Theoretical and Methodical Approaches to Studying Team Cognition in Sports

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Theoretical and methodical approaches to studying team cognition in sports

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Abstract

For most people, the concept of a team is most often associated with the context of sports. Sports permeate our society and are a critical form of entertainment for many. Fans of sports teams intently watch their team, often thinking little about the many complexities involved in any given team sport. Yet, the complexities are many, and one serious area that is historically understudied is the development of team cognition within sports teams. Sports teams are dynamic, in that they rely on both physical and cognitive dimensions of teamwork to be effective. A sports team does not only focus on strategy or developing a game plan to beat their opponent (cognitive), they must also execute this on the field of play (perceptual motor). The integration of both cognition and physical execution is dependent on the development of team cognition. Team cognition allows team members to develop an understanding of their overall strategic goals and implement them on the field. Thus, the development of team cognition within sports has the potential to greatly improve performance.Yet, to fully understand how team cognition develops within sports teams and its impact on and off the field, we need to study the developmental process more within this specific context. As with any domain specific area, conceptual/theoretical approaches and research methodologies must be identified as meaningful for the selected research context. This paper presents and describes theoretical approaches that are useful for studying sports and team cognition. Specifically, this paper explores and describes the theory of Interactive Team Cognition [1]as a perspective and approach to studying the development and implications of team cognition within team sports. As previously noted, sports are a highly dynamic activity and dependent on many functions (communication, coordination, collaboration) to be effective. The theory of Interactive Team Cognition directly aligns with these functions, acknowledging that team cognition is an activity (sports is) that is highly dependent on the context that it is occurring in. In addition, the theory also states that it is best to study and measure team cognition when the team is the unit of analysis. In this paper, we also present methods for how researchers can study team cognition within sports teams. The paper concludes with an overview of the potential to study team cognition within sports teams using the aforementioned approaches and methods.

Keywords: Team Cognition; Sports; Theory; Methodology

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1. The importance of team cognition in sports

Sports are important and critical to our society. Sports permeate much of the world's culture and are a critical form of entertainment for many. Although, sports might seem as though they are only entertainment, there are multiple learning cases vested within the sports context. For example, if you ask most people what a team is, they will most likely respond by directing their answer to the sports context. Simply, for most people, the concept of a team is most often associated with the context of sports. Fans of sports often watch their sports teams with great focus, yet they are not actively thinking about the many complexities associated with physical and cognitive attributes. Sports, specifically at the team level, are dependent on a dynamic relationship between perceptual motor action and cognitive processing. Take for example, the field of play of soccer, team members must cognitively process many different attributes occurring all at the same time: what play is currently being implemented, where are teammates located on the field, where are the defenders, what are the actions taking place at an individual, team, and opposing team level. These cognitive attributes typically feed directly into physical execution on the field. By knowing and processing what is happening on the field of play at an individual and team level, the player is then able to react to the cognitive processing and physically implement a plan. The integration of both cognitive processing and physical implementation in the field of team sports is reliant on the development of team cognition.

Team cognition is cognition that develops at a team level and is shared amongst the team through direct or indirect communication and coordination. Through the development of this cognition, team members are able to develop an understanding of their overall strategic goals and implement them on the field. More specifically, team members generate a better understanding of what the team's goals are and how to accomplish them. We see nods to the importance of team cognition in sports oftenwithout coaches or players specifically identifying it as team cognition. For example, we often hear players mention that they are on the "same page". Another example is the instance of a blind no-look pass being dependent on team cognition due to a shared understanding of both cognitive and physical attributes.

The impact of the development of team cognition during sports has serious implications pointing to the enhancement of team performance. We have seen in many other contexts that team cognition has the potential to improve team level performance through increased awareness and an understanding of goals [2]. Yet, more team cognition research needs to be conducted within the context of sports to first understand how team cognition develops within this context, and then performance metrics can be studied. It is critical that team cognition is studied within the context that it is being discussed, as the context directly affects how team cognition develops. A sports context is one that is highly dynamic and constantly changing, meaning that team cognition will develop in a unique way representative to that context.

To further understand how team cognition develops within the sports context, appropriate theoretical perspectives and methods must be outlined. Traditionally, team cognition is studied using one of two theoretical approaches: information processing (closely linked to shared knowledge) or ecological. In this paper, we will overview each and the specific research found within each that has been conducted in the sports domain. Throughout this review we will provide commentary on the positives and negatives of utilizing each approach in the sports context. Finally, we present some valuable methods for collecting and measuring sports related team cognition data. We conclude by highlighting the promise of team cognition research in the sports context and call for more work to be conducted.

