Monten. J. Sports Sci. Med. 2 (2013) 2: 5–8
Original scientific paper
UDC 796.062(047.31)

Theoretical Issues and Methodological Implications in Researching Visual Search Behaviours: A Preliminary Study Comparing the Cognitive and Ecologic Paradigms

José Afonso
University of Porto, Faculty of Sports, Centre of Research, Education, Innovation and Intervention in Sport, Porto, Portugal

A B S T R A C T

A number of research papers have been devoted to understanding the mechanisms underpinning successful decision-making in sports, and analysis of eye movements has deserved special attention in this concern. A thorough reading of existing literature denotes that research on ocular fixations requires at least 100 milliseconds within the same location. For average eye-tracking systems, this means using at least three frames for each fixation. However, ecological psychology has claimed that as low as 16.67 milliseconds might suffice to capture relevant information, implying using merely one frame to consider that a fixation has been made. The goal of this experiment was to directly compare two systems (one frame-one fixation versus three frames-one fixation) for coding information concerning eye movements in a representative volleyball task in an in situ condition. Specifically, it was intended to analyse emerging differences and their meaning. Results exhibited statistically significant differences with regard to search rate (number of fixations, number of fixation locations, and mean fixation duration). Analysing fixation locations it was apparent that the ecological paradigm for considering visual fixations afforded supplementary information. Furthermore, the additional emerging cues appeared to be meaningful, and the level of noise introduced was very low. It is suggested that future research in eye movements considers using the one frame-one fixation approach, instead of the traditional three frames-one fixation set.

Key words: *decision-making, visual search behaviours, methodology of investigation.*

Introduction

Visual search behaviours represent a mainstream line of research within the study of decision-making, specifically in sports[1,2]. However as different scientific paradigms have emerged when approaching decision-making, with a highlight towards the 'cognitive'[3,4] and 'ecological'[5,6] perspectives, we contend that these paradigms are expected to impact upon designing research methods.

The cognitive paradigm states the brain requires some amount of time to process information, and usually a time interval of around 100 milliseconds is considered minimum for the practitioner to retrieve meaningful information pertaining the situation at hand[7]. Since most head-mounted displays used in eye-tracking studies present a 30Hz-sampling rate (e.g. ASL® 3000), one frame will equal around 33.3 milliseconds. Therefore, research following the guidelines of the cognitive paradigm requires that a gaze upon any location must last at least three frames (≈100 milliseconds). The fixations that lasting less than three frames are not considered, mostly due to the reason, it provides insufficient time to retrieve and process meaningful information.

However, proponents of the ecologic paradigm have suggested that information retrieval is continuous[8], hence changing the nature of concepts such as reaction time and information processing. More specifically, claims have been made supporting that fixation as quick as around 16 milliseconds may suffice to capture relevant information from the environment[9]. Despite considerable disparities between the two theoretical propositions, practical approaches have exclusively applied the cognitive paradigm[10-14], while no study to our knowledge has applied the ecologic paradigm.

The purpose of this study is therefore to compare two systems for coding eye movement data. Using a representative design for a defensive task in volleyball, in an in situ condition, both systems will be used for coding the ocular fixations. We intend to unfold whether there are relevant differences emerging from the two cataloguing systems, and their implications for research and practice alike.

Materials and Metods

Participants

Twelve adult women volleyball players (the oldest with 31 years of age and the youngest with 19) were recruited from a 1st division team. 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.

Material and apparatus

We applied a representative task design previously developed to evaluate the participants' eye-movement behaviours in volleyball[10]. Participants played in 6 vs. 6 simulated matches during a training session, while acting as defenders in centre backcourt position (zone 6, see Figure 1). The players moved and tried intercepting the ball, as they would normally do. The starting point was common to all the participants.

Received for publication July 5, 2013

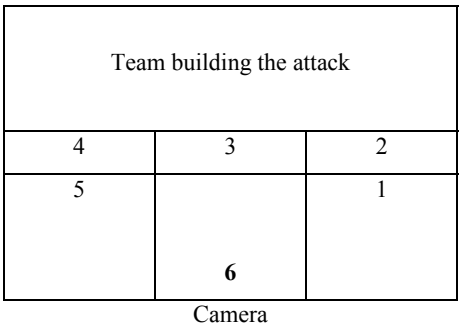

FIGURE 1
EXPERIMENTAL SET-UP. THE PARTICIPANT IN ZONE 6 IS USING THE EYE-TRACKER

The team could play without restrictions and the participants would take turns in the backcourt defensive tasks. The participant momentarily using the eye-tracking system would play in zone 6. Each time the participants made a defence or an attempt to defend in their area of responsibility a trial was attributed to them. Six trials per participant were collected, totalizing 72 trials overall. All trials lasted around five seconds, starting with a serve from the participant's team, followed by an attack sequence by the opposing team, and the endpoint was established as soon as the ball crossed the block. Action took place on a standard size volleyball court.

