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An Affordance Based Approach to Decision Making in Sport: Discussing a Novel Methodological Framework

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AN AFFORDANCE BASED APPROACH TO DECISION MAKING IN SPORT: DISCUSSING A NOVEL METHODOLOGICAL FRAMEWORK

KEYWORDS: Affordances, Ecological Psychology, Virtual Reality, Decision Making.

ABSTRACT: Decision making is a fundamental element of any sport, particularly open, fast, dynamic team sports such as football, basketball and rugby. At the elite level, athletes appear to consistently make good decisions in situations that are highly temporally constrained. To further understand how this is done has been the aim of researchers within the perception-action field for several decades. The purpose of this article is to present novel contributions, both theoretical and methodological, that are pushing the boundaries of this area of research. The theoretical framework (Ecological psychology) within which the work is posited will be described, followed by a description of Virtual Reality (VR) technology and how it relates to the theoretical aims. Finally, an applied example will be summarised in order to demonstrate how the theoretical approach and the methodological approach come together in practice.

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— *Artículo invitado con revisión*

In order to position the ecological approach adopted for this work, we will begin with an overview of the different perspectives taken to study perception-action; that is the study of how perception influences action and how action influences perception.

Background

To observe successful, skilful performance is to observe a relationship between skilful perception and skilful action. Whilst this is widely accepted to be the case in sport (Williams, Davids and Williams, 1999), debate surrounds the nature of this relationship. One side of this debate sees perception as an "indirect" process where meaning is attached to meaningless sensory information via 'detailed internal representations' (Handford, Davids, Bennett and Button, 1997). This model of mind-body dualism underpins the 'cognitive approach' to perception and action. From this perspective, perception and action are viewed as separate processes, mediated by an internal representation. In a description of the cognitive approach, Bootsma and Hardy (1997) state that perception, on one hand, are the processes whereby a meaningful internal representation is constructed and on the basis of this, decisions are made regarding appropriate actions. On the other hand, movement organisation is seen as the process whereby these decisions are translated into meaningful action, i.e. perception of the environment and action within the environment are separate processes, mediated by internal representations. This cognitive approach also places a heavy emphasis on past experience and memory that is related to a particular task. This task specific information is stored as a representation in our memory and is recalled to influence subsequent action. Expertise, according to this approach, is a result of having a more elaborate task-specific knowledge base and this has been shown in several sports (e.g. in basketball, French and Thomas, 1987). Expert performers are not only thought to differ from novices in the amount and type of information pertaining to specific sport situations but are also thought to use this information differently when making decisions or anticipating events. This approach proposes that when planning a motor response, skilled performers use internally represented knowledge to a) attend to relevant sources of environmental information; b) search the visual field systematically and skilfully; c) anticipate time-constrained events ahead of time; and d) verify the impoverished information which the perceptual system receives from the environment (Williams, Davids and Williams, 1999).

The cognitive approach has dominated perception-action research to date, demonstrating an expertise effect in key sport behaviours such as anticipation (e.g. in squash (Abernethy, 1990); cricket (Abernethy and Russell, 1984); tennis (Jones y Miles, 1978); ice hockey (Salmena y Fiorito, 1979, cited in Williams et al., 1999); rugby union (Jackson, Warren and Abernethy, 2006); soccer (Williams and Burwitz, 1993, cited in Williams et al., 1999), visual search behaviour (e.g. in soccer (Salvesbergh, Williams, Van Der Kamp and Ward, 2002; Helsen y Starkes, 1999; french boxing (Ripoll, Kerlirzin, Stein and Reine, 1995)) and lastly, tactical decision making (e.g. in ice hockey (Thiffault, 1980); volleyball (Macquet, 2009)). However, this approach perhaps does not best account for consistent, skilful performance under variable conditions and high temporal constraints. Time is needed to recognise 'snapshot' patterns in the environment, recall "similar" patterns from a stored bank of previously experienced patterns, organise an action by executing 'if then do' rules (based on previous experience or considering situational probabilities), and finally carrying out the action.

The other side of the debate supports the notion of direct realism; a philosophical concept which assumes that 'what you see is what there is'. This concept proposes that the relationship between perception and action is not indirect (i.e. not mediated by internal representations) but is instead "direct". That is to say mutual, circular relationships exist between perception and action, which should be considered as the relationship between an organism and its specific environment (ecological approach). According to Kugler y Turvey (1987), an ecological approach "emphasizes the study of information transactions between living systems and their environments, especially as they pertain to perceiving situations of significance to planning and executing of purposes activated in an environment" (p. 12). That is to say, an ecological approach emphasises the role of information in the environment in shaping actions rather than focusing on internalised knowledge structures (Handford et al., 1997). This conceptualisation negates the need for mediating internal representations in the relationship between perception and action and thus lends itself to explaining decision making behaviour in highly temporally constrained environments like that of sport. The notion that information needed to guide action is directly available from the given set of environmental conditions and how they change over time, also accounts for the variability in sport scenarios as each one is different and unique, yet the action-relevant information is always there. The following section describes in more detail, the Gibsonian concept of 'affordances' and the 'information' that defines them. It is the identification of informational variables and how they are used to influence decisions about when and how to act in sport that forms the overarching aim of this research.

