ARTICLE

Toward a better theoretical and practical understanding of field players' decision-making in handball: A systematic review

Guillaume Bonnet^{1,2,*}, Thierry Debanne³, and Guillaume Laffaye^{1,2,4}

¹ CIAMS Univ. Paris-Sud – Université Paris-Saclay, 91405 Orsay Cedex, France

² CIAMS, Université d'Orléans, 45067 Orléans, France

³ UR LIRTES, Université Paris-Est Créteil Val-de-Marne, Bât. La Pyramide, 94009 Créteil Cedex, France

⁴ Research Center for Sports Science, South Ural State University, Chelyabinsk, Russian Federation

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Abstract– The aim of this review is to summarize current literature about decision-making in handball in order to identify potential gaps in the cognitive domain, and to propose directions for future research. Studies used various methods but rarely specified the theoretical framework. Two theoretical approaches are commonly used to study the decision-making in team sports. The cognitive approach was used in two thirds of the studies reported in this review. It focuses on skills used by a player to respond to different stimuli often in a non-specific context. These skills include attention, memory and perception. As expected, expert players tend to perform better in these cognitive tests compared to novices, especially when the task's complexity is high. In contrary, the naturalistic approach studies the way the player analyzes a real and experienced situation. The studies look first at the generation of options, for which expert players appear superior. Second, they assess team cognition which concerns the way a decision is integrated into a collective plan. In this paper, we've described some practical applications and highlighted the limitations and complementarity of these two approaches to study the importance of expertise in decision-making.

Key words: cognitive skills, perception, expertise, cognitive approach, naturalistic decision making

Résumé – Vers une meilleure compréhension théorique et pratique de la prise de décision des joueurs de champ au handball : une revue systématique. Le but de cette revue est de résumer les études actuelles traitant de l'activité décisionnelle au handball, d'identifier les manques potentiels de la recherche en sciences cognitives, et de proposer des orientations pour de futures recherches. Ces études ont utilisé différentes méthodes mais ont rarement précisé le modèle théorique utilisé. Deux approches théoriques permettent d'étudier l'activité décisionnelle en sports collectifs. L'approche cognitive représente deux tiers des études trouvées. Elle s'intéresse aux compétences utilisées par un joueur face à différents stimuli dans un contexte souvent non spécifique. Ces compétences incluent l'attention, la mémoire et la perception. Les joueurs experts apparaissent meilleurs que les novices, notamment lorsque la complexité de la tâche est élevée. En revanche, l'approche naturaliste étudie la façon dont le joueur analyse une situation réelle et expérimentée. Les études de cette approche s'intéressent tout d'abord à la génération d'options, dans laquelle les experts apparaissent supérieurs aux novices. Ensuite, ces études évaluent la cognition d'équipe qui concerne la façon dont les décisions sont prises dans le cadre d'un plan collectif. Nous avons décrit dans cette revue plusieurs applications pratiques et exposé les limites et la complémentarité de ces 2 approches pour étudier le lien entre expertise et activité décisionnelle.

Mots clés : capacités cognitives, perception, expertise, approche cognitive, prise de décision naturaliste

*Corresponding author: guillaume.bonnet@u-psud.fr

^aPresent address: Laboratoire CIAMS, Université Paris Sud, Bât 335, 91405 Cedex, France.

Introduction

Handball¹ is an invasion and collision team sport with intermittent efforts and high intensity actions, with the objective to score more goals than the opposing team (Karcher & Buchheit, 2014). Handball players have to quickly decide on the appropriate action, taking into account various parameters and with a certain degree of uncertainty. Over the past thirty years, several authors have studied decision-making in handball (Johnson & Raab, 2003; Schapschroer, Baker, & Schorer, 2016a, Schapschroer, Baker, & Schorer, 2016b; Tenenbaum, Yuval, Elbaz, Bar-Eli, & Weinberg, 1993). They focused primarily on perceptive aspects. They demonstrated that experts perform better in decision-making tasks, as they are better at analysis visual cues and other parameters influencing decision-making. However, no systematic review has been done on decision-making in handball. The aim of this paper is to summarize the current literature in this field and to propose directions for future research.

In handball, decision-making can be studied in different actors such as players, coaches or referees. Obviously, the type of decisions they must make is different because of their role and their position in or off the field. Whereas coaches must manage the players and make strategic decisions for their team (Debanne & Chauvin, 2014), referees must have to make disciplinary decisions (Souchon, Cabagno, Traclet, Trouilloud, & Maio, 2009). Similarly, the activity of field players is very different from that of goalkeepers. The decision-making of the field player is more complex because it involves their activity with or without the ball and in offensive or defensive phases. Moreover, they have to consider the balance of the power between themselves and their direct opponent: can they outrun them for example. In this study, we focused solely on decision making of field players.

Approaches to study decision-making in team sports

Researchers in cognitive ergonomics (Kobus, Proctor, & Holste, 2001) and sports sciences (Bossard & Kermarrec, 2011) agree that it exists two approaches to study decision-making processes. The cognitive one was the first to be developed and does not take into account the context of a decision. This approach focuses on micro-cognition, defined as the study of separate units of cognition (Klein, Klein, & Klein, 2000). In contrary, the naturalistic approach studies the way a player analyzes a situation in a real context, taking into account its complexity. This

approach focuses on macro-cognition (Klein *et al.*, 2000), defined as the description of complex cognitive functions performed in a natural environment.

The cognitive approach

Presentation

The cognitive approach examines the information processing. It studies the processes and specific skills used by a player exposed to different stimuli to assess the situation and make a decision (Lex, Essig, Knoblauch, & Schack, 2015). In this approach, the athlete is considered a rational and omniscient actor who assesses different possibilities to maximize their own behaviour (Macquet & Fleurance, 2007). This method evaluates three main parameters: 1) the strategies to collect information in the environment, 2) the organization of the knowledge mobilized by the player and 3) the memory processes implicated (Bossard & Kermarrec, 2011). These analyses are quantitative and performed using implicit methods, explicit methods or perceptive tasks. The explicit methods use simple questions, and verbalizations (McPherson & Vickers, 2004). The implicit methods use recall tasks and recognition tasks, in which the subjects must find the correct objects or localizations (McMorris & Beazeley, 1997). Studies on visual perception use occlusion methods and eye-tracking (Williams, Janelle, & Davids, 2004). Finally, the cognitive approach allows the collection of accurate and objective measures on perceptive and decision skills as the variables measured are controlled and can be internally validated.

