Symposium/Forum
TITLE
Macrocognition: The next frontier for team cognition research

ABSTRACT
Macrocognition is a process by which teams collaboratively generate knowledge to solve unique problems. This symposium presents a theoretical framework to guide the study of team macrocognition, a measurement typology to capture forms of macrocognitive knowledge and its emergence, and two empirical investigations examining communication and training that shape formation.

PRESS PARAGRAPh
Macrocognition involves the transformation of internalized knowledge (knowledge “in the heads” of individuals) to externalized knowledge (knowledge shared “out of the head” with others) in order to build team knowledge. This symposium addresses theory, measurement, and empirical research on how teams generate knowledge and adapt to deal with novel situations and how new knowledge emerges to solve problems. Research results showed that better performing teams first converged on the rules governing a task, then on the approach the team used to complete the task and allocate work. Furthermore, training interventions can be used to enhance macrocognition and improve team performance.
Macrocognition

GENERAL SUMMARY

Macrocognition: The next frontier for team cognition research

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Almost twenty years ago, Cannon-Bowers, Salas, and Converse (1993) applied a mental model construct to team cognition. Their theory of shared mental models described how team members who developed common models of their taskwork and teamwork can anticipate one another’s needs and behaviors. These cognitive frameworks help teams make decisions effectively, particularly in situations that are dynamic, complex and uncertain.

We know from meta-analytic research that team cognition is an important predictor of team behavior, motivational processes, and team performance (DeChurch & Mesmer-Magnus, 2010). However, research has generally not carefully distinguished the processes of collaborative knowledge construction and the knowledge outcomes that result from that process. Thus, we know relatively little about the learning and knowledge creation processes that underlie shared cognition (Kozlowski & Ilgen, 2006). The focus of this symposium is on understanding the process of collaborative knowledge building in teams – team macrocognition. The purpose is to present a theoretical framework to guide research on team macrocognition, a measurement typology to capture different forms of macrocognition and their patterns of emergence, and two empirical investigations that focus on how communication and training influence team knowledge creation.

Macrocognition is used to describe how cognition occurs in real-world problem solving and decision making (Schraagen, Militello, Ormerod, & Lipshitz, 2008). But, whereas team cognition theory tends to emphasize coordinating actions among individuals, for example, understanding how team members are able to sequence their actions in service of team tasks, macrocognition in teams focuses more on the knowledge work done by a team (Letsky, Warner, Fiore, Rosen, & Salas, 2007). The symposium begins with a presentation of a theoretical model of macrocognition in teams. With this, macrocognition in teams is defined as the process of
transforming internalized knowledge into externalized team knowledge through individual and team knowledge building processes. This work emphasizes, for example, how teams are able to generate or adapt rules when dealing with novel situations and how individuals and teams generate new knowledge for addressing unique problems.

With a theoretical foundation of macrocognition established, the symposium next presents a measurement typology for capturing the emergence of new knowledge within teams. Kozlowski, Chao, Grand, Keeney, Braun, and Kuljanin developed a team knowledge typology to measure different forms of macrocognition and their emergence in teams. Specifically, they focus on forms of emergence that represent (a) the pooling of individual and team knowledge types, (b) patterns or configurations of the knowledge pool, and (c) within and between team variance in the rates of knowledge acquisition and rates of knowledge emergence from the individual to the team level. Although the specific operationalization of these measures is dependent on a specific task involved, the conceptual representation is designed to generalize across a wide range of collaborative tasks.

The symposium then presents two empirical studies on team macrocognition. McComb’s study examines how macrocognitive processes can aid in the process of mental model convergence among team members. Specifically, she examined team-level communication strings to identify patterns that inform our understanding of how (and what) mental model contents is exchanged among team members, how the mental model convergence process unfolds over time, and what impact the exchange of mental model content, and the corresponding convergence process, have on team performance. Results showed that better performing teams first converged on the rules governing the task, then on the approach the team used to complete the task, and finally on how work was allocated.