2. A review of theoretical approaches relevant to team cognition and sports

2.1. Team cognition

Many organizations try to utilize teams to conquer complex problems in many different domains[3]. Team cognition is an overarching concept that engulfs topics such as coordination and communication. It is vital to note that team cognition is often greater than individual team member's cognitions added together [1]. In addition, it's important to cite thata team of experts is not necessarily an expert team [4]. Proper team communication and coordination meshes together multiple team affairs to achieve sufficient performance[5]. In general, any process a team physically and/or mentally experiences could fall under the concept of team cognition.

Historically, there have been two primary theoretical perspectives associated with research on team cognition. The first, and most commonly held, is based on information processing. The field of Industrial/Organizational (I/O) Psychology has shown great interest in team cognition. Illgen et al. [6] provide a review of how teams have been studied within organizations and the standard Input-Process-Output (I-P-O) model. Specifically, they address the downfalls of this approach. For instance, an I-P-O model restricts research by suggesting a one-cycle linear route from inputs to outputs. They insist research in this area should be conducted using Input-Mediator-Output-Input (IMOI) model. This approach allows for more flexibility and is open to the interplay of each aspect within the model.

A second perspective is inspired by ecological psychology[7].A specific ecological theory of team cognition is Interactive Team Cognition (ITC), which states that team cognition is an activity, not simply a product. ITC and the context in which it occurs are inseparable. Team cognition is not a static snapshot. However, it often evidences itself in the form of explicit communications. ITC has been empirically researched for the military, specifically in Unmanned Aerial Vehicle (UAV) studies. These UAV bounded experiments demonstrate that ITC emerges in team member interactions. These collaborations distinguish high-performing teams from average teams, and transfer across different tasks [8].

Corresponding to the two theoretical perspectives, there have been two main methodologies used tostudy team cognition. Some researchers have taken a collective approach, which involves studying the team at the level of the individuals within it, and aggregating those results to the team as a whole. This collective methodology aligns with the information processing/shared knowledge perspective.Others have adopted a holistic approach, which includes measures of individual knowledge and team processes. The holistic style aligns with the ecological perspective. Historically, the collective approach has been used to study team cognition, often utilizing elicitation methods, team metrics, and an aggregation method. This method suggests that team knowledge is the sum of the individual's knowledge within the team. The holistic method suggests overall team knowledge results from cognitive processing at the team level in the form of communication, situation assessment, and coordination [9].

2.2. Shared knowledge in sport

At face value, *shared knowledge* is fairly self-explanatory. It is collective knowledge shared by a team of individuals. The shared information is often stable. For example, most hockey players know what icing the puck is during a hockey game. Shared knowledge can often achieve a greater complexity than the rules of just a sports game. Possibly, a basketball team could know prior to a game that a player on the opposition is poor at dribbling with their left hand, which could affect the team's defensive preparation in dealing with that player and team.

Under the umbrella of shared knowledge is the idea of a mental model. In general, mental models are knowledge webs that are found at an individual level. When individual mental models are shared amongst team members, a *shared mental model* (SMM) may develop [10. SMMsoften provide teammates with the ability to coordinate thoughts and actions without necessarily explicitly communicating in dynamic situations [10]. Over the years, SMMs have become a common way to articulate how teammates coordinate with each other, making thema popular method for studying team cognition. Traditionally and typically, SMMs are observed at the individual level and then aggregated to the team level. The definition of what exactly a SMM is differs between researchers, with some preferring the term *team knowledge* over SMM [9].

Next, we will briefly review articles that have focused on SMMs within the sports domain. Overall, there is a lack of literature that studies team cognition in sports. Yet, when it has been studied it is studied from the perspective of shared knowledge. This brief review is not meant to be comprehensive; rather we have chosen to highlight articles that we feel are most relevant to this paper's purpose and discussion.

As an example of the use of a SMM,Bourbousson et al. [11] researched team cognition in basketball. Their goal was to assess how often in-game dilemmas were shared and how that sharedness changed throughout a game. They categorized sharedness into three forms: (1) moments of nonsharedness, which occurred during 1% of all activities (2) partial sharedness, which accounted for 87% of instances (3) and complete sharedness, which represented12% of the total amount of shared events. This information was obtained using the qualitative method of knowledge elicitation through interviews. A limitation of this study, which the authors state, is that the type of cognition being

measured is only the type that the players can remember and report (retrospective). Also, the players were interviewed individually. Their answers to the questions were compiled and compared to other teammates responses. This aggregation of individual knowledge to evidence team cognition may not be the best way to conduct research for team cognition. This is an issue often found withinthe overall literature in this domain.

