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Visual behaviour of tennis coaches in a court and video-based conditions.

Análisis del comportamiento visual de entrenadores de tenis en situaciones de pista y videoproyección.

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Resumen

Este estudio analiza el comportamiento visual realizado por entrenadores de tenis, con diferente nivel de experiencia, cuando observan segundos servicios liftados en situaciones de videoproyección y campo durante un proceso de detección de errores. Se empleó el sistema de seguimiento de la mirada ASL SE5000 para la recogida de datos y posterior análisis de los puntos de fijación visual sobre la escena que los entrenadores observaron. Se desarrolló un diseño experimental de medidas repetidas con tres tomas de datos (A-B-A´): una situación de videoproyección en laboratorio (2D), una situación en pista (3D) y otra nueva situación en laboratorio (2D´).

Los entrenadores experimentados realizaron un menor número de fijaciones visuales que los entrenadores noveles en todas las situaciones de medida. Entre las dos situaciones en videoproyección, los entrenadores realizaron fijaciones visuales más largas en la segunda de ellas, con mayores diferencia obtenidas en el grupo de entrenadores experimentados. Ambos grupos realizaron el mayor número de fijaciones visuales sobre el miembro superior, con valores superiores sobre esta localización para el grupo de entrenadores noveles. Si la localización con mayor tiempo de fijación visual fue el miembro superior, la localicen que menos tiempo recibió fue la bola. El número de fijaciones Visuales realizadas por ambos grupos disminuyó a medida que se sucedieron las situaciones de medida. Las dos variables que fueron más sensibles al efecto de la dimensionalidad de la escena fueron el número de fijaciones visuales sobre el brazo que sostiene la raqueta y el tiempo de fijación visual sobre el miembro superior.

Abstract

This study analyses the visual behaviour performed by tennis coaches with different levels of experience, when they shown a second top-spin serves in a video-based and court situations during a performance error detection process. The ASL SE5000 eye tracking system was used to detect and record the point of gaze in the visual field. Three experimental measures were carried out (A-B-A'): a two-dimensional situation in a laboratory (2D), a three-dimensional situation on court (3D) and another two-dimensional situation in a laboratory conditions (2D').

The visual fixations performed by the expert coaches were lesser than the novice ones in all conditions. Between the two video-based conditions, the coaches performed longer visual fixations in the second one, with greater differences in the experienced group. Both groups performed the highest number of visual fixations on the upper body, with higher scores by the novice group. The location with longer fixation time was the upper body, whereas the location with shorter fixation time was the ball. The number of visual fixations for both groups decreases as they participated in the experimental situations. Two variables have been found to be affected by the dimensionality of display: the number of visual fixations on the perform-arm and the time of visual fixation on the upper-body.

Palabras clave: Comportamiento visual, dimensionalidad de la escena, tenis, entrenador.
Key Words: Visual behaviour, dimensionality of display, tennis coaching.

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Introduction

There are several authors that suggest that the visual system is the most efficient way to obtain information about events going on around us (Gregg, 1987; Kerr, 1982; Magill, 1980; Revien & Gabor 1981; Rosenbaum, 1991). It is established that vision is the most precise perceptual system regarding the movement of objects, spatial and temporal features of the environment (McLeod, 1991). Magill (1980) describes the visual system as the predominant sensorial system and argues that visual information is important to control motor skills. Kerr (1982) argues that vision is the most active, organised and informative sensorial system, being the one that provides the most knowledge of reality. The present study is understood under a cognitive approach regarding visual perception. It could be suggested that information that we receive from the environment is not structured and other psychological processes are necessary to carry out the perception, which it is related with the learning and experience of the subject (Oña, Martínez, Moreno, & Ruiz, 1999).

