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Enhancing decision making during sports performance: Current understanding and future directions

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Abstract

Making decisions is a fundamental requirement for effective sports performance. As a result, an understanding of the processes underpinning the generation of these decisions is crucial to researchers and applied practitioners alike. However, while there is much research that explores decision making from a number of different perspectives in sport there are still significant gaps in our knowledge and understanding of the mechanisms and processes involved. There is an increasing body of literature that seeks to understand decision-making from a number of perspectives including classical decision-making, naturalistic, ecological, and intuitive approaches to decision-making. Often this understanding has been developed in isolation, and as a result has failed to coherently impact upon applied practice. This review seeks to clarify current understanding by exploring a number of current views on decision-making in sport and related applied interventions. Areas requiring further research are discussed.

Keywords: Decision-making, problem-solving, intuition, perception, action, tactics, strategy.

Enhancing decision making during sports performance: Current understanding and future directions

Introduction

In sport, successful performance does not solely rely on proficient movement control, an effective decision on the required motor response is also required (Poolton, Masters, & Maxwell, 2006). Sport performance has specifically been defined as "a complex product of cognitive knowledge about the current situation and past events, combined with a player's ability to produce the sport skill(s) required" (p. 259). This definition emphasizes two important components of decision-making: cognitive knowledge (what the decision is); and motor, response execution (is the decision effectively executed) (Gutierrez Diaz del Campo, Gonzalez Villora, & Garcia Lopez, 2011).

Due to time constraints, in some sports, athletes are required to process both a decision and a movement in quick succession (Bard, Fleury, & Goulet, 1994; Poolton et al., 2006). Expert performance in sport occurs at the limits of human performance. In some ball sports (such as cricket, tennis, basketball, squash, and hockey) the time constraints impacting upon perception and action are severe (Müller, Abernethy, & Farrow, 2006). In cricket, for example, there is evidence of a significant relationship between athlete skill level and anticipation ability (McRobert & Taylor, 2005; Penrose & Roach, 1995; Renshaw & Fairweather, 2000). In these circumstances athletes often report that their motor reactions evolve from a given situation without any consciously controlled decision-making (Kibele, 2006). This type of decision-making (DM) has been labelled as 'intuitive' (see Gilovich, Griffin, & Kahneman, 2002, for a review).

Within the scope of DM in sport Johnson (2006) highlighted a number of different decision agents (e.g., athletes, coaches, officials), tasks (e.g., reactions, strategy, tactics), and contexts (e.g., discrete passages of play, continuous play, during breaks, and before play). Of particular interest to sports professionals and coaches is the fact that experts appear to be better than novices in making effective decisions, suggesting that it is possible to develop and train DM ability (Vaeyens, Lenoir, Williams, Mazyn, & Philippaerts, 2007),

In team sports, the dynamics of DM are further complex. For players on both teams, playing well is underpinned by selecting the right course of action at the right moment and performing those course of action efficiently time and time again during the game (Gréhaigne, Godbout, & Bouthier, 2001). Gréhaigne, Godbout and Bouthier (1999) speculated that, in turn, this condition requires players to make both strategic (devising a plan) and tactical (making adjustments to the plan in real time) decisions. These strategic and tactical perspectives represent another important aspect of decision-making in sport.

In sport there has been a wide range of perspectives from which DM has been explored. These include: visual search strategies (Farrow & Abernethy, 2003; Savelsbergh, Williams, Van Der Kamp, & Ward, 2002); knowledge bases (McPherson & Kernodle, 2003; Williams & Davids, 1995); the impact of practice on decision-making (Kibele, 2006; Poolton, Masters, & Maxwell, 2006; Raab, 2003, 2007); the option generation process (Johnson & Raab, 2003); cognitive modelling (Johnson, 2006); and perception-action coupling (Araújo, Davids, & Passos, 2007; Fajen, Riley, & Turvey, 2008; Macquet, 2009; Pinder, Renshaw, & Davids, 2009).

