The past, present and future of research on judgment and decision making in sport (50years of FEPSAC Special issue in PSE)

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Abstract

Objectives: The study of judgment and decision-making in sports is at least as old as the anniversary of FEPSAC we celebrate with this special issue. It seems therefore appropriate to look into the past, present and future of this topic. Design: For the *past*, a focus of the review is relating the European perspective of the co-authors into a larger frame of areas in judgment and decision making within the last 50 years and beyond.

Method/Results/Conclusions: For the *present*, scientific current developments will be structured as judgments from the most influential perspectives such as the economical, social cognition, ecological dynamics or cognitive approaches illustrating some milestones in research on judgment and decision-making in sports of today. For the *future*, potentials of the field will be structured based on theory, methodology and practical applications showcasing challenges for the next decades of research ahead of us.

Keywords: choice, social cognition, dynamical system, embodied cognition, economical models, ecological perspective

Introduction

This paper and the special issue take the 50 years of FEPSAC anniversary as an opportunity to reflect on the past, present and future of JDM research in sports. Judgment and decision-making (JDM) are important concepts within FEPSAC's 50 years of existence, nurtured from historic interests in how humans choose. More recently, JDM has diversified into streams influenced by different disciplines such as psychology, economy and neuroscience. These developments such as risk decisions have been highlighted by a Noble Price for economic sciences awarded to the psychologist Daniel Kahneman in 2002, and have led to an intense discussion between different streams of research within the last decades, including sports (e.g. Bar-Eli, Plessner, & Raab, 2011).

For the purpose of this paper, we define choices as the outcome of judgment and decision-making processes. Judgment processes refer to a set of evaluative and inferential or intuitive processes that people have at their disposal and can draw on in the process of making decisions (Koehler & Harvey, 2004, p. xv). Decision-making refers to “the process of making a choice from a set of options, with the consequences of that choice being crucial” (Bar-Eli et al., 2011, p. 6).

Landmarks of phenomena of interest, theory, and methodological as well as practical advancements can describe the past 50 years of JDM in sports. Four important streams of work that reflect how JDM research is currently realized characterize the presence of JDM in sports. The authors of this paper came together to write the paper because they are experts, each in one of these main streams we cluster as economic (Bar-Eli), social judgment (Plessner), ecological (Araújo) and cognitive approaches (Raab). Each approach will exemplify the tenets of the theoretical approach by a leading example. A joint attempt will be made to predict future developments in this fascinating area.

The past: 50 years of JDM in sports

The Beginning. The roots of modern-day research on JDM can be traced back to the seminal work of Nobel Laureate Herbert Simon (1955). Simon challenged the idea that rational human beings make optimal decisions intended to meet some economic criterion of utility maximization ("subjective expected utility" or "SEU"; e.g., Edwards, 1954). Simon suggested the alternative concept of "bounded rationality". According to Simon, economic rationality is only an ideal model, whereas in reality, one's person and the environment in which she or he acts, bound the decisions to make them "good enough" or "satisfying", rather than optimal allowing for fast and frugal choices. In what followed, psychology could then be "mobilized" to account for this gap between the economic/ideal and behavioural/real models of rationality.

In the early 1970's, Israeli psychologists Amos Tversky and Daniel Kahneman began to study human cognition using what was later labeled the "heuristics and biases (H&B)" paradigm (Gilovich, Griffin & Kahneman, 2002; Kahneman, Slovic & Tversky, 1982). In short, their major idea was that human beings use some very fast and simple modes of intuitive thinking (heuristics) when taking risk or making judgments and decisions under conditions of uncertainty. For the majority of people and situation, the use of these heuristics leads to satisfactory outcomes, even if this suboptimal processing of information does not end up with the best result. In fact, quite often, human JDM is then biased in comparison to some "rational" (e.g., economic) benchmark. According to Tversky and Kahneman, we "pay the price" for simplifying and facilitating our JDM processes by getting "biased" under risky and/or (un)certain circumstances, thereby "undoing" several rules of "economic" rationality (Lewis, 2016). Later on, this approach was extended into "prospect theory" (Kahneman & Tversky, 1979; Kahneman, 2013). In a way, H&B and prospect theory operationalize or

98 "map" [as Kahneman (2003) said in his Nobel speech, Stockholm, December 2002] Simon's
99 concept of bounded rationality.