Main skills studied

Cognitive skills encompass the ability to receive, store, retrieve and process information (Bernstein, Penner, Clarke-Stewart, & Roy, 2011). They are necessarily heavily solicited in handball because players' actions involve tactic choices. The necessity to reason, solve problems and make decisions is therefore permanent throughout the game (Wagner, Finkenzeller, Würth, & Von Duvillard, 2014). Many authors associated decision-making with executive functions (Diamond, 2013; Salt-house, 2005), which are involved in complex cognition such as solving novel problems, modifying behavior based on new information, generating strategies or sequencing complex actions. All of that is linked to the game activity of any player of collective sport. Importantly, different cognitive skills are associated with decision-making abilities and studied in the cognitive approach (Tenenbaum & Bar-Eli, 1993). Anticipation, which is an executive function referring to the efforts to predict intentions of one's opponent, appears to be crucial to high level performance in sports (Williams & Ward, 2007). Attention, which is the ability to sustain focus on a particular object, action or thought (Reynolds, 2015), can be divided into sustained attention (focus for long periods), selective attention (focus on one stimuli among several), and divided attention (focus on several stimuli).

¹ "Handball is a team sport played by two male or female teams consisting of seven players (6 fielders and 1 goalie) each. The players are allowed to handle and throw the ball using their hands, but they must not touch the ball with their feet" (except the goalkeepers who may stop the ball with any part of their body) (EHF).

(Barkley, 1997). Attention plays an important role in team sports because players need to monitor multiple information such as the position of their teammates and opponents (Memmert, Simons, & Grimme, 2008). Visual perception is also an important component of decision-making. It gives the athlete complex information allowing them to plan their actions (Williams, Davids, & Williams, 1999). Memory is often studied in the cognitive approach and corresponds to the information stored for a long (long-memory) or a short period (short-term and working memories) (Cowan, 2008). Working memory allows one to recall relevant information, crucial to have in mind in order to think and act appropriately (Miyake & Shah, 1999). Finally, reaction time is part of the response time and is defined as the time between the introduction of a stimulus and the beginning of the motor response (McMorris, 2004). Short reaction and response times give an obvious advantage when facing an opponent (Robinson, 2014). They are associated with various elements in handball and can be shortened with practice (Wagner *et al.*, 2014).

The naturalistic approach

Presentation

The most recent method is the naturalistic approach, which takes into account the context of the decision and the relationship between actors. It relies on two main approaches: semiological approach and theoretical models. The semiological approach, which is based on the theory of the situated action (Suchman, 1987) and the concept of the course of action. The course of action is a chain of activity units that is meaningful for the actor (Theureau, 2006). Individual and collective activities are studied based on self-reporting information. The semiologic approach uses essentially qualitative methods such as self-confrontation (Lyle, 2003) or explanation interviews (Vermersch, 2018). In theoretical models, the individual activity is examined with the recognition primed decision model (RPD) (Klein, 1997) or the situation awareness (Endsley, 1995). The collective activity, on the other hand, is examined through team situation awareness (Endsley & Jones, 2001) and the shared mental models (Mathieu, Heffner, Goodwin, Salas, & Cannon-Bowers, 2000). Whereas in the cognitive approach participants seek to maximize their performance for a given task, in the naturalist approach, participants seek only to have satisfying behaviors in response to real constraints. In the naturalistic approach, studies showed that experts take into account multiple elements to make a decision, including the score, the opponents and teammates actions, the ball trajectory... (Bossard & Kermarrec, 2011; Macquet & Fleurance, 2006). It has been shown that expert players are able to recognize the situations faster than novices, allowing them to make better decisions (Johnson & Raab, 2003).

Main skills studied

The analysis of decision-making processes in team sports based on the naturalistic approach highlighted the

role of a tactical decision, for both offensive and defensive actions (Bossard, De Keukelaere, Cormier, Pasco, & Kermarrec, 2010; Macquet, 2009). A tactical decision involves all the individual skills you need to perform in an opposition situation (Gréhaigne, 1999). First, the relevant cues picked up in the game environment constitute essential information for players to make a decision (Bossard & Kermarrec, 2011). The perception of these relevant cues appears linked to visual attention, mostly selective and divided attention. Players need to respond to questions such as: “What does my opponent want to do? Am I able to overtake them? Which solution or option is the simplest?” (Johnson & Raab, 2003; Macquet, 2009). All these elements were mainly expressed by participants through interviews, but also observed in gaze analysis. The gaze behavior examines the number and the duration of gaze fixations on relevant visual cues (Raab & Johnson, 2007). Second, the experience and knowledge, acquired through practice, contribute to make a judgment adapted to the situation (Mouchet & Bouthier, 2006). Experience helps players to enhance their understanding of the different actions, allowing them to anticipate the opponents’ intentions and adjust their own actions accordingly. This means that experience plays an important role in anticipation (Williams *et al.*, 1999). During interviews, expert handball players explained that they are usually able to guess what is about to happen and can therefore adjust their actions accordingly (Lenzen, Theunissen, & Cloes, 2009). Third, players need to understand the expectations of their partners and their opponents (Macquet, 2009; Mouchet & Bouthier, 2006) to make their decisions in a given situation. Relying on general concepts in team sports and specific concepts in handball, players try to guess what other players will do (Lenzen *et al.*, 2009).

In addition, the ball carrier in team sports needs to decide what to do with. This option can be chosen among several that the player has to imagine, relying on their cognitive processes while being under pressure (Raab, 2002). The different options generated are based on an understanding of the current situation, knowledge and previous experiences (Macquet, 2009). For instance, a ball carrier has different possibilities: throwing, passing the ball to a teammate, dribbling and running in different directions, feinting an opponent or entering a duel with them. Their choice depends on the perceived cues, the player’s skills, their experience, but also on contextual elements, and results from existing interactions between them and their environment (Johnson & Raab, 2003; Macquet, 2009). Finally, the naturalistic approach also examines collective skills: the coordination between players, the development of a strategic plan and the shared awareness (Bourbousson, R’Kiouak, & Eccles, 2015; De Keukelaere, Kermarrec, Bossard, Pasco, & Deloor, 2013; Saury, Durand, & Theureau, 1997). Considering the collective activity, based on the analysis of each individual course of action, allowed to better understand how players interact and what they rely on to make a decision (Bourbousson, Poizat, Saury, & Sève, 2008).

Fig. 1. PRISMA guidelines.

Aim of the current study

As aforementioned, the aim of this review is to summarize current literature on decision-making in handball. We have focused on the following key points: 1) the approaches and theoretical models used in the current literature to study decision-making in handball; 2) the methods used and variables studied (independent and dependent); 3) the main results and handball skills involved in decision-making; and 4) current limitations and perspectives.

Method

Protocol

Published studies detailing the implementation of decision-making methods in handball were reviewed using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines (Moher, Liberati, Tetzlaff, Attman, & PRISMA GROUP, 2009). The process is detailed within Figure 1.

Information sources and search strategy

The search was limited to studies published between January 1990 and June 2019 (the number of publications published before 1990 being negligible) (Prieto, Sampaio,

& Gómez, 2015). We used the following keywords and their combinations: “Handball”, “Team handball”, “Cognition”, “Executive Function”, “Cognitive function”, “Decision-Making”, “Memory”, “Anticipation”, “Perception”, “Attention”, and “Option Generation” as well as their related terms and synonyms in the following electronic databases: PubMed, SPORTDiscus, PsycArticles, PsychINFO, ScienceDirect, European Handball Federation. In addition, a manual reference search was performed on the records found. Documents that were not initially located in full text were requested directly to the main authors.

