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Knowledge Elicitation Methods for Developing Insights into Team Cognition During Team Sports

Nathan J. McNeese, Nancy J. Cooke, Rob Gray and Michael Fedele

Abstract Team cognition is beginning to be realized as an important facet of team sports. As we continue to articulate the role of team cognition during team sports, we need to understand how to measure team cognition. In this paper, we present multiple knowledge elicitation methods to measure team cognition. We also propose new elicitation methods that account for the dynamic nature of team sports.

Keywords Team cognition · Knowledge elicitation · Team sports

1 Introduction

As outlined by McNeese et al. [1], the development of team cognition within team sports is critical to effective performance on the field of play. Although a great deal is known about teamwork in sports, little attention has been paid to the concept of team cognition. Team cognition is the cognitive activity that occurs at the team level [2]. Team cognition allows sports teams to link the physical (play on the field) and cognitive (strategy or game plan) demands of sports, effectively implementing them at a team level. As a result, the role and potential of team cognition development can directly impact team performance [3].

To this point, the research community is beginning to realize the potentially important role and impact of team cognition during team sports. Yet, we must move past simply understanding team cognition and team sports at a conceptual level to

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empirically validating theoretical assumptions. Both conceptual and theoretical arguments are important in articulating the relationship between team cognition and team sports, but empirical truth is necessary to confirm theoretical representations.

In order to explicitly and empirically understand the role of team cognition during team sports, more studies linking these concepts to performance data from actual play are needed. In addition, scholars in this field need to understand how to effectively measure team cognition through multiple methodologies. The identification and measurement of team cognition is challenging, but over the years, multiple effective and validated metrics have been developed. More specifically, many of these metrics have revolved around the utilization of *knowledge elicitation* methods. Knowledge elicitation is the “process of collecting from a human source of knowledge, information that is thought to be relevant to that knowledge” [4, p. 802]. Essentially, knowledge elicitation methods allow for researchers to probe humans’ cognition. Specific to team cognition, knowledge elicitation can be conducted at both an individual and team level.

In this paper, we present multiple knowledge elicitation methods that are relevant to team cognition in the team sports context. A sampling of the specific methods we will outline and explicitly explain how to utilize within the sports context are: (1) observations and interviews, (2) process tracing, (3) conceptual techniques. For each of these categories, we will present what they are, the many specific ways to utilize each, and an application section connecting each specifically to team sports. These are traditional knowledge elicitation methods that can be adequately used for team sports. Although, with these traditional efforts comes some limitations, most significantly that they are often oriented towards aggregation of individual knowledge. In the team sports context, we need additional elicitation methods that also measure cognitive processing at the team level. In response to this, we present a discussion on the challenges of using traditional knowledge elicitation methods within the context of sports. Finally, we present a section outlining new knowledge elicitation methods that are more pointed at team level cognitive processing during team sports.

2 Team Cognition in the Literature

Team cognition is cognitive processing that occurs at the level of the team [2]. Over the years, team cognition has provided insight and understanding to the effectiveness of teams [3]. Due to its wide spread prevalence, team cognition has been investigated in many different contexts, with the focus on many specific aspects of team cognition—a few examples include: team training [5], teams with artificially intelligent teammates [6] and the use of collaboration technologies [7].

Historically, team cognition has been viewed from a *shared knowledge perspective*, which suggests that team members have separate mental representations (consisting of specific knowledge) which they share across the team to help make decisions [8, 9]. More recently, an *ecological perspective* has been asserted, which

views team cognition purely as a team activity that should be examined at the team level, and is inseparable from the environment in which it exists [2]. The latter perspective has been suggested as being appropriate to apply to the team sports context [1].

The shared knowledge perspective is typically defined and conceptualized by the shared mental models (SMMs) approach. The SMM concept postulates that team members share their individual mental models of taskwork and teamwork knowledge throughout the team to create an overall shared mental model [8, 9]. These shared representations allow teams to plan, process, and respond to typical and novel scenarios [8, 9]. The content of shared knowledge can refer to collective representations of objectives, materials, relationships, and scenarios [10]. It has been found that congruent knowledge among team members is the primary reason for team success [11]. In addition, shared knowledge of a task environment has led to improved performance in teams [12].