100 Nothing of the above found an echo in the early sport-psychology literature, in which the
101 study of JDM had substantially lagged behind its potential until the middle of the first
102 decade of the 2000s. This was quite surprising because, for example, already in 1985, one of
103 the most provocative investigations in the history of JDM was published, namely Gilovich,
104 Vallone and Tversky's (1985) study on the (absence of) "hot hand" in basketball. Gilovich et
105 al. (1985) found that players who hit two or three times in a row compared to previous
106 situations in which they miss two or three shots have an equal probability to hit again and
107 thus are not 'hot'. This was provocative or at least contra-intuitive for sport fans, based on
108 their beliefs and experiences. Despite the great deal of research inspired by this study in
109 other areas (e.g., cognitive psychology), it was generally disregarded by sport psychology, as
110 were other aspects of JDM, which had – as it turned out later - a huge theoretical and
111 practical potential for advancing this discipline.

112 Introducing JDM to sport. Upon the establishment of "Psychology of Sport and Exercise"
113 (PSE) in 2000, its Founding Editor, Stuart Biddle encouraged the publication of special issues
114 intended to strengthen the newborn journal. One outcome was a special issue on JDM
115 initiated by Michael Bar-Eli, who was at that time Associate Editor of PSE. Co-edited with
116 Markus Raab, this special issue (Bar-Eli & Raab, 2006a) put systematic attention on JDM,
117 namely by bringing to the front several JDM theoretical perspectives applied to sports. It was
118 followed by and extended to a book (Bar-Eli et al., 2011) – the first in the English language
119 (see recent books such as Williams & Jackson, 2018).

120 Bar-Eli and Raab (2009a) and Bar-Eli et al. (2011) developed a taxonomy of theories and
121 observed a tendency of theories and models to become increasingly dynamic and

probabilistic, that is, more realistic. In addition, Bar-Eli and Raab (2009a) noted a trend toward integrating a number of different description levels (i.e., behavioural, computational and neurophysiological) in theorizing and modeling which were then prevalent. Finally, a number of theory-led applications of knowledge in the sport area were observed (Bar-Eli et al., 2011).

Despite these positive developments, Bar-Eli and Raab (2009a) and Bar-Eli et al. (2011) were still concerned about the broader theories of cognition and action being adopted and applied far too slowly by researchers in sports. The delay of 5 to 10 years (see Bar-Eli et al., 2011,Fig. 3.2) between the original publication of a particular theory in the social sciences and its subsequent application in sports were considered unfortunate, but nonetheless inevitable due to the nature of sports involving both cognition and action . Thus, JDM research may come to play a more important role in better understanding not only how people make judgments and decisions, but also how they are expressed through movements.

The present: An economic, social judgment, ecological and cognitive approach

In 2018 using Web of Science and search for the American and British spelling of Judg(e)ment or Decision Making and Sport we compiled a list of 168 papers matching the content. One of the authors (MR) and a research assistant in JDM research (SE) read title and abstract and included the paper if the content refers to judgment and decision making processes of individual persons as defined above. The path analyses was given to the remaining authors of the manuscript (ME, HP, DA) for accept or reject relations based on their expertise in the specific subarea of JDM research. Figure 1 aims at summarizing these publications into a citation-network description. Papers that influence the recent work theoretically in the last decades for each approach were added. Most important from a

theoretical description of 50 years of JDM in sports in relations to 50 years of FEPSAC are the developed independent theoretical streams of economic, social judgment, ecological and cognitive approaches. As Figure 1 indicates the overlap and historical trace between some approaches are differently strong.

An economic approach to judgment and decision making in sports

The hot hand example. Among the approaches considered by Bar-Eli and Raab (2006a, 2006b, 2009a, see also Bar-Eli et al, 2011) to be more appropriate for sports settings, "decision field theory" (DFT; see Busemeyer and Townsend, 1993) and Gigerenzer's (2000) "simple/fast and frugal heuristics (FFH)" were included. However, the most substantial development in this respect occurred when the scientific community, slowly but surely, acknowledged, that "sports research is a great idea, because people here take many decisions that are of great importance to them under standard conditions. In fact, this is one of the best fields to do that" (Kahneman, 2008). In other words, research relying on data from sports has been gradually conducted not only for the sake of understanding sports, but rather, for being used as a laboratory for assessment of important psychological and/or economic theories. Evidently, Gilovich et al.'s (1985) study was a showcase of such research, with over 1300 citations on Google Scholar thus far – but being almost completely disregarded by sport-psychology from 1985 to 2006!

