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ORIGINAL ARTICLE

Visual search behaviours and verbal reports during film-based and *in situ* representative tasks in volleyball

JOSÉ AFONSO[1], JÚLIO GARGANTA[1], ALLISTAIR MCROBERT[2], MARK WILLIAMS[2], & ISABEL MESQUITA[1]

[1]*Faculty of Sport, University of Porto, Porto, Portugal,* [2]*School of Sport and Exercise Sciences, Liverpool John Moores University, Liverpool, UK*

Abstract
Several researchers have explored the processes underlying perceptual-cognitive expertise, mainly using film-based studies. However, few have compared the extent to which data from film-based settings differ from those obtained through *in situ* collection. This gap in the literature is a relevant concern, since scientific research is used to provide guidance for designing training programmes. In this paper, eye movement recording and verbal reports of thinking were combined to explore the processes underpinning skilled performance in a representative volleyball task involving both film-based and *in situ* data collection. Nine volleyball players performed as backcourt defenders while wearing an eye-tracking device and providing verbal reports of thinking after each sequence. A number of significant differences were observed between the data gathered under film-based and *in situ* conditions. Namely, in the *in situ* condition participants employed longer fixations (728.11 ± 129.27 ms) than in the film condition (659.57 ± 178.06 ms), and there were differences in the nature of the fixation locations. With respect to verbal reports, participants exhibited superior level of sophistication in the *in situ* condition (2.57 ± 0.50 vs. 2.30 ± 0.84 in the film condition), while denoting a greater concern with the opponents under this condition (1.00 ± 0.73) than in the film condition (0.59 ± 0.60). These differences emerged despite task design and constraints being highly similar. No differences were apparent in the number of gaze fixations and fixation locations across conditions or in the number of verbalised condition concepts. Although exploratory, our data suggest that the mechanisms underpinning skilled decision-making in sports differ between film-based and *in situ* conditions.

Keywords: *Perceptual expertise, test design, task specificity*

Introduction

The ability to make accurate and well-timed decisions is crucial to performance at the elite level (Roca, Ford, McRobert, & Williams, 2011; Williams, Ford, Eccles, & Ward, 2011). So far, it has been demonstrated that expertise is highly sport- and function-specific (Abernethy, Baker, & Côté, 2005), and that the perception–action couplings supporting decision-making are context-specific (Passos, Araújo, Davids, & Shuttleworth, 2008). In this vein, representative simulated environments may not suffice to fully understand the processes underlying decision-making (Dicks, Button, & Davids, 2010; Mann, Abernethy, & Farrow, 2010). There is a need for researchers to develop representative task designs (Brunswik, 1955; Ericsson & Ward, 2007), as the magnitude and nature of the expertise-based differences may depend on the specificity of the task (Ericsson, 2008; Vaeyens, Lenoir, Williams, Mazyn, & Philippaerts, 2007). In a meta-analysis of 42 papers conducted by Mann, Williams, Ward and Janelle (2007), experts consistently outperformed non-experts, but the magnitude of the expertise-based differences was more evident as the task and experimental designs were more closely aligned with the demands of competition.

Although some researchers have collected verbal reports in live-action settings (cf. McPherson, 2000; McPherson & Kernodle, 2007), most work using eye movement registration techniques are film-based, as

Correspondence: José Afonso, Faculty of Sport, University of Porto, Rua Dr.Plácido Costa, 91, Porto 4200-450, Portugal. E-mail: jafonsovolei@hotmail.com

demonstrated by existing work in cricket (McRobert, Ward, Eccles, & Williams, 2011), football (North, Williams, Hodges, Ward, & Ericsson, 2009) and volleyball (Piras, Lobietti, & Squatrito, 2010). The use of film-based simulations reduces the three-dimensional world to a two-dimensional display (Mann et al., 2007), presents reduced image size (Al-Abood, Bennett, Moreno, Ashford, & Davids, 2002) and induces different visual search behaviours compared to live-action settings (Button, Dicks, Haines, Barker, & Davids, 2011; Dicks et al., 2010), all of which affect visual search behaviours. Therefore, it is important to design a representative task and compare players' decisional processes between a laboratory setting and a live-action context to promote a further understanding of the nature and magnitude of the differences.