During the trials, participants' gaze behaviours were registered using the Applied Science Laboratories (ASL) 3000 MobileEye™ registration system (Bedford, MA, USA). This is a video-based, monocular corneal reflection system that registers eye point-of-gaze with respect to a head-mounted colour scene camera. It allows measuring the relative position of the pupil and corneal reflection in relation to each other using an infrared source, which is then used to compute point-of-gaze. The sampling frequency is of 30Hz (30 frames per second), meaning that a cognitive coding system will require a minimum of three frames for a fixation to be considered. System accuracy was ±0.5º visual angle, with a precision of 0.5º in the horizontal and vertical fields alike. The resultant superimposed videos were analysed frame-by-frame using Avidemux® 2.5.4. for Mac.

Procedure

The participants were first introduced to the purposes of the investigation and were familiarized with the experimental setting. They were instructed to play at will and to assume their usual ready defensive position. Participants should try to intercept the ball, despite some limitations imposed by wearing of the eye-tracking system (e.g., players should avoid quick falls in order to avoid damaging the device). Before starting the trials, the system was fitted to the participants, ensuring maximum comfort during performance. Calibration was conducted using five non-linear points in the visual space, to ensure that the recorded indication of point-of-gaze would be accurate. Participants were then positioned in backcourt zone 6 and played until six trials were achieved.

Data analysis

Search rate comprised the number of fixation locations, mean fixation duration and number of fixation locations per trial, measured in milliseconds. A fixation was defined as the eye remaining stationary within 3º of movement tolerance during a period of time ≥100ms (three video frames) for the cognitive coding system, and ≤40ms (one video frame) for the ecologic coding system. The between-group differences were analysed using a Mann-Whitney *U* with coding system (cognitive vs. ecologic) as the between-participants factor. Effect size measures were calculated through the formula $r=Z/\sqrt{N}$. The level of significance was fixed at .05. Data was analysed using SPSS version 20.0 for Mac.

Percentage viewing time characterizes the percentage of time spent gazing upon each area of the display, which was divided into nine locations, following similar the protocol of Afonso et al.[10]: ball flight paths (reception trajectory, setting trajectory); players performing with the ball (receiver, setter, attacker, blocker); players performing without the ball (potential attacker); visual pivot (VP - between a potential attacker and the setter; between the attacker and the blockers). There was also an unclassified category, included to account for fixations falling outside the scope of the previous categories, and did not exceed 1.65% of total viewing time for the ecologic system and was absent in the cognitive system. Descriptive statistics were applied to highlight the categories that emerged in the ecologic system in addition to those already present using the cognitive system of coding.

Reliability of the observation

One randomly selected trial per participant was reanalysed for reliability purposes, in a total of twelve out 72 trials, representing 16.7% of the sample, above the value suggested by Tabachnick and Fidell[15]. Cronbach's Alpha ranged from 0.760-0.994 for inter-observer testing.

Results

Search rate

As shown in Table 1, there were significant system-based differences in the number of fixations, mean fixation duration, and number of fixation locations. Namely, there was a superior number of fixations and of fixation locations when using the ecologic system for coding gaze behaviour. Conversely, mean fixation duration was lower using the ecologic system.

Percentage viewing time

Regarding percentage viewing time, the ecologic system of classification promoted the emergence of more cues (see Table 2). These additional visual cues appear in supplement to those also observed when using the cognitive system for coding the gaze, but fall within the same categories.

Overall, coding the visual search behaviour using the ecologic system reveals 74 additional visual fixations into ten different locations. Altogether, around 15% of the visual cues emer-

ged only when applying the ecologic framework. Unclassified fixations represent less than 2% of the total percentage viewing time, but have emerged only when using the ecologic coding paradigm.