As a matter of fact, the hot-hand debate was one of the most inspiring controversies between the H&B and FFH approaches (Lewis, 2016). The first literature review ever conducted on this issue (Bar-Eli, Avugos & Raab, 2006b) found no solid evidence for the existence of a "hot hand" – a finding further validated by a more recent meta-analysis (Avugos, Koeppen, Csienskowski, Raab & Bar-Eli, 2013a). These results turned also to be provocative and problematic not only within JDM, but even more so, for Bandura's (1997)

widely accepted self-efficacy theory. For this theory "success breeds success and failure breeds failure" in the sense of positive correlations (or "streaks") being expected (but not found) between successive trials. As demonstrated by controlled shooting field experiments conducted by Avugos, Bar-Eli, Ritov and Sher (2013b), such streaks are rather illusory. These findings also challenge other important psychological concepts such as momentum (Avugos & Bar-Eli, 2015).

In response to these accumulating H&B-oriented findings, FFH-researchers argued that even if the evidence for a "hot hand" in sports was "controversial" (e.g., Bennis & Pachur, 2006), the belief in its existence might be adaptive in the "boundedly rational" sense. This argument was empirically investigated by a recent doctoral dissertation comprised of three published articles (Csapo, 2015). Taken together the published papers examined the effect of defensive pressure on the "hot hand" phenomenon in basketball, and revealed that even though defenders behaved according to the "hot hand" belief (e.g. defended the hot attacker closer or with two players), no evidence in favor of a real "hot hand"- effect could be found. Csapo (2015) even observed that a "hot hand"-behaviour on defense in specific cases could not be considered adaptive. At any rate, the ongoing debate around this fascinating controversy provides an excellent example of sports being used for studying interesting psychological and/or economic issues, such as "streaks" of successes or failures of investments in the stock market (Kahneman, 2011).

Penalty kicks. Another phenomenon from sports, which stimulated plenty of recent research is the penalty kick in soccer. In his fascinating book entitled "Beautiful game theory", economist Ignacio Palacios-Huerta (2014) demonstrated "how soccer can help economics" (not the opposite), among others, by intensively investigating penalty kicks. Palacios-Huerta justified the use of real penalty kicks for the study of game-theoretical concepts such as

194 "Minimax Theorem" and "Mixed Strategy Nash Equilibrium (MSNE)" by arguing that in the
195 past, they had been examined empirically in laboratory experiments with low external
196 validity, as opposed to real data from soccer matches (Azar & Bar-Eli, 2011). The fact that
197 penalties are often taken as a series of shootouts in a constant situation and with large
198 incentives, made them attractive for researchers who were interested in the study of
199 approach motivation (Roskes, Sligte, Shalvi, & De Dreu, 2011), gambler's fallacy (Misirlisoy &
200 Haggard, 2014) and choking under pressure being reflected by surprising order effects
201 (Palacios-Huerta, 2014).

202 Bar-Eli, Azar, Ritov, Keidar-Levin and Schein (2007) analyzed penalty kicks in top leagues
203 and championships worldwide and found that whereas the optimal strategy for goalkeepers
204 is to stay in the goal's center, goalkeepers almost always jump to the left or right. The
205 authors explained this non-optimal behaviour by norm theory (Kahneman & Miller, 1986).
206 The goalkeepers' norm is to act (jumping), and a goal scored yields worse feelings for the
207 goalkeeper following inaction (staying in the center) than following action (jumping), thus
208 leading to a bias for action. However, Bar-Eli, Azar and Lurie (2009b) noted that goalkeepers'
209 behaviour can be defined as biased (towards action) only if we assume – in line with
210 traditional economic theory (e.g., SEU; see Edwards, 1954) – that their utility function
211 reflects the strategy of maximizing the chances of stopping the ball.

212 Bar-Eli and Azar (2009c) used the set of penalty kicks included in Bar-Eli et al.'s (2007)
213 study to investigate the behaviour of the kickers. It was found that whereas the optimal
214 shooting strategy, which maximizes the chances of scoring, is to aim the ball to the upper
215 third of the goal - in particular to the upper two corners - kickers rarely shoot to this
216 direction. It seems as if, at all costs, they try not to miss the goal-frame even though this
217 does not maximize the chances of scoring. In the last case, failure can be viewed only as the

kicker's fault, not as the outcome of the goalkeeper's skills a possible interpretation, when the goalkeeper stops the ball. As with the goalkeepers, it seems that shooters do optimize – but not a "classic" utility function (i.e., maximizing the chances of scoring). Instead, their utility function also reflects their substantial disutility from missing the goal-frame, which is higher than their disutility from a kick being stopped by the goalkeeper.