Eligibility criteria

Full-text articles were eligible for inclusion in this systematic review if the studies filled the following requirements: (a) published in scientific journals (Peer reviewed); (b) written in English or French; (c) published in a journal included in the database Scimago Journal and Country Rank; (d) examined only dependent variables associated with decision-making; (e) tested a cohort composed exclusively of handball players or provided separate results for this group; (f) concerned novices in handball if this group was compared to expert handball players; (g) focused exclusively on field player’s decision-making.

Extraction of data of interest

For each article included in the analysis, the following data were extracted: authors and year of publication, main goal, characteristics of the handball player cohort, theoretical framework, methods used and variables examined, main results and main skills investigated, limits and perspectives mentioned. These different categories form the different columns of the [Tables 1](#) and [2](#). We divided each article into two categories (cognitive approach [C], and naturalistic approach [N]), three first order themes for the cognitive approach (the organization of the knowledge [CK], the memory process [CM], and the perceptive strategies [CP]), two first order themes for the naturalistic approach (semiological approach [NS], and naturalistic decision-making [NDM]), two second order themes for the NS (Individual [NSI] and Synchronized [NSS] bottom-up interviews) and two second order themes for the NDM (Individual [NDMI] and Collective [NDMC] models). For the cognitive approach, studies were associated with one of the first order themes according to the tasks performed by the participants and the variables measured. Recognition and specific tasks with handball images were associated with CK. Recall and memory tasks were associated with CM. Perceptive, reaction tasks and evaluation of the executive functions were associated with CP. The NS corresponds to the course of action ([Theureau, 1992](#)), which can concern individual (NSI) or synchronized (NSS) bottom-up interviews. The naturalistic decision-making ([Klein, 1997](#)) corresponds to a set of theoretical models: the RPD model and the situation awareness in one hand (NDMI), and the shared mental models and the team situation awareness (NDMC) on the other hand. Moreover, some authors are clearly associated with the theoretical models cited above such as Theureau, or De Keukelaere for the NS approach and Klein for the NDM approach, that contributes to repartition of the different studies. We proposed a classification for each study: CP, CM, CK, NSI, NSS, NDMI, NDMC (see [Tabs. 1](#) and [2](#)).

We specified for each study: 1) the different tests and tasks used, 2) the independent and dependent variables (VI and VD respectively), 3) the qualitative or quantitative methods, 4) the specific or non-specific tests. A test was considered as specific if the task is closed to player's action during a match. Then, we described the main results and the specific skills associated, the kind of decision participants must make (individual/collective, offensive/defensive), and the main limits and perspectives proposed by authors (see [Tabs. 1](#) and [2](#)).

Reliability of the coding process

Two coders (first and second authors) classified all of the articles into the different categories and themes. Reliability points were estimated using Kappa index (k), which represents the normalized proportion of inter-observer agreement in excess of what would be expected based on chance or random assignments. We used

Statistica software version 13.3, which calculates both general and conditional coefficients and tests the statistical significance of agreement among two observers assigning objects to nominal scales. The overall Kappa revealed a considerable rate of agreement among the different coders ($k=0.95$; $z=9.62$, $p<0.0001$). All the conditional coefficients were also high and significant (see [Tab. 3](#)) taken as a whole, these results showed an acceptable reliability of the coding. The coding revealed the lack of the NSS code, meaning that no study relied on the synchronized bottom-up interviews.

Results

The results highlighted the following key points, presented in the introduction: 1) the approaches and theoretical models, 2) the methods and variables studied, 3) the main results and handball skills studied, 4) the main limits and perspectives. The cohorts examined in these studies were composed on average of 69 participants (from 6 to 332). Seventy-six percent of participants were men and 50% are adults (as specified in [Tabs. 1](#) and [2](#)).

Approaches and theoretical models

The cognitive approach was used in 19 studies (65%), whereas the naturalistic approach was used in 10 studies (35%) (see [Tabs. 1](#) and [2](#)). We noted that more than a third of the studies did not specify the theoretical framework used. The lack of information regarding the theoretical approach used make understanding the results more difficult and thus hinder scientific progress. The principal aspects studied in the cognitive approach were perception and psychomotor abilities (12 studies, 41%), whereas memory process was examined in 4 studies (13%) and knowledge in 3 studies (10%). In the naturalistic approach, the principal category studied was naturalistic decision-making (7 times in individuals and twice in a collective approach, 24% and 7% respectively), whereas the semiologic approach was examined only once in individuals (3%). Moreover, the RPD model was used only 3 times (30%), while is a major theoretical model concerning this approach. It is important to note that the collective dimension in the semiologic category was not studied.

Methods and variables studied associated with handball decision-making

The principal independent variables examined in the cognitive approach were the expertise and the experience in 10 studies (53%). The reaction and decision times constituted the main dependent variables measured (9 studies, 47%), whereas the accuracy was examined in 6 papers (31%) and the quality of the decision only once (5%). Eye-tracking data and collective cognitive skills were not assessed in studies using this approach. When it's specified, the game's phases examined corresponded essentially to offensive phases (6 papers; 67%) and to

Table 1. Studies based on the cognitive approach.

Authors, year of publication, and aim of the study	Characteristics of handball players' sample	Theoretical framework (Classification)	Methods and variables	Main results and main skills investigated	Limits and perspectives mentioned
Dane & Erzurumluoglu, 2003 To investigate the sex and handedness differences in eye-hand reaction times.	T M ($n = 160$) + F ($n = 166$) level	CP	NS – QT (see legend) Visual reaction time VI: gender, handedness VD: reaction time	Men right-handers had longer visual reaction times than women right-handers. The left-handers had better visual reaction time than right-handers. Skill	/
Fruchart <i>et al.</i>, 2010 To compare the way in players use informational cues for deciding a quick start or play.	T + A M ($n = 200$) regional level ($n = 160$) (12 to 18 years) national level ($n = 40$) ($M_{age} = 24.1$ years)	CK Functional theory of cognition	S – QT 36 stories were presented. Participants need to give a score on a scale. VI: context of the match VD: scale for quick restart or not	A higher level of experience was linked to 1) a higher importance granted to the numerical status and the current score; 2) a higher influence of the time factor. Skill: offensive phase. The visual attention performance was influenced by a potential pre-activation of objects in the working memory (more errors and less speed if more players to consider). Skill: offensive phase, decision of whom to pass the ball.	The physical and mental conditions should be considered.
Furley & Memmert, 2013 To explore experience related differences on attentional guidance effects from working memory.	A M + F experienced ($n = 12\&26$) no experience ($n = 12\&26$)	CP	S – QT recall tasks and pass options computer based sport tasks VI: set size, attentional guidance VD: accuracy, response time	The visual attention performance was influenced by a potential pre-activation of objects in the working memory (more errors and less speed if more players to consider). Skill: offensive phase, decision of whom to pass the ball.	Human behavior needs to be studied with its environment. “Within cognitive psychology a further promising approach – cognitive ethology has recently been put forth due to converging evidence that cognitive processes substantially depend on the situational context in which a person is embedded”.
Kiss & Balogh, 2019 To explore the decision-making strategies of players, their reactive stress tolerance, their attention and concentration skills.	A M ($n = 45$) + F ($n = 47$) level	CP	NS – QT Vienna test system (VTS) VI: gender, age, position VD: concentration, reaction time	Goalkeepers, wingers and center-backs reacted faster than other players. Center-backs reacted faster under great pressure than other players. The young group performed better both in terms of concentration as well as	The tests used in this research are general and not closely related to handball. It will be interesting to examine abilities and skills in a more special testing arrangement appearing also at handball trainings and matches.