Within this framework, some researchers suggest that skilled players tend to use more global and efficient visual search behaviours, making fewer fixations of longer duration to a smaller number of locations, compared to less-skilled players, (cf. Huys & Beek, 2002; Piras et al., 2010; Ripoll, Kerlirzin, Stein, & Reine, 1995). However, results are controversial (cf. North et al., 2009; Roca et al., 2011), and it is now considered that visual search strategies vary considerably across sports as well as within each sport, depending on the specific task (Mann et al., 2007; Vaeyens et al., 2007). The same trend is found with respect to fixation (McRobert, Williams, Ward, & Eccles, 2009; Piras et al., 2010; Roca et al., 2011). Furthermore, attention may be distinct from point-of-gaze because of the role of peripheral vision and kinaesthetic information (Huys & Beek, 2002; Tenenbaum, 2003; Vickers, 2009).

These findings support the need for research on decision-making to combine eye movement registration and verbal reports of thinking (Ericsson & Williams, 2007; McPherson & Vickers, 2004), which provide a window into the players' cognitive processes during competition (McPherson & Kernodle, 2007) and allow differentiating between experts and non-experts, as shown by research in baseball (McPherson & MacMahon, 2008), football (Roca et al., 2011), tennis (McPherson & Kernodle, 2007) and volleyball (Botelho, Afonso, Araújo, & Mesquita, 2011). However, verbal reports themselves present some limitations, as they frequently generate misleading summaries or after-the-fact reconstructions (Araújo, Travassos, & Vilar, 2010). In some occasions, the players are simply incapable of verbalising their procedure knowledge (McPherson, 1994). Indeed, motor learning is highly implicit, meaning that verbal reports on motor actions tend to be imprecise and not very reliable (Seidler, 2010).

Therefore, the combination of eye movement registration and verbal reports of thinking could afford powerful insights into the processes underpinning skilled decision-making, but few researchers have sought to combine these two process-tracing measures during performance. There are a few exceptions, such as the work of Roca et al. (2011) with football players, although the two measures were taken in different experiments. McRobert et al. (2009) using cricketers and McPherson and Vickers (2004) with volleyball players collected both data sets within one experiment.

Our purpose in this paper was to analyse the nature and magnitude of the differences in the process of decision-making between film-based and *in situ* data collection. A representative and complex volleyball task was created, attempting to reproduce the constraints observed in real-life settings. Participants were submitted to both experimental conditions. Eye movement registration and verbal reports of thinking were collected concurrently to provide a deeper understanding of the processes underpinning decision-making.

Methods

Participants

Nine female volleyball players were recruited (14.9 ± 0.3 years of age). They had a mean of 5.0 ± 1.2 years playing experience at an elite national level for their specific age group. The study was approved by the Foundation for Science and Technology – Ministry of Science, Technology and Superior Teaching of Portugal and followed the University of Porto's Ethics Committee guidelines. The participants and their parents were fully informed of its procedures and purposes and provided written consent to participate in this study. Participants were healthy and reported normal or corrected to normal levels of visual function. They were free to withdraw from testing at any stage.

Materials and apparatus

In the *film-based condition*, participants watched stimuli that were back-projected (Epson EMP-S3 3LCD Projector) onto a large screen (1.8 m height × 2 m wide) placed 4 m in front of them. The film clips were played through QuickTime Player® for Mac (version 10.1). Participants were free to move. Twelve females (mean age 22.9 ± 4.7 years), top national-level volleyball players, were invited to produce the film-based sequences and instructed to create game sequences at their will. The selection of the intended scenarios would be made after the session. A digital HD video camera (Sony Handycam HDR-XR550VE) was used to record the film stimuli from a backcourt perspective at a frequency

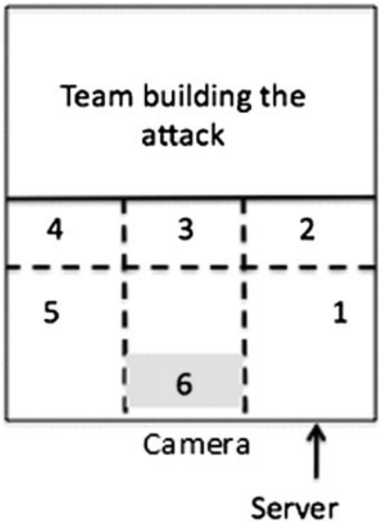

Figure 1. Experimental set-up. The participant in zone 6 is using the eye-tracker.

