Skill-Based Differences In Visual Search Behaviours And Verbal Reports In A Representative Film-Based Task In Volleyball

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Skill-Based Differences In Visual Search Behaviours And Verbal Reports In A Representative Film-Based Task In Volleyball

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Abstract

A desire to increase understanding of the mechanisms underpinning expert performance has motivated a large body of research. We examined the processes supporting skilled performance in a complex film-based volleyball task using a representative simulated environment. Participants were presented a complex, game-like volleyball task. We combined eye movement recording with immediate retrospective verbal reports of thinking in fifteen elite female volleyball players, ranked into skilled and less skilled groups. Skilled players employed longer fixations than their less skilled counterparts, and spent a greater amount of time fixating the receiver and functional spaces between two or more players. Skilled participants generated significantly more condition concepts, and presented a superior level of sophistication in their verbal reports. Data suggests that it is relevant to use tasks that simulate real-life environments. The definition of functional spaces, aiming for locations that stimulate retrieving information from more than one cue at a time, affords researchers to use eye-tracking devices to analyze peripheral vision. Based on collection of verbal reports researchers could assess if those functional spaces were relevant for the subjects. Researchers need to be thoughtful when designing representative tasks in order to accurately simulate competitive contexts.

Key words: perceptual expertise; gaze behavior; thought processes; test design

1. Introduction

Perceptual and cognitive skills are assumed to be core concepts of performance in dynamic, time-constrained domains such as in sport (Dicks *et al.*, 2010), the military (Janelle and Hatfield, 2008), and even daily activities (Patla and Vickers, 2003). However, limited effort has been devoted to identifying the processes underpinning superior performance (McRobert *et al.*, 2009). It is acknowledged that experts have the ability to adapt more rapidly to specific task constraints and to anticipate the outcome of the action (Williams *et al.*, 2011), but the nature and magnitude of these differences varies considerably depending on the type and complexity of the task (McRobert *et al.*, 2011), as well as the experimental design employed (Button *et al.*, 2011). Although research findings have been shown that the superiority of experts over non-experts is more pronounced as the complexity and specificity of the task is enhanced (Williams *et al.*, 2008), most of the experiments applied in those studies have used tasks that present smaller complexity than real-life events (e.g. Piras *et al.*, 2010).

With regard to research methods, a number of researchers have applied film-based simulations of performance context to examine the visual search behaviors used during performance (Roca *et al.*, 2011). However, published reports suggest that the relationship between gaze and attention is not linear (Vaeyens *et al.*, 2007). In order to effectively capture the mechanisms supporting superior performance, it is necessary to use complementary methods by, for example, combining eye-movement registration with verbal reports of thinking (Ericsson and Williams, 2007). Visual search data provide an indication of how the visual system is used to extract information from the display, whereas verbal reports provide a measure of how the information extracted is translated into a decision. Thus far, research using eye-movement recording and verbal reports of thinking has followed almost parallel streams. The tendency has been to apply the two methods independently, often in separate experiments (for an exception, see McRobert *et al.*, 2011).

In the present study, we examined the processes underpinning skilled performance in a dynamic, externally paced complex volleyball task using a representative simulated environment while combining simultaneous eye movement recording and verbal reports of thinking. The task required defenders to analyze sequences of offensive moves. Taking into account the highly complex, game-like scenarios presented in the task, it was expected that its data was representative of the specific task constraints in volleyball. The combination of eye tracking data and verbal reports is expected to provide a deeper understanding of the mechanisms behind decision-making in sports.

2. Methods

2.1. Participants

Fifteen elite female volleyball players were recruited. A panel of five expert coaches knowledgeable of the participants ranked them into skilled (n=9; 16.1 ± 2.0 years of age) and less skilled (n=6; 16.8 ± 2.0 years) groups based on a subjective evaluation of their decision-making skills, according to the procedures reported by Baker *et al.* (2003). The inter-observer agreement percentages ranged from 80 to 86.7%. Participants signed an informed consent form and reported normal or corrected to normal levels of visual function. They were free to withdraw from testing at any stage. The study followed the lead institution’s ethics guidelines.

2.2. Materials and apparatus

A simulated task environment was developed to assess participants’ decision-making in volleyball. Participants were exposed to filmed sequences that were back-projected (Epson EMP-S3 3LCD Projector) onto a large screen (1.8 m height x 2 m wide). The film clips were played through QuickTime Player® (version 10.1), and the screen was placed 4 m directly in front of the participant. Participants were free to move, as they would do when playing in a match.

