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The Cognitive Underpinnings of Effective Teamwork: A Meta-Analysis

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Major theories of team effectiveness position emergent collective cognitive processes as central drivers of team performance. We meta-analytically cumulated 231 correlations culled from 65 independent studies of team cognition and its relations to teamwork processes, motivational states, and performance outcomes. We examined both broad relationships among cognition, behavior, motivation, and performance, as well as 3 underpinnings of team cognition as potential moderators of these relationships. Findings reveal there is indeed a cognitive foundation to teamwork; team cognition has strong positive relationships to team behavioral process, motivational states, and team performance. Meta-analytic regressions further indicate that team cognition explains significant incremental variance in team performance after the effects of behavioral and motivational dynamics have been controlled. The nature of emergence, form of cognition, and content of cognition moderate relationships among cognition, process, and performance, as do task interdependence and team type. Taken together, these findings not only cumulate extant research on team cognition but also provide a new interpretation of the impact of underlying dimensions of cognition as a way to frame and extend future research.

Keywords: team cognition, mental model, transactive memory, shared cognition, meta-analysis

> Winning is about having the whole team on the same page.
> —Bill Walton

> If everyone is thinking alike, then somebody isn't thinking.
> —George Patton

The reality for many organizations today is that work has become complex enough to require the use of teams at all hierarchical levels. Organizational success hinges upon the ability of teams to collaborate effectively and work efficiently toward solving complex problems. Therefore, understanding how information is collectively processed has become critical (Hinsz, Tindale, & Vollrath, 1997). As the opening quotes illustrate, there are commonly held beliefs that effective teamwork requires members to hold similar cognitive structures, and also those suggesting distinctive knowledge configurations are key. Consistent with these commonsense views of cognition, researchers have invoked constructs such as shared mental models (Cannon-Bowers, Salas, & Converse, 1993) and transactive memory systems (Moreland, Argote, & Krishnan, 1996) to examine the role of emergent collective cognition in team functioning. Since the early 1990s, investigators have attempted to uncover the importance of collective cognition using a variety of conceptualizations, empirical methods, and research strategies. Despite this substantial progress, the substantive and methodological differences across studies present a challenge for discerning a clear pattern of relationships in a way that enables research in this area to move forward (Cannon-Bowers & Salas, 2001).

In the current study, we used meta-analysis to empirically organize prior work on the basis of underlying dimensions of cognition, team features, and study characteristics. In doing so, we have integrated previously disjointed areas of research on collective cognition (e.g., shared mental models and transactive memory), provided an aggregate interpretation of past work in terms of the impact of core dimensions, and offered a theoretically driven redirection intended to hasten creation of future knowledge.

Our overarching research questions were threefold. First, *how important is cognition to team performance?* Major theoretical reviews of teams converge in specifying three types of mediators important to team functioning: behavioral process, motivational–affective states, and cognitive emergent states (Ilgen, Hollenbeck, Johnson, & Jundt, 2005; Kozlowski & Bell, 2003; Kozlowski & Ilgen, 2006; Mathieu, Maynard, Rapp, & Gilson, 2008); we not only estimated the impact of cognition but also examined the relative contribution of the "big three" drivers of team performance. Second, *which aspects of cognition are most pivotal to team process and performance?* The existing knowledge base on team cognition is composed of an eclectic group of studies with different conceptual and operational definitions of cognition; we examined the extent to which particular aspects of cognition (i.e., varying in nature of emergence, form of cognition, and content) affect team process and performance. Third, *which types of teams most benefit from team cognition?* Teams vary greatly in terms of interdependencies and task types, and we investigated differences

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in the impact of cognition across different types of teams. Figure 1 summarizes the relationships examined in the current study.

Perspectives on Team Cognition

Team effectiveness is largely a function of interaction processes and emergent states (Kozlowski & Ilgen, 2006; Marks, Mathieu, & Zaccaro, 2001); both are considered mechanisms linking inputs such as leadership, training, and composition to valued team outcomes (Mathieu et al., 2008). Emergent states are cognitive, motivational, and affective properties of teams. Whereas team process describes the nature of team member interaction (Marks et al., 2001), emergent states describe conditions that dynamically enable and underlie effective teamwork. Team cognition is an emergent state that refers to the manner in which knowledge important to team functioning is mentally organized, represented, and distributed within the team and allows team members to anticipate and execute actions (Kozlowski & Ilgen, 2006). Research on team cognition has generally explored two cognitive constructs as they apply to teams: mental models and transactive memory systems. The major distinction between the two constructs centers on the importance ascribed to knowledge that is in some way held in common by team members (shared mental model) versus knowledge that is distributed among team members (transactive memory; Kozlowski & Ilgen, 2006).

Team Mental Models

Prior to their introduction into team effectiveness research, mental models had been explored extensively in human factors psychology to explain human–system interactions (Rouse & Morris, 1985). Mental models are defined as "mechanisms whereby humans are able to generate descriptions of system purpose and form, explanations of system functioning and observed system states, and predictions of future system states" (Rouse & Morris, 1985, p. 351). Cannon-Bowers and Salas (1990) first invoked the notion of team mental models on the basis of their observations of expert teams: "When we observe expert, high performance teams in action, it is clear they can often coordinate their behavior without the need to communicate" (Cannon-Bowers & Salas, 2001, p. 196). In this way, team cognition has been proffered as an explanatory mechanism. Expert teams develop compatibility in members' cognitive understanding of key elements of their performance environment and, by doing so, are able to operate efficiently, without the need for overt communication, and hence perform tasks more effectively (Cannon-Bowers et al., 1993; Cooke, Gorman, Duran, & Taylor, 2007).