Table1. (continued).

Authors, year of publication, and aim of the study	Characteristics of handball players' sample	Theoretical framework (Classification)	Methods and variables	Main results and main skills investigated	Limits and perspectives mentioned
Lagner et al., 2014 To examine the link between mood, memory and executive control in a real-life situation.	A M ($n=61$) first district league of Dresden (Germany).	CM	NS – QT Tasks: memory, verbal fluency, cognitive flexibility VI: mood VD: cognitive skills	decision-making skills and reactive behavior. Skill After a winning match, performance in tasks assessing basic memory processes was impaired. Cognitive performance seems to be mediated by the more positive mood states reported after a winning match compared with training.	It might be interesting to examine the link between executive functions and mood in everyday life.
Lidor et al., 1998 To compare psychomotor tests performances in skilled players and novices.	A F ($n=23$) skilled ($n=13$) and novices ($n=10$)	CP	NS + S – QT Different tasks measuring cognitive skills VI: Expertise VD (lab): reaction, movement, anticipation times VD (field): accuracy and speed of throwing and passing S – QL	Skill Skilled players performed better in field activities (throw, pass) and laboratory tasks (reaction time, anticipation time, movement time). Skill: offensive phase	/
Memmert & Furlley, 2007 To explore the link between breadth of attention, inattentional blindness, and tactical decision making.	T M exp. 1: $n=34$ exp. 2: $n=29$ exp. 3: $n=16$ level	CK Inattentional blindness paradigm	Participants must identify the white defender in video sequences. VI: kind of instruction, kind of stimuli VD = position of the defender, tactical decision	More tactical instructions can lead to a decrease of attention and an increase of inattentional blindness. Several exogenous stimuli reduce inattentional blindness. Team players often fail to find the optimal tactical solution to a situation because the coach narrows their focus of attention by giving restrictive instructions.	Participants were adolescents. The findings of this study could be checked in tasks where the decision is made physically. Longitudinal studies could examine the link between breadth of attention and creativity in training sessions.

Table1. (continued).

Authors, year of publication, and aim of the study	Characteristics of handball players' sample	Theoretical framework (Classification)	Methods and variables	Main results and main skills investigated	Limits and perspectives mentioned
Memmert et al., 2008 To examine the link between expertise and performance in general attention tasks.	A M + F ($n = 80$) players ($n = 40$) novices ($n = 40$)	CP	NS – QT Functional field of view task Multiple object tracking task Inattentional blindness task VI: expertise VD: reaction time, accuracy NS + S – QT Inattentional blindness and divergent thinking tasks VI: expertise VD: score	Skill: offensive phase, tactical decision for the ball carrier. Team sports players showed no better performance on the basic attention tasks than novice athletes. Skill	The task's measures were not robust enough to produce stable individual or group differences. Future research could interest specific attention tasks.
Memmert, 2011 To examine the link between creativity and inattentional blindness in children.	C + T M ($n = 90$) + F ($n = 30$) 3 skilled groups 3 non-skilled groups (M age = 7, 10 and 13 years old)	CP		Skilled players produced more original solutions than non-skilled players, especially when their attention score was high. Inattentional blindness appears essential in the production of solutions in general and sport game situations. Skill	It could be interesting to examine attention performance in programmes for the promotion of creativity, with appropriate instructions and methods.
Menevse & Arslan, 2012 To examine reaction time differences in games.	A M ($n = 48$) 2nd division	CP	S – QT Ulrich's scale Nelson hand reaction test and Nelson Foot Reaction Test VI: pre-post game; victory-defeat VD: reaction time, accuracy	Reaction times were shorter for winners than losers in pre-game. Skill: reactivity (individual skill)	/
Przedhowek et al., 2019 To compare psychomotor abilities in professional players and novices.	A M ($n = 90$) 1st–2nd league of Polish men's ($n = 40$) non-training men ($n = 50$)	CP	NS – QT Computer Systems Test2Drive Tests: reaction time, hand-eye coordination, spatial anticipation VI: expertise VD: reaction and movement times, accuracy	Players had better reaction times and movement times than novices. More experience is associated with shorter reaction time. Centre back players performed better in reaction time	The pivot and left-handed players were less numerous than other players. The Test2Drive may help coaches to examine individual abilities in players.

Table1. (continued).

Authors, year of publication, and aim of the study	Characteristics of handball players' sample	Theoretical framework (Classification)	Methods and variables	Main results and main skills investigated	Limits and perspectives mentioned
Rousanoglou et al., 2015 To compare self-paced and temporally constrained throwing performance between experts and novices.	A M ($n=30$) expert-national Greek league ($n=15$) novices ($n=15$)	CP	S – QT To complete shots under temporal constraint or not. VI: temporal constraint or not, expertise, kind of throw VD: throwing accuracy and velocity	tasks. Skill: reaction time and eye-hand coordination. Experts have best results than novices in throwing velocity and accuracy. The temporal constraint leads to a decrease in the throwing velocity in the 3-step shot and in the throwing accuracy in the standing shot. Skill: offensive phase, throwing abilities.	The tests used were not closed to in-game situations (without goalkeepers).
Rulence-Pâques et al., 2005 To examine whether simple algebraic rules may be found in sport decision making.	A M ($n=60$) players	CK Functional Theory of Cognition	S – QT 36 stories were presented. Participants need to give a score on a scale for playing a quick restart or not. VI: context of the match VD: scale for quick restart or not	The score is the most important factor to decide to play a quick restart or not. The time and a combination of these the time and the score are great factors to decide to play quickly or not. Skill: offensive phase, quick restart.	The athletes experience and skills were not assessed with precision. It could be interesting to examine the process in experts.
Schapschröer et al., 2016a To examine whether a specific physical exercise load influenced participants' speed and accuracy in a specific flicker task.	A F ($n=35$) experts-3rd German league ($n=8$) advanced-6th German league ($n=13$) novices ($n=14$)	CM	S – QT Specific flicker task recall tasks on animated videos containing structured situations. VI: rest or physical exercise, expertise VD: speed, accuracy	Participants performed more accurately and faster in the structured videos. No significant differences were found for the two exercise conditions. Skill: offensive and defensive phase combined. Reaction time.	The tasks and the stimuli need to be closed to real game situations. It could be interesting to examine the influence of physiological stress on specific flicker task performances.
Schapschröer et al., 2016b To investigate the influence of expertise and different physical	A F experts-1st/3rd German league ($n=9&10$) advanced-5th German league ($n=12&13$) novices ($n=12&12$)	CM	S – QT Recall tasks on animated videos containing structured situations. VI: rest or physical exercise, expertise VD: speed, accuracy	Experts performed better than novices in recall tasks, especially in structured and specific situations. No significant difference was found between rest and	The computer-generated images used were not enough realistic. The physiological demand in study's exercises might be different of the physiological demand

Table 1. (continued).