We will analyse the extrinsic ocular motility, understood as the visual ability that performs voluntary eye movements. Regarding this visual ability it can be distinguished two ocular movements: a) saccadic movements, as quickly movements of both eyes in the same direction in order to determine important sources of information separately from each other, and b) visual fixations, as the time that elapses between two saccadic movements (Rosenbaum, 1991). Visual fixations are of great interest for most researchers, as the duration of the visual fixation seems to denote the relative importance of an area of the scene for the athlete (Just & Carpenter, 1976). We have considered here a visual fixation as a spatial location that is kept in focal vision for more than 60 ms (Moreno, Luis, Salgado, García, & Reina, 2005), because tennis serve is a rapid sport action, and there are many changes of the point of gaze. Furthermore, smooth pursuit movements enable the eyes to track slow-moving targets within the visual field, such as the motion of the arm or the racquet, so that a stable retinal image may be maintained. We have considerer therefore a smooth pursuit movement on any limb, the racquet or ball in movement as a visual fixation too. Certain inferences can be drawn from the location and duration of the perceiver’s visual fixations (Moran, 2004). The location of the visual fixations usually regarded as an index of the relative importance of a given cue within a stimulus display, while the number and duration of fixations recorded (denominated “search rate”) are believed to reflect the information-processing demands placed on the perceiver. Also, visual fixation characteristics are indicative of the perceptive strategy used by the observer to extract specific information of the sport setting.

We will also study attention as a cognitive procedure that we use to develop voluntary control for both perceptive and motor processes. In the case of visual attention, a stimulus is supposedly initially detected within the peripheral vision, which supports information about “where it is”. This stimulus is then identified or perceived in the focal vision, obtaining the information regarding “what it is” (Moreno, Ávila, & Damas, 2001). The detection of the stimulus in the peripheral vision may be considered as an automatic process and allows a parallel processing of all input signals in the visual sensorial memory (Neumann, 1990). The results of this process determine those aspects of the scene that require more attention in the focal vision. The period of time in which the image is focused, is called the attention phase in the visual search process (Neisser, 1967). This pattern of two stages in vision is clearly in line with several motor models that support the existence of wide input channels followed by a more detailed analysis of selected sensorial information (Neisser, 1967; Norman, 1969). An active observer often has to make an instantaneous selection of pertinent cues of the visual field, while discarding the ones judged irrelevant (Bard, Fleury, Carriére, & Halle, 1980). Therefore, the subject must select the areas of the visual field given priority in processing (Lum, Enns, & Pratt, 2002), and certain visual search strategy is controlled by some knowledge that the coach has been developed over years of training, coaching or observing (Sonneschein, 1993).

A highly interesting current approach is the design and development of sport situations to record and analyse sportsmen’s behaviour. Current research is being conducted to find out the effects of a simulated situation created in a laboratory. According to Abernethy, Thomas and Thomas (1993), these laboratory settings may not accurately portray expert advantages due to (a) removal of experience factor are associated with actually performing the task in an ecologically valid setting, (b) the introduction of potential floor or ceiling effects in measurement variability, and (c) constraining the expert’s typical responses to either use using different information to create a response or preventing access to information normally available in the performance context.

To avoid these difficulties, researchers try to combine the largest number of variables present in real world situations in laboratory conditions, in order to increase the ecological validity of the measurements (Cauraugh & Janelle, 2002). Some studies in this direction have been applied to teachers and tennis coaches (Ávila & Moreno, 2002; Petrakis, 1986), return of serve in tennis (Moreno, Oña, & Martínez, 2002; Reina, Luis, Sanz, & Moreno, 2004b; Singer, Williams, Frehlich, Janelle, Radlo, Barba, & Bouchard, 1998; Williams, Singer, & Weigelt, 1998) or wheelchair tennis (Reina, Moreno, Sanz, & Luis, 2004b). However, this study does not only attempt to simulate a video-based situation similar to a real world situation, but rather it also attempts to study the effect on the visual behaviour when coaches observed tennis serves in front of different conditions. The study analyses the visual behaviour developed by tennis coaches of different levels when they shown a second top-spin serves in a video-based conditions (two-dimensions) and in a real on-court setting (three-dimensions) during a performance error detection process. The purpose of the study is to determine the effect of the display conditions on the tennis coaches' visual behaviour.