of 60Hz. The camera was situated at a slightly elevated perspective (approximately 3 m) near the endline of the serving team, in order to enable the entire width of the playing field to be viewed and to improve perception of depth. Each film sequence involved a serve from behind the camera towards the opposite side, and the opposing team would run an attack in response to the serve. Five players simulated the server's team, three performing blocking actions in the net (zones 4, 3 and 2) and two defending in the lateral defensive positions (zones 1 and 5; see Figure 1). The scenarios were approximately 5 seconds in length, and the endpoint for visual search data was the moment in which the ball crossed the net, to ensure standardisation of the sequences initiation times and endpoints.

Six film sequences were produced and the filming was conducted on a standard size volleyball court. Filming was conducted over a 2-hour session and a panel of three specialist volleyball coaches selected the six trials deemed most representative of the game. The selected game patterns had to be similar to those used with younger players; hence, more evolved game patterns were not selected. The footage was digitally edited using Apple iMovie'09 to assemble a number of six short clips to be used in the film-based task. Before the beginning of each clip, a black screen with a centred numbered countdown (3-2-1) was shown, to set up the participants for visualisation.

In the *in situ condition*, participants engaged in 6 vs. 6 simulated situations during training sessions on a standard volleyball court, where they assumed a backcourt defence position in zone 6 (the centre backcourt area; see Figure 1) and were free to move and interact with the action sequences, as they would do when playing in a match. The teams had to serve and to create game sequences. The experiment finished after six successful attack trials had unfolded. The trials had to be identical to those used in the film-based condition, and standardisation procedures were applied, with each sequence lasting around 5 seconds and having the same beginning and endpoints.

In *both experiments*, an Applied Science Laboratories (ASL) 3000 Mobile Eye™ registration system (Bedford, MA, USA) was used to collect gaze data. This is a video-based, monocular corneal reflection system that registers eye point-of-gaze in relation to a head-mounted colour scene camera. It operates by measuring the relative position of the pupil and corneal reflection in relation to each other using an infrared light source. This information is used to calculate point-of-gaze by superimposing a crosshair onto the scene image captured by the head-mounted camera optics. The image is transferred to MiniDV format and copied to a computer as an.avi file at a sampling frequency of 30 Hz. System accuracy was $\pm 0.5^\circ$ visual angle, with a precision of 0.5° in both the horizontal and vertical fields. The superimposed videos were analysed twice in a frame-by-frame manner using Avidemux® 2.5.4 for Mac.

Verbal reports of thinking were recorded by means of a Sony ICD-UX70 digital audio recorder. The.mp3 files were copied to an Apple MacBook Pro (2.4 GHz Intel Core 2 Duo), opened with VLC Media Player version 1.1.111 and copied to a datasheet on Microsoft Excel® 2008 for Mac. Prior to testing participants were provided with a detailed explanation on how to provide verbal reports of their thoughts (Araújo, Afonso, & Mesquita, 2011).

Procedure

Participants were provided with information concerning the experiment and a demonstration of the simulated task environment. They also had the chance to participate in one or two pre-test trials, and to present any doubts concerning their action and on providing verbal reports. In both conditions, participants were instructed to assume their ready defensive position and to try and defend the ball in each trial. The Mobile Eye™ tracker was fitted to the participants. The eye movement registration was calibrated so that the recorded indication of fixation position corresponded to each participant's point-of-gaze. In the film-based condition, a nine-point grid was used and five different points were fixated; in the *in situ* condition, five non-linear points in the scene image were used (McRobert et al., 2009; Roca et al., 2011). An eye calibration was performed for each participant to verify point-of-gaze before the trials.