Rentsch’s study examined three macrocognitive processes: knowledge transfer, knowledge interoperability, and task schema congruence. She investigated the effect of a theoretically based intervention aimed at increasing these processes. The intervention focused on communication methods to enhance knowledge building and included training and
technology. The results supported the effectiveness of the intervention because teams in the experimental condition had higher scores on the three cognitive variables and higher performance than control teams. Thus, while much research supports the difficulty teams have in sharing unique information to make complex decisions, Rentsch’s results demonstrate that this problem can be overcome. She will also highlight the assessments of macrocognitive variable.

In summary, the four presentations introduce macrocognition as the next frontier for team cognition research. It presents a theoretical foundation to guide team macrocognition research, a conceptual typology for representing macrocognitive knowledge emergence, and two empirical examinations of macrocognition in teams. Following the four presentations, the chairs will moderate a discussion of team macrocognition with the panel and audience. The primary goal of this discussion is to initiate innovative thinking and research on macrocognition and teams.

References


Macrocognition in Teams: Developing Theory to Examine Complex Collaborative Cognition

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In the modern organization, the increase in interconnectedness and interdependence amongst people and machines continues unabated. Concomitant with this is an even greater degree of cognitive work distributed among people and machines. Despite this, our theories of collaborative cognition are still rooted in dated conceptualizations of mind such as information processing theory. As such, there is an important need to move beyond metaphors of cognition so as to understand how individuals and teams in organization actually work together to plan, think, decide, solve problems, and take action as integrated units. This presentation discusses these issues under the label macrocognition. We first provide some background on the emergence of the macrocognition construct in order to ground the development of a set of theoretical issues surrounding the study of complex collaborative cognition.

Arising out of a variety of disciplines, macrocognition as a construct emerged to contrast what was termed microcognition so as to illustrate varied forms of cognitive processes. Researchers in the cognitive sciences described macrocognition as involving communication and reasoning processes occurring at levels greater than a single processing unit (e.g., Bara, 1995; Wilkes, 1997). Theorists in cognitive engineering proposed the term to describe how cognition emerges in natural environments when people engage in complex tasks and when interacting with their work environment (Cacciabue & Hollnagel, 1995). This was deliberately contrasted with “micro-cognitive” processes (e.g., analogical problem solving) which were described as the type of cognition typically studied in laboratory studies (see also Helander, 2006; Hutton, Miller, & Thorsden, 2003; Klein et al., 2003; Schraagen, Militello, Ormerod, & Lipshitz, 2008). Others have considered this in the context of macrocognition in teams. Here the term is used to capture cognition in collaborative contexts (Letsky, Warner, Fiore, & Smith, 2008) and encompasses both internalized and externalized processes occurring during team interaction. These processes include not only internalized individual processes such as mental model development, but also
externalized processes such as the creation of cognitive artefacts and solution alternative negotiation.

Although there is an underlying similarity across these usages, there is still some conflation of core constructs. In particular, what complicates the issue is that these distinctions consider not only the realization of cognition in the real world (see Hoffman & Deffenbacher, 1993) but also a varied level of analysis. What makes this problematic from the standpoint of theory development is that there are a number of inter-related issues that must be clearly parsed (e.g., variations in complexity, contextual factor, individual versus team cognition). Perhaps most critically, these levels of analysis have associated with them differences in time scale (Klein et al., 2003; see also Liljenström & Svedin, 2005). Responses generally occur in a time-frame of milliseconds to seconds at the microcognitive level. But responses generally occur at the rate of minutes to tens of minutes at the macrocognitive level. From this, we suggest that it is critical to account for the differing levels (e.g., Kozlowski & Klein, 2000), and the varied time scales, when conceptualizing and measuring complex cognition.