This paper will seek to clarify what is understood by DM relating to sport performance, review the theories that explain the processes that underpin our DM, explore current thinking regarding enhancing DM in practice, and suggest future avenues for research.

What is decision making?

It is important at this point to clarify the focus on DM adopted in this paper. The area of decision-making and judgment in psychology is broad in its scope. Travassos, Araújo, Davids, O'Hara, Leitão, & Cortinhas (2013) highlighted differences in the nature of the decision (deterministic or probabilistic) and the temporal nature of the decision (static or dynamic) as key factors. The specific focus adopted in this paper views DM through the lens of sports performance, exploring the decisions required to underpin effective (dynamic) performance outcomes. From this perspective, DM can be viewed as the process of committing to a particular course of action. More specific definitions of DM have been suggested in the literature including "the selection of one option from a set of two or more options" (Klein, Calderwood, & Clinton-Cirocco, 1986, p. 186) and "a set of evaluative and inferential processes that people have at their disposal and can draw on in the process of making decisions" (Koehler & Harvey, 2004: preface xv.). DM in this context is seen as a process that exists between the perceptual and executional aspects of performance. Effective DM requires the integration of perceptual information with knowledge that has been accumulated via previous experiences (Masters, Poolton, Maxwell, & Raab, 2008).

A distinction is often drawn in the literature between consciously and non-consciously controlled DM. Historically, non-consciously controlled DM has been labelled as 'intuitive' (Gilovich, Griffin, & Kahneman, 2002). This concept of intuitive DM has been explored in a range of social, work, and business settings (Hogarth, 2001), and more recently in sport (Raab, 2003). Intuition in this context is defined as "an involuntary, difficult to articulate, affect-laden recognition or judgement that is based on prior learning and experiences and is formed without deliberate or conscious rational choice" (Raab & Laborde, 2011, p. 89). Or specifically, judgments that appear in consciousness quickly, do not rely on deep knowledge of reasons for that judgment, and are strong enough to act on (Gigerenzer, 2007). In sport, intuition is a way that some expert athletes can find effective tactical solutions without considering all of the possible solutions and comparing them (Gréhaigne & Wallian, 2007). Intuitive decisions are thought to be reactive, effortless, speedy, non-consciously controlled, triggered automatically, and highly sensitive to action contexts (Kieble, 2006). However, there is currently a lack of consensus in the literature regarding how intuitive decisions occur. Some authors argue that intuitive decisions are the result of an awareness of some phenomenological internal and discriminative physiological state that evolves from non-conscious stimulus (Perrig & Wippich, 1995). While other authors assume that these physiological states may be induced rather than preceded by intuitive decisions (Hogarth, 2001). However, regardless of the underpinning mechanism, these intuitive decisions are crucial within sport settings.

Another important aspect of DM in sport is the tactical and strategy choices that are made. These are, in turn, underpinned by strategic and tactical knowledge. Gréhaigne, Godbout, and Bouthier (1999) clarified the two concepts as follows: strategic knowledge reflects the competence to plan ahead and therefore influence decisions within a situation, whereas tactical knowledge is the situation-specific information accumulated through past experience that guides the DM about the selection of movements and their execution. Another crucial perspective of DM in sport is that perception and decisions of action are strongly interwoven (Gréhaigne & Wallian, 2007). As such, perception forms an important aspect of the DM process. With the perception of environmental information specific to the individual performance setting, it is important that athletes improve their capacity to discriminate between informative and irrelevant cues (Pinder, Renshaw, & Davids, 2009).

Finally, Johnson (2006) suggested that a key feature of DM in sport is that it is naturalistic, meaning that it is made by agents with a degree of task familiarity in the environment where they naturally encounter the decision. There also needs to be recognition that the majority of decisions in sport are dynamic and take place in real time, that is athletes have to make decisions while play is in motion. The implication of this is that real understanding of DM in sport can only be gained by understanding the real environment.

Theoretical explanations for the way we make decisions

Within the psychology literature, there are a number of consistent approaches that have been adopted that seek to understand the processes through which individuals make decisions. In particular, Classic Decision Making theory (CDM), Naturalistic Decision Making theories (NDM), and Ecological approaches to understanding DM have been particularly prominent.