Theoretical Framework

In order to study decision making, we adopt James Gibson's (1979) ecological approach to visual perception which provides a theory within which to understand the nature of the meaningful, direct relationship between an actor and its environment. His theory emphasised the mutuality of an organism and their environment by proposing that information is specific to environmental properties (e.g. surface layouts (pitch), objects (ball), events (set-play)) and perception is specific to information. That is to say lawful relationships exist between environmental properties and patterns of surrounding energy. This relationship is encapsulated by Gibson's concept of affordances. Affordances are invitations to act within an environment; however, they are not properties of the environment *per se*, but rather a property of the Environment-Agent-System (EAS; Lee, Bootsma, Frost, Land, Regan and Gray, 2009). Gibson's (1979) concept of affordances argued that the environment is described not in physical terms (e.g. mass, length, time), but in terms that are relevant to the performer's action capabilities, e.g. a ball affords kicking, a gap affords passing through. Perceiving affordances allows us to determine which actions are possible and which are not (Turvey, 1992) and therefore provide an appropriate framework under which to study decision making behaviour, where so many actions are possible within constantly changing environments.

Action Capabilities

The notion of what actions an athlete is capable of performing is central to decision making. "To perceive an affordance, in Gibson's view, is to perceive how one can act when confronted with a particular set of environmental conditions" (Fajen, Riley and Turvey, 2009, p. 87). Affordances are defined by invariant, spatio-temporal properties in the environment that are action-relevant to an animal at a given moment in time. They are therefore both objective and subjective (Fitch and Turvey, 1978) in that they allow for the differing morphologies and capabilities of different people and it is these limitations that constrain intentional behaviours. Affordances are therefore said to be body-scaled (i.e. constrained by body dimensions) or action scaled (constrained by an actor's action capabilities). as shown by Pepping and Li (1997) when studying the volleyball block, where novices were able to accurately perceive maximum block-able height which entails accurately perceiving both geometric (body-scaled; e.g. how tall they are) demands as well as kinetic (action-scaled; how high they can jump) demands.

Within an Environment-Agent-System, affordances are grounded in the geometric properties of that system, and have been shown to be used in the control of movements. However, these properties are delivered in body-scaled terms such as eye-height which can be optically specified. Eye-height is related to other body dimensions due to the physiological constraints of the human body. This means that other objects in the optic array can be specified as ratios to this measurement. Results from several studies have consistently demonstrated the use of eye height scaled optical information when perceiving affordances (Pass-through-ability: Warren and Whang, 1987; step-onto-ability: Warren, 1984; Step-over-ability: Pufall and Dunbar,1992; Walking-up-ability: Kinsella-Shaw, Shaw and Turvey, 1992; Sit-on-ability: Mark, 1987; step-across-ability: Cornus, Montagne and Laurent, 1999; Pass-under-ability: White and Shockley, 2005). However, as Pepping and Li (2000) point out that the specific set of relevant properties that define an affordance are not solely defined by geometric variables, and that action capabilities are important in assessing what an environment affords at any given time. In sport, it is often the case that affordances are action scaled. For instance, in rugby, a player can implement rugby specific behaviours that would aid gap crossing, e.g. perform a 'hand off' (fend) to a defending player.

Identifying Action-Relevant Information

While it is affordances that we directly perceive, it is important to identify what information defines an affordance? In the visual domain, affordances may be specified directly by the structure of the optic array, i.e. the distribution of light energy which is lawfully structured as it reflects from surfaces within the environment. Optic flow refers to how this distribution changes as a 'perceiver' moves through the environment. This is both unique and invariant and can specify, for instance, forward motion and rate of approach. An animal's optic flow according to Gibson (1979) "specifies locomotion and the invariants specify the layout of surfaces in which locomotion occurs" (p. 227). Optic flow thus represents changes over time of the animal in relation to its environment and can provide information about future states. Introducing a temporal component in terms of changes to the optic array over time, allows us to directly perceive the time until something will happen in the near future.

Temporal information such as Tau (an optic variable specifying time to contact; Lee, 1976), is an example of an action-relevant optic variables that is available to the actor (athlete), and that can be used to prospectively guide action (Lee et al., 1982). This conceptualisation provides the corner stone for our work on decision making in sport: identifying the informational variables athletes use in order to inform decisions about not only how to act but also when to act, through online guidance of action.