In sports, Reimer and colleagues [13] state that in order for SMMs to be advanced and improved, teammates must be “on the same page.” Eccles and Tennenbaum [14] have also noted that athletes have knowledge structures in place which enable predictions and alterations to be made to present and upcoming events. SMMs have been found to exist in hockey and handball players by comparing questionnaires regarding on-court thoughts and behaviors [15]. Professional basketball players have also been retrospectively questioned about their shared knowledge, where it was found that 87 % of the time teammates partially share knowledge, 12 % of the time teammates fully share information, and 1 % of the time teammates are not sharing information at all [16].

The ecological approach asserts that the interactions occurring during teamwork is team cognition [2]. The ecological approach and the theory of Interactive Team Cognition (ITC) are interrelated takes on team cognition. As reviewed by Cooke [17], ITC aligns with modern views of individual cognition, articulating that it can reside outside of the brain, (e.g., embodied cognition or activity theory) [18, 19]. In teams, the ecological perspective asserts that cognition exists in the many behaviors of interaction. In sports, an interaction could be something as explicit as demanding the ball from a teammate, or subtle behaviors, such as, eye contact, winking, or head nodding.

Athletic competition spurs profound changes which can never be fully anticipated. During these novel experiences and perturbations, teammates spawn shared affordances because of synergetic processes [20], therefore, it is possible the ecological perspective may be a more valuable technique for examining teamwork in sports compared to the shared knowledge perspective. This perspective does not suggest that individual cognitive processes do not play a role in teamwork and team interactions. But, the perspective does stress that individual cognition is not observable, while team processes can be reliably examined. ITC does not attempt to abolish shared mental models, it encompasses them. It may be valuable for researchers in this field to begin considering the importance of interactions as they happen. Here may lie the opportunity for the purest observation of teamwork and team cognition in sports.

3 Methods for Studying Team Cognition

Over the past 20 years, many methods for capturing and understanding team cognition have been put forth in the literature. At one point, the research community struggled greatly in understanding how to empirically measure team cognition, mainly because there was still a great deal of misunderstanding regarding the concept itself. But, as the team cognition research community has grown, numerous different methodologies have been developed that allow us to gather data that is directly representative of team cognition.

Most studies related to team cognition have traditionally occurred within the lab using experimental methodologies (see review of shared mental models by [21]). The reasons for this are that the experimental context allows research to isolate for specific aspects of team cognition (such as knowledge, situational awareness, communication and coordination, etc.) in a controlled environment void of confounding variables. In addition, a growing number of laboratory studies are also incorporating aspects of knowledge elicitation to better understand team cognition [22, 23].

Yet, as interest in team cognition grows, researchers are becoming interested in learning about how it occurs in real teams, outside the lab. For these types of studies, knowledge elicitation methods are recommended due to their wide-ranging scope and flexibility. Below, we outline knowledge elicitation and how it should be defined for the team sports context.

3.1 Knowledge Elicitation: A Historical Perspective

Knowledge elicitation methods have long been used in multiple communities (such as human factors, psychology, cognitive science, information sciences, computer sciences, etc.) to understand the cognitive aspects of many different types of work. In general, *knowledge elicitation* refers to “process of collecting from a human source of knowledge, information that is thought to be relevant to that knowledge” [4, p. 802]. The actual process of eliciting knowledge can vary drastically depending on the specific method the researcher is using. Yet, all knowledge elicitation methods are aimed at discovering information and knowledge that is utilized to help one perform a specific action.

Historically speaking, by collecting domain and task relevant knowledge, we can then articulate what a person’s cognition is. Traditionally, knowledge has been viewed as a direct outlet for cognition [24]. Referring to the previous section, we can see this notion in action. The concept of a shared mental model is based on knowledge, more specifically team members sharing their relevant taskwork and teamwork related knowledge amongst each other.