Classical DM theories (also referred to as the normative DM model) view DM as a structured formulaic and highly cognitive process. This CDM approach focuses on the accuracy of the decisions made and assumes that, in all DM settings, the correct decision outcomes can be identified through a process of rational analysis (Mascarenhas & Smith, 2011). The process of making an effective decision includes a clear identification of the problem, the generation of a range of possible solutions, critical evaluation of these options, and selection of a preferred solution (Beach & Lipshitz, 1993). There is much research that demonstrates this process is true in laboratory settings, usually when the speed of the decision is not important. However, applying this approach to understanding decisions made in time pressured, complex, and dynamic situations across performance domains (e.g., sport, business, medicine) has been far more difficult (Balagué, Hristovski, & Vazquez, 2008; Beach & Lipshitz, 1993). Indeed, a number of criticisms have been levelled at this approach including: an inability to explain DM in uncertain, dynamic environments (Montgomery, Lipshitz, &Brehmer, 2005); and failure to consider the expertise of the decision maker in the process (Mascarenhas & Smith, 2011). However, while this approach might not adequately explain the process through which decisions are made during game play, it can explain those decisions that are made when there is less time pressure (e.g., strategic decisions prior to the start of the game / competition). As such, the CDM approach appears to offer insight into some aspects of DM in sport.

Naturalistic Decision Making (NDM) has emerged as a framework with which to better understand the processes that expert decision makers engage in under time-pressured conditions. There are a number of different NDM models and theories (see Klein, 2008, for a review) that share some common principles. First, decisions are made by holistic evaluation of potential courses of action (Lipshitz, Klein, Orasanu, & Salas, 2001). Second, decisions are recognition based in that the decision maker relies on recognition of the situation and pattern matching courses of action rather than comparing alternatives (Klein & Calderwood, 1991). Third, decision makers adopt a satisfying criterion rather than search for an optimal solution (Klein & Calderwood, 1991), searching for a workable rather than optimal solution. In response to criticisms of this approach, more recent NDMs have also suggested that there is a combination of intuition and analysis in the making of decisions (Klein, 2008). Suggesting that both intuition and analysis are important as a purely intuitive strategy relying solely on pattern matching generates flawed options and a purely deliberative and analytical strategy would be too slow. As a result, Klein (2008) suggested that the real process must be a combination of the two. In this NDM approach the workload of the decision maker, task/situation familiarity, and level of experience appear to be crucial (Flin, Slaven, & Stewart, 1996; Klein, 1992; McMenamin, 1992). Recent evidence though has suggested that this NDM approach appears to be most applicable in explaining situations where time pressures and poorly defined goals dominate (Abraham & Collins, 2011; Mascarenhas & Smith, 2011). These conditions are not necessarily true in sport, and as such, this approach might not provide a full picture of DM in sport. Indeed, Abrahams and Collins (2011) presented the view that this set of approaches currently fails to consider the impact that the complexities of the environment can have upon DM. Similar to CDM though, the NDM approach does appear to offer answers in understanding some aspects of DM in sport.

More recently ecological perspectives have been adopted in an attempt to understand DM in sport (Araújo, Davids, Bennett, Button, & Chapman, 2004; Araújo, Davids, & Serpa, 2005). The ecological approach stresses the lawful relations (i.e., relations based in the natural sciences) between any individual and the environment in which he or she functions (Turvey & Shaw, 1999; Turvey, Shaw, Reed, & Mace, 1981). Ecological psychology assumes a performer-environment, in which both components combine to form a whole ecosystem. Under this synergy, biology and physics come together with psychology to define a science at a new ecological scale (Turvey &

