

1 The past, present and future of research on judgment and decision making in sport
2 (50years of FEPSAC Special issue in PSE)

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32 Abstract

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

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

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

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49 Introduction

50

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

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

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

74 The past: 50 years of JDM in sports

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

85 In the early 1970’s, Israeli psychologists Amos Tversky and Daniel Kahneman began to
86 study human cognition using what was later labeled the “heuristics and biases (H&B)”
87 paradigm (Gilovich, Griffin & Kahneman, 2002; Kahneman, Slovic & Tversky, 1982). In short,
88 their major idea was that human beings use some very fast and simple modes of intuitive
89 thinking (heuristics) when taking risk or making judgments and decisions under conditions of
90 uncertainty. For the majority of people and situation, the use of these heuristics leads to
91 satisfactory outcomes, even if this suboptimal processing of information does not end up
92 with the best result. In fact, quite often, human JDM is then biased in comparison to some
93 “rational” (e.g., economic) benchmark. According to Tversky and Kahneman, we “pay the
94 price” for simplifying and facilitating our JDM processes by getting “biased” under risky
95 and/or (un)certain circumstances, thereby “undoing” several rules of “economic” rationality
96 (Lewis, 2016). Later on, this approach was extended into “prospect theory” (Kahneman &
97 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

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

127 Despite these positive developments, Bar-Eli and Raab (2009a) and Bar-Eli et al. (2011)
128 were still concerned about the broader theories of cognition and action being adopted and
129 applied far too slowly by researchers in sports. The delay of 5 to 10 years (see Bar-Eli et al.,
130 2011, Fig. 3.2) between the original publication of a particular theory in the social sciences
131 and its subsequent application in sports were considered unfortunate, but nonetheless
132 inevitable due to the nature of sports involving both cognition and action. Thus, JDM
133 research may come to play a more important role in better understanding not only how
134 people make judgments and decisions, but also how they are expressed through
135 movements.

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

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

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

150 An economic approach to judgment and decision making in sports

151 *The hot hand example.* Among the approaches considered by Bar-Eli and Raab (2006a,
152 2006b, 2009a, see also Bar-Eli et al, 2011) to be more appropriate for sports settings,
153 “decision field theory” (DFT; see Busemeyer and Townsend, 1993) and Gigerenzer’s (2000)
154 “simple/fast and frugal heuristics (FFH)” were included. However, the most substantial
155 development in this respect occurred when the scientific community, slowly but surely,
156 acknowledged, that “sports research is a great idea, because people here take many
157 decisions that are of great importance to them under standard conditions. In fact, this is one
158 of the best fields to do that” (Kahneman, 2008). In other words, research relying on data
159 from sports has been gradually conducted not only for the sake of understanding sports, but
160 rather, for being used as a laboratory for assessment of important psychological and/or
161 economic theories. Evidently, Gilovich et al.’s (1985) study was a showcase of such research,
162 with over 1300 citations on Google Scholar thus far – but being almost completely
163 disregarded by sport-psychology from 1985 to 2006!

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

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

176 In response to these accumulating H&B-oriented findings, FFH-researchers argued that
177 even if the evidence for a “hot hand” in sports was “controversial” (e.g., Bennis & Pachur,
178 2006), the belief in its existence might be adaptive in the “boundedly rational” sense. This
179 argument was empirically investigated by a recent doctoral dissertation comprised of three
180 published articles (Csapo, 2015). Taken together the published papers examined the effect
181 of defensive pressure on the “hot hand” phenomenon in basketball, and revealed that even
182 though defenders behaved according to the “hot hand” belief (e.g. defended the hot
183 attacker closer or with two players), no evidence in favor of a real “hot hand”- effect could
184 be found. Csapo (2015) even observed that a “hot hand”-behaviour on defense in specific
185 cases could not be considered adaptive. At any rate, the ongoing debate around this
186 fascinating controversy provides an excellent example of sports being used for studying
187 interesting psychological and/or economic issues, such as “streaks” of successes or failures
188 of investments in the stock market (Kahneman, 2011).