Authors, year of publication, and aim of the study	Characteristics of handball players' sample	Theoretical framework (Classification)	Methods and variables	Main results and main skills investigated	Limits and perspectives mentioned
intensities on performances in recall tasks.				exercise conditions. Skill: offensive and defensive phase combined.	induced by real game situations. It could be interesting to examine specific physiological exercises on perceptual-cognitive expertise.
Szczybinska & Mikicin, 2019 To examine attention, perception and sensorimotor coordination in handball players.	A M + F ($n = 18$) F ($n = 9$) 1st Poland League M ($n = 9$) 2nd Poland League ($n = 9$) A	CP	NS – QT General attention test Vienna test system VI: gender, age, pre/post training	Training in the attention measurement test enhanced general attention. Peripheral perception was improved for men but not for women. Skill: attention.	/
Tenenbaum <i>et al.</i>, 1993 To examine the importance of the cognitive processes in a decision-making task.	M ($n = 118$) experienced ($n = 39$) moderate experience ($n = 37$) novices ($n = 42$) Age	CP	NS + S – QT Different cognitive tests VI: visual and auditory stimuli, target's speed, exercise condition, experience VD: reaction time, accuracy	Experience is the best indicator of the decision-making ability during two different exercise intensities. Attention, short-term memory, reaction time and general intelligence were associated with the decision-making ability. Skill: offensive and defensive phases.	The cognitive skills should be examined in specific situations.
Tenenbaum <i>et al.</i>, 1994 To study the role of experience on perception of structured situations.	M ($n = 38$) experienced (A, $n = 19$) less experienced (T, $n = 19$)	CM	S – QT Recall tasks VI: experience, complexity of situation VD: accuracy	In recall tasks, experts performed better than less experienced when the complexity increases and in structured situations. Skill: offensive and defensive phase combined.	Age and experience were not differentiated.
Zwierko, 2007 To compare peripheral perception between players and novices.	A gender experts ($n = 16$) novices ($n = 16$)	CP	NS – QT Vienna test system Peripheral perception VI: expertise VD: reaction time	Players had shorter response time in peripheral vision tasks than novices. Skill	It is difficult to associate performances in perception tasks with result of training or with genetic skill.

C: Children; T: Teenagers; A: Adults; M: Male participants; F: Female participants; NS: Non-specific tests; S: Specific tests; QT: Quantitative measures; QL: Qualitative measures.

Table 2. Studies based on the naturalistic approach.

Authors, year of publication, and aim of the study	Characteristics of handball players' cohort	Theoretical framework (Classification)	Methods and variables	Main results and main skills investigated	Limits and perspectives mentioned
De Keukelaere et al., 2013 To identify elements which contribute to shared understanding between players during rapid attack situations.	A F ($n=6$) International level	NDMC Team cognition Course of action RPD model team situation awareness	S – QL Auto-confrontation interviews VI: typical shared sequences VD: typical forms of individual activities articulation	Authors identified seven typical shared sequences and four typical shared understanding. The shared elements concerned essentially few players and are transient. Skill: offensive phase, team coordination The collective performance feeling was associated with fluidity in actions' sequence and to a security judgment about the situation's evolution. There were three dimensions of perceived team performance (isolated action <i>vs.</i> successions of actions; actions flow <i>vs.</i> skating in the string of action; judgement of safety <i>vs.</i> insecurity). Skill: offensive phase, team coordination	/
De Keukelaere et al., 2014 To analyze the evolution of shared elements about the perceived team performance.	A F ($n=6$) International level	NDMC Team cognition Course of action RPD model team situation awareness.	S – QL Auto-confrontation interviews VI: typical shared sequences VD: typical forms of individual activities articulation	There were high difficulties to generalize the results. Analysis about team cognition could allow coaches to organize training sessions with the collective performance opinion.	
Glockner, Heinen, Johnson, & Raab, 2011 To compare two classes of models able to explain choices based on gaze behavior.	Players ($n=74$) age/gender/level	NDMI	S – QL Model simulations (generated options and gaze behavior measurements) VI: deterministic <i>vs.</i> probabilistic model VD: time of fixation, performance in prediction S – QT option generation paradigm VI: 3D or 2D video or tactic board, pre/post retention	Both deterministic and probabilistic models could fit and predict participants' initially generated options based on gaze behavior data. Skill: offensive phase, pass or throw decision.	The models used in this study could be applied within the naturalistic approach to many domains, such as parking and selecting living spaces, or problem-solving in chess.
Hohmann et al., 2016 To compare the effectiveness of video-based decision training programs.	T 1) F ($n=20$) 2) M ($n=30$) national candidates	NDMI		1) The presentation of a 3D video in training seemed to be more effective than the presentation of a 2D video for improving	The 3D video decision-training programs could be used to identify talents. An additional video decision-making training could be used to

Table2. (continued).

Authors, year of publication, and aim of the study	Characteristics of handball players' cohort	Theoretical framework (Classification)	Methods and variables	Main results and main skills investigated	Limits and perspectives mentioned
Johnson & Raab, 2003 To examine the link between the use of different strategies and the options generated, the choice quality and dynamic inconsistency.	T M ($n = 85$) German and Brazilian medium skill level	NDMI Critic decision method	VD: quality of decisions (first and best option), decision time S – QT generated options (frozen videos) VI: specific action VD: options generated, quality of choice	decision time. 2) Decision-making training improved the decision-making abilities of participants. The quality of decisions was not improved. Skill: offensive phase, option-generation process. Producing few generated options results in better and more consistent decisions. A higher number of generated options is associated with a higher inconsistency between the first/fast option and the final/best choice. Time-pressure led to better decisions for highly trained players. Skill: offensive phase, option-generation process.	focus on decision quality. It will be interesting to create a test measuring the transfer between training interventions and performances in real match situations. “Due to the fact that the study was conducted as a part of a larger study with a broader scope, perhaps all of the necessary experimental controls were not in place”.
Laborde & Raab, 2013 To examine the link between mood and option-generation process.	A M experts ($n = 30$) near-experts ($n = 30$) non-experts ($n = 30$)	NDMI	S – QT Generated options (frozen videos). VI: mood VD: options generated, quality of choice, decision time S – QL Self-confrontation interviews VI: offensive or defensive situations VD: mobilized skills	The option-generation process was associated with the physiological component of mood. Skill: offensive phase, option-generation process. Four elements contribute to the decision-making: perception, knowledge, expectations, and contextual elements. Skill: offensive and defensive phases.	The preference for certain options, the process of the decision, and the effect of discrete emotions were not examined. Results could not be generalized to other populations and contexts. It was difficult to access to players' subjective experience. Results constitute “a reliable source of
Lenzen <i>et al.</i>, 2009 To investigate what do elite players consider deciding in real game situations.	A F ($n = 6$) D1 Belgium	NSI Theory of situated action			

Table2. (continued).