Another example was a recent study conducted by Giske, Stein, &Hoigaard[12]to determine whether or not a SMM exists in expert hockey and handball players. They were concerned with whether or not teams had established collective priorities, such as, their general attack pattern. Also, they wanted to find out whether or not teams participated in particular types of training to develop those overall strategies. Lastly, they measured whether or not teams collectively understood their opponent's strengths and weaknesses for particular matches. Their findings indicate that athletes perceived a SMM and their pregame preparations were dedicated to the SMM. Essentially, this study asked individual players if their teams had common goals and if they ever practiced or discussed those common goals. In sports teams, having a general overall strategy or philosophy is quite normal and necessary. In this article, and similar to the previous article, individual knowledge is aggregated to draw information about team cognition.

Past literature suggests teammate synchronization occurs because of a shared knowledge model of the athletic environment. This mental blueprint persists within team members and allows them to actively solve problems on the field of play. There are multiple issues pertaining to this mental representation approach, such as, how do these individual ideas of teammates change collectively? What is the length of time it takes for this assembled blueprint to form? Individuals can perceive information quite differently, how do these separate perceptions come together as one coordinated representation. An alternative theory to this shared knowledge point of view is known as a dynamic interaction or ecological dynamic approach. Ecological enthusiasts argue that the shared knowledge model may be relevant to teammates before a competition, but is incapable of adapting to the unstable arena that is a sporting event. A staple of the dynamic ecological approach is that harmonized actions by sports teams are due to the generation of shared affordances between team members due to collaborative processes, which occur in the sporting venue [13].

2.3. An ecological vs. shared knowledge approach to team cognition in sport

As is indicated above, there is a relatively small amount of research that examines team cognition in a sports context. The work that has been done in sports and SMMs and in the field of team cognition in general, subscribes to information processing theories with a focus on team member knowledge. Consistent with this knowledge-based perspective, assessment of team cognition has predominantly focused on the measurement of individual knowledge and subsequent aggregation and comparison of that knowledge among team members. These types of data are tied to constructs such as SMMs with the general idea that the more similar team member mental models are the more effectively they can perform (e.g., through implicit communication). Though SMMs may be part of what underlies team effectiveness, this theoretical approach is limited to periodic knowledge snapshots of individuals. It seems to miss the *teamness* of the team and the dynamic context of sports.

The ecological approach to team cognition in sports offers a very different perspective on team coordinationto that just described. Instead of team cognition being based on shared knowledge in the form of stored representations and schema, coordination amongst teammates is achieved through shared attunement to perceptual information [13]. The distinction between shared knowledge and shared attunement can be understood by considering an example from soccer. Imagine a midfielder lobs a pass over the defenders at the exact moment a striker teammate breaks to the net. How did both players come to execute such coordinated actions without any explicit communication beforehand? In the shared knowledge account, this type of coordination occurs because both players have a stored schema for the "lob pass play" and both decided to execute this action after processing the available perceptual cues (i.e., the relative positions of the players). This may also involve an intermediate step of identifying the defensive strategy that is being played by the opponent (e.g., a 3-4-3 flat formation in soccer or a zone defense in basketball). In this account, the perceptual cues are non-informative in and of themselves – instead they have come to be associated with this particular action/play through extensive practice and/or a coach's instruction (e.g., being told that when the defenders do X you should do Y). Thus, the keys to team cognition in this account are that: (i) both

players have stored similar set of schema (i.e., they learned the same set of plays) and (ii) these schema are associated with the same perceptual cues for each player.

The primary distinction with the shared attunement account comes at the level of the players' perception. Instead of detecting non-informative perceptual cues that must be processed and associated with stored knowledge so that a decision about which action to execute can be reached, the ecological approach argues that perception involves the pick-up of information sources which directly specify opportunities for action. For example, in the soccer example described above, the two teammates might detect the higher-order perceptual variable τ_{Diff} which gives the difference between the time of arrival of the defender at the pass landing point and time of arrival of the striker at the same location. τ_{Diff} is optically specified by the ratio of the angular gap between each player and the landing location and the rate of change of this gap [14]. This variable is informative because it directly specifies whether there is an opportunity for a lob pass (i.e., $\tau_{Diff}>0$) or not (i.e., $\tau_{Diff}<0$). Coordination between players occurs in this case occurs because both players are attuned to τ_{Diff} (i.e., are relying on it to control motor action) and thus would simultaneously detect when the environment affords the opportunity for a lob pass. On the surface, since the perceptual information needed for the action is available to anyone with a functional visual system and does not require one to learn the schema for the "lob pass play", it might be assumed that practice is less important for the development of team coordination in the ecological approach. However, it has been shown that practice is often required for actors to become attuned to such higher order variables as novice performers often rely on simpler (and less effective) information sources [15].Furthermore, these information sources must be scaled by the action capabilities of both performers [16], which again would presumably occur during practice. For example, the τ_{Diff} value that affords lob passing also depends on the maximum running speed that can be achieved by the striker and the maximum velocity at which the midfielder can accurately pass the ball. In summary, the keys to team cognition in the ecological account are that: (i) both players are attuned to the same information sources and (ii) both players perceptions are effectively calibrated for the action capabilities of their teammates.