189 *Penalty kicks.* Another phenomenon from sports, which stimulated plenty of recent research
190 is the penalty kick in soccer. In his fascinating book entitled “Beautiful game theory”,
191 economist Ignacio Palacios-Huerta (2014) demonstrated “how soccer can help economics”
192 (not the opposite), among others, by intensively investigating penalty kicks. Palacios-Huerta
193 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

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

223 It seems, then (see Bar-Eli et al., 2009c), that both goalkeepers and kickers alike do not
224 attempt to maximize their chances of stopping or scoring a goal, respectively. At first sight,
225 this looks as though it were quite irrational (i.e., not trying to maximize utility). However, if
226 we interpret their behaviour as reflecting utility functions, which are different from the ones
227 assumed by the investigators, then they are rational. More specifically, in terms of
228 Gigerenzer's (2000) concept of “social rationality”, they seem to be very rational: in an
229 environment where the “base rate” (i.e., probability of scoring) is about 75 - 80% (Palacios-
230 Huerta, 2014), a goalkeeper wants to look good, doing his best to stop the ball by jumping in
231 a situation in which he is clearly the “underdog”. Similarly, the shooter wants to avoid
232 “looking bad” in a situation where he/she is a clear “favorite”. Thus, from a social point of
233 view, both are very rational in terms of self-presentational considerations (Bar-Eli et al.,
234 2009b). Paradoxically, however, this behaviour is, at the end, “economically rational”,
235 because it is the social environment (e.g., club owner, coach, fans, media, press etc.) which
236 evaluates and rewards them also financially (Sabag, Lidor, Morgulev, Amon, Azar & Bar-Eli,
237 2018).

238 Social Cognition in judgment and decision making in sports

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

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

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

266 position, that is when they expected a low performance. Now, the use of judges' protocol
267 sheets as the dependent variable enabled the researcher to determine the processing stages
268 that were influenced by judges' performance-related expectancies. Among others, it was
269 found that the categorization of perceived value parts (i.e., the attributed difficulty to single
270 gymnastic elements) was already biased by judges' expectancies. Accordingly, it could be
271 excluded that the expectancy effect is mainly due to processes of information integration.
272 Together, this experiment represents a prototypical application of the social cognition
273 approach to sport because it (a) investigates a judgment bias of practical concern, (b)
274 assesses cognitive processes, and (c) can tell between different theoretical explanations. In
275 an ideal manner, studies like this one do not only help to understand human processes of
276 JDM but provide hints on how errors and biases can be prevented in the domain of sport. In
277 order to do so, however, these studies are supposed to take the context of application as
278 serious as possible, i.e. they should strive for high external validity. For example, this can be
279 achieved by confirming laboratory results with the analysis of field data (Schwarz, 2011).
280 Luckily, there are a number of studies that fulfil these aspirations (for an overview see
281 Plessner & Haar, 2006). On the other hand, there are an even higher and increasing number
282 of studies that simply demonstrate potential biasing influences of certain factors on JDM in
283 sport without any attempt to assess underlying cognitive processes and/or to differentiate
284 between alternative theoretical explanations. For example, several (unwanted) factors have
285 been shown to supposedly influence decisions of referees in association football: Colour of
286 players' jersey (Krenn, 2014), teams' reputation (Jones, Paull, & Erskine, 2002), crowd noise
287 (Nevill, Balmer & Williams 2002), minute of play (De Oliveira, Orbetelli, & de Barros Neto,
288 2011), players' skin color (Wagner-Egger, Gyga, & Ribordy, 2012), players' size (van
289 Quaquebeke & Giessner, 2010), players' direction of motion (Kranjec, Lehet, Bromberger &

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

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

300 Ecological dynamics in judgement and decision making in sports

301 Cognitive psychology in general and JDM in particular were challenged in the late 60's by
302 new concepts and methods coming from ecological and dynamical approaches to perception
303 and action (Bernstein, 1967; Gibson, 1966, 1979). This challenge was amplified by the
304 subsequent synthesis of both approaches (Kugler, Kelso, & Turvey, 1980; Turvey, 1977).

305 Previous research on cognition and action has typically been grounded on theories of
306 memory enrichment through mental representations (e.g., schemas, programmes), which
307 consider stimuli in the environment to be impoverished for individuals. The role of mental
308 representations is to enhance meaning and richness of stimuli, interpret the environment
309 and programme the body to implement actions. Alternatively, non-representational
310 approaches, such as those derived from Gibson's approach are predicated on the idea that
311 perception and cognition are embedded and embodied, emphasizing the study of the
312 performer-environment system as the appropriate scale of analysis (see Shaw, 2003, for a
313 distinction between Gibson and Simon's views on cognition). Interestingly, prominent

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

320 A further impact in sport psychology was made in developing an ecological dynamics
321 rationale for decision-making by Araújo et al. (2006), where among other points, the link to
322 Brunswik's (1956) concept of representative design was firmly established. This ecological
323 dynamics' framework is an action-based, non-representational approach to cognition,
324 where, cognition is the on-going, active maintenance of a robust performer– environment
325 system, achieved by closely coordinated perception and action (see Araújo et al., 2017).