It seems, then (see Bar-Eli et al., 2009c), that both goalkeepers and kickers alike do not attempt to maximize their chances of stopping or scoring a goal, respectively. At first sight, this looks as though it were quite irrational (i.e., not trying to maximize utility). However, if we interpret their behaviour as reflecting utility functions, which are different from the ones assumed by the investigators, then they are rational. More specifically, in terms of Gigerenzer's (2000) concept of "social rationality", they seem to be very rational: in an environment where the "base rate" (i.e., probability of scoring) is about 75 - 80% (Palacios-Huerta, 2014), a goalkeeper wants to look good, doing his best to stop the ball by jumping in a situation in which he is clearly the "underdog". Similarly, the shooter wants to avoid "looking bad" in a situation where he/she is a clear "favorite". Thus, from a social point of view, both are very rational in terms of self-presentational considerations (Bar-Eli et al., 2009b). Paradoxically, however, this behaviour is, at the end, "economically rational", because it is the social environment (e.g., club owner, coach, fans, media, press etc.) which evaluates and rewards them also financially (Sabag, Lidor, Morgulev, Amon, Azar & Bar-Eli, 2018).

Social Cognition in judgment and decision making in sports

In social psychology, JDM is mainly studied in a research field that is called social cognition. It comprises the study of how people make sense of other people and themselves (Fiske & Taylor, 2013). Accordingly, in sport it is mainly of concern when it comes to the

judgment/evaluation of athletes and their performance (Plessner & Haar, 2006). Social cognition focuses on cognitive processes as basis for social interaction, hence it follows an information processing framework and investigates how social information is perceived, encoded, transferred to and recalled from memory. Just like the seminal heuristics and biases approach (see above), social cognition frequently uses paradigms where people make systematic judgments errors (biases or cognitive illusions) in order to study cognitive processes. In the following, we will present the specific characteristics of the social cognition approach with an example of a prototypical social cognition study in sport.

Based on a series of older studies (Ansorge, Scheer, Laub, & Howard, 1978; Scheer, 1973; Scheer & Ansorge, 1975, 1979), Plessner (1999) conducted an experiment on expectancy effects in judging gymnastics. It made use of an unwritten rule according to which gymnastics coaches typically place gymnasts in rank order from poorest at the beginning to best at the end in a team competition. It has been shown before that this unwritten rule leads to different performance expectancies if an athlete starts as the first of his team than if he or she starts as the last. Prior research already demonstrated a biasing influence of these expectancies on the evaluation of gymnastic exercises. In line with the social cognition approach, Plessner (1999) aimed at going beyond the mere replication of this effect by revealing its underlying cognitive processes. In fact, different theories predict expectancy effects to stem from different stages of information processing, as for example depicted in the continuum model of impression formation by Fiske and Neuberg (1990). In the experiment, performance related expectancies have been induced in gymnastic judges by the manipulation of athletes' order of appearance in a videotaped competition. Half of the judges were presented with routines in the last position of a team order, that is when they expected a high performance, and the other half of the judges saw these routines in the first

position, that is when they expected a low performance. Now, the use of judges' protocol sheets as the dependent variable enabled the researcher to determine the processing stages that were influenced by judges' performance-related expectancies. Among others, it was found that the categorization of perceived value parts (i.e., the attributed difficulty to single gymnastic elements) was already biased by judges' expectancies. Accordingly, it could be excluded that the expectancy effect is mainly due to processes of information integration. Together, this experiment represents a prototypical application of the social cognition approach to sport because it (a) investigates a judgment bias of practical concern, (b) assesses cognitive processes, and (c) can tell between different theoretical explanations. In an ideal manner, studies like this one do not only help to understand human processes of JDM but provide hints on how errors and biases can be prevented in the domain of sport. In order to do so, however, these studies are supposed to take the context of application as serious as possible, i.e. they should strive for high external validity. For example, this can be achieved by confirming laboratory results with the analysis of field data (Schwarz, 2011). Luckily, there are a number of studies that fulfil these aspirations (for an overview see Plessner & Haar, 2006). On the other hand, there are an even higher and increasing number of studies that simply demonstrate potential biasing influences of certain factors on JDM in sport without any attempt to assess underlying cognitive processes and/or to differentiate between alternative theoretical explanations. For example, several (unwanted) factors have been shown to supposedly influence decisions of referees in association football: Colour of players' jersey (Krenn, 2014), teams' reputation (Jones, Paull, & Erskine, 2002), crowd noise (Nevill, Balmer & Williams 2002), minute of play (De Oliveira, Orbetelli, & de Barros Neto, 2011), players' skin color (Wagner-Egger, Gygax, & Ribordy, 2012), players' size (van Quaquebeke & Giessner, 2010), players' direction of motion (Kranjec, Lehet, Bromberger &