David Lee's (1976) seminal paper provided a formal description of optical information available to an actor which enabled them to prospectively control action. Tau is an optic variable that describes the time to closure of a motion gap between a current state and a goal state at its current closure rate and thus, can define future time to contact. Information about the closing of motion gaps can therefore be extrapolated into the future (given conditions do not change) and used to regulate goal directed action. In sport, parameters are likely to change. However, information regarding the 'current future' (what will happen in the near future if things remain unchanged), nevertheless 'establishes the required temporal relation that can subsequently be influenced' (Lee et al, 2009, p. 851). This was originally demonstrated in the case of ongoing braking (Lee, 1976) where perception of changing size, velocity and deceleration of the gap to the obstacle was not found to be necessary. Instead, the only information needed was tau-dot or the rate of change of tau (1st order derivative). This allowed for a simple rule that could explain controlled braking when driving so as to avoid collision. Evidence that such visually guided regulation occurs in the timing of actions is provided in various sporting instances, mostly involving interceptive action (e.g. catching and hitting: Bootsma y Peper, 1992; Gray and Sieffert, 2005; Lee, Young, Reddish, Lough and Clayton, 1983; Regan and Gray, 2000; Savelsbergh, Whiting and Bootsma, 1991;). Outside of sport applications, this has been found to be used in collision detection in driving/braking (Bootsma and Craig, 2003; Bootsma and Oudejans, 1993; Gray and Regan, 2000; Gray, 2005).

Using this conceptualisation, differences in novice and expert performance are thought to 'reflect, in part, differences in the informational variables upon which they rely' (Fajen, Riley and Turvey, 2009, p. 85), rather than differences in task-specific knowledge structures that the cognitive approach would suggest. That is to say that novice and expert attunement to informational variables may differ and could offer an explanation as to the superior decision making performance of expert athletes being better able to pick up useful, action-relevant informational quantities within the environment. An ability to detect when an action is possible and when it is not is an important perceptual skill that athletes must possess. For this reason, we apply the expert-novice paradigm to our work with the aim of gaining insight into *what* information sources experts and novices use rather than simply demonstrating an expertise effect.

Summary: An Affordance Based Approach to Studying Decision Making

The preceding sections have outlined key concepts in our approach to decision making in sport. We do not see a decision in this context as being a linear process that starts with recognising a familiar pattern in the game, matching that pattern with a stored internal representation followed by selecting a course of action from a stored bank of possibilities. This does not allow for the dynamic and unique nature of every new sporting scenario. Instead, we see a decision as a result of directly perceiving affordances from the environment at any given moment of time (defined by invariant sources of prospective information) which will culminate in the selection of a prospective action given that set of environmental conditions and the action capabilities of the performer. As Gibson stated, 'We must perceive in order to move but we must also move in order to perceive' (Gibson, 1979). That is to say, in the context of sport, we are constantly engaging in exploratory behaviour through a continuous cyclical relationship between perception and action (see Figure 1). Decisions from this perspective can therefore be seen as emerging from rather than being selected through the successful perception of what the environment affords at a given moment of time (perceptual processes) and what the actor is capable of doing (action capabilities).

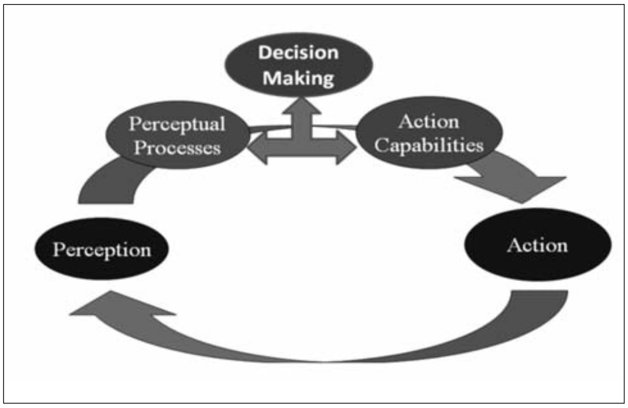

Figure 1. Graphical representation of the cyclical relationship between perception and action to include decision making as a result of the interplay between perceptual processes and action capabilities.

Method

Virtual Reality

Under the umbrella of the ecological approach, our work aims to identify what optical information defines affordances, which in turn, will result in a decision to take a certain course of action. In order to do this, methods must be employed so that the relationship between actor and environment in terms of its optical specification can be maintained. For this and many other reasons, we propose that immersive, interactive virtual reality can provide a suitable methodological tool for studying this behaviour. Although other forms of non-immersive simulation have previously been used to some extent as a research tool in sport (Araújo, Davids and Serpa, 2005; Bideau, Multon, Kulpa, Fradet, Arnaldi and Delamarche, 2004; Bideaum et al., 2003; Petit and Ripoll, 2008), the use of fully immersive interactive virtual environments is very much in its infancy. The few studies that have adopted fully immersive techniques have done so to study phenomena that are particularly difficult to control in the real world (e.g. curved free kicks in soccer; Craig, Berton, Rao, Fernandez and Bootsma, 2006; Dessing and Craig, 2010).

Why use VR?

Gibson (1979) himself advocated that "the laboratory must be like life" when studying perception and action. In order for this to hold true, the relationship between the organism and the environment (the EAS) must be maintained as far as possible and so behaviour in the artificial setting must resemble behaviour in the natural setting. Immersive, interactive VR allows for the presentation of realistic sport scenarios in a lab setting, i.e. simulations using realistic surroundings, realistic movement of other players, realistic timing etc. Previous decision making research from the cognitive approach, have made attempts to represent realistic stimuli in order to explore sporting behaviour. Behavioural indicators (e.g. response latency, Williams, Davids, Burwitz and Williams, 1994) or behaviour itself (e.g. physically passing a football) are usually measured (e.g. Helsen and Pauwels, 1993; Williams, Davids and Burwitz, 1994).