326 One consequence of understanding decision-making as emerging from the performer-
327 environment system is that behaviour can be understood as self-organized, in contrast to
328 organization being imposed from the inside (e.g., the mind) or the outside (e.g., the
329 contingencies of reinforcement). From the player's point of view, the task is to exploit
330 physical (e.g., the pitch characteristics as determined by the rules) and informational (e.g.,
331 the movement of other players) constraints to stabilize behaviour. Constraints have the
332 effect of reducing the number of configurations available to a dynamical system at any
333 instance. In a performance environment, behaviour patterns emerge under constraints as
334 less functional states of organization are dissipated. Changes in performance constraints can
335 lead a system towards bifurcation points where choices emerge as more specific information
336 becomes available, constraining the environment-athlete system to switch to a more
337 functional path of behaviour (such as running into a larger gap on court rather than another

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

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

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

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

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

391 A cognitive approach to judgment and decision making in sports

392
393 A cognitive approach that for instance describes a playmakers' choice in basketball of whom
394 to pass or to shoot to the basket would separate different constructs and processes (e.g.
395 cue-use in perception/recognition or recall in memory) that could influence the choice.
396 Dependent on the specific cognitive approach a specific theory drives the description and
397 potential modelling of behaviour, (e.g. see the application of the Decision-Field-Theory to
398 sports, Johnson, 2006). Due to the expertise of one of the authors we will focus on the
399 simple heuristic approach. A simple heuristic is a rule of thumb that consists of building
400 blocks called search, stop and decision rules.

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

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

412 The above examples are prototypical for the previous summaries of applications to sports
413 (Bennis & Pachur, 2006; Raab, 2012). Further examples include applications for heuristics
414 that are tuned to fast choices of allocation decisions in team-sports (e.g. Hepler & Feltz,
415 2012), or motor control related processes (e.g. Raab, Masters, & Maxwell, 2005). In addition,
416 heuristics have been applied to betting behaviour of spectators (Serwe & Frings, 2006), or
417 coaches' decisions in talent selection and development (De Oliveira, Lobinger, & Raab,
418 2014). Finally, recent theoretical comparisons have been put forward which include a table
419 of elements of building blocks and heuristics relevant for different applications in sport
420 psychology (Raab, 2018).

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

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

433 *The Future: Theoretical challenges and solutions*

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

438 Economic theoretical challenges

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

447 Social cognition theoretical challenges

448 The application of the social cognition approach in the field of sport aims at promoting
449 progress in corresponding fields, such as officiating (MacMahon et al., 2014), sport
450 performance evaluation (Fasold, Memmert & Unkelbach, 2015), and person (athlete)
451 perception (Greenlees, 2007). As has been described above, in order to do so research needs
452 to overcome the stage of capturing effects and must follow the road to explanation and
453 theory based interventions. Therefore, the most urgent challenge is the
454 development/shaping of theories that are concerned with specific judgment tasks in sport.
455 For example, some efforts have already been made in this regard concerning refereeing in
456 game sports (Brand, Schweizer & Plessner, 2009; Plessner, Schweizer, Brand, & O'Hare,
457 2009). These theoretical considerations led to the development and evaluation of a video-