Following calibration, participants were provided with instructions on how to present immediate retrospective verbal reports. Subsequently, participants assumed their position with regard to the screen, in the film-based condition, or stepped into the court and acted as backcourt defenders for as many trials as needed until the six different scenarios had been ran in the *in situ* condition. Recall interviews were realised after each trial, consisting of a single question (McPherson, 2000): 'What were you thinking about while playing that point?' This question was specifically developed for application during simulated game situations and has been used in studies conducted for volleyball (Araújo et al., 2011; Moreno, Moreno, Ureña, Iglesias, & Del Villar, 2008). There was no time limit to respond, and additional feedback on generating verbal reports was provided when necessary.

Participants completed six trials in each condition. Testing lasted around 10 minutes for the film-based condition and between 15 and 20 minutes for the *in situ* condition (excluding instructions and calibration procedures). In the *in situ* condition, participants completed between 8 and 17 trials until the same 6 from the film-based condition were obtained.

Data analysis

Visual search data. Search rate includes the mean number of fixation locations, the mean number of fixations and the mean fixation duration per trial, measured in milliseconds (Dicks et al., 2010). A fixation was defined as the period of time $\geq$100 ms (roughly three video frames) when the eye remained motionless within 3° of movement tolerance (Panchuk & Vickers, 2006). The between-condition differences on each variable were analysed using a one-way ANOVA with condition (film vs. in situ) as the between-participants factor. Partial eta squared values (η_p^2) of effect size measures were calculated.

Percentage viewing time is the percentage of time spent fixating on each area of the display (Dicks et al., 2010). Ten locations of the visual display were defined: ball trajectories (subdivided into serve trajectory, reception trajectory and setting trajectory); players performing the action (subdivided into receiver, setter and attacker); players who are not performing an action but may play a role in the action (potential attackers); space (subdivided into space between a potential attacker and the setter, and space between the attacker and the blockers); and unclassified. The 'unclassified' category was incorporated to report all the fixations that fell outside the scope of the other categories (Roca et al., 2011) and did not exceed 1% of the occurrences. Data were analysed using a two-way ANOVA with condition (film vs. *in situ*) as the between-participants factor and fixation location as the within-participants factors. Partial eta squared values (η_p^2) of effect size measures were calculated. Significant main effects were followed up using Bonferroni-corrected pairwise comparisons. Significant interaction effects were followed up using Scheffé post hoc tests.

Verbal reports. Verbal statements were transcribed and encoded following the model of protocol structure for tennis (McPherson, 2000) and adjusted to volleyball (Araújo et al., 2011; Botelho et al., 2011; Moreno et al., 2008). Units of information were classified according to three main categories: goal concepts; condition concepts; and action concepts. Condition concepts describe conditions supporting game actions (e.g. the attacker aimed at crosscourt). Consistent with the findings of Botelho et al. (2011), participants failed to mention goal concepts (e.g. 'to put the ball in good conditions for the setter'). Since volleyball is a non-invasion game, the goal of defence is to put the ball in good conditions for the team to put up a counter-attack. In this context, goals are implicit to the task, thus participants do not generate such verbal statements. Moreover, no statements concerning action concepts were produced (e.g. 'I tried rotating to the right to intercept the ball').

Condition concepts were further analysed concerning their *hierarchical levels*: concepts about skill and themselves (level 0); concepts about team members (level 1); concepts about the opponents (level 2); and concepts about goals or conditions of other nature (level 3). Hierarchical level 3 was excluded from the analysis since all the codes could be integrated in the previous levels. Condition concepts were also classified according to their *level of sophistication*, a measure of the appropriateness and level of detail of the statements, including inappropriate or weak (quality level 0), appropriate without any details or features (quality level 1), appropriate with one detail or feature (quality level 2) and appropriate with two or more features (quality level 3). The level of sophistication was evaluated comparing the verbal reports with video images from the corresponding situation, available through the eye-tracker's scene camera. Differences in the *number of condition concepts*, *levels of sophistication* and *hierarchical levels* related to the experimental conditions were analysed using a one-way ANOVA with condition as the between-participant factor. Partial eta squared values (η_p^2) of effect size measures were calculated.