However, these studies presented static slides or dynamic film clips via a screen. The problem with this approach is that the film clips are captured from a fixed, allocentric viewpoint, thus failing to capture the scenario from the perspective of the athlete (egocentric viewpoint). Where small screens were used, a loss of dimensionality or real life scale also takes away from realism. This, in turn, fails to capture the actor's unique optic array and how the information contained within it changes over time. Araújo et al. (2005) state that 'the experimental task should be designed in such a way that picking up a perceptual variable that specifies a property of interest in the task should allow one to make reliable judgements about this property' (p. 676). This is in accordance with the concept of representative design (Brunswik, 1955). It has been shown in the literature on expertise in decision-making and anticipation in sport that where task constraints are unrepresentative, expert performance advantage is undermined (Abernethy, Thomas and Thomas, 1993) which may be due to restricted access of key sources of information that are usually available in the real world.

In the real world, we do not see sport unfold from the position of a TV camera or any fixed viewpoint. We see the world from our own egocentric viewpoint that changes as we move and orientate around our environment. To date, some efforts have been made in order to represent a players' viewpoint more realistically in experimental stimuli, by capturing video sequences from within the field or from an 'internal' viewpoint in basketball (Farrow y Abernethy, 2003; Farrow and Fournier, 2005); soccer (Savelsbergh, Wiliams, Van der Kamp and Ward, 2002) and tennis (Williams, Ward, Knowles and Smeeton, 2002). In one study, Petit and Ripoll (2008) investigated the effects of an internal viewpoint (within the field at eye level) and an external viewpoint (broadcast view) on expert decision making. Expert soccer players made forced choice decisions to pass or not to pass based on static frames of simulated football scenes. Results reported faster and more accurate decisions for the internal viewpoint. However, while the viewpoint was in field, it still was not egocentric in the sense that the participant's head movements did *not* create optic flow.

Immersive, interactive VR allows for an egocentric viewpoint to be updated in real time through the integration of a tracking system. It also offers the potential for users to interact with stimuli and through this interaction, record real time responses via any type of measure (e.g. full biomechanical analysis of movement by coupling motion capture systems or button press responses). That is to say that it maintains various aspects of realism from the natural setting. The correspondence between how a user feels in the real world and how they feel in the virtual world is referred to as presence. This comes from the term 'telepresence' which refers to 'the phenomenon that a human operator develops a sense of being physically present at a remote location through interaction with the system's human interface' (Ijsselsteijn, Ridder, Freeman andAvons, 2000). A high degree of presence suggests an adequately represented relationship between the actor and their environment in the virtual world. Many factors will contribute to presence, such as graphic realism or comfort when wearing the hardware.

However the most important aspect of realism in perception-action research is perhaps behavioural realism i.e. how much behaviour in the virtual world resembles that found in the real world. Arguably the most advantageous feature of this methodological tool however, is the control that it offers in terms of coupling and decoupling perception-action and presenting stimuli to observers. Virtual reality allows us to study perception only and/or perception-action within experimental setups. Information can be displayed to stationary participants but the HMD and tracking system combined also allows the participant to move in real time within a virtual environment. It also offers the ability to capture real human motion data from any number of actors, in any scenario. This motion data can then be used as the basis for avatar motion in a virtual world, thus adding to behavioural realism. The ability to maintain complete control over visual variables such as texture, colour, velocity, size, optic flow allows researchers to simulate exactly the sporting scenario in question over and over again i.e. allowing reproducibility between trials (Tarr y Warren, 2002). Stereoscopic displays also allow for depth perception; which is absent in a 2D video display.

VR Equipment

The main elements of a fully immersive VR system are the display and the tracking devices. Below, a brief description is given of each.

Display. 'The central component of any VR system, whether it be desktop or immersive, is the display' (McMenemy y Ferguson, 2007, p.47). An enclosed, wrap around HMD (Head Mounted Display) offers a high level of immersion, in that the user cannot see anything but the virtual environment they are immersed in.

An HMD is a head mounted device that houses either one or two screens that are positioned close to the eyes. Two screens represent a binocular display (different images transmitted to each eye via two screens, thus allowing for stereoscopic vision). The HMD also features headphones where audio information can be transmitted to the ears.

Tracking system. A tracking system such as the InterSense IS-900 hybrid system is an important component of an immersive, interactive VR setup as it allows for an egocentric viewpoint and realistic optic flow. This is paramount when exploring how perception in the virtual world influences action as results need to be generalisable to the real world. A wireless tracker is attached to the HMD so that any head movements (translations and rotations) are automatically

Figure 2. Image of a participant wearing a HMD. Note the straps of the back pack that house the control box. This control box in turn is connected by a long DVI cable to the computer rendering the images and interfacing with the tracking system.

sensed by the tracker and update the viewpoint presented within the HMD in real time. This makes the set-up very life like where head movements in real life are represented accurately in the VR environment. This means the user can turn their head to the right and the image they see will be immediately updated so they can view whatever is on their right in the virtual environment. In other words the user can choose where they look in the VR environment (see Figure 3).