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

463 Ecological theoretical challenges

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

480 Cognitive theoretical challenges

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

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

494 Conclusion

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

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505 References

- 506 Ansoorge, C. J., Scheer, J. K., Laub, J., & Howard, J. (1978). Bias in judging women's gymnastics
507 induced by expectations of within-team order. *Research Quarterly*, *49*, 399-405.
- 508 Araújo, D., Davids, K., & Hristovski, R. (2006). The ecological dynamics of decision making in
509 sport. *Psychology of Sport and Exercise*, *7*, 653-676.
- 510 Araújo, D., Diniz, A., Passos, P., & Davids, K. (2014). Decision making in social neurobiological
511 systems modelled as transitions in dynamic pattern formation. *Adaptive Behaviour*,
512 *22*(1), 21–30.
- 513 Araújo, D., Hristovski, R., Seifert, L., Carvalho, J., & Davids, K. (2017). Ecological cognition:
514 Expert decision-making behaviour in sport. *International Review of Sport and Exercise
515 Psychology*. 1-25.
- 516 Avugos, S., & Bar-Eli, M. (2015). A second thought on the success-breeds-success model:
517 Comment on Iso–Ahola and Dotson (2014). *Review of General Psychology*, *19*, 106–
518 111.
- 519 Avugos, S., Koeppen, J., Czienskowski, U., Raab, M., & Bar-Eli, M. (2013a). The “hot hand”
520 reconsidered: A meta-analytic approach. *Psychology of Sport and Exercise*, *14*(1), 21-
521 27.
- 522 Avugos, S., Bar-Eli, M., Ritov, I., & Sher, E. (2013b). The elusive reality of efficacy–
523 performance cycles in basketball shooting: an analysis of players’ performance under
524 invariant conditions. *International Journal of Sport and Exercise Psychology*, *11*(2),
525 184-202.
- 526 Azar, O. H., & Bar-Eli, M. (2011). Do soccer players play the mixed-strategy Nash
527 equilibrium?. *Applied Economics*, *43*(25), 3591-3601.
- 528 Bandura, A. (1997). *Self-efficacy: The exercise of control*. New York: Freeman.
- 529 Bar-Eli, M. (2018). *Boost! How the psychology of sports can enhance your performance in
530 management and work*. New York, NY: Oxford University Press.
- 531 Bar-Eli, M., & Raab, M. (Eds). (2006a). Judgment and decision making in sport and exercise.
532 *Psychology of Sport and Exercise*, *7* (8).
- 533 Bar-Eli, M., Avugos, S., & Raab, M. (2006b). Twenty years of “hot hand” research: Review
534 and critique. *Psychology of Sport and Exercise*, *7*(6), 525-553.
- 535 Bar-Eli, M., Azar, O. H., Ritov, I., Keidar-Levin, Y., & Schein, G. (2007). Action bias among elite
536 soccer goalkeepers: The case of penalty kicks. *Journal of economic psychology*, *28*(5),
537 606-621.

- 538 Bar-Eli, M., & Raab, M. (2009a). Judgment and decision making in sport and exercise: A
539 concise history and present and future perspectives. *Perspectives on cognition and*
540 *action in sport*, 149-156.
- 541 Bar-Eli, M., Azar, O. H., & Lurie, Y. (2009b). (Ir) rationality in action: do soccer players and
542 goalkeepers fail to learn how to best perform during a penalty kick?. *Progress in brain*
543 *research*, 174, 97-108.
- 544 Bar-Eli, M., & Azar, O. H. (2009c). Penalty kicks in soccer: an empirical analysis of shooting
545 strategies and goalkeepers' preferences. *Soccer & Society*, 10(2), 183-191.
- 546 Bar-Eli, M., Plessner, H., & Raab, M. (2011). *Judgement, decision making and success in sport*.
547 *Chichester: Wiley-Blackwell*.
- 548 Belling, P. K., Suss, J., & Ward, P. (2015). Advancing theory and application of cognitive
549 research in sport: Using representative tasks to explain and predict skilled
550 anticipation, decision-making, and option-generation behavior. *Psychology of Sport*
551 *and Exercise*, 16, 45–59.
- 552 Bennis, W. M., & Pachur, T. (2006). Fast and frugal heuristics in sports. *Psychology in Sport*
553 *and Exercise*, 7, 611–629.
- 554 Bernstein, N. A. (1967). *The co-ordination and regulation of movements*. Oxford: Pergamon
555 Press.
- 556 Bootsma, R. J. & van Wieringen, P. C. W. van (1990). Timing an attacking forehand drive in
557 table tennis. *Journal of Experimental Psychology: Human Perception and*
558 *Performance*, 16, 21-29.
- 559 Brand, R., Plessner, H., & Unkelbach, C. (2008). Basic psychological processes underlying
560 referees' decision-making. In P. Anderson, P. Ayton & C. Schmidt (Eds.), *Myths and*
561 *facts about football: The economics and psychology of the world's greatest sport* (pp.
562 173-190). Cambridge: Cambridge Scholars Press.
- 563 Brand, R., Schweizer, G., & Plessner, H. (2009). Conceptual considerations about the
564 development of a decision-making training method for expert soccer referees. In D.
565 Araújo, H. Ripoll & M. Raab (Eds.), *Perspectives on cognition and action in sport* (pp.
566 181-190). Hauppauge, NY: Nova Sciences.
- 567 Brunswik, E. (1956). *Perception and the representative design of psychological experiments*
568 (2nd ed.). Berkeley: University of California Press.