Reliability of the observation. Data reliability was established using the intra- and inter-observer agreement methods. In total, 22.2% of the data were randomly selected and re-analysed to provide agreement figures using the procedures recommended by

Table I. Differences in search rate per trial across groups

	Film	*In situ*	df	*F*	*p*	η_p^2
Number of fixations	5.15 ± 1.38	5.35 ± 0.91	1	0.82	0.37	0.01
Mean fixation duration (ms)	659.57 ± 178.06	728.11 ± 129.27	1	5.24	0.02*	0.05
Number of locations	4.98 ± 1.09	5.30 ± 0.86	1	2.77	0.10	0.03

*Significant for the 0.05 level.

Tabachnick and Fidell (2007). For search rate and percentage viewing time, Cronbach's alpha ranged from 0.95 to 0.98 for intra-observer reliability and from 0.90 to 0.95 for inter-observer testing. Agreement concerning verbal reports was determined with Cohen's Kappa. Intra-observer testing showed Kappa values between 0.84 and 1.00. Inter-observer values varied from 0.84 to 1.00.

Results

Visual search data

Search rate. Significant differences were observed between experimental conditions in mean fixation duration ($F_1 = 5.24$, $p = 0.02$, $\eta_p^2 = 0.05$) (see Table I). Visual search strategies in the in situ condition involved longer fixations compared with the film condition. No other effects were significant.

Percentage viewing time. With regard to percentage viewing time, a significant main effect for fixation location was registered ($F_9 = 36.90$, $p \leq 0.001$, $\eta_p^2 = 0.39$). A significant Experimental Condition × Fixation Location interaction was observed ($F_9 = 5.50$, $p \leq 0.001$, $\eta_p^2 = 0.09$). Post hoc Scheffé tests revealed that participants spent significantly more time fixating the attacker (26.84 ± 6.62%) in the in situ condition compared to the film condition (19.93 ± 8.21%). In contrast, in the film condition participants spent significantly more time fixating on the receiver (26.99 ± 9.14%) and potential attacker (19.92 ± 4.27%) compared with the in situ condition (22.08 ± 6.73% and 5.09 ± 0.86%, respectively).

Verbal report data

Number of condition concepts. There were no significant differences with regard to the number of condition concepts (see Table II).

Level of sophistication. There were differences in the level of sophistication ($F_1 = 3.99$, $p = 0.05$, $\eta_p^2 = 0.04$), with the participants presenting a superior level of sophistication in the in situ condition, although the proof value is marginal.

Hierarchical levels. There were between-conditions differences for both level 1 – team members ($F_1 = 9.96$, $p = 0.002$, $\eta_p^2 = 0.09$) and level 2 – opponents ($F_1 = 10.10$, $p = 0.002$, $\eta_p^2 = 0.09$). In the in situ condition, participants generated a greater number of condition concepts referring to the opponents, whereas in the film condition they presented a superior number of condition concepts with respect to team members.

Discussion

In order to better understand the processes underpinning skilled decision-making, it is necessary to design experimental conditions that reproduce as best as possible the task specificity and complexity exhibited in real-life contexts (Ericsson & Ward, 2007). Nonetheless, existing work has mainly relied on laboratory tasks (e.g. McRobert et al., 2009), with only a few studies involving live-action designs (e.g. Lee, 2010). Furthermore, there have been few attempts to compare between the two task conditions (e.g. Bruce, Farrow, Raynor, & Mann, 2012; Dicks et al., 2010). Therefore, we explored the mechanisms underpinning decision-making in a

Table II. Differences in verbal reports across groups

	Film	*In situ*	df	*F*	*p*	η_p^2
Number of condition concepts	1.54 ± 0.57	1.52 ± 0.80	1	0.02	0.89	≤0.001
Level of sophistication	2.30 ± 0.84	2.57 ± 0.50	1	3.99	0.05*	0.04
Hierarchical level 1 – team members	0.87 ± 0.62	0.52 ± 0.54	1	9.96	0.002*	0.09
Hierarchical level 2 – opponents	0.59 ± 0.60	1.00 ± 0.73	1	10.10	0.002*	0.09

*Significant for the 0.05 level.

representative and complex volleyball task, comparing two distinct conditions: film-based vs. *in situ* data collection. The tasks were made as similar as possible in order to standardise experimental conditions (e.g. the same scenarios were recreated and in both cases they were allowed to move). Participants' eye movements and immediate retrospective verbal reports of thinking were recorded.