Shaw, 1995). In sport, the ecological approach has predominantly developed using a Gibsonian approach, but other perspectives exist including those suggested by Brunswick, Barker, and Brofenner (Araújo et al., 2005). In this ecological approach, decisions are no longer just the result of internal cognitive processes but are self-organizing processes that emerge as a consequence of the individual's non-linear interaction with their environment. The perception and the action are viewed like an irreducible cycle (Araújo, Davids, & Hristovski, 2006). Specifically, that it is not necessary to follow a mental process to produce the required decisions; instead decisions emerge spontaneously out of the nonlinear interaction of the elements under influence of personal, task, and environmental constraints that form each specific context (Araújo et al., 2004). The effectiveness of decisions are therefore, clearly constrained by the level of attunement of each athlete to the relevant information and the respective calibration of his/her movements to that information (Jacobs & Michaels, 2002). If this is true, the process through which the athlete perceives the environment and identifies the correct energy flows is of paramount importance (see Jacobs & Michaels, 2002, for a review). The implications here for DM training in sport re clear, the best way to enhance DM is to place the athlete in the real DM context. So, for example, cricketers should be playing on grass pitches against a full complement of opposition players.

Recent research has explored the applicability of this ecological approach in a range of sport-specific settings including basketball, sailing, rugby and some combat sports (Araújo et al., 2006; Hristovski, Davids, & Araújo, 2006). Instead of offering direct competition to each other, CDM, NDM, and ecological perspectives appear to explain different aspects of DM in the sporting domain. This reflects the diverse range of DM contexts that exist within sport. There are times when the individual athlete has to make deliberate, considered decisions; decisions that take place under time pressures; and instances where direct perception and action are required. What appears to be absent at the current time is an integrated model of decision making in sport. The development of such a model in the future would further enhance holistic understanding of DM in sport.

Current methodological approaches to understanding decision making in sport

Much existing research into DM in sport has adopted standardized or simulated situations (Farrow & Abernethy, 2003; Johnson & Raab, 2003; Kibele, 2006; Pinder et al., 2009; Poolton, Masters, et al., 2006; Raab, 2003; Royal, Farrow, Mujika, Halsom, Pyne, & Abernethy, 2006; Savelsbergh, Williams, Van Der Kamp, & Ward, 2002; Williams & Davids, 1995). Indeed, Macquet (2009) argued that the context of this existing research was fundamentally different to real competitive situations, and as such, the applicability to the real environment could be questioned. As a result, more recent studies have sought to explore the dynamics of DM in sport in more ecologically valid contexts (Araújo, Davids, & Hristovski, 2006).

While there is an increasing body of knowledge exploring DM in discrete tasks, there is currently a limited amount of research exploring the DM that occurs during game play. Limited examples to date include tennis (McPherson & Thomas, 1989); baseball (French, Spurgeon, & Nevett, 1995); basketball (French & Thomas, 1987); and soccer (Fontana, Mazzardo, Mokgothu, Furtado, & Gallagher, 2009; Gutierrez Diaz del Campo et al., 2011). In a review of 192 DM and expertise studies conducted by Starkes, Helsen, and Jack (2001), 28 different sports were analysed. The authors reported that the majority of these studies focused on either soccer or racquet sports. This has now been expanded to cover wider range of sports and environments (see Table 1.).

The expert-novice design is an approach that has been extensively adopted in DM research (e.g., Fadde, 2006). However, Starkes, Helsen, and Jack (2001) questioned the effectiveness of this approach highlighting the fact that in these studies the performance of athletes can be highly variable. Instead, it has been suggested that observations of experts in their natural performance environment demonstrates consistently higher levels of performance (Araújo et al., 2005; Starkes

& Ericsson, 2003). While this, in part, makes intuitive sense, observing decisions in the natural environment can also prove problematic due to ethical and safety considerations. As a result, Araújo et al. (2005) suggested that an alternative approach might be to utilize computer simulations. There are currently a limited number of studies that have adopted this approach (Alain & Sarrazin, 1990; Raab, 2002).