- 569 Busemeyer, J. R. & Townsend, J. T. (1993). Decision field theory: a dynamic-cognitive
570 approach to decision making in an uncertain environment. *Psychological review*,
571 *100*(3), 432.
- 572 Csapo, P. (2015). The effect of defensive pressure on the hot-hand phenomenon in
573 Basketball. Dissertation. Deutsche Sporthochschule, Köln.
- 574 Carvalho, J., Araújo, D., Travassos, B., Fernandes, O., Pereira, F., & Davids, K. (2014).
575 Interpersonal dynamics in baseline rallies in tennis. *International Journal of Sports
576 Science & Coaching*, *9*(5), 1043–1056.
- 577 Davids, K., Handford, C., & Williams, M. (1994). The natural physical alternative to cognitive
578 theories of motor behaviour: An invitation for interdisciplinary research in sports
579 science? *Journal of Sports Sciences*, *12*, 495–528.
- 580 De Oliveira, M. C., Orbetelli, R., & De Barros Neto, T. L. (2011). Call accuracy and distance
581 from the play: A study with Brazilian soccer referees. *International Journal of Exercise
582 Science*, *4*, 30–8.
- 583 De Oliveira, R. F., Lobinger, B. H., & Raab, M. (2014). An adaptive toolbox approach to the
584 route to expertise in sport. *Frontiers in Psychology*, *5*. p. 709.
- 585 Edwards, W. (1954). The theory of decision making. *Psychological bulletin*, *51*(4), 380.
- 586 Ericsson, K. A., & Lehmann, A. C. (1996). Expert and exceptional performance: Evidence on
587 maximal adaptations on task constraints. *Annual Review of Psychology*, *47*, 273–305.
- 588 Fajen, B., Riley, M., & Turvey, M. (2009). Information, affordances, and the control of action
589 in sport. *International Journal of Sport Psychology*, *40*(1), 79–107.
- 590 Fasold, F., Memmert, D., & Unkelbach, C. (2015). A theory-based intervention to prevent
591 calibration effects in serial sport performance evaluations. *Psychology of Sport and
592 Exercise*, *18*, 47–52.
- 593 Fiske, S. T., & Neuberg, S.L. (1990). A continuum of impression formation, from category-
594 based to individuating processes: Influences of information and motivation on
595 attention and interpretation. In M.P. Zanna (Ed.), *Advances in experimental social
596 psychology* (Vol. 23, pp. 1-74). New York: Academic Press.
- 597 Fiske, S. & Taylor, S. E. (2013). *Social cognition – From brains to culture* (2nd Ed.). New York:
598 McGraw-Hill.
- 599 Gibson, J. J. (1966). *The senses considered as perceptual systems*. Boston, MA: Houghton
600 Mifflin.

- 601 Gibson, J. J. (1979). *The ecological approach to visual perception*. Boston, MA: Houghton
602 Mifflin.
- 603 Gigerenzer, G., & Goldstein, D. G. (1996). Reasoning the fast and frugal way: models of
604 bounded rationality. *Psychological review*, 103(4), 650.
- 605 Gigerenzer, G. (2000). *Adaptive thinking: Rationality in the real world*. Oxford University
606 Press, USA.
- 607 Gilovich, T., Vallone, R., & Tversky, A. (1985). The hot hand in basketball: on the
608 misperception of random sequences. *Cognitive Psychology*, 17, 295-314.
- 609 Gilovich, T., Griffin, D., & Kahneman, D. (Eds.). (2002). *Heuristics and biases: The psychology
610 of intuitive judgment*. New York: Cambridge University Press.
- 611 Greenlees, I. (2007). Person perception and sport performance. In S. Jovett & D. Lavallee
612 (Eds.), *Social psychology in sport* (pp. 195-208). Champaign, Ill: Human Kinetics.
- 613 Griffin, L. L., Mitchell, S. A., & Oslin, J. L. (1997). *Teaching sport concepts and skills. A tactical
614 games approach*. Champaign, IL: Human Kinetics.
- 615 Hepler, T. J., & Feltz, D. L. (2012). Path analysis examining self-efficacy and decision-making
616 performance on a simulated baseball task. *Research quarterly for exercise and sport*,
617 83(1), 55-64.
- 618 Johnson, J. G. (2006). Cognitive modeling of decision making in sports. *Psychology of Sport
619 and Exercise*, 7(6), 631-652.
- 620 Johnson, J. G., & Raab, M. (2003). Take the first: Option-generation and resulting choices.
621 *Organizational behavior and human decision processes*, 91(2), 215-229.
- 622 Jones, M. V., Paull, G. C., & Erskine, J. (2002). The impact of a team's reputation on the
623 decisions of association football referees. *Journal of Sports Sciences*, 20, 991-1000.
- 624 Kahneman, D. (2008). Personal communication with Michael Bar-Eli.
- 625 Kahneman, D., & Tversky, A. (1979). Prospect theory: An analysis of decision under risk.
626 *Econometrics*, 47, 263-291. Retrieved from: <http://www.jstor.org/pss/1914185>.
- 627 Kahneman, D., Slovic, P., & Tversky, A., (Eds.). (1982). *Judgment under uncertainty: Heuristics
628 and biases*. Cambridge: Cambridge University Press.
- 629 Kahneman, D., & Miller, D. T. (1986). Norm theory: Comparing reality to its alternatives.
630 *Psychological Review*, 93, 136-153.
- 631 Kahneman, D., & Egan, P. (2011). *Thinking, fast and slow* (Vol. 1). New York: Farrar, Straus
632 and Giroux.