Methods and Materials

Participants

Participants were ten male Spanish tennis coaches. There were five experienced coaches (M = 34.6, SD = 5.4 years old) and five novice coaches (M = 20.4, SD = 2.9 years old). Coaches' experience is considered as a combination of the years they have had the required sports certificate and the years they have been coaching tennis. The serves were performed by three male tennis players with a consistent second top-spin service. Experienced coaches are at the high national level and have been tennis coaches for at least eight years in such level. Novice coaches only hold the national instructor level[1] and have been teaching for no longer than four years in this level.

[1] Tennis coaches grades for the Spanish Tennis Federation.

Measures

The ASL SE5000 eye tracking system was employed to collect visual behaviour data. It is a video-based monocular corneal reflection system, which measures eye line-of-gaze with respect a helmet-mounted scene-camera. The corneal reflex is measured by the reflection of an infrared light source from the surface of the cornea, and the system also measures pupil position. The relative location of theses features was used to calculate visual gaze with respect to the optics. Displacement data from the left pupil and cornea were recorded by a camera, and the result is a precise point of gaze over the scene image (Figure 1). This image was then recorded using a video recorder (Panasonic NV-HS1000ECP) for a more detailed frame-to-frame analysis at 50 frames/s data frequency. The serves for the video-projection (two-dimensional situation) were recorded by a video-camera (Sony CCD-TR840E). The film was edited using an S-VHS video-recorder (Panasonic NV-HS1000ECP), also used for the video-projection of the serves in a laboratory situation through a multimedia projector (Hitachi CP-S833).

The location of coaches´ point of gaze over several body areas of the server was analysed: head, torso, shoulder of the racquet-arm, shoulder of the free-arm, racquet-arm, racquet-hand, racquet, free-arm, free-hand, ball, hip, legs and feet. These locations are grouped as follows: (a) *enhanced ball (EBA)*, which contains the visual fixations on the ball’s trajectory, and the fixations on the shoulder of the free-arm, the free-arm and the hand holding the ball, from the beginning of the serve until the ball toss; (b) *enhanced perform arm (EPA)*, which only contains spatial locations of the shoulder of the racquet-arm, the racquet-arm, the racquet-hand and the racquet; (c) *upper body (UB)*, which contains spatial locations of the torso, the shoulder of the racquet-arm, racquet-arm, racquet-hand, shoulder of the free-arm, free-arm and the hand which holds the ball; and (d) *lower body (LB)*, which contains spatial locations on the hips, legs and feet.

Also, two parameters have been distinguished about the visual fixations: (a) *number of visual fixations (NF)* carried out during the error detection process on the serves performed. It is considered as the times that the subjects carry out a displacement of their point of gaze within the scene to locate a visual fixation on a spatial location; and (b) *time of visual fixations* (ms) *(TF)* for each serve/trial, as the mean duration of the visual fixations. These two dependent variables have been applied to the grouped locations. Therefore, there are four variables for the number of visual fixations (NF_EBA, NF_EPA, NF_UP, NF_LB) and four regarding the duration of these fixations (TF_EBA, TF_EPA, TF_UP, TF_LB), besides the two variables about the mean number of visual fixation (NF) and the time expended per visual fixation (TF) in each trial/serve. Ten dependent variables about the visual behavior will be studied.

A within-group independent variable was the *dimensionality of the display* where the experimental situation took place, which it is considered as the number of planes of the scene where the observations took place. There are two levels of such variable: (a) two-dimensional condition, which is the observation of a motion image over one plane (screen), or the observation of a video-projection in a laboratory setting; and (b) three-dimensional condition, which is the observation of real world tennis serves. Another independent variable (between-groups) was the *experience* of the participants.