Chatterjee, 2010). Only few of these and similar studies match the demands for social cognition applications in sport as described above (for a notable exception see for example Unkelbach & Memmert, 2010). This is a bit unsatisfactory because in this case studies do not contribute much to the understanding of JDM in sport, neither from a theoretical nor from a practical perspective.

Together, the social cognition approach bears the potential to gain insights in the specifics of JDM in sport and to serve as a solid basis for the development of measures that help to improve JDM in sport. However, in order to do so research must pay attention to the underlying processes of social judgment and respect the specific sport context. Just to gather fancy effects does not contribute much to the field.

Ecological dynamics in judgement and decision making in sports

Cognitive psychology in general and JDM in particular were challenged in the late 60's by new concepts and methods coming from ecological and dynamical approaches to perception and action (Bernstein, 1967; Gibson, 1966, 1979). This challenge was amplified by the subsequent synthesis of both approaches (Kugler, Kelso, & Turvey, 1980; Turvey, 1977). Previous research on cognition and action has typically been grounded on theories of memory enrichment through mental representations (e.g., schemas, programmes), which consider stimuli in the environment to be impoverished for individuals. The role of mental representations is to enhance meaning and richness of stimuli, interpret the environment and programme the body to implement actions. Alternatively, non-representational approaches, such as those derived from Gibson's approach are predicated on the idea that perception and cognition are embedded and embodied, emphasizing the study of the performer-environment system as the appropriate scale of analysis (see Shaw, 2003, for a distinction between Gibson and Simon's views on cognition). Interestingly, prominent

cognitive psychologists also support the idea that action is not a mere implementation of a mental process, but it is, in itself, a very cognitive process (e.g., Wolpert & Landy, 2012). Although some previous literature already existed (e.g., Withing, 1990; Bootsma & van Wieringen, 1990; Lee et al., 1982), Davids and colleagues provided a comprehensive discussion of these ideas, and their implications for sport scientists (Davids, Handford, & Williams, 1994; see also Williams, Davids, Burwitz, & Williams, 1992).

A further impact in sport psychology was made in developing an ecological dynamics rationale for decision-making by Araújo et al. (2006), where among other points, the link to Brunswik' s (1956) concept of representative design was firmly established. This ecological dynamics' framework is an action-based, non-representational approach to cognition, where, cognition is the on-going, active maintenance of a robust performer– environment system, achieved by closely coordinated perception and action (see Araújo et al., 2017). One consequence of understanding decision-making as emerging from the performer-environment system is that behaviour can be understood as self-organized, in contrast to organization being imposed from the inside (e.g., the mind) or the outside (e.g., the contingencies of reinforcement). From the player's point of view, the task is to exploit physical (e.g., the pitch characteristics as determined by the rules) and informational (e.g., the movement of other players) constraints to stabilize behaviour. Constraints have the effect of reducing the number of configurations available to a dynamical system at any instance. In a performance environment, behaviour patterns emerge under constraints as less functional states of organization are dissipated. Changes in performance constraints can lead a system towards bifurcation points where choices emerge as more specific information becomes available, constraining the environment-athlete system to switch to a more functional path of behaviour (such as running into a larger gap on court rather than another

which is smaller). Transitions among stable behavioural patterns emerge as a result of dynamic instability, providing a universal decision-making process for switching between distinct patterns (Araújo et al., 2014; Kelso, 1995). Such stabilities and instabilities do not exist a priori in the structure of the player or in that of the environment but are co-determined by the confluence of constraints and information.