Knowing that knowledge is a critical facet of cognition, it is imperative that we understand how to adequately capture and measure knowledge at both an individual

and team level. For this reason, knowledge elicitation methods have become a popular mechanism for developing insights into individual and team cognition. Cooke [4] has provided the most comprehensive review of knowledge elicitation methods to date. In this publication, she outlines that knowledge elicitation is generally separated into three distinct families: (1) observations and interviews, (2) process tracing, and (3) conceptual techniques. Within each of these families are multiple other specific methodological techniques. Observations and interviews are self-apparent in their meaning, but process tracing and conceptual techniques are not as pronounced. Process tracing techniques refer to gathering knowledge relevant data while a person performs a task, such as creating a verbal report of what the participant is thinking in concurrence with their actual task performance. Conceptual techniques are used to create representational visualizations that include relevant knowledge (content) and the associated linkages and relationships between direct or indirect information or knowledge.

The researcher must examine the task and the context that they are conducting their research in, and then systematically choose which specific techniques they are going to use for their study. Understanding the context that the research is occurring in, and the pros and cons of each technique is one of the keys to adequately utilizing knowledge elicitation. One could seemingly pick any of these techniques to capture knowledge but if the technique is not aligned with the context or not logistically possible, then the data will be jeopardized. This is why it is important that each of these families is reviewed in accordance with the context of team sports. In addition, when one considers knowledge at the team level, it is important to understand which techniques work best for conceptually and logistically eliciting team cognition. In the next section, we do just that, outlining the details of each family and how they can be applied to a team sports context. First, we further delineate our meaning of knowledge elicitation, expanding its conceptual means to better afford for the team cognition that occurs during team sports.

3.2 A New Conceptualization of Knowledge Elicitation for Team Sports

Traditional knowledge elicitation methods are highly dependent on the aggregation of individual's cognition to then represent team cognition. This perspective is useful depending on the task and context that is being studied. In a setting that is highly dynamic, such as team sports, the focus needs to account for more than just individual aggregation of knowledge. Although individual knowledge is an important facet of team cognition within this setting, there are many other variables that are impacting team cognition. Most notably, cognitive processing occurring at the team level is impactful to team cognition occurring in a dynamic environment. Examples of team level cognitive processing are communication and coordination occurring amongst and within the team. Due to the characteristics of the dynamic environment

that team sports occur in, measurements of team cognition need to account as much for team level cognitive processing as individual knowledge aggregation. There is a place for both of these aspects of team cognition to be studied within the context of team sports, yet better metrics representative of team level cognitive processing need to be developed. For this reason, we recommend that knowledge elicitation needs to be conceptually updated to include aspects team level cognitive processing.

This is not to indicate that traditional knowledge elicitation methods are not valuable to the team sports context. In fact, we feel that individual knowledge is important to fully understanding team cognition. In addition, not all knowledge elicitation methods are dependent on individual knowledge aggregation. There are significant opportunities to use traditional knowledge elicitation methods at the team level, which we outline in the next section. The purpose of the rest of this paper is to show how traditional knowledge elicitation methods can be applied to the sports team context, and also outline new knowledge elicitation methods that account for team level cognitive processing. By utilizing traditional knowledge elicitation methods in addition to newer cognitive processing methods, we feel that team cognition can be holistically measured in the context of team sports.

4 Traditional Knowledge Elicitation Methods for Studying Team Cognition in Sports

4.1 Observations and Interviews

Observations and interviews are two of the most popular knowledge elicitation methods, and have been used to elicit knowledge in a variety of different contexts. First, we will discuss observations. Observations are insightful into cognition, as there is a direct link between interactions and cognition. Observations allow us to observe aspects of a human's cognition in real time. Typically, when one is probing for cognition they will go directly to the individual or team of individuals and ask them what they were thinking during a specific instance in time. Although this is an effective means of capturing cognition, humans are often unreliable in describing their own cognition. For this reason, it is valuable to triangulate that data with observable data. Pairing both sets of data together has the potential to strengthen validity. Cooke [4] operationalizes observations into three different varieties: active, focused, and structured. We will not outline each of these in depth, but active participation involves the researcher being a part of the actual observation, whereas focused and structured methods are ways to systematically observe different parts of the environment.