Another important difference between these two approaches is the point in time in which team coordination is achieved. On the one hand, in the shared knowledge approach, coordination is achieved when teammates have developed the same set of schema and same set of cue-responses contingencies. Thus, team cognition in sports can be assessed *offline* since it is not actually dependent on the events of a particular game/match and can be studied *independently* since it does not depend on the interaction between teammates. On the other hand, in the shared attunement approach, coordination can only be understood within the context of the performance itself since the information sources only exist when the perception-action cycle is intact and when the teammates interact since these information sources are defined relative to the action capabilities of the different performers. Thus, in the ecological approach, team cognition research must be *online* and *interactive*.

Interactive Team Cognition (ITC) is a theory that is ecologically inspired that holds that team cognition is an activity that is tied to context and best measured at the team-level [1]. Studies of military command-and-control teams indicate that interaction data in the form of explicit communications are more related to team performance than is knowledge similarity. Communication patterns based on flow data (who is talking to whom) have been used to distinguish effective from ineffective teams and to identify perturbations in the environment that impact performance [17]. Communication among team members can be thought of as cognitive processing at the team level. Moreover, communication, unlike individual cognitive processing can be readily observed. Dynamical analysis of communication patterns could similarly be applied to sports teams to reveal cognitive underpinnings of team performance.

3. Sources of ecological data in sports and using an ecological approach in the future

Previous ecological approach research on team cognition has utilized both micro and macro level methodologies. At a micro level, researchers have begun to identify candidate perceptual information sources that could be used for coordinated behavior. Again, because the information sources only exist online, research in this area has involved the analysis of either real (via video) or simulated game play. For example,Araujo et al.[18] examined player dyads in basketball and defined a collective variable based on the distance of each player from the basketball. They further showed that this variable alternates between stables states (entrainment) and abrupt changes, which can related to

players decisions to attack the basket. Similar to the soccer example described above, another approach has been to analyze the use of temporal gap (τ) information. For example, Correia et al.[19] showed, using a rugby simulation, that a rugby ball carrier's decision to run, pass short or pass long is based on the relative temporal gaps between players.

At a macro level, some recent studies have sought to understand the nature of the coordinated behaviors that emerge from the interaction between teammates. This has involved using GPS data collected from multiple teammates during actual game play to calculate a variety of dynamical group based metrics including centroids, team dispersion, synchrony and team communication networks [20]. This line of research has produced several interesting findings including that changes in centroid and surface area metrics (indicated a loss of stability) frequently occur just before an assisted pass is made [21] and that group metrics are influenced by the number players and size of the playing field [22].It will be important for this relatively new line of research to further relate these macro level measures of coordination to performance measures (e.g., goals and wins) and to understand the relationship between the micro level perceptual information and macro-level outcomes.

Theecological data gathered in sports thus far are based on movements or actions. These action patterns are interpreted in terms of coordinated team behaviour and inferences can be made about team cognition. However, the cognitive underpinnings or correlates of the behaviour are not obvious. How can wecapture the dynamics of team cognition? The use of communication data may provide a rich source of information on team cognition.

Ideally, the dynamical analysis of communication behaviour could supplement the action-oriented patterns to provide a richer understanding of behavioural and cognitive coordination. These approaches can be conducted in real-time and in the context of the sport. On the other hand, they do not take into account individual and team knowledge.Individuals know the rules of the game, other team behaviors, strengths and limitations of team members, and tactics and strategies for a particular game. The team members may overlap in terms of this knowledge to different extents and the degree of overlap may be relevant for performance. Thus, there is a role for the static, knowledge based approach with assessment occurring off-line. The assessment of teams' communication dynamics, behavioral dynamics, and mental models together would provide a rich assessment of team knowledge and cognitive and behavioral coordination.

A final note concerns an important limitation of the ecological approach to team cognition that will need to be addressed in future research, namely a lack of a role of prior knowledge of one's opponents. In its current form, the shared attunement approach is not influenced by information about the opposing team (e.g., their defensive tendencies, the situational probabilities of their attacking plays, etc) yet we know in sport a considerable effort is put into reviewing these information sources [23]. It will be important for future team research to combine perceptual attunement to information with the use of advance information as has been done for individual sports performance [24].

