Literature Review of Shared Cognition

Pam Hopp
C.A.P. Smith
Stephen C. Hayne

College of Business
Colorado State University
Fort Collins, CO

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Executive Summary

Overall, it seems that situation awareness is the broadest goal state within group cognition (Figure One illustrates the current state of the literature). Within situation awareness is the concept of team or shared mental models. These mental models can be taskwork or teamwork-related, and can focus on knowledge structures or belief structures. Within shared mental models is the concept of transactive memory as well as schema similarity. However, schema similarity contributes to the development of transactive memory as well as the concept of group sensemaking. Within schema similarity are the concepts of shared internal frames of reference, schema agreement and accuracy, and cognitive consensus. Group learning consists of information sharing and the use of transactive memory, and contributes to the development of shared mental models.

Coordination can occur if there are shared interpretations of the salient features of a decision context (Richards, 2000). Preferences may be structured by shared mental models, which then lead to coordination or group decision making. This same viewpoint is shared by Tindale and Kameda (2000) who assert that shared information, mental models, or identity lead to shared preferences, which facilitates consensus.

Additionally, these various concepts can roughly be grouped according to the four stages of group development: Forming, Storming, Norming, and Performing. Within the forming stage is the initial process of the group coming together with expectations, identity, preferences, beliefs, and knowledge to share. The next stage is storming, where the members are negotiating through communication and social interactions. Here, the processes involve group learning and cognitive conflict. This stage is where role differentiation, status of team members, experience with the team, and familiarity with teammates come into play. The third stage is the norming stage, where grounding is achieved. Hopefully, the team develops a transactive memory system, schema similarity, and shared mental models that comprise team knowledge and situational awareness. The fourth stage is performing, which entails completing the task, whether it be making a decision, or efficiently performing an action.

The process is not a strictly linear process; it appears to include circular processes of feedback loops and reciprocal action. The shared mental models affect team performance through improved team processes like communication and coordination. Communication leads to grounding, yet grounding leads to more efficient communication. Situation awareness is affected by team processes and information processing functions, yet also affects these processes in return.

Mohammed and Dumville (2001) prefer to focus on team mental models and argue that the field of team mental models encompasses and can benefit from the literature on information sharing, transactive memory, group learning, and cognitive consensus. They contrast information sharing with the notion of team mental models by pointing out that information sharing is focused only on how much something is mentioned or by the decision made. Team mental model research looks at a broader picture that includes the structure of the knowledge and how it impacts processes and performance. Team mental model research can take from this field of study the factors that affect discussion of group knowledge, such as what conditions extract unshared information.

Group learning plays a role in the development, modification, and reinforcement of mental models (Mohammed & Dumville, 2001). Information sharing and development of a transactive memory system is important for group learning to occur. Group learning is viewed as a subset of team mental models, a critical factor in their development. They both emphasize the “common” part of sharing.

Information Sharing: make better decisions by pooling information; sharing distinct pieces of info whereas Mental Models deal with the structure of the info; the social interaction that leads to the development of Shared Mental Models; influences consensus and judgment through preference sharing.

Shared Beliefs: desired states, preferences, expectations; leads to motivational outcomes like cohesion, trust, morale, and better team processes like communication, consensus, coordination; predicts performance; affected by leadership

Shared Preferences: leads to consensus

Shared Identity: members of same group; leads to preference sharing and thus consensus; leads to better communication

Situation Assessment: processing info using pre-existing knowledge and predispositions; can affect and be affected by info processing

Cognitive Conflict: Thinking about multiple ideas, sharing and developing ideas; necessary process in developing shared strategic cognition; leads to shared understanding; affected by value similarity, interaction norms; help understand task expectations; positively related to organizational performance.

Group Learning: includes info sharing and transactive memory; plays role in development and reinforcement of Mental Models. Subset of Shared Mental Models; emphasizes the "common" definition of sharing.

Grounding: development of mutual understanding (knowledge, beliefs, goals, attitudes).