For the team sports context, observations will be very important in helping to understand team cognition. Depending on the sport, there may or may not be active verbalization in the field of play. In addition, specific cognitive probing via

interviewing will have to occur retroactively after the sport has concluded. So, observations may be the only real time dataset that can provide insights into how the team is working together. The potential for specifically understanding team coordination (directly linked to team cognition) through observation during the game is apparent by tagging and tracking each player's movements and interactions back and forth with each other.

Interviews are extremely impactful in gaining insight into team cognition. Through an interview, the researcher has the potential to explicitly probe for specific aspects of the team's cognition. There are two ways to utilize interviewing for the purposes of team cognition. First, individual interviews of team members can be conducted and then analyzed (or aggregated) to the team level. This method is adequate as long as the researcher amends the aggregated dataset with a team level dataset (such as observations or process tracing of team level communication). Secondly, interviews may also occur in the form of focus groups where all members of the team are present.

The content and structure of the interviews is dependent on the researchers and can span from unstructured, semi-structured, and structured. The variation in each of these types of interviews is dependent on how focused the interview is. A structured interview would indicate that the researcher has a set of interview questions that they have predetermined to ask the interviewee. Determining what type of interview to conduct is an important consideration, and should be dictated by the goals of the knowledge elicitation. If the researcher is interested in a very specific aspect of knowledge, then a more structured interview may be most appropriate. In general, we recommend semi-structured interviews, as they provide an overarching structure yet also afford additional cognitive probing.

In the team sports context, we see interviews as an important means to articulating team level cognition. Interviews may take place before or after the game and at the level of the individual or the entire team. We recommend that observations are paired with interviews in the sports context. Pairing these two datasets allows for the researcher to ask specific questions related to what was observed during the game.

4.2 Process Tracing

Process tracing refers to data used to make cognitive inferences aligned with task performance [4]. There are multiple specific process tracing methods, but for the purposes of this paper we will focus on verbal reports. Verbal reports are viewed as a direct dialogue into cognition and knowledge. A verbal report is classified by being online or offline [4]. An online report indicates that the individual or team of individuals are actively and concurrently verbalizing what they are thinking while performing a specific activity. An example of online reporting is the think aloud method. Whereas, an offline report is dependent on the individual or team retroactively reporting what they were thinking. In addition, it is also important to

note that a verbal report can be achieved simply by collecting the verbal communication that occurs during an activity (assuming it is a team level activity that require communication).

Verbal reports have the potential to provide insights into team cognition during team sports. In particular, depending on the sport, communication occurs during the game. This is often communication that helps the team coordinate themselves in a meaningful way or to run a specific play. This communication is a direct link to specific cognition occurring at both the individual and team level. In addition, other ideas for using verbal reports in the sports context are to use offline reports where individuals are asked to conduct a think aloud while watching the actual game they played in. Similarly, the entire team could produce a verbal report while watching the game together.

4.3 Conceptual Techniques

Conceptual techniques are a means to elicit conceptual knowledge or cognition and explain the relationships and hierarchies among the concepts. Much like the previously highlighted families, there are many specific methods that fall within conceptual techniques (for full review see, [4]). In this paper, we choose to focus on one of the most widely used methods, concept mapping. Concept mapping is a research methodology that requires individuals and teams to specify concepts and relationships of cognitive content and structure [25]. A concept map may be an open ended activity where the participant(s) are given a focus question and asked to concept map based on the question, or the researcher can interview the participant(s) and help them produce a map. The power of concept maps for articulating team cognition is that they can be developed both individually and at a team level, and represent a direct link to cognition. In the sports context, concept maps can be applied either before or after the game at both an individual and team level.