For example, Carvalho and colleagues (2014) studied how dynamic decision-making behaviour, expressed as successive strokes in a tennis rally, was based on concatenated affordances (i.e., opportunities for action, Gibson, 1979). In that study, instead of measuring some variables reflecting some aspect of the player (like response time, accuracy in relation to a norm, or neurophysiological data), the authors presented an eco-physical variable that captured the player-environment system. This variable was the *goal-directed displacement (GDD) index*, a measure that simultaneously considered the distance of the players in relation to two on-court reference points –the central line of the court and the net- during each rally. In one of their exemplar rallies with expert players, in the sixth shot, player 1 made a parallel variation with a backhand down-the-line that pressured player 2 to make a major move from the left-hand side to the right-hand side of the court. After this time, both players were playing facing each other and when player 1 hit the coming shot, he was closer to the centre of the court in a position to score the point. When one player moves away from the central line of the court to hit the ball, the other player approaches the central line of the court to defend his/her court. This is the circumstance where a point may be scored, because in addition to the difficulty of returning a ball after a large displacement, an empty space is created on the other side of the court that can be exploited by the adversary to win the point. Whenever the players were moving away from the more stable and intertwined courses of action a system perturbation (a rally break) may emerge, as the values of the GDD

index expressed. Therefore, the advantage in a rally, as captured by the dynamic model of the GDD index, is a process that is developed though successive actions, where nested affordances are dynamically assembled through perceptual attunement of skilled players to information for the next affordance. This study showed that different courses of action (i.e., dynamic decision-making behaviour) could be established between expert players attuned, open, and responsive to match affordances. This also signifies that a player with an advantage is perceiving and creating affordances for the other (see Fajen, et al, 2009), where the other is invited (pressured) to act upon such affordances. On the other hand, the stability of the interactions between players is highly constrained by the co-positioning of the players (near or away from the central line of the court, or from the net) and the pattern of interactions developed during play (cross-court or down-the-line rallies). In such field of affordances, a player with an advantage tries to create a successively more unstable situation for the other player, stroke after stoke, in an effort to de-stabilize the strength of the co-dependence of their courses of action.

What stands out in in this study is that decision-making behaviours can be sustained by simultaneous and successive affordances, and not necessarily by a hierarchical plan or representation capturing a sequence of performance operations (Araújo et al., 2017). In other words, these local interactions are coupled to larger scale dynamics, guiding the formation of the behavioural trajectory over longer time scales. Reciprocally, the longer-term dynamics could influence the short-term interactions (and thus highlighting specific affordances), for example, by altering environmental conditions. Because a behavioural trajectory is assembled anew on each occasion, the action sequence is contingent and variable, allowing for the flexibility observed in ordinary action sequences.

Since action itself is an expression of the cognitive process, it should be possible to look at organizational and functional aspects of contextualized action as evidence for and against hypotheses about cognitive aspects of those behaviours. The measurement of the dynamics of eco-physical variables (e.g., the GDD index) enables formal modelling and understanding of how the cognitive processes might be predicated on emergent, on-going performer-environment interactions in sport (Araújo et al., 2017).

A cognitive approach to judgment and decision making in sports

A cognitive approach that for instance describes a playmakers' choice in basketball of whom to pass or to shoot to the basket would separate different constructs and processes (e.g. cue-use in perception/recognition or recall in memory) that could influence the choice. Dependent on the specific cognitive approach a specific theory drives the description and potential modelling of behaviour, (e.g. see the application of the Decision-Field-Theory to sports, Johnson, 2006). Due to the expertise of one of the authors we will focus on the simple heuristic approach. A simple heuristic is a rule of thumb that consists of building blocks called search, stop and decision rules.

An example: A playmaker behaving according to the Take-The-First heuristic (Johnson & Raab, 2003) would search for the most valid option on the field, stops searching after generating two or three further options and chooses the first option. A Take-The-Best heuristic (Gigerenzer & Goldstein, 1996) describes how within a given set of two or more options people choose. Take-The-Best heuristics uses sequentially cues (e.g. distance of the attacker to the basket, distance of the defender) in order of their validity and decides to pass to the player in which the first cue discriminates between the two options (e.g. closer to the basket). If the first cue 'distance to the basket' differentiates between the two options, the playmaker would pass to the player that is near the basket. However, if two players were

comparably close to the basket, the second cue would be considered and the ball would be played to the less-defended player.

The above examples are prototypical for the previous summaries of applications to sports (Bennis & Pachur, 2006; Raab, 2012). Further examples include applications for heuristics that are tuned to fast choices of allocation decisions in team-sports (e.g. Hepler & Feltz, 2012), or motor control related processes (e.g. Raab, Masters, & Maxwell, 2005). In addition, heuristics have been applied to betting behaviour of spectators (Serwe & Frings, 2006), or coaches' decisions in talent selection and development (De Oliveira, Lobinger, & Raab, 2014). Finally, recent theoretical comparisons have been put forward which include a table of elements of building blocks and heuristics relevant for different applications in sport psychology (Raab, 2018).