In short, we bring out these distinctions because they are foundational to clarifying how the concept of macrocognition can be more efficaciously pursued. In this presentation we describe how it is conceivable to account for each of these to provide clarity in specifying what exactly is being examined and at what level. Our goal is to outline how we can use concepts that provide a number of boundary conditions for understanding the emergence and use of complex cognition in collaborative environments. With these broader theoretical issues as our stepping off point, in this presentation we more specifically present an approach for examining _macrocognition in teams_. We draw from the literature in team cognition (e.g., Salas & Fiore, 2004) as well as recent thinking in macrocognition in teams (Letsky et al., 2008), cognitive engineering (Hollnagel, 2002), and cognitive science (Stahl, 2006). From these, we discuss a meta-model which integrates three theoretical elements to account for the complex nature of collaborative problem solving. First, our approach is multi-level in that it encompasses individual and team factors. Second, it addresses internalized and externalized cognitive
functions as they arise during interaction with each other and with technology. Finally, it incorporates temporal characteristics to address the phasic nature of problem solving. Our goal is to motivate discussion and debate, as well as empirical examination, to help determine the viability and the uniqueness of ideas on macrocognition within the broader literature on shared cognition.

References


Macrocognition and Teams: The Emergence and Measurement of Team Knowledge

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Macrocognition is an emerging multidisciplinary area of theory development and research activity that is focused on understanding how groups, teams, and other collectives learn, develop meaningful knowledge, and apply it to resolve significant and challenging problems. The literature on team effectiveness has also exhibited considerable interest in team learning and cognitive representations of team knowledge such as team mental models, transactive memory, or knowledge stocks (Mohammed, Ferzandi, & Hamilton, 2010). However, the origins and process of team learning remains conceptually murky and there is considerable diversity in the ways that researchers have attempted to represent and measure team (and higher level) knowledge (DeChurch & Mesmer-Magnus, 2010; Klimoski & Mohammed, 1995; Rentsch, Small & Hanges, 2008; Salas & Wildman, 2009) and the processes by which it is acquired, emerges, and manifests as a team-level property. Indeed, a recent monograph concluded that although there is high interest in these phenomena and promising research progress, much more conceptual clarity is needed to enhance understanding of the nature of team learning (Kozlowski & Ilgen, 2006). The focus of our research is to advance robust theoretical representations to drive the measurement of collective knowledge constructs.

Macrocognition involves the transformation of internalized knowledge (i.e., knowledge “in the heads” of individuals) to externalized knowledge (i.e., knowledge shared “out of the head” with others) that can be used to build team knowledge. Second, the emergence of macrocognition over time, converts knowledge at the individual level to actionable knowledge at the team level of analysis. Finally, these transformative processes are not “either-or,” rather, they
are simultaneous. The challenge is measuring and tracking the transformation – internal to external – and emergence – individual level to team level – over time in ways that can be usefully applied to shape, improve, and enhance macrocognitive processes in team problem solving. The core focus of our theoretical approach is centered on understanding and measuring the processes by which macrocognition emerges from the dynamic interaction of individual-level, internal knowledge building and its transformation to team-level, externalized knowledge building in the service of collaborative problem solving.

Our approach builds on the foundation of macrocognitive theory and multilevel theory (Kozlowski & Klein, 2000). The conceptual drivers of our approach are founded on a distinction between learning processes and knowledge outcomes; the iterative process of knowledge acquisition and formation; and the origins of learning and knowledge at the psychological level (i.e., individual), but its pattern of emergence and manifestation at the collective level of the team. Team learning and team knowledge are multilevel in nature. Understanding the dynamics of emergent phenomena is at the cutting-edge of research on multilevel theory (Kozlowski, in press).

Based on this foundation, we have developed a team knowledge typology to capture different forms of knowledge emergence and have linked the typology types to corresponding techniques for measuring them. The goal of this theoretical and operational effort is to develop a robust conceptualization of team knowledge emergence as collective phenomena and a set of measurement tools to capture it that can be applied across a wide range of team task situations. Specifically, we focus on forms of emergence that represent (a) the pooling of individual and team knowledge types, (b) patterns or configurations of the knowledge pool, and (c) within and between team variance in the rates of knowledge acquisition and rates of knowledge emergence.
from the individual to the team level. The specific operationalization of the measures is
dependent on the specific task involved, but the conceptual representation is designed to
generalize across a wide range of collaborative tasks. Given a common underlying knowledge
representation, rates of knowledge acquisition and rates of emergence can be compared across
different collaborative tasks.