It is apparent that all three knowledge elicitation families have a place in articulating team cognition during team sports. Yet, it is also apparent that not every method is a perfect fit for capturing cognitive processing in real time at the team level. The next two sections outline the challenges of using knowledge elicitation in sport and how to innovatively create new methods to study team sports via measuring team level cognitive processing in real time.

5 Challenges of Using Knowledge Elicitation in Sport

Traditional knowledge elicitation techniques can certainly be applied to individuals on sports teams. Knowledge of the rules of the game, the requirements of one's own position, and the capabilities and limitations of teammates or those on the opposing teams is clearly critical for effective performance. The degree to which such

knowledge is shared can also be assessed and is most likely also important. However, for other action-oriented teams it has been found that knowledge and its distribution or overlap among team members, though important, is not what distinguishes effective teams from ineffective teams [2]. Rather it is the interaction among the teammates reflected in coordination dynamics and communication behaviors or cognitive processing at the team level that is central to team effectiveness. How can this kind of team expertise be elicited?

Much of the research on team interaction and its analysis has taken place in the context of military command-and control teams, such as teams who operate uninhabited aerial vehicles from the ground [2]. Parallels have been drawn between military command-and-control teams and sports teams [26], however there are also differences particularly in regard to the details of interaction. In military action-oriented teams the team-level cognitive processing happens through communication—much of it explicit. Various aspects of communication have been recorded and analyzed that include frequency, number of words, vocal tone, flow dynamics, and content [27]. This information provides a descriptive look at the team interactions or team cognition, however, it does not reveal the underlying perceptual and cognitive processes of individuals that are associated with team-level cognition and that may be useful in training individuals for teamwork. Further, extending this interaction-based approach to sports teams raises several challenges.

In contrast to military command-and-control, in which the interaction is primarily through verbal communication, team sport involves fast-paced physical interaction. Team cognition in sports can be observed less through explicit verbal communication and more so through the physical interaction among teammates. Verbal communication that does occur is often quite limited in sports (e.g., a player's name is called) or purposefully terse and obscure (e.g., the name of a play). Nonverbal communication is more common and may be as subtle as making eye contact or pointing. The challenge is to measure interaction that occurs in this manner and to be able to do so unobtrusively. Collecting data on player positioning through GPS has been used in this regard and can provide an indication of interaction patterns [28], however, as previously mentioned, this information is devoid of individual teammate "knowledge" that generated the pattern.

There are also other differences between sports teams and the traditional action-oriented teams that have been studied in the literature and that make knowledge elicitation challenging. Sports teams tend to be larger than the teams of 3–5 individuals that have been studied in the literature. In fact, sports teams may be multiteam systems [29] in the sense that the larger team can be divided in sub-teams (e.g., defense, offense). In addition, the team should probably include the coach. There are other individuals involved that may also impact the team and they include the fans and referees. Most importantly, the opposing team needs to be considered as well, as it is the primary environmental trigger for a team's actions. In understanding team cognition, these other teams and individuals are important parts of the context and need to be considered.

In sum, the assessment of team cognition in sports raises several challenges due to the focus on physical interaction as opposed to verbal interaction and due to the unclear bounds of those on the team. Team cognition in sports teams can be understood at one level through the analysis of the physical interactions of teammates. The physical interaction patterns that can be observed reflect changing dynamics of a team that indicate adaptation to the environment and resilience. However, these patterns alone are not instructive for training individual team members in that they do not provide an indication of the individual cognition that helps to generate these patterns. Some traditional knowledge elicitation methods can loosely be used for this, but new context specific methods are needed for eliciting this kind of knowledge from teammates.

6 New Methods of Knowledge Elicitation for Sport

Studying team cognition from an ecological approach will require the development of new methods of investigating the “knowledge” shared by teammates. Traditional methods of knowledge elicitation, which typically involve conscious, passive responses recorded out of context, will not be fully effective in capturing the shared coordination and communication between teammates which, according to the ecological approach, emerges during actual play and is more implicit. At the same time, research which focuses only on the macro level behavior of teammates (e.g., the movements of players from GPS data) does little to elucidate the underlying perceptual-cognitive processes. We next consider some possible paradigms that could represent a middle ground between purely passive knowledge elicitation methods and macro level measures of team performance outcomes.