Twelve female (mean age 22.9 ± 4.7 years) volleyball players were recruited to create the test stimuli. A digital HD video camera (Sony Handycam HDR-XR550VE) was used to record the stimuli from a backcourt perspective at 60Hz. The camera was positioned at a slightly elevated perspective (approximately 3 m) near the endline of the serving team. The sequences included a serve towards the opposite side, after which six players would run an offensive sequence and three blockers tried to stop the attack. In total, six video trials were created. A panel of three expert volleyball coaches determined their content and structure. All trials were approximately 5 s in length each ending at the moment in which the ball crossed the block so as to standardize sequence duration. The filming was conducted on a standard size volleyball court. The test footage was collected over a 2-hour session and was later digitally edited using Apple iMovie'09 to construct a number of short clips to be used in the simulation task. At the start of each clip, a black screen with a centered numbered countdown (3-2-1) appeared to prepare the participants.

Participants assumed a backcourt defensive position and had to follow attacking sequences from the opposing team. Visual search data were recorded using the Applied Science Laboratories 3000 MobileEye™ registration system (Bedford, MA, USA), which is a video-based, monocular corneal reflection system that records eye point-of-gaze with regard to a head-mounted color scene camera. The system measures the relative position of the pupil and corneal reflection in relation to each other through an infrared light source, using these features to compute point-of-gaze by superimposing a crosshair onto the scene image captured by the head-mounted camera optics. The image exhibits a sampling frequency of 30Hz (30 frames per second). System accuracy was ±0.5º visual angle, with a precision of 0.5º in both the horizontal and vertical fields. The video footage was analyzed frame-by-frame using Avidemux® 2.5.4. for Mac.

Verbal reports were recorded with a Sony ICD-UX70 digital audio recorder and copied to an Apple MacBook Pro (2.4GHz Intel Core 2 Duo), opened with VLC Media Player version 1.1.111 and copied to a datasheet on Microsoft Excel® 2008 for Mac. Before being tested, the players were given a thorough explanation on how to provide verbal reports (Araújo *et al.*, 2011).

2.3. Procedure

The MobileEye™ tracker was fitted to the participants and checked for their overall commodity. The eye-movement registration was calibrated using a 9-point grid so that the fixation mark corresponded precisely to the participant's point-of-gaze. An eye calibration was performed for each participant to verify point-of-gaze before the trials and periodic calibration checks were conducted during testing. After calibration, participants were presented with the six trials in the simulated task environment. These trials allowed participants to provide immediate retrospective verbal reports of thinking. Participants completed six trials and each individual test session was completed in approximately 20 min. The clips' order of presentation was kept consistent across all participants. Interviews were conducted after each trial, and consisted in one question: 'What were you thinking about while playing that point?', following the interview protocol reported by McPherson (2000) and adapted to the requirements of volleyball by Moreno *et al.* (2008) and Araújo *et al.* (2011). In this protocol, immediately after each play the participant is removed from the court and inquired about his thoughts during the play. The participants had no time limit to respond.

2.4. Data analysis

2.4.1. Visual search data

Search rate comprised the mean number of fixation locations per trial, the mean number of fixations per trial and the mean fixation duration per trial in milliseconds. A fixation was defined as the period of time ≥100 ms (≈3 video frames) when the eye remained stationary within 3º of movement tolerance (Panchuk and Vickers, 2006). The between-group differences were analyzed using a One-Way ANOVA with Group (skilled vs. less skilled) as the between-participants factor. Effect size measures were obtained through calculation of Partial eta squared (η^2_p).

Percentage viewing time was the percentage of time spent in fixation on each area of the display. The display was divided into ten locations: ball flight paths (subdivided into serve trajectory, reception trajectory, and setting trajectory); players that perform the action (subdivided into receiver, setter, attacker); players that are not performing an action (potential attackers); space (subdivided into between a potential attacker and the setter, and between the attacker and the blockers); and unclassified. The 'unclassified' category was included to account for all the fixations that did not fall within any of the other, and did not exceed 2% of total viewing time, indicating that the bulk of the data could be properly categorized in the established categories. Data were analyzed using a two-way ANOVA with Group (skilled vs. less skilled) as the between-participants factor and Fixation Location (ten locations as described above) as the within-participants factors. Partial eta squared values (η^2_p) effect size measures were calculated. Significant main effects were followed up using Bonferroni-corrected pairwise comparisons. Interaction effects were followed up using Scheffé post hoc tests.