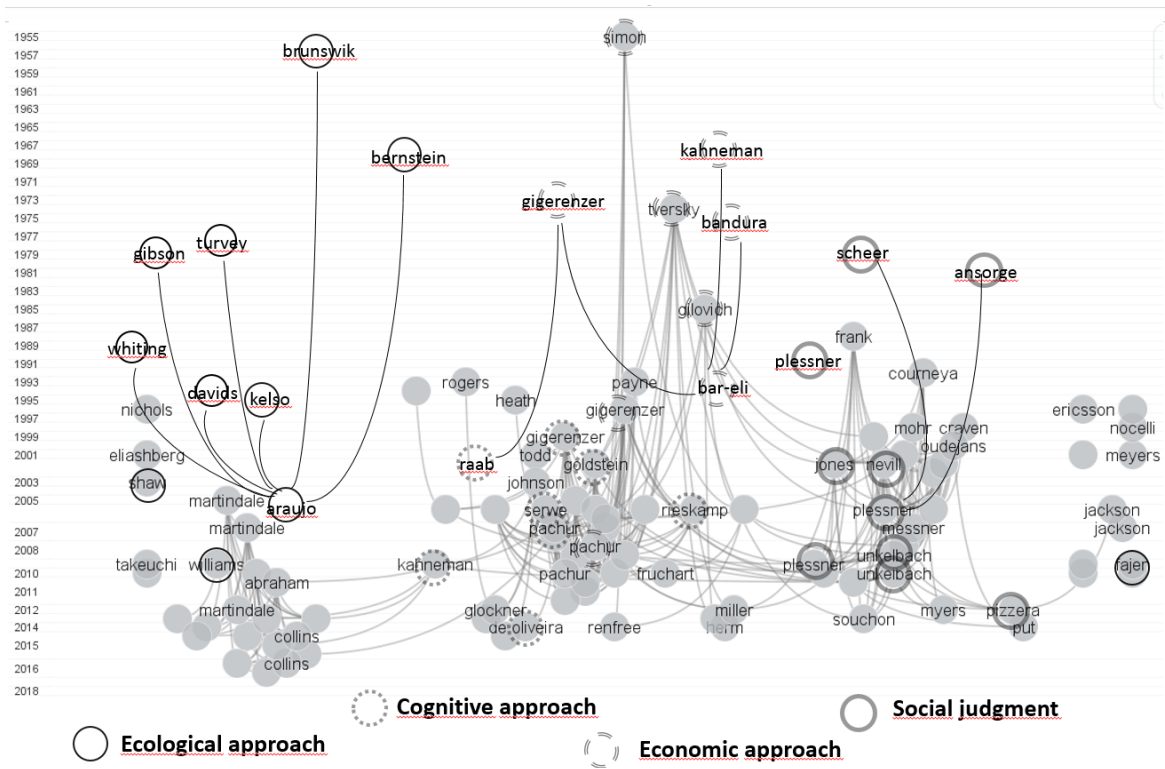
- 633 Kahneman, D., & Tversky, A. (2013). Prospect theory: An analysis of decision under risk. In
634 *Handbook of the fundamentals of financial decision making: Part I* (pp. 99-127).
- 635 Kelso, J. A. S. (1995). *Dynamic patterns: The self-organization of brain and behaviour*.
636 Cambridge: MIT Press.
- 637 Kiefer, A. W., Silva, P., Harrison, H., & Araújo, D. (in press). Antifragility in sport: Leveraging
638 adversity to enhance performance. *Sport, Exercise, and Performance Psychology*.
- 639 Koehler, D. J., & Harvey, N. (2004). *Blackwell handbook of judgment and decision making*.
640 Malden, MA: Blackwell.
- 641 Kranjec, A., Lehet, M., Bromberger, B., & Chatterjee, A. (2010). A sinister bias for calling fouls
642 in soccer. *PLoS ONE*, 5(7).
- 643 Krenn, B. (2014). The impact of uniform color on judging tackles in association football.
644 *Psychology of Sport and Exercise*, 15, 222-225.
- 645 Kugler, N. P., Kelso, J. A. S., & Turvey, M. T. (1980). On the concept of coordinative structures
646 as dissipative structures: I. Theoretical lines of convergence. In G. E. Stelmach & J.
647 Requin (Eds.), *Tutorials in motor behavior* (pp. 3-47). Amsterdam: North-Holland
648 Pub.
- 649 Laborde, S. & Raab, M. (2013). The tale of hearts and reason: the influence of mood on
650 decision making. *Journal of Sport & Exercise Psychology*, 35(4), 339-357.
- 651 Lee, D. N., Lishman, J. R., & Thomson, J. A. (1982). Regulation of gait in long jumping. *Journal*
652 *of Experimental Psychology: Human Perception and Performance*, 8, 448-459
- 653 Lewis, M. (2016). *The undoing project: A friendship that changed our minds*. WW Norton &
654 Company.
- 655 MacMahon, C., Plessner, H., Pizzera, A., Oudejans, R. R. D., & Raab, M. (2014). *Sports officials*
656 *and officiating: Science and practice*. London: Routledge.
- 657 Marasso, D., Laborde, S., Bardaglio, G., & Raab, M. (2014). A developmental perspective on
658 decision making in sports. *International Review of Sport and Exercise Psychology*,
659 7(2014), 1-23.
- 660 Memmert, D., & Roth, K. (2007). The Effects of Non-Specific and Specific Concepts on
661 Tactical Creativity in Team Ball Sports. *Journal of Sports Sciences*, 25, 1423-1432.
- 662 Misirlisoy, E., & Haggard, P. (2014). Asymmetric predictability and cognitive competition in
663 football penalty shootouts. *Current Biology*, 24(16), 1918-1922.