Cognitive Consensus: similarity regarding definition and conceptualization of issues; used in decision-making; leads to more similarity in interpreting and communicating; focuses on belief structures rather than knowledge structures (knowledge structures – info sharing, transactive memory, group learning and shared mental models); helps achieve shared interpretations; a form of schema similarity – when similar perceptions and are able to describe others' perceptions accurately.

Schema Similarity: similar or compatible knowledge structures for organizing and understanding; agreement and accuracy; leads to interpreting and communicating more similarly; aids sense-making; influences recall; can be task or teamwork; experience in teams leads to it; similar perceptions lead to it; communication and membership influences it; teamwork schema similarity leads to communication and coordination; taskwork schema similarity leads to strategy agreement.

Shared Internal Frames of Reference: part of schema similarity; able to describe others' perceptions accurately.

Schema Agreement: component of schema similarity; refers to similar content, structure; affected by team composition (demographics and experience), mode of acquiring team members, and team size; is a mediator of these factors and team effectiveness.

Collective Mind: attempted to get at with concepts of transactive memory and organizations being described as info processing structures (overlapping task knowledge); focus on method rather than content.

Group Sensemaking: elicitation and creation of group knowledge; scan and filter to create a Shared Mental Model; the forming of shared cognition

Team Knowledge: contains Team Mental Models and situational models – the team's understanding of a situation. (task, team, situation knowledge).

Team Cognition: relies on team knowledge; includes team mental models, shared frames of reference, and schema similarity.

Transactive Memory: a system where others are used as memory aids; includes a shared awareness of who knows what; pooling of unshared info; applies to the dividing aspect of shared; familiarity leads to development of it; key component to Shared Mental Models.

Shared Mental Models: organized knowledge members have in common regarding the task, each other, goals, and strategies; organize interpretations; schemas; leads to shared preferences; arise from situation assessment (interpretations) and metacognition; discussion leads to convergence of SMM; need to be distinguished: task MM vs. team MM; knowledge vs. belief structures; content, form and function. Aka shared understanding, shared knowledge; broader than decision-making; broader than transactive memory.

Shared Cognition: process and outcome

Situational Awareness: up to date view of situation; influenced by team knowledge; critical in dec-making; need to integrate and understand info through situation assessment, group theory achieved through sharing individual theories (mental models); depends on communication; SMM are a component; sharing of common perspectives; key is info sharing.

The past decade has seen a resurgence of interest in the notion of shared cognition. However, the research on group processes and group performance comes from different fields of study, such as cognitive psychology, social psychology, organizational behavior, decision science, and communication. Thus, researchers are addressing related concepts from slightly different angles, resulting in a multitude of terms. Not only does the study of this notion span various fields, but it is also complex and multidimensional. Therefore, it is evident that clarification is needed on exactly what is encompassed by the notion of shared cognition.

Cannon-Bowers and Salas (2001) clearly lay out what needs to be clarified when discussing shared cognition. First, one must define what is shared: task-specific knowledge, task-related knowledge, knowledge of teammates, or attitudes/beliefs. They suggest that each of these may be a different construct with its own unique nomological net. Additionally, there are different conceptions of what shared means. Shared can mean overlapping, similar, identical, complimentary, or distributed. Third, the 'sharedness' of cognition can be measured by assessing structure or content of the knowledge. Ensley and Pierce (2001) note that the term should refer to both group process and outcome. Therefore, we can separate related terms based on that distinction.

Additionally, another clarification needs to be made about whether the unit of analysis is a group or a team. Groups are defined by Klimoski and Mohammed (1994) as collections of individuals whose tenure together and division of responsibilities can vary considerably, whereas teams consist of differentiated and interdependent members. Often times, group and team are used interchangeable, yet it is important to draw a distinction between the two. Furthermore, shared is often used interchangeably with both group and team, and can apply to situations of just two people. Thus, the future of this field of study needs to see a careful application of terminology to ensure the use of the most appropriate and specific term.

