Dependent variable: TSR.

	Unstandardised coefficients		**Standardised coefficients**	**T**	***p***
	B	**Std. Error**	***Beta***		
Duration (s) SHOULDER-ELBOW (SE)	-41.897	8.429	-0.896	-4.971	0.000

Duration (s) HEAD (HD)	-19.815	7.794	-0.319	-2.542	0.016
R^2: 0.528					

The same happens with success rate in zone 3 (table 3) and success rate in zone 4 (table 4); it is confirmed that the highest success rates are achieved when spending the shortest possible fixation time on the SE and HD areas.

Table 3. Regression model based on duration. Dependent variable: SR3.

	Unstandardised coefficients		Standardised coefficients	T	*p*
	B	**Std. Error**	***Beta***		
Duration (s) SHOULDER-ELBOW (SE)	-24.802	7.979	-0.44	-3.109	0.004
Duration (s) HEAD (HD)	-21.756	10.613	-0.29	-2.05	0.048
R^2: 0.306					

Table 4. Regression model based on duration. Dependent variable: SR4.

	Unstandardised coefficients		Standardised coefficients	T	*p*
	B	**Std. Error**	***Beta***		
Duration (s) SHOULDER-ELBOW (SE)	-21.334	5.897	-0.479	-3.618	0.001
Duration (s) HEAD (HD)	-20.954	7.844	-0.354	-2.671	0.011
R^2: 0.393					

TSR was positively affected by the mean number of fixations on the BW area, but negatively affected by the mean number of fixations on the HD area (table 5).

Table 5. Regression model based on the number of fixations. Dependent variable: TSR.

	Unstandardised coefficients		Standardised coefficients	T	*p*
	B	**Std. Error**	***Beta***		
Number of fixations BALL-WRIST (BW)	28.76	10.174	0.45	2.827	0.008

	Number of fixations HEAD (HD)	-16.071	7.093	-0.361	-2.266	0.03
R^2: 0.220						

According to the regression model for SR4, the mean number of fixations performed on the HD area negatively affects the success rate (table 6).

Table 6. Regression model based on the number of fixations. Dependent variable: SR4.

		Unstandardised coefficients		Standardised coefficients	T	*p*
		B	**Std. Error**	***Beta***		
	Number of fixations HEAD (HD)	-21.16	7.089	-0.499	-2.985	0.005
R^2: 0.263						

No appropriate model that allows for SR3 prediction was obtained due to a very low correlation coefficient.

DISCUSSION

The aim of this study was to learn which visual information the blocker focuses her attention on. In particular, the purpose of the analysis was to determine whether the number and duration of the visual fixations performed by the participants affect decision-making success or failure.

Prolonged duration of fixations on the SE and HD areas negatively affected the total success rate, as well as the success rate in zone 3 and 4.

These were two of the most frequently fixed areas by the study's participants, the HD area holding the second place and the SE area, the third one. Given that the HD area may be considered as a visual pivot, this negative influence on the success rate may be explained due to the fact that this location is used to collect relevant information from several sources within the scene through peripheral vision, but it is the foveal vision what allows the athlete to process in detail what happens in the scene. In 1-on-1 situations, since the attacking players are not seen in the scene, it seems necessary to collect information accurately and immediately and, therefore, to use the foveal vision most of the time (Williams & Davids, 1998). Spending a long time on the HD area may cause a loss of detailed and important information from other more informative areas, what could lead to worse decisions. In previous studies, the fixation on the thrower's head area was related to the visual pattern used by novice players (Goulet, Bard & Fleury, 1989), while experts would rather focus their attention on areas of the executing arm (Huys et al., 2009;

Bourne, Bennett, Hayes, Smeeton & Williams, 2013), it being regarded as a source of relevant information.

As regards the fixation duration on the SE area, it must be highlighted that this area provides information during the central time interval of the setter's action and that, after that moment, other locations become more relevant (Vila-Maldonado, Sáez-Gallego, Abellán & Contreras, 2015). Therefore, it is logical to think that the player should not spend too long fixing the SE area or the outcome would be worse.

It has been shown how the mean number of fixations on the BW and HD areas affected the TSR. The more fixations conducted on the BW area, the higher the success rates while, by contrast, the more fixations conducted on the HD area, the lower the success rates.

As it has been mentioned before, it was confirmed that the HD location does not provide information on its own, but it is used as a visual pivot to obtain information from relevant areas from its surroundings. Thus, the excessive use of this resource would lead to worse decision making, since it would prevent from focusing the attention on other more informative areas.

The BW area provides relevant information regarding the setter's wrist and the ball, mainly during the final part of the action, where both locations come together at the moment of the contact. With the aim to mislead the opposing defence, the setters avoid the flexion-extension movement of the upper and lower limbs, relying more on their wrists to pass the ball to one field zone or the other (Ureña, 2007). Fixing this segment may, therefore, be of great help to blockers' decision making.

CONCLUSION

As a conclusion, according to the model obtained, higher success rates can be achieved when performing a higher number of fixations on the BW area and a lower number on the HD area. Regarding duration, the best outcomes were reached when spending the shortest time possible on fixations on the HD and SE areas.

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