2.4.2. Verbal reports

Verbal statements were transcribed *verbatim* and encoded according to the model of protocol structure for tennis (McPherson, 2000), later adapted to volleyball (Araújo *et al.*, 2011; Moreno *et al.*, 2008). No *goal concepts* emerged, probably due to the purpose of defensive actions being highly implicit. Furthermore, no *action concepts* were registered. *Condition concepts* were encoded, referring to the conditions under which certain actions are applied in order to achieve the goal (e.g., the attacker was outside of the antenna). *Condition concepts were* further examined by considering two *hierarchical levels*: concepts about team members (level 1), and concepts about the opponents (level 2). Each identified condition concept was further classified according to one of the following four *levels of sophistication*: 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). Regarding the *number of condition concepts*, *levels of sophistication*, and *hierarchical levels*, skill-based differences were analyzed using separate One-Way ANOVAs with Group as the between-participant factor. Partial eta squared values (η^2_p) effect size measures were calculated.

2.4.3. Reliability of the observation

Altogether, 26.7% of the data were randomly selected and re-analyzed. For *search rate* and *percentage viewing time*, Cronbach's Alpha ranged from 0.983 to 0.997 for intra-observer reliability and from 0.963 to 0.981 for inter-observer testing. These values reflect an excellent internal consistency (Kline, 1999). Agreement concerning verbal reports' variables was determined with Cohen's Kappa. Intra-observer testing showed Kappa values between 0.906 and 1.000. Inter-observer values varied from 0.824 to 1.000. All values are above 0.75, established as the minimum for considering the testing to be reliable (Fleiss *et al.*, 2003).

3. Results

3.1. Visual search data

Search rate. There were significant skill-based differences in the mean fixation duration ($F_{(1, 88)}$=5.737, p=0.019, η^2_p=0.061, see Table 1). The skilled participants employed longer fixations compared with the less skilled participants. There were no significant differences in the number neither of fixations nor of fixation locations. However, these results were close to statistical significance, as they presented *p* values under 0.085, indicating an error likelihood of less than 10%. There was a trend for less skilled participants presenting a higher number of fixations and of fixation locations.

Table 1. Differences in search rate per trial across groups.

	Skilled	Less skilled	df	F	p	η^2_p
No. Fixations	5.17±1.42	5.75±1.59	1-88	3.296	0.073	0.036
Mean Fixation Duration (ms)	674.94±190.62	576.08±193.66	1-88	5.737	0.019	0.061
No. Locations	4.94±1.12	5.39±1.25	1-88	3.093	0.082	0.034

Percentage viewing time. With respect to percentage viewing time, significant Group x Fixation Location interaction was observed ($F_{(1, 414)}$=4.749, p≤0.001, η^2_p=0.094). Post hoc Scheffé tests revealed that skilled participants spent significantly more time fixating the receiver (30.9±8.8%, p=0.001) and the space between the attacker and the blockers (22.3±6.6%, p≤0.001) compared to the less skilled participants (24.6±10.5 and 8.9±5.9%, respectively). In contrast, the less skilled participants spent significantly more time fixating the attacker (23.7±6.6%, p=0.013) compared with their skilled counterparts (18.3±9.3%).

3.2. Verbal report data

Condition Concepts. There were significant skill-based differences in the number of condition concepts ($F_{(1, 88)}$=8.403, p=0.005, η^2_p=0.087) (see Table 2). Skilled participants generated significantly more condition concepts than their less skilled counterparts.

Level of Sophistication. Skill-related differences were extended to the level of sophistication ($F_{(1, 85)}$=6.064, p=0.016, η^2_p=0.067), with the skilled group presenting a superior level of sophistication. Specifically, the skilled group exhibited a value near 2, which means that their reports were usually appropriate and included one relevant detail or feature. Otherwise, the less skilled group was closer to 1, which imply that many reports were appropriate but failed to include specific details or features.

Table 2. Differences in verbal reports across groups.

	Skilled	Less skilled	df	F	p	η^2_p
No. Condition Concepts	1.96±0.91	1.44±0.70	1-88	8.403	0.005	0.087
Level of Sophistication	2.66±0.56	2.29±0.84	1-85	6.064	0.016	0.067
Hierarchical Level 1 – Team Members	1.13±0.73	0.50±0.51	1-88	20.315	≤0.001	0.188
Hierarchical Level 2 - Opponents	0.80±0.69	0.89±0.75	1-88	0.385	0.536	0.004

Hierarchical Levels. With respect to the hierarchical levels, differences between groups were found for level 1 – team members ($F_{(1, 88)}$=20.315, p≤0.001, η^2_p=0.188), but not for level 2 – opponents. The skilled participants reported more condition concepts referring to their team members when compared to the less skilled participants. Therefore, the superior number of condition concepts reported by the skilled players relies on the generation of a greater number of concepts related to their team members.