Below is a review of recent literature on various concepts all within the realm of shared cognition. The literature is organized by the terminology used within that particular work, starting with the most broadly applied terms. Following the review is an initial attempt at cleaning up and straightening out the various usages.

The broadest terms applied to this area of inquiry are social cognition, collective cognition, group cognition, and team cognition. The use of the term 'cognition' implies a wide range of constructs, such as thinking, remembering, believing, interpreting, and decision making. Gibson (2001) conceptualizes collective cognition as four process phases. First is accumulation, where information and knowledge are acquired and interpreted, which sets individual perception. Next is interaction, where transactive memory, group structure and communication patterns affect the recall of previously shared information. The third phase is examination, where impressions and interpretations are shared, negotiated, and evaluated. Roles and status carry weight in this phase and may bias the negotiations. The fourth phase is accommodation, where perspectives are integrated, and a decision or action is completed. The movement through the phases can be reciprocal or even reversed at times. Gibson (2001) names catalysts that can serve to move groups from one phase to another, such as task uncertainty and routine, leadership and role ambiguity, conflict and consensus, and feedback and social comparison.

Ensley and Pierce (2001) examined shared cognition by breaking it down into cognitive conflict and affective conflict as the processes, and the overlap of strategic cognitive maps as the event. Cognitive conflict refers to the process of sharing and developing ideas by going back and forth with team members. Affective conflict is the emotional aspect of conflict. They tested their theoretical model of

conflict and shared strategic cognition on top management teams of new ventures. Path analysis indicated a good fit for their model. Specifically, they found a positive relationship between cognitive and affective conflict, a strong negative relationship between cohesion and affective conflict, and a negative relationship between cohesion and cognitive conflict. Shared cognition was not related to firm performance, but cognitive conflict was positively related to firm performance and affective conflict was negatively related to firm performance. This suggests that the process of developing shared strategic cognition is more important than the components of that cognition, which is in line with Klimoski and Mohammed's (1994) suggestion that the performance effects of shared cognition would be experienced through processes that lead to the creation of it.

Tindale and Kameda (2000) use the term social sharedness to refer to sharing of preferences, information, mental models, identity, and metacognitions. The sharing of metacognitions refers to sharing systems like transactive memory and shared mental models, and reflects the idea that being aware that models are shared can aid group performance.

Information sharing comes from the idea that groups can make better decisions by pooling information. Research in this area has revolved around the biased sampling model of group discussion, which claims that discussion tends to be biased towards shared information (Mohammed & Dumville, 2001). Many studies have used hidden profile tasks to show that face-to-face groups are better at discussing widely shared information rather than pooling diverse information.

Group sensemaking can be seen as a process by which people process information in order to create shared mental models. Nosek and McNeese (1997) provide a review of this process and discuss potential issues for augmenting group sensemaking with technology. This concept focuses on situations that are constantly evolving and ill-defined, which leads to multiple and conflicting interpretations. Thus, the group knowledge must not only be elicited and created, but also stored and retrieved in a meaningful way. Therefore, it appears that there is a relationship between the elicitation/creation of group knowledge and transactive memory.

Another broad concept common in this literature is situation awareness. Situation awareness is a critical state in decision-making that is dynamic and thus, continuously modified/updated over time (Salas, Prince, Baker, & Shrestha, 1995). The process of achieving situation awareness consists of team members testing out their theories (mental models) of the situation by collecting and sharing information and then negotiating to endorse one theory of the situation to use as a common frame of reference for the task. The amount and quality of communication is key to this process. Specifically, communication leads to similar expectations, which allows for similar perceptions of environmental information. One viewpoint emphasizes the group sharing a common perspective, which implies identical information sharing, whereas another viewpoint suggests that situation awareness is maximized by each member monitoring different segments of information and pooling varying perspectives. Wellens (1993) is a proponent of this latter viewpoint, but says that the key is having a balance between overlap and separation.