- 664 Nevill, A. M., Balmer, N. J., & Williams, A. M. (2002). The influence of crowd noise and
665 experience upon refereeing decisions in football. *Psychology of Sport and Exercise, 3*,
666 261-272.
- 667 Palacios-Huerta, I. (2014). *Beautiful game theory: How soccer can help economics*. Princeton
668 University Press.
- 669 Plessner, H. (1999). Expectation biases in gymnastics judging. *Journal of Sport and Exercise*
670 *Psychology, 21*, 131-144.
- 671 Plessner, H., & Haar, T. (2006). Sports performance judgments from a social cognition
672 perspective. *Psychology of Sport and Exercise, 7*, 555-575.
- 673 Plessner, H., Schweizer, G., Brand, R., & O'Hare, D. (2009). A multiple-cue learning approach
674 as the basis for understanding and improving soccer referees' decision making. In M.
675 Raab, J. Johnson & H. Heekeren (Eds.), *Progress in Brain Research: Mind and Motion: The Bidirectional Link between Thought and Action* (pp. 151-158). Amsterdam:
676 Elsevier Press.
- 677
- 678 Raab, M., Masters, R. S., & Maxwell, J. P. (2005). Improving the 'how' and 'what' decisions of
679 elite table tennis players. *Human movement science, 24*(3), 326-344.
- 680 Raab, M. (2012). Simple heuristics in sports. *International Review of Sport and Exercise*
681 *Psychology, 5*(2), 104-120.
- 682 Raab, M. (2015). SMART-ER: a situation model of anticipated response consequences in
683 tactical decisions in skill acquisition - extended and revised. *Front. Psychol. 5*:1533.
- 684 Raab, M. (2018). Performance Psychology. In G. Tenenbaum & R. Eklund (eds.). *Handbook of*
685 *Sport Psychology* (4th Edition). New York: Wiley.
- 686 Raab, M., MacMahon, C., Avugos, S. & Bar-Eli, M. (in press). Heuristics, Biases, and Decision
687 Making. In M. Williams & R. Jackson (Eds.), *Anticipation and Decision Making in*
688 *Sport*. Routledge.
- 689 Rieskamp, J. & Otto, P. E. (2006). SSL: A theory of how people learn to select strategies.
690 *Journal of Experimental Psychology: General, 135*, 207-236.
- 691 Roskes, M., Sligte, D., Shalvi, S., & De Dreu, C. K. (2011). The right side? Under time pressure,
692 approach motivation leads to right-oriented bias. *Psychological Science, 22*(11), 1403-
693 1407.