Our team knowledge typology is designed to capture how domain relevant knowledge is
distributed across team members and held collectively, how it is acquired over time, and how it
emerges across multiple levels -- individuals, dyads, and the team – and emerges in different
ways – composition and compilation. We believe our framework approach offers several
important contributions to theory and research in the area of team macrocognition. First, it meets
key challenges specified in the literature to distinguish process and outcome; second, it
recognizes dynamic team processes by incorporating time; and third, it examines emergence as a
multilevel phenomenon. Characteristics in team member networks and team regulation can
identify promising leverage points for improving knowledge acquisition and emergence in teams.

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Capturing the Mental Model Convergence Process through Team Communication

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Mental models are simplified representations (Johnson-Laird, 1983) that individuals use to describe, explain, and predict their surroundings (Rouse & Morris, 1986). They are comprised of content and any relationships or structure among the content (Mohammed, Klimoski, & Rentsch, 2000). In the team domain, researchers are interested in changes in team members’ mental models that occur as a result of collaborative activities. In particular, researchers have focused primarily on how similar, or shared, mental models are at two or more distinct points in time after teams have completed collaborative activities (e.g., Edwards, Day, Arthur, & Bell, 2006; Levesque, Wilson, & Wholey, 2001; Mathieu, Heffner, Goodwin, Salas, & Cannon-Bowers, 2000; Mathieu, Heffner, Goodwin, Cannon-Bowers, & Salas, 2005; McComb, 2007). This approach, however, may be overlooking the dynamics of the convergence process.

Mental model convergence is a critical process for consideration when examining teams facing operational tasks such as team decision making, shared understanding development, or intelligence analysis. As Warner and Letsky (2008) point out, such operational tasks are effectively accomplished through macrocognitive processes. Warner and Letsky identify individual mental model construction and the convergence of individual mental models as important macrocognitive processes. Moreover, macrocognitive processes, such as individual knowledge object development, may aid in the mental model convergence process. The shared mental models resulting from the mental model convergence process, in turn, may aid other macrocognitive processes like team negotiation. Thus, understanding the process of mental model convergence is paramount.

The purpose of the present study is to uncover how mental model convergence occurs during collaborative activities. To facilitate this study, we exploit the theoretical connection that has been established between communication and cognition (Kennedy & McComb, 2010).
Specifically, we examine team-level communication strings to identify patterns that inform our understanding of how (and what) mental model contents is exchanged among team members, how the mental model convergence process unfolds over time, and what impact the exchange of mental model content, and the corresponding convergence process, have on team performance.

Data was collected in a controlled laboratory setting. Undergraduate students from a research university in the Northeastern United States earned class extra credit for participation. They were assigned to teams of three and completed a scheduling task, where ten employees earning different wages were assigned to two-hour shifts during seven, twelve-hour days. The team’s goal was to minimize the schedule’s cost; teams with the lowest cost schedules were awarded $150 (odds of winning were 1:5). To encourage collaboration, each team member was given unique rules about how assignments could be made (e.g., no more than 10 hours per day; at least 30 hours per week). Team members met either face-to-face or via computer-mediation. Performance was measured as the cost of a team’s schedule.

The verbal exchanges among the face-to-face team members were transcribed and the chat logs of the computer-mediated teams were captured. Each exchange among team members was coded as to its topic and type of exchange by two researchers unfamiliar with the study hypotheses (agreement ranged from 87% to 99%). The codes were developed by subject matter experts, who reviewed the initial transcripts with a focus on activities that have been shown to enhance team collaboration such as understanding the rules governing the task and the approach the team will use (Hackman, Brousseau, & Weiss, 1976; Weingart, 1992; Woolley, 1998). A set of four primary topics was identified, namely Approach, Rules, Task, and Work Allocation. Any exchange not about one of those topics was coded as Other. On a second pass through the transcripts, the subject matter experts identified six types of exchanges occurring, namely Agree, Apply, Clarify, Information, Suggest, and Summary. These exchange types capture why teams are discussing particular topics.