Approaches to enhancing decision making in sport

Until recently, it was assumed that in order to develop elite performance levels, years of hands-on experience were required. However, such amassing of experience does not necessarily result in expert levels of performance. A number of authors now argue that trying to train and improve DM in an individual may be a significantly more beneficial approach compared to merely accumulating vast experience (Cotterill, 2014; Mascarenhas & Smith, 2011). This is true for both tactical / strategic DM as well as for enhancing perception action-coupling (Cotterill, 2014). Vickers (2007) highlighted that when a decision-training approach is used in sport, the same emphasis should be placed on physical and technical aspects of performance, but that the cognitive skills underlying higher levels of performance are also trained at the same time. Indeed, Vickers concluded that the main difference between standard training and decision training was the degree of athlete cognitive effort required.

Tactical and strategic decision-making

Raab (2007) highlighted four specific approaches that seek to provide a framework for developing DM in sport: the Teaching Games for Understanding (TGFU) approach (Bunker & Thorpe, 1982); the Decision Training (DT) approach (Vickers, 2003); the Ball School (BS) model (Kröger & Roth, 1999); and the Situation Model of Anticipated Response consequences of Tactical training (SMART) model (Raab, 2003).

The TGFU approach focuses on tactical training, building on the premise that tactical awareness is composed of making correct decisions in skill execution (how to do it) and skill selection (what to do). The main focus of this approach is the playing of ‘real’ or modified versions of games. McMorris (1998) described this approach as a ‘cognition-to-technique’ approach that begins with understanding the tactical problems of the sport. There is some empirical evidence to support this approach. For example, Turner and Martinek (1999), conducted research with school children who were taught field hockey by physical education teachers. They reported that the games for understanding group scored significantly higher than the control on pass decision making. However, while there is some support there are also a number of criticisms including the stage of learning targeted, and its application to performance sport (Dokas, Chatzopoulos, & Tsitskaris, 2002; McMorris, 1998).

Vickers (2003) suggested a DT model that is composed of three specific steps: (1) identify a decision to be trained; (2) Design a drill with a cognitive trigger; (3) Use decision-training tools to train the decision. In the first step, one of the following seven cognitive skills should be the main focus: anticipation, attention selection, focus, pattern recognition, memory, problem solving, and decision-making. In the second step, there is a cognitive trigger that feeds back if the decision was effective or not. Vickers (2003) outlined seven specific cognitive skills: object cues, location cues, quiet-eye cues, memory cues, reaction-time cues, kinaesthetic cues, and self-coaching cues. The third, and final, step involves one of the seven highlighted decision-training tools being applied. The seven identified tools within the DT model are: variable practice, random practice, bandwidth feedback, questioning, video feedback, hard-first instruction and modelling, and external focus instruction.

While more comprehensive than previous approaches, the DT model has been criticised for being too prescriptive. Indeed, Gréhaigne and Wallian (2007) highlighted the importance of flair, resourcefulness, vigilant attention, and a sense of opportunity as being important factors, and that the perspective on decision-making adopted was too narrow in its focus.

The BS model focuses on broad training over early sport-specific specialization. Training, according to this model, is build upon three main pillars: ability orientated, playful situation orientated, and skill orientated (Kröger & Roth, 1999). Ability orientated predominantly refers to coordination abilities such as rhythm, balance, or orientation. Playful situation orientated refers to the idea that skills are developed through play, finally skill orientated suggests that a set of tactical skills are learnt (Raab, 2007). However, while intuitively appealing in terms of development it is less a model and more a general approach. Also, this approach lacks specificity in terms of the development of DM ability in athletes. As a result of these limitations there is currently no empirical evidence to support this developmental approach.

The SMART model developed by Raab (2007) advocates the use of both implicit and explicit learning processes. The basic underlying principles to this approach are that decisions in sport are developed through the mapping of a situation, the movement, and the effect on the environment (Raab, 2007). In this model, implicit or explicit recognition leads to an option generation, this in turn informs a choice, which ultimately results in an effect of the choice (outcome). There are though criticisms for this approach with Gréhaigne and Wallian (2007) suggesting that the SMART approach has been built upon an “incomplete frame of reference in team sport modelling didactics”(p. 20). In particular, the notion of ‘transfer’ from one activity, outlined in this approach, has been questioned.