Kraut, Fussell, and Siegel (in press) investigate the use of visual information in a collaborative physical task. They point out that it is important for group members to have task and situation awareness, meaning an up-to-date view of the situation and the state of the task. Grounding occurs when there is development of mutual understanding regarding knowledge, beliefs, goals, or attitudes. They first used a between-subjects comparison of 60 undergrads in a bicycle repair task. The research design was an incomplete factorial comparing solo performance to collaborative performance and collaborative groups in different audio/video conditions where guidance was offered. They found that

group work was in fact better than solo work, and that when the participants and experts were sharing a view, the experts could be less explicit and their communication was more efficient and helpful. Next, they conducted a within-subjects design, comparing three guidance conditions with either an expert or novice helper. Again, an incomplete factorial design was used on 25 undergraduate and graduate students. They found that expertise of the helper did not matter. The side-by-side condition had more effective dialog and performed faster. The groups having audio/video versus just audio did not differ in performance. The interpretation of these findings are that the helper could perceive readiness to receive help and could infer what kind of help was needed before the participant had to ask due to task and situation awareness.

Team knowledge is the preferred term by Cooke, Salas, Cannon-Bowers, and Stout (2000) because it restricts the unit to teams, does not imply the aspect of sharing that refers to holding in common, and restricts it to knowledge instead of everything that falls under the umbrella of cognition. Within team knowledge are team mental models (a collective knowledge base of task and team-relevant information) and situational models (which make use of team mental models, but also include situational characteristics and develop while engaged in the task).

Schema similarity is the commonality among individuals' schemas, or knowledge structures (Rentsch & Hall, 1994). If schema similarity is achieved, team members are more likely to attend to, interpret, and communicate about the environment more similarly. Schemas seem to be regarded as much like mental models – they organize information and facilitate understanding to aid sensemaking. They influence perception and recall. The content can be task-related or team-related. Taskwork schema similarity leads to improved task performance, while teamwork schema similarity leads to improved team processes. Rentsch and Hall (1994) argue for the term schema similarity because they are focused on similarity of knowledge and understanding, rather than complete agreement on identical knowledge. Because schemas are based on the individual's own experience, they are never going to be exactly the same. A form of schema similarity is consensus, which occurs when there is high perceptual agreement and accuracy. They present a model of schema similarity with antecedents being team membership influences (demography and person-environment fit) and team-related schema communications.

Rentsch and Klimoski (2001) also discuss possible antecedents of team member schema agreement, which are then postulated to have indirect effects on team effectiveness. They suggest that team composition will affect schema agreement, in that the more similar the demography and the more team experience team members have, the more communication, which leads to greater cohesion and consensus. Additionally, the mode of acquisition of members may be critical, in that naturally occurring groups tend to be more homogenous, which would result in similar thinking. Groups that were recruited would be more homogenous since principles of attraction and selection would be in effect. Finally, team size would affect schema agreement in that size dictates interaction opportunity. Rentsch and Klimoski (2001) tested this notion with 315 people who were members of 41 work teams. Teams ranged in size from 2-27 people. All types of teams were included. They used multidimensional scaling analysis on paired comparison data and applied an individual differences multidimensional scaling model. They found that education, organizational level, and high team experience correlated with schema agreement. They also found that recruited members had higher schema agreement. Team size was negatively associated with schema agreement. Schema agreement correlated with team effectiveness as well. However, it should be noted that team effectiveness was measured by self-report scales. The authors point out that the next step is to consider whether team size and experience are directly related to schema agreement or are mediated by team member interaction and communication. Interestingly, exploratory analyses revealed that advice teams had

significantly higher means for overall effectiveness and schema agreement, indicating that team type may matter.

Cognitive consensus refers to the reconciliation of diverse issues and backgrounds to arrive at a similarity among group members in understanding and conceptualizing issues. Groups that have more cognitive consensus are likely to attend to, interpret, and communicate about issues more similarly (Mohammed & Dumville, 2001). An extreme consensus or extreme diversity will negatively influence decision making. A balance is needed based on environment, interdependence of members, task, and stage of decision-making. Cognitive consensus literature focuses on belief structures rather than knowledge structures and deals with interpretation and opinions rather than raw information.