With respect to visual search rate, participants exhibited strategies involving longer fixations in the *in situ* condition in comparison to the film-based condition. This finding contradicts that reported by Button et al. (2011) where longer durations were reported under film compared with *in situ* conditions. As the length of the scenarios was standardised, longer fixations may induce a fewer number of fixations to less fixation locations. There were also differences between the two experimental conditions for percentage viewing time. Participants spent more time fixating on the attacker in the *in situ* condition, while in the film-based condition more time was spent fixating a potential attacker. The difference between attacker and potential attacker presents an important functional difference. An attacker is a player that was previously solicited by the setter; the ball was set and it was overtly known that attacker would be responsible for contacting the ball and performing the attack. In turn, a potential attacker is any player who is ready to attack the ball, but the ball has not been set yet. Therefore, fixating on a potential attacker means the participant is attending to a potential anticipatory cue.

These differences may be related to image size, since this factor is known to influence visual search strategies (Al-Abood et al., 2002). As distances between distinct points of interest become reduced in the film-based condition, it is easier for participants to attend to cues emerging in their peripheral vision (case in point: movements from certain attackers before the setting), while in the *in situ* condition they will tend to focus more closely on the ball and on the players more closely involved in the move. Furthermore, the *in situ* condition affords a real possibility of contacting the ball, therefore presenting a different challenge than that of the film-based condition. This seems to confirm that the mechanisms underpinning perception and decision-making are highly dependent on the nature of the experimental tasks (Dicks et al., 2010; Mann et al., 2010).

With regard to verbal reports of thinking, no differences emerged in the number of condition concepts generated by the participants across both experimental conditions. However, the level of sophistication associated with the generated concepts was superior in the *in situ* condition in comparison to the film-based condition, even though statistical significance was marginal ($p = 0.05$); hence, caution is warranted when drawing conclusions. As participants are trained and prepared to perform under *in situ* conditions and not under film-based conditions, they may be better attuned to the *in situ* conditions highlighting the task-specific nature of expertise (Abernethy et al., 2005; Ericsson & Lehmann, 1996; Passos et al., 2008). The possibility to actually intercept the ball may be modulating such differences, as it has been demonstrated that the possibility to engage in such action changes the process of decision-making (Bruce et al., 2012).

Finally, there were differences in the hierarchical levels of the verbal reports. In the film-based condition, participants mentioned significantly more often concepts referring to their team members. In contrast, more concepts referring to the opponents were generated in the *in situ* condition. In the *in situ* condition, participants spent more time fixating on the attacker, impairing their perception of the blockers. This finding provides support for the perspective of attuning to specific affordances, which is dependent on the specific context of performance (Anson, Elliott, & Davids, 2005; Passos et al., 2008). In fact, it has been demonstrated that different task constraints rely on divergent perceptual-cognitive processes (Bruce et al., 2012; Dicks et al., 2010; Mann et al., 2010). In this case, the possibility of actually intercepting the ball may explain why the participants referred more often to the opponents under the *in situ* condition.

In sum, it has been proposed that film-based studies and live-action research generate different measures of perceptual expertise (Mann et al., 2007; Williams et al., 2011). In our study, differences across experimental conditions were shown for both visual search strategies and verbal reports of thinking. However, it should be acknowledged that notably no differences emerged on a number of variables such as the number of gaze fixations and fixation locations, as well as the number of verbalised condition concepts. Furthermore, the slightly elevated perspective through which the participants view the film footage may influence our findings, but it was required to produce a good viewing angle. In real-life situations, players can move their heads and bodies to better observe certain details of the surroundings, but a camera film is static. In this case, filming from a regular perspective would occlude relevant cues.

Although our data are exploratory, they demonstrate that the mechanisms underpinning skilled decision-making in sports may differ to some degree between film-based and *in situ* conditions, in line with previous research (Bruce et al., 2012; Button et al., 2011; Dicks et al., 2010). Moreover, these differences exist even when using extremely similar tasks and standardised experimental procedures. It is suggested that different image size and action possibilities afforded by each condition may have emerged as core components in explaining such differences. Therefore, it is strongly suggested that in future researchers explore the nature and magnitude of such differences.

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