TABLE 1
DIFFERENCES IN SEARCH RATE PER TRIAL ACROSS PARADIGMS

	Ecologic Mean rank	Cognitive Mean rank	U	z	p	r
Number of fixations	6.72±2.65 80.72	5.67±1.68 64.50	2,000.00	-2.42	0.016*	0.29
Mean fixation duration (ms)	420.86±123.90 64.50	466.54±107.12 80.50	2,016.00	-2.30	0.021*	0.27
Number of locations	5.75±1.37 82.25	5.14±1.12 62.75	1,890.00	-2.93	0.003*	0.35

Legend: * Significant for the 0.05 level

TABLE 2
VISUAL CUES EMERGING WHEN USING THE DIFFERENT CODING PARADIGMS

	Ecologic (n)	Cognitive (n)	Ecologic only	
			n	% within total
Attacker	72	66	6	1.24
Blocker	18	10	8	1.65
Potential attacker	30	26	4	0.83
Receiver	46	44	3	0.41
Reception trajectory	72	66	6	1.24
Setter	80	76	4	0.83
Setting trajectory	48	30	18	3.72
VP attacker-blocker	48	40	8	1.65
VP setter-middle-attacker	62	52	10	2.07
Unclassified	8	0	8	1.65
Total	**484**	**410**	**74**	**15.29**

Legend: VP – visual pivot

Discussion and Conclusion

Decision-making has elicited considerable research and, within it, visual search behaviours have been deeply scrutinized[1,2]. Nonetheless, a thorough analysis of the existing literature reveals that a cognitive perspective not only dominates, but is actually exclusive. Even when the authors advocate the need to move towards a more ecological framework, they still apply the notion of information processing in a discrete manner, requiring that a gaze last at least 100 milliseconds for a fixation to be considered, catalogued, and analysed. Notwithstanding, the logic behind ecologic psychology states that perception is continuous, changing the nature of each event, since it cannot be analysed as a series of discrete actions; instead, each action is part of a meaningful whole. In consequence, it has been suggested that a time interval under 17 milliseconds can allow the person to retrieve meaningful information[9]. Our purpose was therefore to compare these two systems for cataloguing eye movements' data during a representative task in volleyball.

Results showed that the ecologic coding (minimum one frame for a fixation to be considered) presented a significantly greater number of fixations and fixation locations when compared to the traditional cognitive coding (minimum three frames for a fixation to be considered). Additionally, mean fixation duration was inferior in the ecologic coding system. These results are naturally expected, as they derive from the constraints of each coding system itself. As such, these differences merely confirm that using two different systems of coding will produce distinct sets of results. Such results should, however, translate into meaningful information if one is to make a statement concerning the merits and gaps of each coding system.

Indeed, data concerning percentage-viewing time reveals that the visual cues emerging when using the ecologic system of coding are coherent with those emerging also in the cognitive system. Thus, using the one frame-one fixation coding process does seem to add relevant information concerning the visual search strategies of the players, while at the same time not producing significant noise (a mere 1.65% of unclassified fixations). It is therefore proposed that research in visual search behaviours should move towards adopting a new practical procedure, considering single-frame fixations as providing relevant information. Admittedly, this research was exploratory and more detailed studies should be conducted.