Authors, year of publication, and aim of the study	Characteristics of handball players' cohort	Theoretical framework (Classification)	Methods and variables	Main results and main skills investigated	Limits and perspectives mentioned
Raab & Johnson, 2007 To investigate expert performance and understand the mechanisms associated with levels of expertise in complex choice situations.	T M + F ($n = 66$) experts ($n = 29$) near experts ($n = 22$) non-experts ($n = 18$)	NDMI	S – QL Generated options (frozen videos), quiz and recognition test, decision-making video test and eye-tracking VI: expertise VD: eye-tracking, position of players, quality of tactical option S – QT + QL Generated options face to frozen videos. PID scale decision-making video test VI: expertise VD: eye-tracking, position of players, quality of tactical option, decision time	Expertise is associated with higher quality of the first generated options. The first option generated by experts is often the final choice. Skill: offensive phase, option-generation process.	inspiration for teaching strategies and didactic contents”. “Future researchers need to employ continuous ratings for association strength between a situation and an option as well as similarity ratings between options and potentially new study designs to distinguish and weigh these processes”. Results could not be generalized to other sports. The tests were performed in a lab. It could be interesting to examine when a decision is defined as intuitive, and how “individuals’ movement capacity can limit the options they generate”. “Future research should focus on the influence of emotions on sport decisions”.
Raab & Laborde, 2011 To investigate whether a preference for intuition over deliberation results in faster and better lab-based choices in attack situations”.	T M + F ($n = 54$) experts-1st league ($n = 16$) near experts-2nd league ($n = 22$) non-experts-3rd ($n = 18$)	NDMI		Intuitive athletes made decisions faster and better than deliberative decision makers. Experts should be intuitive and trained to intuitive decisions. Non experts have a lower number of generated options and have a faster generation time of first option. Skill: offensive phase, option generation and tactical individual decision for the ball carrier.	
Weigel et al., 2015 To examine eye-tracking movements during the decision-making process.	T gender/elite players ($n = 9$)/district players ($n = 9$) novices ($n = 8$)	NDMI RPD model	S – QT + QL To verbalize the final action for a player on virtual tactic boards and real attack scenes VI: experience VD: fixations, score, quality of generated action	The capture of relevant information was faster for experts. The description of decision-making situations was more efficient for experts. Experts generated options with higher probability of success, especially in more complex situations. Skill: offensive phase.	It could be interesting to examine the quality of gaze behavior.

C: Children; T: Teenagers; A: Adults; M: Male participants; F: Female participants; NS: Non-specific tests; S: Specific tests; QT: Quantitative measures; QL: Qualitative measures.

Table 3. Inter-rater agreement.

Categories	Kappa	<i>z</i>	<i>p</i>
CK	1	5.38	< 0.001
CM	0.87	4.72	< 0.001
CP	0.93	5.01	< 0.001
NDMI	1	5.38	< 0.001
NDMC	1	5.38	< 0.001
NSI	1	5.38	< 0.001
NSS	/	/	/

a combination between offensive and defensive phases (3 papers; 33%). However, 10 publications did not specify the phase studied (53%), meaning that tasks were not realized in a specific context. Interestingly, only two studies integrated participants into an imagined specific context closed to handball (Fruchart, Pâques, & Mullet, 2010; Rulence-Pâques, Fruchart, Dru, & Mullet, 2005).

In the naturalistic approach, the principal independent variables examined were expertise and experience (3 studies, 30%). The quality of the generated options constituted the main dependent variables measured (6 studies, 60%), whereas the eye-tracking data were examined three times (30%) and the collective cognitive skills twice (20%). The accuracy was not measured in this approach. The measurements represent qualitative variables in 5 out of the 10 studies (50%), quantitative variables in 3 studies (30%), and both in 2 studies (20%). Concerning the handball phases examined, 9 out of the 10 studies examined only offensive phases (90%). The tenth study examined both offensive and defensive actions.

Main results and handball skills studied

Cognitive approach

The studies examined only individual cognitive skills and mainly interested on the playmaker activity. First, Tenenbaum *et al.* (1993) revealed that short-term memory was a significant predictor of the decision-making ability. Globally, expert players performed better than novices in these tasks (Furley & Memmert, 2013; Schapschröer *et al.*, 2016b; Tenenbaum, Kolker, Bar-Eli, & Weinberg, 1994), especially when the complexity increased (Furley & Memmert, 2013). However, experts performed better only when the proposed situations are structured (Schapschröer *et al.*, 2016a; 2016b; Tenenbaum *et al.*, 1993). Furley & Memmert (2013) explained the superiority of experts by a greater ability to use their working memory and visual attention. However, authors noted that the visual attention is influenced by a potential pre-activation of objects in the working memory. Then, Lagner *et al.* (2014) revealed that the mood states mediates positively cognitive performances and the memory processes.

Second, perceptive skills appear essential in decision tasks (Tenenbaum *et al.*, 1993), including the reaction and response times, which represent the principal data measured in handball. Studies revealed that these skills are strongly linked to expertise, experience, gender,

laterality or position in the field. The reaction time is shorter for skilled players than novices (Lidor, Argov, & Daniel, 1998; Przednowek *et al.*, 2019; Rousanoglou, Noutsos, Bayios, & Boudolos, 2015; Schapschröer *et al.*, 2016a; Zwierko, 2007). Menevse & Arslan (2012) revealed that tournament's winners have shorter reaction time. Experience is also a factor to shorten response time in peripheral vision tasks (Zwierko, 2007), or reaction time in simple reaction tasks (Przednowek *et al.*, 2019). The reaction time is shorter for left-handers than right-handers players and for men than women (Dane & Erzurumluoglu, 2003). Similarly, the wings and central back players react faster than other players (Kiss & Balogh, 2019; Przednowek *et al.*, 2019).