McPherson and Kernodle (2003) suggested that experts developed the ability to make better decisions through the generation of action plan profiles and current event profiles. These action plan profiles are used by the athlete to activate general sport-specific rules for DM. So, if a certain condition should occur (a tennis player is at the back of the court) then the athlete must respond in a certain way (play the drop shot). Current event profiles contain tactical scripts and situation prototypes that guide the response process (Williams & Ford, 2008). Information about past, current and future events is stored in the athlete’s memory and monitored for activating or updating as appropriate. These current event profiles provide the athlete with access to more recent information through specialist processes that link previous experiences to the current sport-specific situation. Based on this, improvements in anticipation and DM are underpinned by changes in perceptual-cognitive skills, knowledge, and the mechanisms that determine how the brain processes information and controls performance (Williams & Ford, 2008).

Understanding how an athlete's knowledge bases can influence DM performance could significantly enhance the way in which DM is taught and developed. For example, if it is simply the case that more knowledge equals better performance, coaches and athletes should focus on learning and developing greater levels of knowledge. However, research concerning the issue of knowledge and DM performance within a sporting context is rare. One exception is expertise research, which concentrates on the description of the correlation between knowledge and performance. French and Thomas (1987) found that skilled children who possessed more basketball knowledge demonstrated better performance in actual game situations. However, it is unclear how to interpret this correlation (Wickens, 1992). The “more-is-better” emphasis in this report suggests that if the knowledge can be verbalized then it facilitates DM. However, there is also contradictory evidence showing that this verbalized knowledge does not facilitate DM (Broadbent, Fitzgerald, & Broadbent, 1988). As a result, further exploration is required to clarify the nature of this relationship.

Another avenue to enhance athlete DM in the literature focuses on implicit learning (Masters, 2000). Bar-Eli, Plessner, and Raab (2011) suggested that withholding the original objectives and supporting an indirect attention focus on relevant players and game set-ups create implicit learning processes for DM in sport. Indeed, Raab (2003) reported that implicit DM training in basketball, handball and volleyball produces better decisions in simple DM scenarios than explicit training. However, in more highly complex situations explicit learners out performed their implicit learning contemporaries.

There are also athlete-led perspectives on improving DM in sport. In their study of Australian national team athletes, Baker, Côté, and Abernethy (2003) reported that players felt video training, organized training, and watching games on television helped them to develop their perceptual skills and that competition, video training and organized training helped them to develop their DM skills. This view is supported by Lorains, Ball, and McMahon (2013) who utilized video to enhance DM with Australian Rules footballers. In this study participants undertook a 5-week training programme that involved watching a series of specific video clips (n=12) once a week. Post intervention testing demonstrated an improvement in DM performance on a computer-based sport-specific DM task.

Enhancing perception-action coupling

Athletes learn to pick up important cues (specifying variables) that underpin the movement decisions they make in the performance environment through the education of attention, often referred to as perceptual attunement (Fajen, Riley, & Turvey; 2008; Jacobs & Michaels, 2002). Davids, Renshaw and Glazier (2005) suggested two stages in this perception-action coupling process: (i) the education of attention to key informational sources, and (ii) the fine-tuning of movements to a critical source. This suggests that the removal of key information sources (by changing the nature of the task or the environment in training) could impede learning for the competitive environment. The implication of this is that practice that is focused on reducing task complexity to facilitate skill development has a negative impact upon DM ability that is underpinned by this perception-action coupling. Learners pick up specifying variables to support action in specific performance environments through the education of attention, or perceptual attunement (Jacobs & Michaels, 2002; Fajen, Riley, & Turvey, 2008). Jacobs and Michaels (2002) suggested that individuals should not be advised to search for any movement features that they are unable to identify under time pressure (Kibele, 2006). This is supported by the inconclusive nature of research that has sought to identify specific locations for movement cues embedded within the movement sequences of an opponent (e.g. Williams & Grant, 1999).