A significant proportion of research focuses on shared mental models, or team mental models. Rentsch and Klimoski (2001) also noted that many of the terms that fall under the category of team cognition have to do with shared mental representations regarding team-related information. Klimoski and Mohammed (1994) prefer the term team mental models because it refers to team members as a collectivity and excludes dyads, while also allowing for multiple levels of shared knowledge.

Cannon-Bowers, Salas, and Converse (1993) are the most widely cited source on the topic of shared mental models. They describe how the idea of shared mental models provides insight into team decision making the teamwork in general. They discuss four types of mental models that may be useful for effective team performance. The equipment model refers to content on functioning of tools, operating procedures and equipment limitations. The task model contains information about task procedures, strategies, and likely scenarios. The team interaction model deals with roles and responsibilities, information sources, patterns of interaction and channels of communication. Finally, the team model refers to knowledge about teammates' knowledge, skills, abilities, preferences and tendencies. They also discuss the balance necessary for the overlap in shared mental models, in that too much can lead to groupthink, which is what happens when the desire for unanimity overrides realistic appraisal. They also introduce the possibility of training mental models in teams.

Klimoski and Mohammed (1994) also provide a thorough review of team mental models, discussing the varying content, form, and function as well as antecedents and consequences. They claim that content can be the about the tools/technology, the task, problems facing the team, KSAs for team functioning, and representations of environmental events and projected future states. Form refers to the type of knowledge, which can be declarative or procedural. The function of team mental models can be to describe, explain, or predict, to aid sensemaking, or to choose a course of action. They suggest that antecedents are formal training, membership change, communication, cohesion, and social interactions such as information sharing, participation, and negotiation.

The relative importance of team mental models is dependent upon the amount communication that is possible (Mathieu, Heffner, Goodwin, Salas, & Cannon-Bowers, 2000). For example, when there a heavy workload and time pressure, communication is difficult and thus, team mental models may serve a greater function than when communication is easy.

Mohammed and Dumville (2001) discuss team mental models in a team knowledge framework. They suggest four categories of determinants: environmental, organizational, team, and individual. There has been some research on what fosters the development of team mental model convergence, such as planning, self-correction training and computer-based training. Stout, Cannon-Bowers, Salas, and Milanovich (1999) investigated 40 male college students in a helicopter surveillance/defense mission simulation. They used Pathfinder to measure shared mental models, counted errors, and monitored

communications. Teams either planned well or had poor planning before completing the simulation. They found that planning led to more efficient communication, better performance, and the development of greater convergence in shared mental models.

Mathieu, Heffner, Goodwin, Salas, and Cannon-Bowers (2000) examined the effects of shared mental models on team process and team performance. They studied 56 pairs of undergraduate students performing a flight simulation. They assessed teammates' mental models using ratings and analyzed mental model convergence by a network-analysis program. They found the process to improve from Time 1 to Time 2, but not any convergence of mental models over time. They confirmed the distinction between taskwork mental models and teamwork mental models and found that the task mental models had an indirect effect on team performance through team processes. They found that the impact of team mental model convergence on team performance. was fully mediated by team process. However, the results of this study may apply only to new teams of novices in low-fidelity situations, with no expectations of future interaction.

Levesque, Wilson, and Wholey (2001) also investigated whether shared mental models converge more in time. The Mathieu et al. (2000) study did not find more convergence over time, but they had looked at undergraduate dyads working together in a single session of 2-3 hours. To improve on this design, they looked at 62 software development project teams, consisting of 4 to 7 undergraduates. The teams worked together for 3.5 months and filled out online surveys on team process, expertise, role differentiation, and team interaction. A repeated measures ANOVA found that the similarity of mental models actually decreased over time. Structural equations modeling found that high role differentiation at Time 1 led to less interaction at Time 2, which led to less mental model convergence at Time 3. As roles become increasingly specialized, there is less interaction and communication, which decreases similarity of shared mental models. Many temporary, task-focused teams have highly specialized roles. However, this finding may not apply to more permanent teams with longer histories of working together. Also, it should be remembered that the divergence of knowledge may be functional in some situations.