4. Discussion

We examined the mechanisms underpinning skilled performance in a dynamic, externally paced complex volleyball task using a representative simulated environment. Participants assumed a backcourt defensive position and had to follow attacking sequences from the opposing team. We recorded eye-movements concurrently and retrospective verbal reports of thinking to provide a more thorough understanding of the processes underlying decision-making in the task. Our data showed that skilled players employed longer fixations. A trend was observed for less skilled players to make more fixations to a greater number of locations. This finding supports previous research conducted in volleyball in which the skilled participants had produced fewer fixations of longer duration compared with less skilled participants (Piras *et al.*, 2010), even though this latter study was conducted in low-complexity settings. However, our results contradict previous findings emerged from studies in cricket and football in which skilled players make more fixations of shorter duration to a higher number of locations in the visual display compared with their less skilled counterparts (McRobert *et al.*, 2009; Roca *et al.*, 2011). Therefore, although task complexity interferes with the product and process of performance (Williams *et al.*, 2008), these data suggest that the inconsistency in the findings may be due to differences in the size and number of players involved in the trials, reflecting variations in task constraints. In the present study, results support a more economical visual search pattern by skilled players using fewer but longer fixations.

There were skilled-based differences in percentage viewing time, with skilled participants spending a greater amount of time fixating the space between the attacker and the blockers in comparison with the less skilled participants. Skilled players were therefore less dependent on the ball trajectory, being more likely to allocate attention towards other cues in the visual display (cf. Piras *et al.*, 2010). A possible explanation is that skilled players may be capable of simultaneously observing the attacker and the blockers and fixating on the functional space between them (cf., Roca *et al.*, 2011), which suggests greater use of peripheral vision (Behrmann and Ewell, 2003; Williams *et al.*, 2011). This enhanced utilization of peripheral vision denotes two important implications for practice: *a)* the fixation locations have to go beyond specific physical cues (e.g., ball, arm of the player) and move towards the concept of functional spaces (e.g., space between the setter and a probable receiver of the set); and *b)* it further underlines the need to complement visual data with verbal reports of thinking, in an attempt to clarify dubious situations.

Analysis of verbal reports revealed that skilled participants generated significantly more condition concepts than less skilled counterparts (cf., McPherson, 2000). Moreover, their statements also presented a superior level of sophistication in comparison to the less skilled peers, supporting findings in sports such as baseball (McPherson, 1993), tennis (McPherson and Kernodle, 2007) and volleyball (Araújo *et al.*, 2011), and suggesting that skilled players possess a more detailed perception of the situation. Examination of the hierarchical levels revealed that skilled participants focused more on team members than their less skilled peers. This finding is consistent with our eye-movement data, which suggest that skilled players fixate more on the space between the attacker and the blockers, while the less skilled players fixate more on the attacker. This strategy allows the skilled players to better perceive the actions of their team's blockers, which has translated into differences in verbal reports of thinking. Accordingly, it is important to highlight that collecting verbal reports allowed a useful confirmation of the appropriateness of the defined functional spaces. It also informs research that more than one method should be combined if there is interest in understanding the complex nature of a given phenomenon.

In summary, a complex, representative task was used to highlight skill-based differences in the process of analyzing visual displays. Taking into account that research mainly uses simple, easier to control tasks, the utilization of a highly complex, game-like task aims to provide data that better translate into practical implications. Furthermore, it reveals that it is possible to conduct rigorous research in rich environments. Also, there remain only a limited number of reports where eye movement and verbal report data have been collected simultaneously (McRobert *et al.*, 2009). In the present study, skilled players made longer fixations with a trend for making fewer fixations to a smaller number of locations than less skilled players. Skilled players fixated more often on functional spaces in comparison to less skilled participants, suggesting greater use of peripheral vision. In addition, skilled players generated more condition concepts and showed superior concept sophistication.

These data suggest that it is relevant to use tasks that simulate real-life environments, and this concept should be extended for domains other than sport. More so, the definition of functional spaces, aiming for locations that stimulate retrieving information from more than one cue at a time, affords researchers to use eye-tracking devices to analyze peripheral vision in addition to foveal vision. The collection of verbal reports may allow a better understanding about the relevance of those functional spaces for the subjects. Therefore, researchers need to be thoughtful when designing representative tasks in order to simulate as accurately as possible real competitive contexts (Ericsson and Ward, 2007).