Third, Tenenbaum *et al.* (1993) underlined the role of attention in experts to identify relevant information and ignore irrelevant one. Several studies in the 2000's confirmed that visual attention was strongly associated with greater performances in decision-making tasks (Memmert, 2011; Memmert & Furley, 2007; Memmert *et al.*, 2008). Guided by working memory (Furley & Memmert, 2013), performances in different attention tasks were associated with the amount of instruction received and the type of stimuli. These results reveal that attention ability improve with training (Szczypinska & Mikicin, 2019). Nonetheless, too many instructions given by a coach can lead a decrease of the attention (Memmert & Furley, 2007) and consequently potential difficulties of understanding the instructions or to apply them. Then, the anticipation ability appears to be superior for expert players than novices (Lidor *et al.*, 1998).

Finally, two studies (Fruchart *et al.*, 2010; Rulence-Pâques *et al.*, 2005) focused on the mobilization of knowledge, relying on the functional theory of cognition (Anderson, 2008). They revealed that the score is the main factor, which allows players to decide a quick restart of play or not, no matter the level of players' experience. However, these authors indicated that numerical status is more important for experienced players than for novices.

Naturalistic approach

Based on the semiologic approach and particularly on the theory of situated action (Suchman, 1987), Lenzen *et al.* (2009) revealed that four elements contribute to decision-making. The first one is the ability to perceive relevant cues. The second one corresponds to the base of fundamental and specific knowledge. Then, players need to understand the expectations from coach, partners and opponents. Finally, players need to take into account contextual elements such as the score, the opponent's level or the stake's match.

Based on an heuristic approach, Raab & Laborde (2011) studied the link between intuition and the decision-making. Intuition was defined by the authors as an involuntary judgment based on previous learning and experiences. Authors revealed that intuition allows to decide faster and better for experts. This study gets closer to the RPD model, which identifies the first reasonable

reaction from the relevant cues and situations already experienced. Moreover, expert players generate the options with the highest probability of success, especially in more complex situations (Johnson & Raab, 2003; Raab & Johnson, 2007; Weigel, Raab, & Wollny, 2015; for a review see Raab, De Oliveira, & Heinen, 2009). Furthermore, experts generate less options than novices but with higher quality, the first one being the best (Johnson & Raab, 2003; Raab & Johnson, 2007). The decision time in the option generation process was strongly associated with a better efficacy in training with 3D video than 2D video (Hohmann, Raab, Schlapkohl, & Obeloer, 2016). In addition, Glockner *et al.* (2011) revealed that the study of the generated options, based on behavior data, could be predicted by both deterministic and probabilistic models. Then, Laborde & Raab (2013) revealed that the option-generation process was associated with the physiological component of mood.

Finally, only two studies focused in the collective dimension of a decision through the evaluation of team cognition and the team situation awareness (De Keukelaere *et al.*, 2013; De Keukelaere, Kermarrec, Bossard, & De Loor, 2014). The team situation awareness studies the cognitive elements integrated into the collective organization and shared by players on the field and their evolution during a played action. Authors revealed that the shared elements are articulated around a collective plan or an adaptation to the context. Their layout in the field during offensive phases depends on the number of players who shared these elements (De Keukelaere *et al.*, 2013). Additionally, the collective performance appears better for players when actions are fluent and safety (De Keukelaere *et al.*, 2014).

Limits and perspectives

The limitations proposed by authors studying decision-making abilities concerned 1) the sample of participants, 2) the context of the decision, 3) the generalization of the results and 4) the prioritization of the generated options. First, the number of participants was sometimes less than 50 (Menevse & Arslan, 2012; Przednowek *et al.*, 2019). Two studies suggested that evaluating decision-making ability in teenagers might have certain limitations (Memmert & Furley, 2007; Tenenbaum *et al.*, 1994). The lack of precision in measuring the experience of participants appeared also a limitation to study these skills (Rulence-Pâques *et al.*, 2005; Tenenbaum *et al.*, 1994). Second, the study of decision-making skills, according to the cognitive approach, does not take into account the context of the decision, since the objective is to simplify and better control the different variables examined. Several studies suggested that it was a limiting point because the tests used and the executed tasks were too far from the in-game decisions processes (Furley & Memmert, 2013; Kiss & Balogh, 2019; Lagner *et al.*, 2014; Memmert, 2011; Memmert *et al.*, 2008; Rousanoglou *et al.*, 2015; Schapschröer *et al.*, 2016a, 2016b; Tenenbaum & Bar-Eli, 1993). Zwierko (2007) suggested that the results concerning

the responsiveness to visual stimuli did not allow them to ascertain whether better performances were due to a genetic superiority or resulted from training. Third, three studies in the naturalistic approach highlighted the difficulties to generalize the results. This was due to the particular and reductive context of the decisions studied and the difficulty to assess the experience of the players (De Keukelaere *et al.*, 2013, 2014; Lenzen *et al.*, 2009). Finally, in option generation process, the number of options and the speed at which they were generated are often examined but the prioritization of one option *versus* the others was not enough examined (Laborde & Raab, 2013; Raab & Johnson, 2007).

Concerning the main perspectives suggested by authors, it appears necessary to examine elements, which could influence decision-making. Authors cited different components such as mental and physical conditions (Fruchart *et al.*, 2010; Schapschröer *et al.*, 2016a), in-game performances (Memmert, 2011), mood state (Raab & Laborde, 2011), and creativity, especially in longitudinal study (Memmert & Furley, 2007). Moreover, the individual's opinion could be examined in future studies to better understand their importance in the collective performance (De Keukelaere *et al.*, 2014). Several authors suggested that the study of the decision-making ability could be applied to coaches and professors in order to enhance their teaching skills. It could guide the practice of team sports from a cognitive point of view (Lenzen *et al.*, 2009; Szczypinska & Mikicin, 2019). In training, the 3D video appears to be a good tool to enhance the player's ability to better decide (Hohmann *et al.*, 2016). Finally, Furley & Memmert (2013) suggested that an "ethologic" approach could be used to study decision-making and analyze cognitive processes in a real decisional context. In this way, this approach would respond to suggestions made by authors in the cognitive approach (Furley & Memmert, 2013; Kiss & Balogh, 2019; Schapschröer *et al.*, 2016b; Tenenbaum & Bar-Eli, 1993).

General discussion

Specifying the theoretical framework

The theoretical framework was rarely specified or explained in the included studies, which makes understanding and comparing the results particularly challenging. Most of these studies relied on the cognitive approach and quantitative methods, representing more than two thirds of the included papers about handball. The naturalistic decision-making approach was less used, particularly in its collective dimension. This was also true for the semiologic approach, which was used only in one study and only in an individual approach. We highly recommend that future studies specify the theoretical framework in order to facilitate the understanding and the interpretation of the results. Importantly, future studies should also link the results to the existing theoretical models in order to draw theoretical implications.