4. Methods for studying team cognition in sports

Team cognition has a rich history spanning across the past thirty years. Throughout that history, the development of methods to capture team cognition data has been at the center of attention. Dating back twenty years ago, there were very few validated methods to capture team cognition [25]. In present day, we now have many different methods to choose from. The discussion has changed from how can we develop team cognition methods to which strategy is most appropriate for the study or context that the study is taking place. As we have noted multiple times, sports are a dynamic setting and occur at a team level, so the methods that are used to study it should align with these attributes. We recommend using methods that allow for the capturing of data at the team level. This data is typically communication data, which can then be analyzed for content or coordination patterns.

Methods of measuring and capturing team cognition specific to the sports domain are extremely lacking. What is unique about sports is that they are extremely physical. The physical nature of sports is viewed as a positive for team level data collection. Not only aspectsof communication that occur during sports available, but also and maybe more importantly, the physical movement that occurs within the team is available. Verbal communication during sports is not always constant but physical movement is. The physical movement within the team can lead to the analysis of physical coordination patterns, which directly link to team cognition. For example, analyzing the passing patterns of a basketball team has the potential to further understand coordination and communication (aspects of team

cognition). In addition to analyzing team level communication or physical movement, we suggest supplementing this data with knowledge elicitation methods. Cognitive interviews at an individual and team level are helpful in further understanding team cognition aspects. A specific knowledge elicitation activity useful for the sports domain is to have players review video of their own team level sport interactions, and ask them to retrospectively explain their cognition during their play. This can be done individually and then aggregated, or at a team level.

Another distinct method that has rarely been utilized in the team cognition domain is the usage of different team position based perceptual videos. Point of view videos are presented of the same sports scenario, except each video is from the perspective of a different position on the field of play. Decisions are then made based on each position and overlap among the decisions is analyzed to discern the development of team cognition across the team.

These methods are just a few appropriate methods for measuring team cognition in the sports context. There are many more that are not presented in this paper. We hope that researchers will continue to discuss what methods are most aligned with the sports context. In addition, the development of new sports specific team cognition methods is necessary.

5. Conclusion

Team cognition is important to team level sports. Through this paper, we have outlined its specific importance by examining how it can be studied from multiple theoretical perspectives and methods. As evidenced by the background of this paper, some researchers have acknowledged the relationship and importance between/among team cognition in sports. Yet, traditionally, when team cognition has been studied in this context, the theoretical approach of information processing/shared knowledge has been utilized. This approach is important, as it accounts for individual understanding or cognition, which directly leads into team cognition. Anyone who has played team sports before knows that it is a combination of both individual and team work. The same principle is true for team cognition, meaning that individual cognition is required and necessary for team level cognition to derive.

Sports are dynamic, constant, and ever changing. These attributes directly impact team cognition- making it also dynamic and fluid based on the physical, mental, interactional, and cognitive actions that occur during sport. For these reasons, we feel that when researchers are studying team cognition within the context of sport, they should utilize aspects of the ecological approach to studying team cognition, which accounts for the dynamic nature of both sport and team cognition. Team cognition should not be viewed as just developing and then staying the same over time regardless of context or environmental change. Rather, we must understand that team cognition develops in a real time and account for many different types of interactions. Also, once team cognition develops it continues to change based on new interactions or changes in the context.

Therefore, knowing the importance of both theoretical approaches to studying team cognition in sport, we recommend integrating both to allow for a maximum understanding of team cognition development. That being said, the ecological approach is a better fit for the (team) sport context due to the dynamism and interactions occurring at the team level. Simply, a combination of both the shared knowledge and ecological approach to studying team cognition in sports is required.

In hopes that more researchers account for the dynamic nature of both sports and team cognition, we recommend utilizing a specific ecological theory, known as Interactive Team Cognition. As outlined in the paper, this theory accounts for the real time context and development of team cognition at the team level. In addition to prescribing to this theory, we have also outlined new methods that can be used to studying team cognition in the sports context. These methods are aimed at accounting for the varied and complicated nature of sports.

In conclusion, team cognition during sports has not been researched or conceptualized enough. Team sports are an excellent context to learn more about team cognition, and likewise, about team sports- specifically communication, coordination, and performance. For these reasons, more work directly focused on the development of team cognition during sports is needed. In this paper, we hope that we have provided an understanding of what work has been conducted within team cognition and sports, and how to approach studying team cognition during sports in the future.

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