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6. References

Araújo, R., Afonso, J. and Mesquita, I. (2011), Procedural knowledge, decision-making and game performance analysis in Female Volleyball's attack according to the player's experience and competitive success, **International Journal of Performance Analysis in Sport**, 11, 1-13.

Baker, J., Côté, J. and Abernethy, B. (2003), Learning from the experts: Practice activities of expert decision makers in sport, **Research Quarterly for Exercise and Sport**, 74, 342-347.

Behrmann, M. and Ewell, C. (2003), Expertise in tactile pattern recognition, **Psychological Science**, 14, 480-486.

Button, C., Dicks, M., Haines, R., Barker, R. and Davids, K. (2011), Statistical modelling of gaze behaviour as categorical time series: What you should watch to save soccer penalties, **Cognitive Processing**, 12, 235-244.

Dicks, M., Button, C. and Davids, K. (2010), Examination of gaze behaviors under in situ and video simulation task constraints reveals differences in information pickup for perception and action, **Attention, Perception, and Psychophysics**, 72, 706-720.

Ericsson, K. A. and Ward, P. (2007), Capturing the naturally occurring superior performance of experts in the laboratory, **Current Directions in Psychological Science**, 16, 346-350.

Ericsson, K. A. and Williams, A. M. (2007), Capturing naturally occurring superior performance in the laboratory: Translational research on expert performance, **Journal of Experimental Child Psychology: Applied**, 13, 115-123.

Fleiss, J., Levin, B. and Paik, M. (2003), **Statistical methods for rates and proportions** (3rd Ed.). Wiley-Interscience.

Janelle, C. and Hatfield, B. (2008), Visual attention and brain processes that underlie expert performance: Implications for sport and military psychology, **Military Psychology**, 20, S39-S69.

Kline, P. (1999), **The handbook of psychological testing** (2nd Ed.). London: Routledge.

McPherson, S. (1993), The influence of player experience on problem solving during batting preparation in baseball, **Journal of Sport and Exercise Psychology**, 15, 304-325.

McPherson, S. (2000), Expert-novice differences in planning strategies during collegiate singles tennis competition, **Journal of Sport and Exercise Psychology**, 22, 39-62.

McPherson, S. and Kernodle, M. (2007), Mapping two new points on the tennis expertise continuum: Tactical skills of adult advanced beginners and entry-level professionals during competition, **Journal of Sports Sciences**, 25, 945-959.

McRobert, A., Ward, P., Eccles, D. and Williams, A. M. (2011), The effect of manipulating context-specific information on perceptual-cognitive processes during a simulated anticipation task, **British Journal of Psychology**, 102, 519-534.

McRobert, A., Williams, A. M., Ward, P. and Eccles, D. (2009), Tracing the process of expertise in a simulated anticipation task, **Ergonomics**, 52, 474-483.

Moreno, M. P., Moreno, A., Ureña, A., Iglesias, D. and Del Villar, F. (2008), Application of mentoring through reflection in female setters of the Spanish National Volleyball team: A case study, **International Journal of Sport Psychology**, 39, 59-76.

Panchuk, D. and Vickers, J. (2006), Gaze behaviors of goaltenders under spatial-temporal constraints, **Human Movement Science**, 25, 733-752.

Patla, A. and Vickers, J. (2003), How far ahead do we look when required to step on specific locations in the travel path during locomotion?, **Experimental Brain Research**, 148, 133-138.

Piras, A., Lobietti, R. and Squatrito, S. (2010), A study of saccadic eye movement dynamics in volleyball: Comparison between athletes and non-athletes, **Journal of Sports Medicine and Physical Fitness**, 50, 99-108.

Roca, A., Ford, P., McRobert, A. and Williams, A. M. (2011), Identifying the processes underpinning anticipation and decision-making in a dynamic time-constrained-task, **Cognitive Processing**, 12, 301-310.

Vaeyens, R., Lenoir, M., Williams, A. M., Mazyn, L. and Philippaerts, R. (2007), The effects of task constraints on visual search behavior and decision-making skill in youth soccer players, **Journal of Sport and Exercise Psychology**, 29, 147-169.

Williams, A. M., Ford, P., Eccles, D. and Ward, P. (2011), Perceptual-cognitive expertise in sport and its acquisition: Implications for applied cognitive psychology, **Applied Cognitive Psychology**, 25, 432-442.

Williams, A. M., Ward, P., Ward, J. and Smeeton, N. (2008), Domain-specificity, task-specificity, and expert performance, **Research Quarterly for Exercise and Sport**, 79, 428-433.