In addition, the cognitive and the naturalist approaches appear complementary to consider the decision-making as an alternation between simple and complex decisions. The cognitive approach identifies the knowledge and relevant cues used to decide in an easily identifiable situation. However, the naturalistic approach identifies either the parameters of an emerging decision in a dynamic and collective situation (Johnson, 2006; Mouchet, 2005; Weigel *et al.*, 2015), either a recognition process (Klein, 1997). This complementarity between the two approaches has already been shown by Ericsson & Smith (1991). They proposed a framework to study the expert performance that relied on the two approaches. The cognitive approach would be used in a first phase to capture and identify cognitive skills, and the naturalistic approach would be used in a second phase to examine the mediating mechanisms involved in the expertise development. They used questionnaires and interviews to highlight the role of the practice years. For instance, players declare sometimes that they make a decision with “yeux fermés”, meaning that the decision might be automatized or intuitive. Examining the factors that differentiate a deliberate decision from an automated decision appears to us as a relevant research axis in handball. Moreover, an “ethologic” approach which combines the cognitive and the naturalistic ones, appears interesting to study decision-making and cognitive skills in a context closed to the in-game handball context (Furley & Memmert, 2013). Considering the collective dimension in the decision using methods developed recently for other sports (Araújo, Silva, & Davids, 2015; Kermarrec, 2015; Sève, Bourbousson, Poizat, & Saury, 2009) would be an asset to understand how players get to coordinate their actions and make decisions sometimes without defined strategies.

Great variety of methods

Research methods are highly heterogeneous. Similarly, the profile of the subjects studied varies, especially regarding the level of expertise. Indeed, expertise is a very subjective aspect and is hard to evaluate and standardise (Swann, Moran, & Piggott, 2015). There is also a lack of studies involving female participants. Very few studies looked at how teenaged players make a decision in comparison to adults, which would be an interesting line of work (Tenenbaum *et al.*, 1994). Indeed, examining the development of the decision-making abilities over the years would provide valuable data that could greatly contribute to the field. The perceptive skills were mainly studied in the cognitive approach, but few studies focused on the executive functions. However, executive functions are heavily solicited in handball because they help generating strategies and adjusting behavior according to the perceptible information (Diamond, 2013; Salthouse, 2005). When Verburgh, Scherder, Van Lange, & Oosterlaan (2014) studied executive functions in soccer, they found that highly talented players showed superior motor inhibition than amateur

players. Long-term memory is not studied in handball but appears associated with action control and perceptual-cognitive structures (Schack & Mechsner, 2006) and thus would be an interesting aspect to assess.

In the naturalistic approach, the option generation process is often studied and it has been shown in many different sports that the first option generated is usually the best for experts (Belling, Suss, & Ward, 2015; Farrow & Raab, 2008; Hepler & Feltz, 2012). Few studies focused on gaze behaviour associated with the option generation process. However, these studies give quantitative data while the naturalistic approach uses mostly qualitative methods. Experts have a smaller number of gaze fixations and a longer duration of fixation (Savelsbergh, Williams, Van der Kamp, & Ward, 2002). To our knowledge, no study examined others aspect of team cognition in field handball players, including the shared mental models. Importantly, Debanne, Fontayne, & Bourbousson (2014) revealed that different kinds of shared knowledge could be used between coaches and players. This is an important finding and we believe that future research in field handball players should also focus on this aspect.

Main results and practical applications

The studies based on the cognitive approach focused to decisions factors such as the memory processes, the visual attention, the perceptive ability, the reactivity or the anticipation skills. Studies revealed that experts or experienced players performed better than novices in cognitive tasks, both in handball specific and non-specific tests. We could highlight four major findings: 1) working memory and attention appear crucial to perform efficiently in cognitive tasks (Afonso, Garganta, & Mesquita, 2012), 2), working memory can act as a pre-activator of visual attention, thus facilitating the identification of relevant information (Miyake & Shah, 1999; Williams & Ford, 2008), 3) experts need structured situations to perform better and the gap between experienced players and novices increase with complexity, 4) the game score guides tactical decisions regarding how fast players resume the game. These results implicate that high-level performance is associated with an enhance ability to make the appropriate decision. In decision-making tasks, the objective is to manage simple parameters such as the score or the numerical status, and more complex parameters such as players' positions and movements, or the ball position. Therefore, coaches need to train players to listen, collect information, in order to engage their working memory and develop automatisms. Thus, it would be relevant to further investigate the link between executive functions and performances in handball.

The theory of situated action allows to distinguish six elements contributing to the quality of a decision in play: the ability to perceive relevant cues, the fundamental knowledge of handball and playing principles, the guidelines expressed by the coach, the attitude of the partners and opponents, the context of the decision, and the intuitive ability based on experience and training

(Lenzen *et al.*, 2009). This means that players need to practice looking for relevant cues, taking landmarks in play, sharing typical situations several times in order to increase their experience and their handball specific knowledge. Studies revealed that the decision process is associated with a smaller number of generated options for experts, with the first being the most adequate response (Johnson & Raab, 2003; Raab & Johnson, 2007; Raab & Laborde, 2011; Weigel *et al.*, 2015). In addition, it appears necessary to share situations with temporal and spatial constraints in order to encourage quick and efficient information intake. This means that the ability to collect relevant cues has to be practiced with partners (De Keukelaere *et al.*, 2013, 2014). This collective dimension could be examined also with the semiologic approach. Indeed, the decision appears related to the player's adaptative ability according to the perceived interactions between players in a given situation, and to the creation of a collective identity (Mouchet, 2005).

In the two theoretical approaches, most of the studies were interested in decision-making solely for the ball carrier. However, the field decision-making concerns more roles and more actions. For instance, teammates need to anticipate where they could receipt the ball to provide the ball carrier with appropriate throw solutions, while the opponents need to intercept the ball or neutralize the ball carrier before they throw. Further research should be undertaken to investigate decision-making in defenders or the ball carrier's teammates in order to better understand the different types of recognition processes involved (Kermarrec & Bossard, 2014). Finally, few studies looked at contextual elements, which could influence decision-making. For instance, recent changes in game rules, allowing the use of a seventh player in the field instead of the goalkeeper, might require some strategic adjustments. Thus, it would be interesting to investigate whether this strategic choice increase or decrease the likelihood of winning the game.

Limits and perspectives

The obvious limitations proposed by authors were strongly linked to the approach used. Indeed, studies which used the cognitive approach considered that the decision was not so closed to a real task of players. Studies which used the naturalist approach revealed that the results could not be generalized. Therefore, it would be interesting to discuss how the performance in decision-making tasks could be influenced by the mood states or the fatigue (Phillips, Bull, Adams, & Fraser, 2002; Royal *et al.*, 2006). The perspectives proposed by authors in handball appears also strongly linked to the theoretical approach used. However, the "ethologic" approach proves to be a relevant way to study the decision-making. Indeed, it would allow to measure cognitive skills in a context closed to real and experienced situations in the field (Furley & Memmert, 2013). As a result of this review, we encourage researchers to take into account these different points to conduct their future works.

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