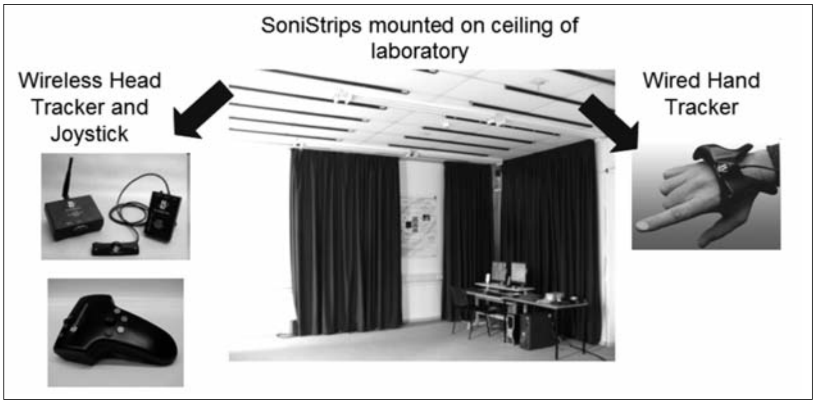

Figure 3. Intersense tracking system (IS-900). SoniStrips pictured on the ceiling of the laboratory emit ultrasonic pulses to microphones within the tracking devices which can be wireless (head tracker and joystick pictured) or wired (hand tracker pictured).

Applied Example: Judging the 'Passability' of Dynamic Gaps in a Virtual Rugby Environment

In order to demonstrate our approach, we will present an example of a decision making study in rugby union. This example in part refers to data presented in Watson, Brault, Kulpa, Bideau, Butterfield and Craig (2010). The aim is to try and identify what optical information, specific to the performer at any time, is picked up and used by both novices and experts. Immersive interactive VR technology was employed as a methodological tool.

Introduction

In rugby, due to its dynamic nature and high temporal constraints, opportunities for action are often fleeting and can come and go in an instance. Fajen, Riley y Turvey (2009) state, for example, "A gap between opposing players can open to afford passing through at one moment and then collapse into an impenetrable barrier at the next moment" (p. 80). Successful attacking play in rugby is often the result of the exploitation of gaps between defenders in the opposing team. The ability of players to perceive passability of a defensive gap ahead of time, in this instance, will influence their choice of action with respect to that gap. Therefore, optical information specifying passability may determine the course of action that a player takes. For example, an attacker is likely to run through a 'passable' gap, or kick or pass as a result of the gap not being 'passable'. While some previous work has explored perception of passability (Warren and Whang, 1987; Wraga, 1999; Wagman and Malek, 2007), it has only done so for static gaps and has not been studied within the context of sport. Passability of dynamic gaps has been researched in road crossing literature (Demetre, Lee, Grieve, Pitcairn and Ampofo-Boateng, 1992; Lee, Young and McLaughlin, 1984; Young and Lee, 1987; Connelly, Conaglen, Parsonson and Isler, 1998; te Velde, van der Kamp, Barela and Savelsbergh, 2005) where prospective passibility judgements (or gap acceptance judgements) have to be made and moment to moment changes in the (traffic) situation have to be scaled to people's own changing action capabilities (te Velde et al., 2005). This work has identified that 'Time to contact (TTC)' or 'Time to arrival' variables as being important in judgements.

The aims of this study were to: i) identify the visual information defining a 'passability' affordance in a simplified gap closure scenario. ii) see if experts (professional rugby players) and novices (Non-rugby players) use this information to make passability judgements ahead of time?

Method

Virtual rugby environment. In collaboration with the M2S lab at the University of Rennes 2, we created a virtual rugby stadium and players (see figure 4 (b)). We used an animation process that involved: a) capturing real motion from real players using a full body marker set and the Vicon motion capture system; b) reconstructing motion using this positional data; c) using this motion as trajectories for the avatars within Virtools (Version 4.0; Dassault Systemes) software, where we control velocities, trajectories, and appearance of the avatars.

Experimental setup and procedure. Figure 4 (a) shows a schematic diagram of the experimental setup. The attacker (participant) was faced with two defenders 20m away, at a certain distance apart from each other (start gap). The attacker approached the midpoint of the defenders who converged in straight lines until they reached a certain distance apart (end gap) at one of two cut off distances. The attacker's motion forward was simulated. At the cut off, the defenders disappeared. At this point, the participant made a perceptual judgement as to whether or not they could pass through the gap between the defenders without making contact. They administered their response via the Microsoft 'sidewinder' game pad, where one button represented 'yes' and another, 'no'.