Procedure

Three experimental measures were carried out (A-B-A'): a two-dimensional situation in a laboratory (2D), a three-dimensional situation in court (3D) and a two-dimensional situation in a laboratory again (2D'). In the first (A) and third (A´) experimental situations, the coaches were seated facing a screen and the eye tracking system was adjusted and calibrated. The coaches observed ten second top-spin serves performed by three tennis players. They were instructed to observe the performance of the tennis players as if analyzing the strokes in order to provide feedback to the performer (error detection process). Once the serve was performed, the coach had to verbalize the detected errors. This feedback was required because high attention levels increase visual acuity (Secadas, 1992), besides a poor attention could modify the visual behaviour (Sonneschein, 1993). Also, verbal reports procedures requires subjects to verbalise the area of the display which they consider particularly informative and, consequently, a more direct measure of attentional allocation and information extraction is provided (Ericsson & Simon, 1993).

In the second experimental situation (B), the coaches were seated facing a real performer. They were positioned two meters away of the baseline, at an angle of 20º from the performer (Figure 1). The instructions for the error detection process were the same as for the video-based/laboratory condition.

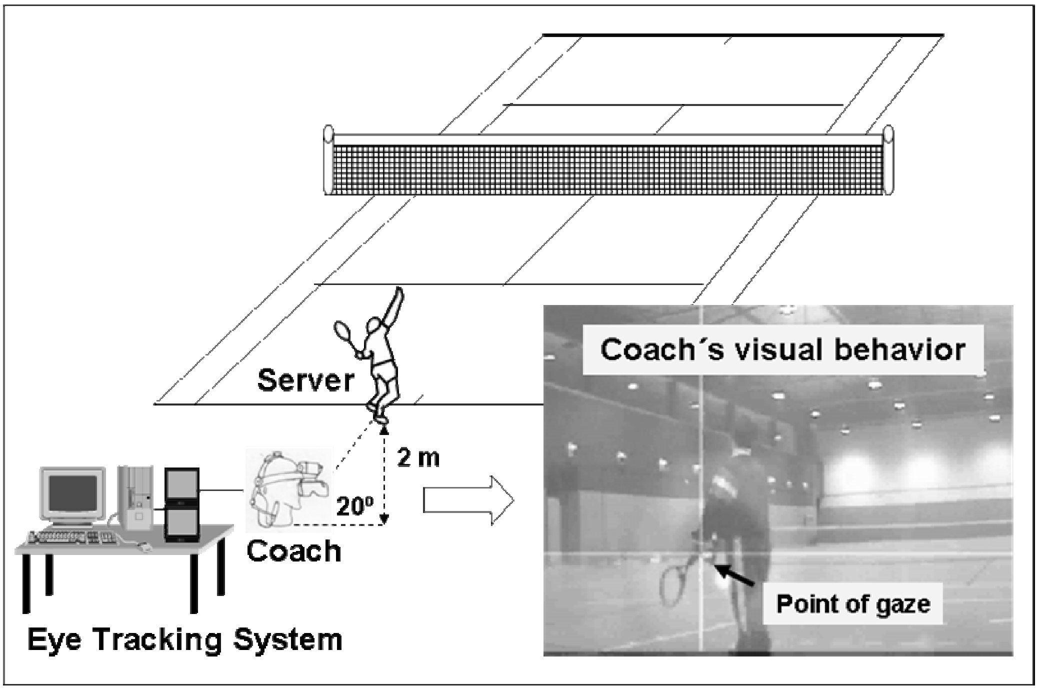

Figure 1. Position of the coaches in real conditions, and detail of a visual behavior.

Results

Results are presented bearing in mind the visual behaviour data (number and duration of the visual fixations), performed by experienced and novice tennis coaches in the three situations of study. More information about the differences between groups can be consulted in Ávila and Moreno (2003).

Visual fixations performed by experienced coaches were lesser than the novice coaches in all motion error detection situations. In both expert and novice coaches the number of visual fixations decrease as the study situations proceed, although this trend was less marked in 3D and 2D' situations. About the duration of the visual fixations, between the two video-based conditions (A and A'), coaches shown longer visual fixation times in the second one, specially the experienced group (A = 403.16 ms; A' = 483.82 ms). Moreover, the experienced group showed longer visual fixations than the novice group. Therefore, the experienced coaches performed less visual fixations with longer duration, while the novice coaches perform a greater number of visual fixations with a shorter duration (Figure 2).