Multiple analytical approaches have been used to examine the coded data and each provides insight into the exchange of mental model content and the mental model convergence
process. For example, survival analysis (a.k.a. event history analysis) was conducted to identify
the convergence points of the multiple mental models being investigated, any time-varying co-
variation among the convergence points, and any performance co-variation. The results
demonstrate a temporal pattern among mental model convergence points. Specifically, team
members converge on the rules governing in the task, then the approach they will use to
complete the task, and finally how they will allocate work among themselves. Results from
other analytical approaches such as cluster analysis and simulation will also be presented.
Implications for research and practice will be discussed.

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Improving Team Cognition and Knowledge Building: Experiment and Measurement

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Congruent knowledge structures have been shown to be related to team effectiveness and to team performance (e.g., Mathieu, Heffner, Goodwin, Salas, & Cannon-Bowers, 2000). In addition, transfer of knowledge through schema enriched communication that reveals underlying meaning and understanding is likely to yield congruent knowledge structures (Meloth & Deering, 1994) and knowledge interoperability. Modest inferential evidence supporting the functionality of prompts that elicit appropriate knowledge transfer among team members to promote the development of congruent knowledge structures had been obtained; thereby suggesting that prompting schema enriched communication may increase team effectiveness. Furthermore, it is hypothesized that when team members understand and implement schema enriched communication and collaborate to analyze meaning among team members that they will develop congruent knowledge structures (or schema congruence) (Rentsch, Delise, & Hutchison, 2008).

The purpose of the present study was to examine the effects of an intervention involving technology and training that aims to increase teams’ ability to transfer knowledge, develop knowledge interoperability, increase task schema congruence, and ultimately improve team decision making. The training and technology emphasized communication methods for sharing information and offered team members a simple information board on which they could develop a knowledge object (e.g., Carlile & Rebentisch, 2003; Nosek, 2004) to aid them in sharing information and building knowledge. The intervention was expected to enhance the decisions the team makes by increasing three important macrocognitive variables. First, it was expected to enable team members to transfer their expert knowledge to their teammates, so that the other teammates would understand the information (i.e., knowledge transfer). Second, it was expected to increase opportunities for team members to use the knowledge transferred by teammates thereby increasing the likelihood that each team member would be able to use the transferred
knowledge when determining which information to share and when developing problem solutions (i.e., knowledge interoperability). Third, it was expected to enable team members to think similarly about the task information such that they will know the same information, organize it the same way (presumably in the way that it is organized on the map), and understand similar relationships among the pieces of information. That is, they will develop schema congruence with respect to the task.

An experiment was conducted in which participants were undergraduate students from a large southeastern university who participated in three member teams. Teams were assigned to make a complex decision. A hidden profile task developed by military personnel was used that involved each team member receiving unique information associated with a specific role. All team members received general information. In order to achieve a high quality solution, teams had to integrate information from the three roles and from the general information. All teams received significant instruction regarding the task.

The experimental design involved two conditions. In addition to the task instruction, teams in the experimental condition received the training and technology intervention while teams in the control condition did not. Teams were given time to review the task material. Then, they worked on the task for an hour. After completing the task, they responded to assessments of knowledge transfer, knowledge interoperability, and task schema congruence. Background information was also collected. The task solutions were scored by two raters using an expert developed solution.

The results supported the primary hypotheses. Teams in the experimental condition had statistically significantly higher knowledge transfer, knowledge interoperability, and higher schema congruence than teams in the control condition.

The results of the present study contribute to the literature on macrocognition by demonstrating that a well-designed technology can have positive effects on team cognition, knowledge building, and team performance. Additional implications of the results will be discussed.
In addition, the study of teams presents many measurement challenges that are more complicated when examining cognitive variables (e.g., McComb, 2007). The present study involved the analysis and development of unique measures of knowledge transfer, knowledge interoperability, and task schema congruence. Due to the many challenges involved in the measurement of team cognition, a significant portion of the presentation will address the measurement issues associated with assessing the knowledge building process.

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