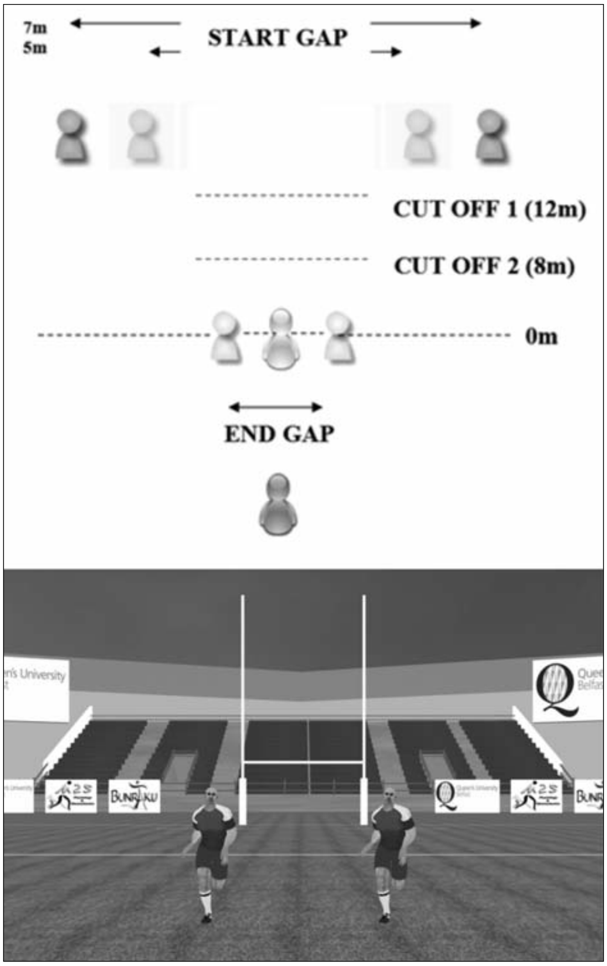

Figure 4. (a) Birds Eye schematic representation of the experimental setup. Two defenders' starting and end positions are shown in shades of blue and the attacker's start and end position in shades of green. Feint figures at the 0m line represent where the attacker would or would not pass at the end gap. Attacker's approach is simulated in a straight line up to this end point (b) Screenshot from the attacker's perspective of the defenders approach within the virtual environment.

We manipulated start gap (2 different gaps), end gap (8 different gaps) and cut off (the point at which the information disappeared; 2 different cut-offs) and each trial was repeated ten times. This resulted in 320 trials in total. Novice participants were 14 non-rugby playing adults consisting of 8 males and 6 females selected from an undergraduate and postgraduate student population. Expert participants were 14 full time professional rugby players with the only professional rugby team in Northern Ireland (Ulster Rugby). Participants wore the HMD and carried out the experiment with breaks as required.

Data analysis. Firstly, we modelled the scenario according to general Tau theory which is based on the concept of the rate of closure of motion gaps. A tau value (or 'time to closure') is negative and approaches 0 as a gap closes. Tau allows for prospective judgements and guidance of action by encapsulating the dynamics of the situation in terms of changes over time. This is irrespective of absolute values and is specific to the optic information available to the actor within their optic flow-field, at any time. Using this model, we consider the current situation as the simultaneous closing of two gaps (see Figure 5). Gap X is 'closed' when the distance between the defenders is less than the width of the attacker's shoulders (i.e. the width of the cylinder represented by dotted lines) and gap Z is 'closed' when the attacker reaches 0 m.

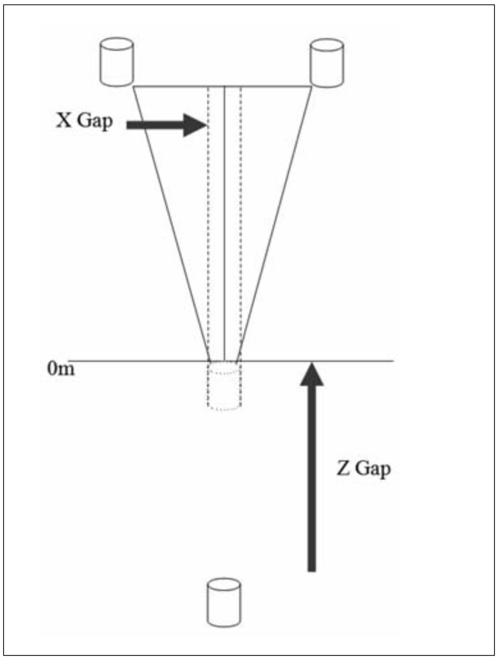

Figure 5. Simplified representation of how the gap between the defenders (X gap) and the gap between the defenders and the attacker (Z gap) are considered to be closing.

If time to closure (Tau) of gap X (between the defenders) is less than time to closure of gap Z, then gap X closes before gap Z (between the line of the defenders and the attacker) and the attacker will not pass through.