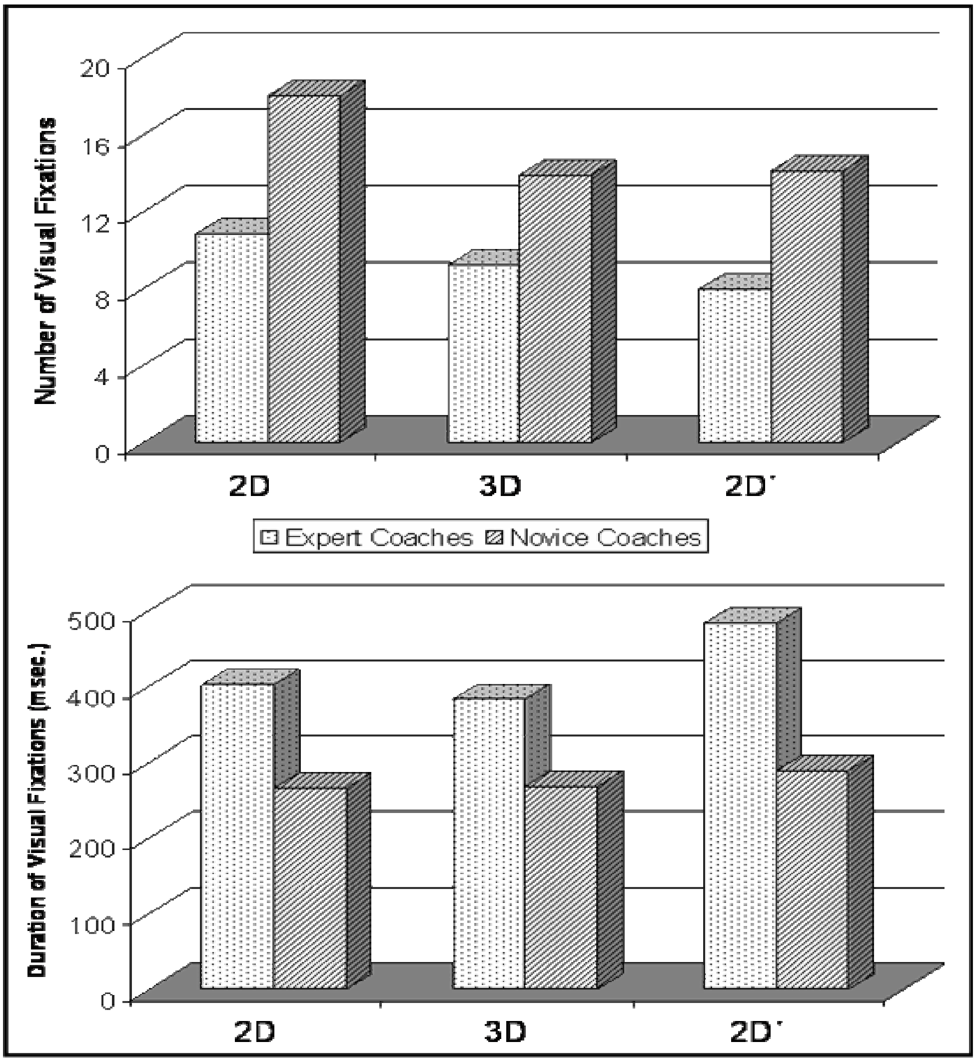

Figure 2. Number and duration of visual fixations performed by expert and novice coaches

Both groups performed the highest number of visual fixations on the upper body, with higher scores for the novice group (Figure 3). The lowest number of visual fixations was performed on the enhanced ball. With regard to the other two grouped locations, the enhanced perform arm received a higher number of visual fixations than the lower body in the video-based conditions, whereas this trend was inverted in the court situation. Therefore, the most relevant informative areas were the same for all coaches, regardless of the dimensionality of the display in which they observe the serve. Generally, the upper body was the area with higher number of visual fixations, followed by the lower body, enhanced perform arm, and enhanced ball respectively. Because the higher total number of visual fixations performed by the novice group, it can also see that this group perform more visual fixations on all locations.