The ‘training’ of visual search strategies and presenting ‘typical’ scenarios have been suggested as approaches to enhance time constrained DM in sport. The presentation of these ‘typical’ scenarios to trainees, alongside expert accounts of factors to consider when reaching a decision, have been suggested as an alternative to ‘on-the-job’ experience learning (Ericsson & Lehman, 1996; Stokes, Kemper, & Kite, 1997). This training may help increase the pattern recognition skills for athletes. Additionally, this process may help athletes to develop both the procedural and declarative knowledge required for effective problem solving in situations not previously encountered (Seel, Al-Diban, & Blumschein, 2000). Through such naturalistic training, athletes learn not only the cognitive skills required to make rapid and accurate assessments of situations, but also the metacognitive skills relating to the effective allocation of their mental resources. These views have been supported by a range of authors including Abernethy, Wood and Parks (1999) and Richards, Mascarenhas, and Collins (2009). Abernethy et al. (1999) reported that squash players who have received a structured and knowledge-based video training programme improved their anticipatory skills more than a group who engage in physical practice alone. A similar feedback system has also been successfully employed in table tennis (Raab, Masters, & Maxwell, 2005). In this study all participants engaged in a behavioural development programme, with half of them also getting video feedback on their tactical and technical performance. The results highlighted increases in tactical and technical decisions for the video training group.

If we can use techniques such as knowledge-based video training as utilized by Abernethy et al. (1999), to improve anticipatory skills and DM in sport, the impact on athlete training and preparation may be substantial. Indeed Pinder, Renshaw and Davids, (2009) suggest that current methods of training (e.g., cricketers using bowling machines) may not benefit the athlete, as they are not representative of the tasks they encounter in real competition. Support for this video training approach adopted by Abernethy et al. (1999) was also provided by Christina, Baresi, and Shaffner (1990) who explored the impact that video training could have on American Football linebacker selection accuracy. Christina et al. (1990) reported that the video training protocol in a laboratory setting had a significant positive impact upon participant selection accuracy. Finally, recent work by Lorains et al. (2013) has suggested that speeding up the video (faster than real-time) can have positive effects upon subsequent DM performance.

Implications for decision-making training

Building upon the key points emerging from the existing body of knowledge a number of authors have suggested that development plans that explicitly target improvements in DM ability may be more beneficial than seeking to enhance DM simply by the accumulation of experience (Cotterill, 2014; Mascarenhas & Smith, 2011). Also, as highlighted by McMorris (1998) playing 'real' or modified versions of games that prioritize DM in the performance environment might be beneficial. One such approach is 'battle zone' training (Vickery, Dascombe, & Duffield, 2014). Where small-sided games have been suggested as a way to develop decision-making, technical ability, and metabolic conditioning (Dellal, Chamair, Pintus, Girard, Cotte, & Keller 2008).

Cotterill (2014) in seeking to present a coherent approach to the development of decision-making ability in the sport of cricket, highlighted three specific points at which interventions / training could take place: (1) Conscious cognitive (developing an understanding of past experience, tactical awareness, and the individual players' predispositions and tendencies; (2) Perception-action coupling (perceiving relevant cues and information); and (3) Abort and reset (responding to rapid changes in the environment). This approach recognises the fact that there are different aspects of DM in sport, and as a result a range of approaches might need to be adopted depending upon the demands of the sport. Crucially though, the task needs to be kept as ecologically valid as possible. For example, Davids et al. (2005) highlighted the view that the removal of key information sources could impact upon transfer to the performance environment.

The use of video training has also been highlighted as an important way to develop exposure to relevant perceptual cues and knowledge about opposition athletes and their tactics (Araújo et al., 2005). This in turn can help in the explicit development of DM ability. In support of this approach, Baker, et al. (2003) reported that players felt video training, organized training, and watching games on television helped them to develop their perceptual skills and that competition, video training and organized training helped them to develop their DM skills, in essence using video as a substitute for direct experience. This approach is further supported by studies in a range of sports including squash (Abernethy et al. (1999), table tennis (Raab et al., 2005), and Australian rules football (Lorains et al., 2013). Interestingly, Loraind et al. (2013) also reported that those athletes trained in above real time (video played faster than normal speed) improved performance earlier in the training intervention compared to those trained in normal speed (Lorains, Ball & MacMahon, 2013). This in particular offers significant potential for the future.