Methodologically, cognitive approaches to judgment and decision making in sports are often quite experimentally-oriented. Experimental approaches use paradigms that differentiate cues from fixed sets of options or ask participants to generate options for a given situation (e.g. Belling, Suss & Ward, 2015). Time pressure is one of the situational variables manipulated. Further developmental aspects of the person have been considered systematically (e.g. Marasso, Laborde, Bardaglio, & Raab, 2014). Finally, developments of the cognitive approach concern the use of psychophysiological data (e.g. Laborde & Raab, 2013) and the modelling of choices and reaction times (Johnson, 2006).

In summary, the cognitive approach set standards to formulate the probabilities and dynamics of judgments and decision making in sports and requires as the others perspectives in this paper a comparison to each other as well as major improvements in the future.

The Future: Theoretical challenges and solutions

As many other areas in sport psychology, JDM sport research began from the need to understand sport phenomena. For this purpose, imported theories were adopted, adapted and applied. For each theory, we list the most urgent theoretical challenges before we propose research for a joint future.

Economic theoretical challenges

In a recent book-chapter, Raab, MacMahon, Avugos and Bar-Eli (in press) focus on the fierce debate between H&B and FFH and how research in sport can contribute to its clarification. From the text above, it is evident that in the "hot hand" controversy, H&B has currently the upper hand. In contrast, Bar-Eli's (2018) penalty studies demonstrate how re-interpreting a bias in terms of different utility functions undoes the bias and can be understood in terms of another type of (bounded) rationality – in this case, social. It is our firm conviction that as long as sport will be increasingly viewed as one of the best fields to study human JDM processes (as noted by Kahneman, 2008), research in this area will continue to flourish.

Social cognition theoretical challenges

The application of the social cognition approach in the field of sport aims at promoting progress in corresponding fields, such as officiating (MacMahon et al., 2014), sport performance evaluation (Fasold, Memmert & Unkelbach, 2015), and person (athlete) perception (Greenlees, 2007). As has been described above, in order to do so research needs to overcome the stage of capturing effects and must follow the road to explanation and theory based interventions. Therefore, the most urgent challenge is the development/shaping of theories that are concerned with specific judgment tasks in sport. For example, some efforts have already been made in this regard concerning refereeing in game sports (Brand, Schweizer & Plessner, 2009; Plessner, Schweizer, Brand, & O'Hare, 2009). These theoretical considerations led to the development and evaluation of a video-

based training for association football referees (Schweizer, Plessner, Kahlert, & Brand, 2011). However, there is still not enough competition between different theoretical approaches in this field. A notable exception is the scientific debate about the cognitive mechanisms that may lead to the high number of erroneous offside decisions in association football (cf. Brand, Plessner, & Unkelbach, 2008).

Ecological theoretical challenges

Recently Withagen, Araújo and de Poel (2017) sketched a dynamical model of the agent-environment relationship where agency is conceptualized as the capacity to modulate the coupling strength with the environment. This model explained that the agent can influence to some extent how he or she is influenced by the different affordances. By modulating the coupling strength, the agent simply alters the dynamics of the performer-environment system and thus the behaviour that emerges. This model opens to ecological dynamics the challenge of understanding how changes in individual variables modulate the coupling strength with the environment. Following the same logic, it opens the possibility to understand how environment's changes (e.g., social, task-related, technology-based) constraints the coupling strength with the performer. A third challenge is to understand how these modulations make the performer-environment system more robust and flexible (i.e. antifragile, a system that is leveraged by adversity; Kiefer, Silva, Harrison, & Araújo, in press) over time. The coupling strength can be captured by eco-physical variables, as we mentioned in the tennis example, where constraints such as court type, adversary level, emotional processes, or fatigue level could be systematically studied to understand how they change the performer-environment coupling strength.

Cognitive theoretical challenges

The cognitive approach is challenged when considering aspects of learning. How do we learn cue-validities? How do we become experts in decision-making? In sports, proposals on decision training (e.g. Vickers, 2007) have been contrasted with Teaching Games For Understanding (Griffin, Mitchell & Oslin, 1997), Ball schools (Memmert & Roth, 2007) or the SMART-ER model (Raab, 2015), but those learning proposals in sports have not yet been related to learning approaches within the specific frameworks such as simple heuristics (e.g. Rieskamp & Otto, 2006).