- 694 Sabag, E., Lidor, R., Morgulev, E., Arnon, M., Azar, O., & Bar-Eli, M. (2018). To dive or not to
695 dive in the penalty area? The questionable art of deception in soccer. *International*
696 *Journal of Sport and Exercise Psychology*, 1-12.
- 697 Scheer, J. K. (1973). Effect of placement in the order of competition on scores of Nebraska
698 high school students. *Research Quarterly*, 44, 79-85.
- 699 Scheer, J. K., & Ansorge, C. J. (1975). Effects of naturally induced judges' expectations on the
700 ratings of physical performances. *Research Quarterly*, 46, 463-470.
- 701 Scheer, J. K., & Ansorge, C. J. (1979). Influence due to expectations of judges: A function of
702 internal-external locus of control. *Journal of Sport Psychology*, 1, 53-58.
- 703 Schwarz, W. (2011). Compensating tendencies in penalty kick decisions of referees in
704 professional football: Evidence from the German Bundesliga 1963-2006. *Journal of*
705 *Sports Sciences*, 29, 441-447.
- 706 Schweizer, G., Plessner, H., Kahlert, D., & Brand, R. (2011). A video-based training method
707 for improving soccer referees' intuitive decision-making skills. *Journal of Applied*
708 *Sport Psychology*, 23, 429-442.
- 709 Serwe S. & Frings C. (2006). Who will win Wimbledon? The recognition heuristic in predicting
710 sports events. *Journal of Behavioral Decision Making*, 19, 321-332.
- 711 Shaw, R. (2003). The agent-environment interface: Simon's indirect or Gibson's direct
712 coupling? *Ecological Psychology*, 15, 37-106.
- 713 Simon, H. A. (1955). A behavioral model of rational choice. *The quarterly journal of*
714 *economics*, 69(1), 99-118.
- 715 Turvey, M. T. (1977). Preliminaries to a theory of action with reference to vision. In R. E.
716 Shaw, & J. Bransford (Eds.), *Perceiving, acting and knowing: Toward an ecological*
717 *psychology* (pp. 211-265). Erlbaum, NJ: Hillsdale.
- 718 Unkelbach, C. & Memmert, D. (2010). Crowd noise as a cue in referee decisions contributes
719 to the home advantage. *Journal of Sport & Exercise Psychology*, 32, 483-498.
- 720 Van Quaquebeke, N., & Giessner, S. R. (2010). How embodied cognition affect judgments:
721 Height-related attribution bias in football foul calls. *Journal of Sport & Exercise*
722 *Psychology*, 32, 3-22.
- 723 Vickers, J. N. (2007). *Perception, cognition, and decision training: The quiet eye in action*.
724 Champaign, IL: Human Kinetics.

- 725 Wagner-Egger, P., Gygax, P., & Ribordy, F. (2012). Racism in soccer? Perception of challenges
726 of black and white players by white referees, soccer players, and fans. *Perceptual &*
727 *Motor Skills*, 114, 275-289.
- 728 Williams, A. M., & Jackson, R. (2018). *Perception and Decision Making in Sports*. London:
729 Routledge.
- 730 Williams, A. M., Davids, K., Burwitz, L., & Williams, J. G. (1992). Perception and action in
731 sport. *Journal of Human Movement Studies*, 22, 147–205.
- 732 Withagen, R., Araújo, D., & de Poel, H. J. (2017). Inviting affordances and agency. *New Ideas*
733 *in Psychology*, 45, 11-18.
- 734 Whiting, H. T. (1990). Decision-making in sport. In Bakker, F.C., Whiting, H. T. & van der Brug,
735 H. (Eds). *Sport psychology: concepts and applications*. Londres: John Wiley & Sons.
- 736 Wolpert, D. M. & Landy, M. S. (2012). Motor control is decision-making. *Current Opinion in*
737 *Neurobiology*, 22, 996–1003.
- 738

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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