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Following on from this, the difference in the two tau values when Tau X is taken away from Tau Z can therefore provide a continuous scale by which to separate all of the 32 conditions. A zero value for the tau difference should separate the pass and no pass conditions, as both gaps will reach 0 (be closed) at the same time. These tau differential values were then plotted as a predictor variable (on the x axis) against the average percentage of 'pass' responses for each group (on the y axis) and a logistic regression was performed. The hypothesis here predicted that if this tau variable was the informational quantity that participants used, then when it is plotted against 'pass' responses, an 's' shaped psychophysical function should fit the data. At either extremes of the x axis, the percentage of 'pass' responses should be low and high respectively, and where responses are at 50% this should correspond to the critical value (cv) which would be a tau-difference value of '0'. The goodness of fit of this function to the data is indicated by an R-square value and the steepness of the slope of the curve indicates how quickly responses shift from 'not pass' to 'pass'.

Results

Results for both groups are presented in Figure 6.

As can be seen from the graphs and the higher R^2 values in Figure 6, the tau difference variable can explain 82% of the variance for the novices and 56% of the variance for the experts. This suggests that for novices, this Tau based informational variable informs passability judgements in this task. Also, the higher slope of the novice curve suggests a more rapid switch between not pass and pass responses, as would be expected if it were this informational quantity that is informing judgements. This switch should occur around a 0 value for the Tau Differential. For both groups, the critical value was close to 0; -0.100 for novices and -0.137 for experts. However, for experts, a smaller proportion of variance can be explained by this variable. In this case, from the graphs, it can be seen that two curves seem to emerge. This would suggest that other information (for example start gap) is also being used by experts when making judgements.

Discussion

It could be concluded therefore that the Tau differential variable is an informational quantity that defines the passability affordance, however novices used this information more so in informing judgements than experts did. Although initial reaction is to be cautious of a situation where experts are less attuned to an informational quantity than novices, findings must be kept in context with the task performed. The present scenario may not be one where a clear cut expertise effect should be expected. As mentioned in the introduction, it is important to note that 'the specific set of relevant properties of the EAS that define an affordance are not solely defined by geometric variables' (Pepping and Li, 2000, p.

118). It may be the case that for experts, who face these situations through contact sport on a daily basis, they may still attune to this variable, but it may not primarily inform their decision. Instead, it is likely that they are approaching the task with attached "rugby specific" behaviours or judgements. For example, even though this information may suggest that geometrically, a gap is not 'passable', they may judge it to be passable with the aid of behaviours such as fending players off or making an "unclean" break, where they do not avoid contact with the defenders yet still successfully "pass" the gap. To summarise, it may be that the rugby context in which the task was set, means that experts are making judgements based on anticipated, rugby-specific action capabilities.

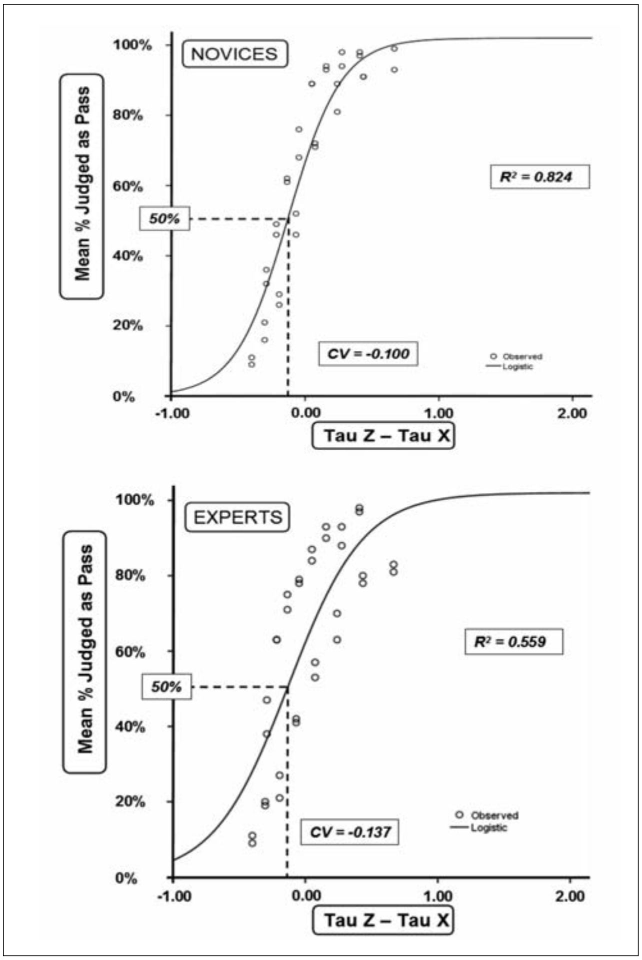

Figure 6. Graphs showing mean % judged as pass as a function of TauZ-TauX for both the (a) novice and (b) expert groups.