A further challenge of the cognitive approach is that it leaves us in the dark about the answer of which model and theoretical approach is valid and would predict different behaviour. For instance, for specific models Take-The-First heuristic assumes a negative correlation between number of generated options and choice quality whereas the Long-Term-Working-Memory model (Ericsson & Lehmann, 1996) predicts a positive correlation that can be put to the test.

Conclusion

Hopefully, the future will bring more research of the kind “Theory A of JDM Phenomenon X” versus “Theory B of Phenomenon X” or “Theory A” versus “Theory of B” in explaining multiple phenomena X, Y and Z. Consequently, this would not only drive the theoretical progress in the field but pave the road to better JDM in sport. Likewise, questions of athletes, coaches, managers and fans not often are well-studied yet and could inform how we should proceed in the next 50 years of JDM research. The list of those phenomena is longer than a single researcher’s life and list of potential studies can easily pursue, as choice is almost everywhere in sports. Thus, the future of JDM research may lie in JDM teams.

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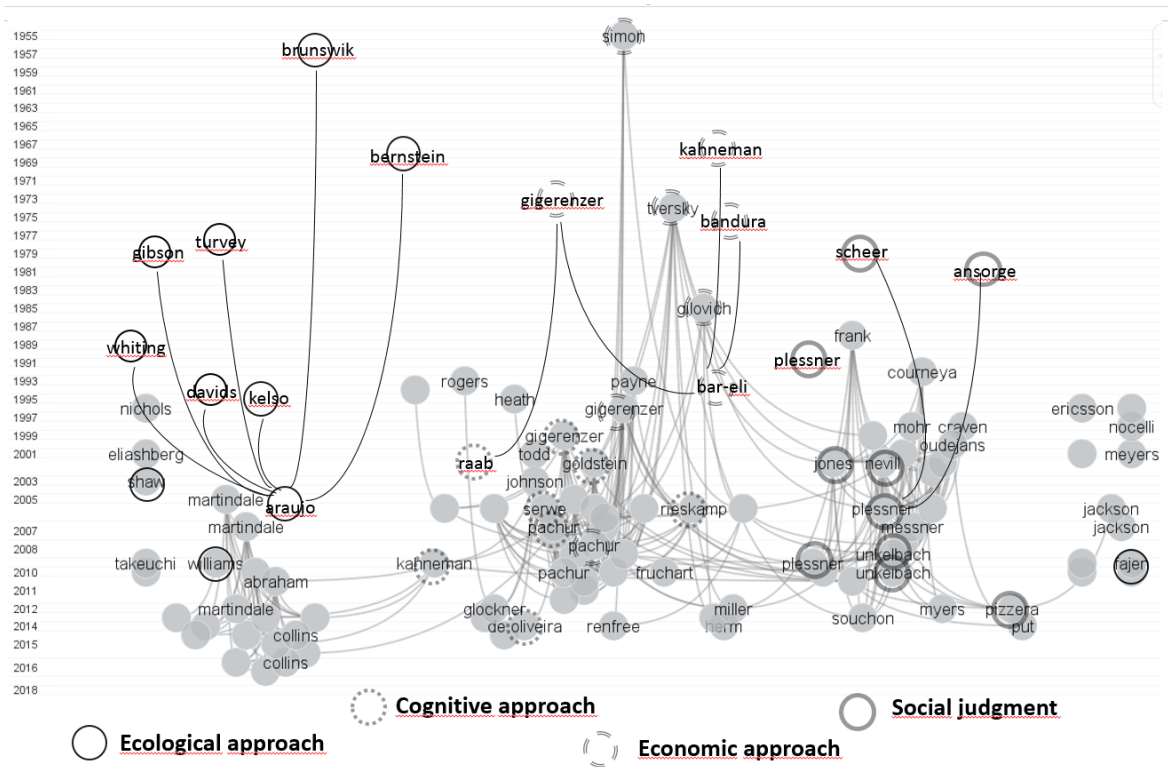
739 Appendix

740 

741 *Figure 1.* Citation-network description reflecting literature on judgment and decision making in sports. Ordinate

742 presents the year of the publication as listed in Web of Science.

743 The four streams of research (economic approach, social judgment, ecological approach, cognitive approach)

744 are shown and separated by symbols.

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