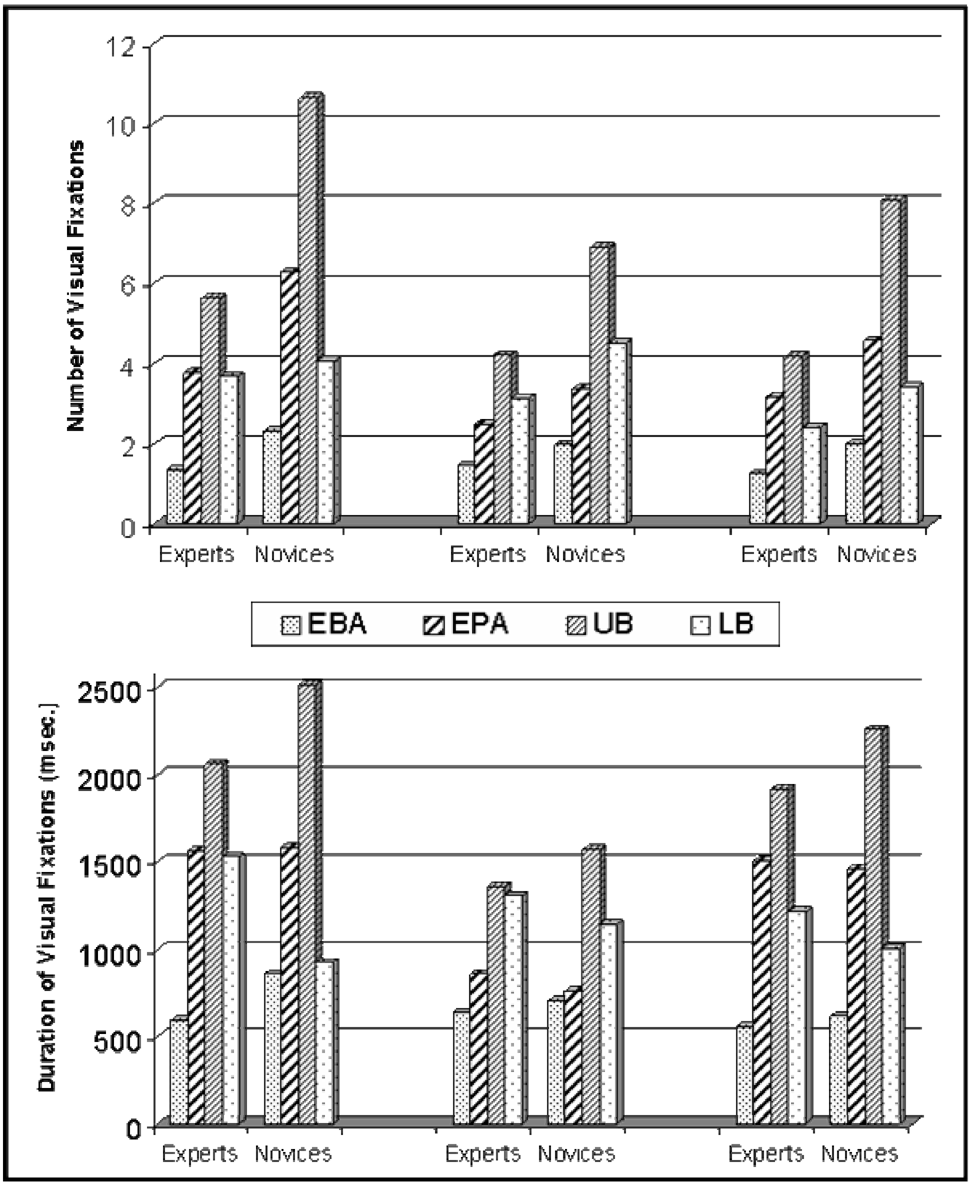

Figure 3. Number and duration of visual fixations on the grouped locations: EBA (Enhanced Ball), EPA (Enhanced Perform Arm), UB (Upper-Body) and LB (Lower-Body).