R E F E R E N C E S

1. DICKS M, BUTTON C, DAVIDS K, Examination of gaze behaviors under in situ and video simulation task constraints reveals differences in information pickup for perception and action. Attention, Perception, & Psychophysics, 72 (2010) 706. – 2. MANN D, COOMBES S, MOUSSEAU M, JANELLE C, Quiet eye and the Bereitschaftspotential: Visuomotor mechanisms of expert motor performance. Cognitive Processing, 12 (2011) 223. – 3. GRÉHAIGNE JF, GODBOUT P, BOUTHIER D, The teaching and learning of decision-making in team sports. Quest, 53 (2001) 59. – 4. MCPHERSON S, Tactical differences in problem representations and solutions in collegiate varsity and beginner female tennis players. Research Quarterly for Exercise and Sport, 70 (1999) 369. – 5. GIBSON JJ, The ecological approach to visual perception (Houghton Miffin, Boston, 1979). – 6. PASSOS P, ARAÚJO D, DAVIDS K, SHUTTLEWORTH R, Manipulating constraints to train decision making in Rugby Union. International Journal of Sports Science & Coaching, 3 (2008) 125. – 7. PANCHUK D, VICKERS J, Gaze behaviors of goaltenders under spatial-temporal constraints. Human Movement Science, 25 (2006) 733. – 8. Hristovski R, Davids K, Araújo D, Information for regulating action in sport: metastability and emergence of tactical solutions under ecological constraints. In Araújo D, Ripoll H, Raab M (Eds) Perspectives on cognition and action in sport (Nova Science Publishers, New York, 2009). – 9. VICKERS J, Advances in coupling perception and action: The quiet eye as a bidirectional link between gaze, attention, and action. Progress in Brain Research, 174 (2009) 279. – 10. AFONSO J, GARGANTA J, MCROBERT A, WILLIAMS AM, MESQUITA I, The perceptual cognitive processes underpinning skilled performance in volleyball: Evidence from eye-movements and verbal reports of thinking involving an in situ representative task. Journal of Sports Science and Medicine, 11 (2012) 339. – 11. MCROBERT A, WARD P, ECCLES D, WILLIAMS AM, The effect of manipulating context-specific information on perceptual-cognitive processes during a simulated anticipation task. British Journal of Psychology, 102 (2011) 519. – 12. NORTH J, WILLIAMS AM, HODGES N, WARD P, ERICSSON KA, Perceiving patterns in dynamic action sequences: Investigating the processes underpinning stimulus recognition and anticipation skill. Applied Cognitive Psychology, 23 (2009) 878. – 13. PIRAS A, LOBIETTI R, SQUATRITO S, A study of saccadic eye movement dynamics in volleyball: Comparison between athletes and non-athletes. Journal of Sports Medicine and Physical Fitness, 50 (2010) 99. – 14. ROCA A, FORD P, MCROBERT A, WILLIAMS AM, Identifying the processes underpinning anticipation and decision-making in a dynamic time-constrained-task. Cognitive Processing, 12 (2011) 301. – 15. TABACHNICK BG, FIDELL LS, Using multivariate statistics (Allyn and Bacon, Boston, 2007). –

J. Afonso
University of Porto, Faculty of Sport, Rua Dr. Plácido Costa, 91, 4200-450 Porto, Portugal
e-mail: jneves@fade.up.pt

TEORIJSKA PITANJA I METODOLOŠKE IMPLIKACIJE U ISTRAŽIVANJU VIZUELNOG PONAŠANJA: PRELIMINARNA STUDIJA KOJA POREDI KOGNITIVNE I EKOLOŠKE PARADIGME

S A Ž E T A K

Određen broj naučnih radova bio je posvećen razumijevanju mehanizama na kojima se zasniva uspješno donošenje odluka u sportu, a analiza očnih pokreta zaslužila je posebnu pažnju kada govorimo o ovom problemu. Temeljnim isčitavanjem postojeće literature dolazimo do saznanja da istrazivanje očne fiksacije zahtijeva najmanje 100 milisekundi u istoj lokaciji. Za prosječne sisteme praćenja oka ovo podrazumijeva korišćenje najmanje tri okvira za svaku fiksaciju. Ipak, ekološka psihologija pokazuje da je s obzirom na to da je svega 16.76 milisekundi dovoljno da se uoči relevantna informacija, dovoljan samo jedan okvir kako bi se fiksacija obavila. Cilj ovog eksperimenta bio je da se direktno uporede dva sistema (jedan okvir-jedna fiksacija naspram tri okvira-jedna fiksacija), kako bi se kodirala informacija koja se tiče očnih pokreta u reprezentativnom odbojkaškom zadatku u spremnom stanju. Naime, cilj je bio analiziranje razlika koje se javljaju i njihovog značenja. Rezultati su pokazali statistički značajne razlike u odnosu na stopu istraživanja (broj fiksacija, broj lokacija za fiksiranje, srednja vrijednost trajanja fiksacije). Analizirajući lokacije za fiksiranje bilo je očigledno da je ekološka paradigma za razmatranje vizuelne fiksacije pružila dodatne informacije. Pored toga, dodatni znaci koji su se pojavili, pokazali su se kao značajni, a nivo predstavljene buke bio je veoma mali. Predlaže se da se ubuduće u istraživanjima očnih pokreta koristi pristup jedan okvir-jedna fiksacija, umjesto tradicionalnog pristupa tri okvira-jedna fiksacija.

Ključne riječi: donošenje odluka, istraživanje vizuelnog ponašanja, metodologija istraživanja.