Espinosa (in progress) is investigating the effects of shared mental models on the coordination of software developers. Specifically, he is looking at the potential effects of distance on coordination, hypothesizing that it is mediated by team communication and shared mental models.

Cannon-Bowers, Tannenbaum, Salas, and Volpe (1995) discuss a specific type of team knowledge that is crucial to effective team function, called interpositional knowledge. This refers to being familiar with the role responsibilities of other members. Volpe, Cannon-Bowers, Salas, and Spector (1996) examined cross-training as a way of providing team members with interpositional knowledge. They conducted a 2 x 2 factorial between-subjects design where 80 male college students participated in a flight simulation. They found that cross-training resulted in more effective teamwork, more efficient communication, and better performance than those who had not been trained in their teammates' responsibilities.

Smith-Jentsch, Campbell, Milanovich, and Reynolds (2001) examined teamwork mental models. This refers to the understanding of the components of teamwork that are critical for effective performance as well as the relationships between those components. They proposed that people with greater experience working with teams have more knowledge and a better understanding of what makes effective teamwork. They assessed 176 navy personnel with a card sorting task to assess their mental models of teamwork. They found a significant correlation between similarity to an expert model of teamwork (accuracy) and navy rank. Additionally, they found that there was greater similarity of

mental models within high ranking groups and within groups where people had been in the service for a long time. Next, they designed a training program to try to teach people to have mental models of teamwork more similar to the expert model. They assessed 42 civilian government employees that had participated in a computer-based training program. Their 3 (condition) X 2 (repeated measures) mixed model ANOVA indicated that accuracy improved after training as did similarity to each other's models.

Cannon and Edmondson (2001) consider another example of a shared mental model: shared beliefs about failure. They argue that shared beliefs can influence one's ability to respond constructively to failure. They examined 53 work groups with a survey and collected supervisor ratings of performance and group behavior. A one-way ANOVA indicated that beliefs about failure were in fact, shared within and vary between groups. Regression analyses indicated that leadership coaching and direction significantly predicted shared beliefs. The beliefs about failure also significantly predicted group performance.

Transactive memory refers to a system where one uses others as memory aids to supplement limited memory. By specializing knowledge in a group and having a shared awareness of who knows what information, cognitive load is reduced, greater access to expertise can be achieved, and there is less redundancy of effort. Wegner, Erber, and Raymond (1991) demonstrated the existence of transactive memory systems in dating college couples on a recall task. Only recently has this term been applied to work groups. Addtionally, most research has been conducted using tasks which are unlike those faced by workers. Moreland (1999) suggests that development of a transactive memory system is probably slow and gradual. Research is currently exploring the idea that familiarity may aid the development of transactive memory. If so, it would follow that groups and teams would want to minimize turnover, improve the group socialization process, and be trained together. Moreland (1999) discusses three experiments conducted by himself and his colleagues that showed transactive memory systems do improve performance of a radio assembly task and that training people together allows for the development of such a system. Mohammed and Dumville (2001) point out that developing a transactive memory system reduces the rehashing of shared information and allows for the pooling of unshared information.

Moreland and Myaskovsky (2000) investigated the possibility of whether performance benefits from being trained together were due to transactive memory or just improved communication. They found that communication was not responsible for improved performance. Specifically, groups that had handouts of each other's skills and did not communicate with each other performed as well as the members of the group who were trained together.

Weick and Roberts (1993) suggest that the concept of transactive memory contributes to the idea of group mind or collective mind. Transactive memory suggests that distributed knowledge is an important concept in addition to within group similarity, and that communication is key.