A fruitful approach for studying team cognition in sport may be to “scale up” paradigms that have been shown to be highly effective for assessing cognition at the individual athlete level. For example, the temporal occlusion paradigm [30]. This method involves a participant viewing an unfolding action (e.g., a tennis serve) either on video or live. At a designated point in time (e.g., 150 ms before racquet-ball contact) that participant’s view is occluded (e.g., by freezing the video or with occlusion glasses). The participant is then required to anticipate the outcome of the action (e.g., cross court or down-the-line serve) either with a verbal response or initiating a movement in reaction. For one-on-one actions in sports (e.g., returning a serve, hitting a baseball or stopping a penalty kick in soccer), this method has consistently demonstrated that skilled athletes are more accurate at anticipating the outcome and can do it successfully at earlier occlusion points as compared to less skilled athletes [31]. This expertise difference occurs because skilled performer are better at picking up the advance cues (e.g., the movement kinematics or body language) of their opponent [31].

The temporal occlusion paradigm has also been applied to sporting actions involving multiple players in team sports. In these studies, the participant is again shown an unfolding action (e.g., the movement of players on a basketball court) that

is occluded at some point. They are then asked to make a decision about what action they would perform next (e.g., dribble the ball to the net, pass to teammate X or pass to teammate Y). Coaches' assessments of the videos are then used to assess the appropriateness of the participant's decision. Research using this paradigm has again showed that skilled athletes make more appropriate and faster decisions as compared to less skilled player (e.g., [32]). For both the anticipation and decision making paradigms it has also been shown using eye tracker data that expert athletes have different gaze behavior than lesser skilled ones. In particular, they tend to fixate longer on a small number of key areas (e.g., [33]).

An interesting extension of these paradigms could involve multiple participants from the same team making coincident decisions or anticipation judgments. For example, a video of an unfolding basketball play could be filmed using mobile cameras attached to three different players on the team (e.g., point guard with ball, shooting guard and forward). These videos could then be shown to three participants who are each asked to make a decision at the same occlusion point. The agreement between their responses could then be used as an index of team coordination. Alternatively, the same unfolding play could be filmed from the perspective of three players on the defending and then used to create a task which involves anticipating the action of the player with the ball. By adding eye tracker it would also be possible to determine the relationship between the visual search behavior of teammates. Do athletes that have a lot of experience playing look at the same areas on their opponent's body? Do they look towards the same openings on the court? By measuring the agreement between player's decision it would also overcome a short coming in sport decision making research that "good" decision are determined by assessments of what "should be done" by a group of coaches, a practice which penalizes any type of unexpected play or creativity.

Another area that needs methodological development in team cognition in sports research is nonverbal communication. Previous research has shown that athletes communicate in many different ways including using gestures, gaze direction, movement, body orientation and touch [34]. For example, in netball, verbal directives given by teammates are accompanied by gestures 12.5 % of the time and failures in taking into account the different orientation of a teammate when making a gesture accounts for a high proportion of communication problems [34]. In basketball, it has been shown that the rate at which NBA teammates touch each other during play is directly related to their level of cooperation and on-court performance [35]. Although these studies have produced some interesting findings, they rely on remote videos which are labor intensive to code and are likely to miss many subtle forms of communication. Furthermore, previous research of this type has been mostly descriptive. While there have been some initial attempts to model non-verbal communication flow in sports (e.g., [36, 37]) it will be important to develop more detailed models of communication flow as has been done for verbal communication in other domains [2].

7 Concluding Thoughts

Team cognition is beginning to be realized as an important facet of team sports. As we continue to articulate the role of team cognition during team sports, we need to understand how to measure team cognition. In this paper, we presented multiple knowledge elicitation methods to measure team cognition, while also proposing new elicitation methods that account for the dynamic nature of team sports.

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