It should also be noted that in this particular example participants are performing a perception only task. Recent developments in the lab have meant that perception and action can now be coupled (see Dessing and Craig, 2010). To really understand how an optical variable like tau can influence decisions about when and how to act, we need to do this in as realistic a task setting as possible where perception and action are coupled in real-time. Correia et al. (2010) have looked at how the tau of the gap between an attacker and a defender in a rugby union match situation will influence the type of pass the player will make. Unfortunately due to the dynamic and unpredictable nature of a game it is difficult to obtain reproducibility between trials. By using immersive, interactive virtual reality where participants can see the scenario in a realistic format, yet as experimenters we can control the rate of gap closure between defenders in a systematic way, we can see the relative contribution of this information when making decisions about when and how to act.

Summary and Concluding Discussion

The aim of this article was to present an overview of a theoretical and methodological framework for investigating decision making in sport. Theoretically, we base our thinking on several of the central concepts within the ecological approach to visual perception and action. We feel that the interplay between the perception of prospective action-relevant information and action capabilities (encapsulated by affordances) influences how an athlete will act within a given set of environmental conditions. This conceptualisation takes a step in a positive direction in understanding decision making in a way that attempts to identify what information allows for prospective judgements to be made. Considering decision making within an affordances framework captures the essence of what decision making is: knowing when environmental conditions afford a certain action, and the ability to prospectively guide those actions, necessary in such a variable, unstable environment such as sport. For example, the direct perception of gap closure (and of course gap opening) between defenders in the cited example might be said to afford the choice of action for the attacker, i.e. make a long pass, a short pass, kick to space or run. The majority of the work into decision making from the cognitive perspective somewhat neglects the temporal aspect of decisions in dynamic, variable settings. The ecological approach can as much account for timing of actions as the action choice itself and Tau theory can present elegant and parsimonious models from which to understand temporally guided action.

Our overarching aim then, and how we hope to contribute to decision making research, is to attempt to identify such action relevant sources of information that are specific to the athlete (can be optically specified) and explore the use of such variables by different populations. The theoretical framework that we work within suggests that expertise is a result of different attunement to informational sources. This was demonstrated in both applied examples that we presented – different sensitivity to a variable that could potentially inform judgements.

In order to achieve this aim, however, we must employ methodology that maintains the cyclical relationship between a performer's movement and their environment. Immersive interactive VR provides such a tool, where we can not only couple and decouple perception and action, but maintain an egocentric viewpoint which does not force participants to use only the information available from one allocentric point of capture. We have full control of the stimuli that we present and maintain behavioural realism by mapping real, captured human movement onto avatars within the virtual environment.

We feel that through the use of Immersive Interactive VR technology, guided by the theoretical standpoint we adopt, we can continue to improve on experimental design and add to a promising start in furthering understanding of decision making behaviour in dynamic sports.

UN ENFOQUE DESDE LAS POSIBILIDADES DE ACCION DE LA TOMA DE DECISIONES EN EL DEPORTE: DISCUSION DE UN NUEVO MARCO METODOLOGICO

PALABRAS CLAVE: Affordances, Psicología ecológica, Realidad virtual, Toma de decisiones

RESUMEN: La toma de decisiones es un elemnto fundamental en cualquier deporte, sobre todo en deportes de equipo, abiertos, rápidos y dinámicos como el fútbol, baloncesto o rugby. En el deporte de élite los deportistas toman consistentemente buenas decisiones en situaciones que requieren una respuesta rápida en muy poco tiempo. El comprender este mecanismo ha sido objeto de estudio, desde hace varias décadas, de los investigadores del ámbito de la percepción-acción. El objetivo de este trabajo es presentar nuevas contribuciones, tanto teóricas como metodológicas, que están desarrollando el conocimiento sobre esta área de investigación. Se describe el marco teórico (psicología ecológica) desde el que se aborda este estudio, así como la relación entre la tecnología de la realidad virtual y los objetivos teóricos. Finalmente, se presenta un ejemplo aplicado que muestra como en la práctica se unen el abordaje teórico y el metodológico desde la perspectiva ecológica.

ENFOQUE A PARTIR DAS POSSIBILIDADES DE ACÇÃO DA TOMADA DE DECISÃO NO DESPORTO: DISCUSSÃO DE UM NOVO MARCO METODOLÓGICO

PALAVRAS-CHAVE: Affordances, Psicologia ecologica, Realidade virtual, Tomada de decisão

RESUMO: A tomada de decisão é um elemento fundamental em qualquer desporto, particularmente desportos de equipa abertos, rápidos, dinâmicos tais como o futebol, o basquetebol e o râguebi. Ao nível do desporto de elite, os atletas tomam consistentemente boas decisões em situações que são altamente constrangidas em termos de tempo. A tentativa de compreender como isto acontece tem sido o objectivo dos investigadores no campo da percepção-acção há várias décadas. O objectivo deste artigo é apresentar novas contribuições, tanto teóricas como metodológicas, que estão a empurrar os limites do conhecimento nesta área de investigação. O enquadramento teórico (Psicologia ecológica) dentro do qual o trabalho assenta será descrito, seguido de uma descrição da tecnológica de Realidade Virtual (RV) e como esta se relaciona com os objectivos teóricos. Finalmente, um exemplo aplicado será sumariado de forma a demonstrar como é que a abordagem teórica e a abordagem metodológica se juntam na prática.

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