Furthermore, the location with longest fixation time was the upper body, whereas the location with the shortest fixation time was the enhanced ball, although the duration of the fixations on the upper body was longer in two-dimensional situations (Figure 3). Moreover, novice coaches performed longer visual fixations than the experienced ones in these two areas. There were similar values for both groups on the enhanced perform arm, although these are slightly higher for the experienced coaches in 3D and 2D' situations. Nevertheless, both groups showed higher values in this area in two-dimensional situations. Regarding the lower body, it can be observed that the experienced coaches showed higher scores than the novices in all observational situations. The scores for the experienced coaches in this area tend to be lower across the observed situations, whereas the scores of the novice coaches were higher in 3D rather than the 2D situations.

A repeated measures ANOVA was carried out about the dimensionality of the display (Table 1). The locations with high differences between situations were the enhanced perform arm and the upper body, as well as both general variables of number and duration of visual fixations. Regarding to the number of visual fixations, there were differences between the 2D and 3D situations (A-B) ($F_{1,97}$ = 37.24, $p < 0.01$), and between the 2D and 2D' situations (A-A´) ($F_{1,98}$ = 83.97, $p<0.01$). With regard to the duration of visual fixations, there were differences between all situations of study, although both video-based situations had higher mean values (*M* 2D = 4649.4 ms; *M* 2D´ = 3880.4 ms) than the court condition (*M* 3D = 3470.8 ms).

Two-pair analysis of variance revealed significant differences in the duration of visual fixations on the upper body for the three situations of study, with higher values in two-dimensional situations (*M* 2D = 2347.4 ms; *M* 2D´ = 2077.4 ms) and lower values in the court situation (*M* 3D = 1472 ms). Nevertheless, regarding the number of visual fixations, differences only appear when we compare between three situations. There were higher mean values in the 2D situation (*M* = 8.41), whereas the values for the other situations were similar (*M* 3D = 5.59; *M* 2D´ = 6.12).

Table 1. Significant differences in the two-pair repeated measures ANOVA between the three situations of study (2D, 3D, 2D´) - (NF = number of visual fixation; TF = time of visual fixation; EBA = Enhanced Ball; EPA = Enhanced Perform Arm; UB = Upper-Body; LB = Lower-Body)

	Mean values			Pair comparison (*sig.*)		
Variables	*M* 2D	*M* 3D	*M* 2D´	2D-3D	2D-2D´	3D-2D´
NF	15.33	11.63	11.08	<.001	<.001	.198
TF	4649.4	3470.8	3880.4	<.001	<.001	<.001
NF_EPA	5.09	2.99	3.85	<.001	<.001	.002
TF_EPA	1570.2	818.4	1478.4	<.001	.346	<.001
NF_UB	8.41	5.59	6.12	<.001	<.001	.111
TF_UB	2347.4	1472	2077.4	<.001	.031	<.001
NF_LB	4.39	3.83	2.94	.171	<.001	.005

Something similar happens with the number of visual fixations on the enhanced perform arm. Once again, there were differences in all three situations, with higher mean values in the video-based conditions (*M* 2D = 5.09; *M* 2D´ = 3.85) than in court one (*M* 3D = 2.99). However, the analysis of variance for the duration of visual fixations on the enhanced perform arm revealed differences when we compare the 3D situation with the 2D and 2D' situations ($F_{1,97}$ = 38.23, p<0.01; $F_{1,98}$ = 38.89, p<0.01), where the coaches performed the lowest scores on this location in the court condition (*M* 3D = 818.4 ms).

We should also highlight the results obtained for the duration of visual fixations on the enhanced ball ($F_{1,98}$ = 6.93, p<0.05), and the lower body for the two video-based situations ($F_{1,98}$ = 4.31, p<0.05). Finally, differences have also been noted for the number of visual fixations on the lower body, between the two video-based situations ($F_{1,98}$ = 18.16, p<0.01) and the 2D' and 3D situations ($F_{1,98}$ = 8.09, p<0.01).