The measurement of these constructs is a considerable problem, being that the constructs themselves are ill-defined. Cooke, Salas, Cannon-Bowers, and Stout (2000) discuss issues relevant to measuring team knowledge. Addtionally, Mohammed, Klimoski, and Rentsch (2000) describe and evaluate four techniques that are used to measure shared models of cognitive structure. They discuss Pathfinder, multidimensional scaling, interactively elicited cognitive mapping, and text-based cognitive mapping. They provide a list of questions that can be used to evaluate any technique. They note that if cognitive process is the target, verbal protocol analysis is the most commonly used technique. The most common methods for examining the content of team mental models have been similarity ratings and

Likert-scale questionnaires. They suggest that multiple measures are necessary to adequately study team mental models.

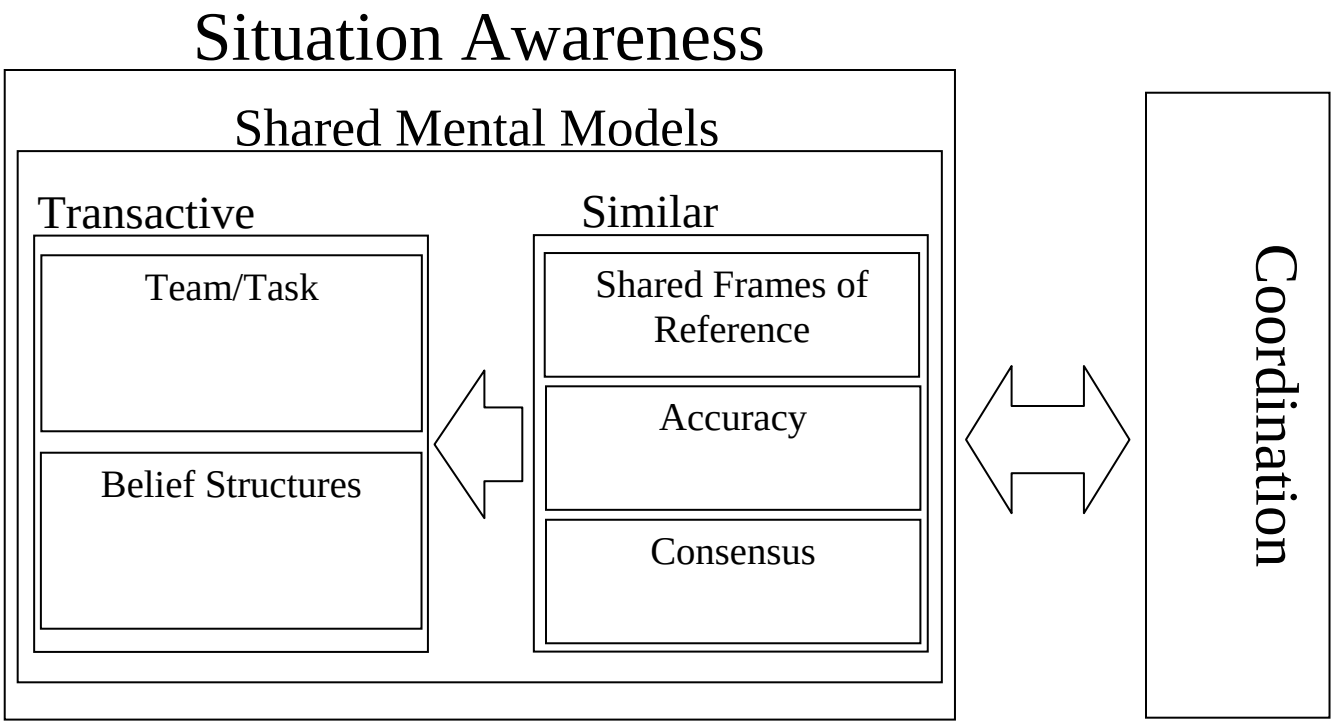

Figure One: Current State of Shared Cognition Literature

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