Gaps in current knowledge and future directions for research

There have been numerous studies investigating DM in sport. However, the majority of these studies have taken place in a laboratory/controlled setting. As a result, there is a need for more studies that emphasize both ecological validity and representative design (Araújo, Davids, & Passos, 2007; Mascarenhas & Smith, 2011). More sport specific NDM studies would provide critical information in developing talent and improving DM skills across a range of sports.

A key question that has yet to be adequately answered is how do you effectively teach and improve DM? Does this differ depending on the nature of the sport (e.g., team Vs. individual)? Gaze training, typical scenarios, situation awareness and video based DM training have all been suggested as appropriate ways to improve DM (Mascarenhas & Smith, 2011), but are these the most effective approaches? To date, there are no longitudinal studies that test these suggested methods and compare the outcomes of each approach. Investigating whether training in a naturalistic setting has a stronger effect on DM performance than other training approaches would also be of interest. This is particularly important as it has been suggested that specifically training DM in the individual athlete may be significantly more beneficial compared to the generation of vast experience over time (Mascarenhas & Smith, 2011).

There is also further work required to develop a broader theoretical framework that incorporates both perceptual and cognitive processes in understanding DM performance under time pressure (Kieble, 2006), and linked to this a greater need to develop a more integrated model of decision-making in sport that incorporates the explanations offered by CDM, NDM and ecological DM (Abrahams & Collins, 2011; Cotterill, 2014).

Another question that remains unanswered relates to what factors influence tactical decisions in sport when the decision maker has a lot of time to consider his options (e.g., cricket captains). Linked to this would be the question of how best to train and develop this conscious and deliberate form of tactical/strategic DM? Also, while much has been made of the value and importance of intuitive decisions we still need to further understand how these intuitive decisions actually occur (Raab & Laborde, 2011).

There is currently a limited amount of research exploring the DM that occurs during game play. As a result, more research needs to explore these decisions in realistic competitive situations. Linked to this is the need for further exploration of the use of knowledge-based video training to improve anticipatory skills. Finally, there is a need to develop a greater understanding of the impact of underlying cognitive and trait differences on DM, to further explore knowledge and DM performance in sport as well as exploring the impact of implicit DM training in more complex DM scenarios.   The field of sport and exercise psychology has developed a good knowledge base from which to build but now needs to look to apply this theoretical in the more complex performance environments that exist in higher level sporting domains.

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Table 1.

Sport	Authors
American Football	Christina, Barresi & Shaffner (1990)
Australian Rules Football	Lorains, Ball & MacMahon (2013)
Baseball	Fadde (2006); French, Spurgeon & Nevett (1995); Paull & Glencross (1997); Vickers, Livingston, Umeris & Holden (1999)
Basketball	French & Thomas (1987); Raab (2002, 2003)
Cricket	Cotterill (2014); McRobert & Taylor (2005); Penrose & Roach (1995); Renshaw & Fairweather (2000)
Soccer	Bar-eli, Plessner, & Raab (2007); Fontana et al., (2009); Gutirrez et al., (2011); Pérez, Nieto, Coll, Manzano, Espín, & Psotta,(2014); Savelsbergh, Van der Champ, William, & Ward, (2005); Williams & Davids, (1998)
Handball	Raab (2003)
Ice hockey	Martell & Vickers (2004); Soberlak & Côté (2003)
Rugby Union	Passos, Araújo, Davids & Shuttleworth, (2008)
Sailing	Araújo, Davids, & Serpa (2005)
Squash	Abernethy (1990); Alain & Sarrazin (1990)
Table tennis	Poulton, Masters, & Maxwell (2006); Raab, Masters, & Maxwell (2005)
Tennis	Johnson & Raab (2003); McPherson & Kernodle (2003); McPherson & Thomas (1989)
Volleyball	Macquet (2009); Raab (2003)
Waterpolo	Royal et al. (2006)