Discussion

According to the results presented above, the number of visual fixations performed by the coaches of both groups decreases as we proceed in the experimental situations. Therefore, the higher values for the number of visual fixations were found in the first video-based condition (A), while the lowest values were found in the second one (A´). It is possible that coaches reduce the number of visual fixations across their practice and, therefore, they pay less attention in later trials (Neisser, 1967). Theories about the automation of the attention suggest that a decrease in the number of visual fixations is a consequence of the efficiency to retrieve information from the memory (Logan, 1988). According to these theories, practice could bear a quick retrieval of relevant information from the observed images and, therefore, the visual search strategy could be guided. This trend has been also observed for the enhanced-ball and lower-body locations, for both number and duration of visual fixations. Data also suggest that these two locations of the tennis serve could be less relevant for the mistakes detection. Recent studies carried out in tennis and wheelchair tennis supports that it is not very important to observe the lower body (Moreno, Reina, Sanz, & Ávila, 2002; Reina, Luis, Sanz, & Moreno, 2004a; Reina et al., 2004b).

However, the downward trend in the number of visual fixations was not observed in their duration. Both groups showed longer fixations in video-based conditions regarding the court situation. This behaviour was also observed over the two main areas of the tennis serve, perform-arm and upper-body (Farrow & Abernethy, 2002; Moreno & Oña, 1998), with shorter visual fixations in the court situation. These results regarding the real world situation may be consistent with Treisman's theory (Treisman, 1988), who suggests that during the visual search process we initially recognize objects on the basis of their sensory features. Therefore, coaches could be more familiarized with the live condition and they could be able to identify quicker the mistakes of the tennis players. This perspective also agrees with the decrease in the number of visual fixations in this situation.

Regarding to the effect of the dimensionality on the visual search strategies and what locations the coaches oriented their point of gaze, there were no clear tendencies. Abernethy (1990) found differences in visual search strategies between two- and three-dimensional situations, where the athletes performed more visual fixations in real world situations. However, these differences were not very significant and similarities were found in both situations. The study carried out by Reina, Moreno, Sanz, Damas and Luis (2006) with tennis and wheelchair tennis players showed that all groups of study (experienced and novice players) performed higher number of visual fixations in the two-dimensional situations. Shim and Carlton (1999) observed a progressive deterioration in expert performance across "live" and film conditions, whereas novices did not significantly differ across viewing conditions. Although there is no deeper research into the effect of dimensionality of the display on visual search strategies in sport, different studies have demonstrated the expert's ability to employ perceptual resources more efficiently in real world conditions than in video-based ones (Abernethy, Gill, Parks, & Packer, 2001; Chamberlain & Coelho, 1993; Christensen, 1995; Vickers & Adolphe, 1997).

During a tennis ground stroke, expert players have been shown to fixate around central body areas, particularly the waist-hip region, as well as racket and racket-ball areas contact areas of the display (e.g. Singer, Cauraugh, Chen, Steinberg, & Frehlich, 1996; Williams & Davids, 1998). In comparison, novice search strategies concentrate around the racket and ball areas, although their search is somewhat inconsistent and, in general, they use cues that are less predictive. A study carried out with tennis coaches revealed that the level of expertise did not influence the number or duration of fixations (Petrakis, 1986). In this study two variables have been found to be affected by the effect of dimensionality: the number of visual fixations on the perform-arm and the duration of these fixations on the upper-body, with significant differences between video-based and live conditions. The main areas of interest for both groups of coaches were similar in both situations, and there was not clear the effect of the dimensionality of the display on the visual behaviour of the coaches during the mistakes detection process. Further research is necessary in order to study visual behaviour of coaches in different stimuli conditions as well as the development of follow-up studies with between-subjects designs, where counterbalanced measures of the visual behaviour in court and laboratory conditions should be carried out.

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