Team Transactive Memory

Around the same time research on team mental models began in earnest, Moreland and colleagues (Liang, Moreland, & Argote, 1995; Moreland, 1999; Moreland et al., 1996) adapted Wegner's (1987) notion of transactive memory as a cognitive explanation for the observation that teams trained together outperformed teams trained as individuals. Transactive memory systems are a form of cognitive architecture that encompasses both the knowledge uniquely held by particular group members with a collective awareness of who knows what.

Team transactive memory has been examined in both laboratory and field settings and has been linked to both team performance and satisfaction (cf., Austin, 2003; Hollingshead, 1998; Lewis, 2004; Liang et al., 1995; Pearsall & Ellis, 2006). Important aspects of transactive memory include the degree of specialization or differentiation of knowledge within the team, the coordination

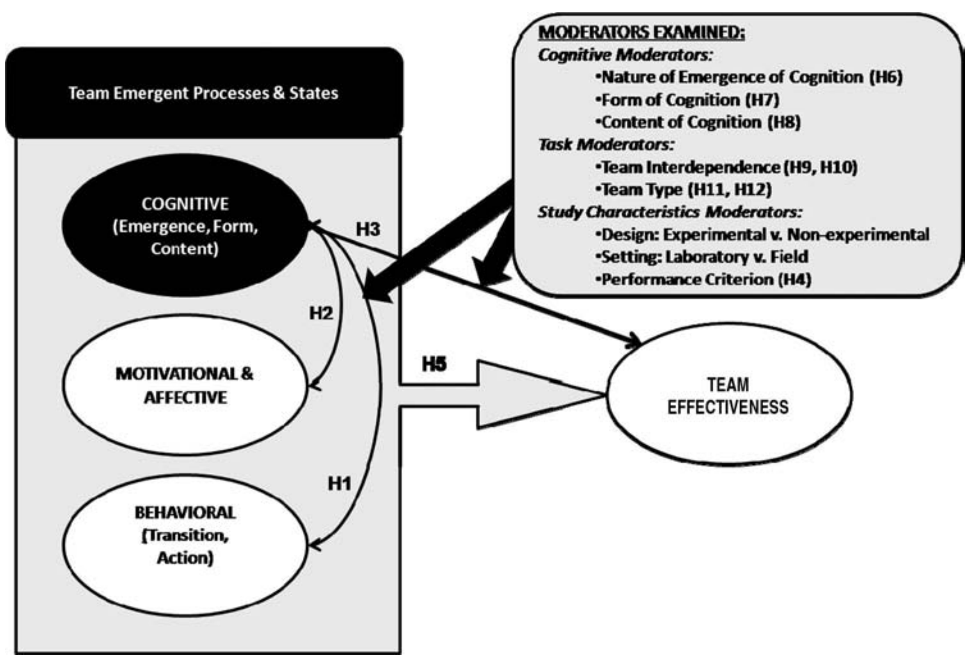

Figure 1. Summary of relationships involving cognition and team functioning examined in the current meta-analysis.

ability afforded to teams, and the credibility or beliefs about the reliability of one another's knowledge (Austin, 2003; Lewis, 2003).

An Integrative View of Team Cognition

Although research conducted within both the transactive memory and shared mental model traditions has shown the importance of collective cognition, these research streams have progressed largely in silos.[1] In the sections that follow, we integrate past research on shared mental models, transactive memory, and other cognitive relatives (e.g., strategic consensus, collective mind, expertise specialization) using three underpinnings of collective cognition: the nature of emergence, form of cognition, and content of cognition. Our aim was to isolate the impact of each form of collective cognition on team process and performance and to provide an integrative perspective that would enable a more coherent literature on team cognition going forward. Before considering the moderating impact of these cognitive underpinnings, we elaborate on the direct relationships linking team cognition to important aspects of team functioning.

Team Cognition and Team Effectiveness

The first question is: How important is cognition to team effectiveness? Cannon-Bowers and Salas (2001) summarized three types of outcomes that team cognition has been thought to impact: (a) behavioral process, (b) motivational states, and (c) team performance. Team behavioral processes refer to "members' interdependent acts that convert inputs to outcomes through cognitive, verbal, and behavioral activities directed toward organizing task work to achieve collective goals" (Marks et al., 2001, p. 357). Examples of team process include planning, goal setting, coordinating, and team-backup behavior. Motivational states describe team members' collective reactions to interpersonal aspects of team functioning (e.g., cohesion, collective efficacy). Team performance is an objective or subjective judgment of how well a team meets valued objectives (Salas, Rosen, Burke, & Goodwin, 2009).

A recent comprehensive review of team effectiveness research suggests a strong reciprocal linkage between team cognition and behavioral process: "The repeated interactions among individuals that constitute processes tend to regularize, such that shared structures and emergent states crystallize and then serve to guide subsequent process interactions. Process begets structure, which in turn guides process" (Kozlowski & Ilgen, 2006, p. 81). This reciprocal relation is evidenced by empirical findings that team processes relate to shared team cognition (Stout, Cannon-Bowers, Salas, & Milanovich, 1999) and that shared team cognition relates positively to team process (Mathieu, Heffner, Goodwin, Salas, & Cannon-Bowers, 2000). In essence, team cognition serves as a structure that guides team members' behaviors. The reciprocal is also true: Through the course of interaction, team members entrain their behavior to one another, giving rise to collective cognitive structures. Therefore, we expect:

> *Hypothesis 1:* Team cognition will be positively related to behavioral team process.

Team cognition is also thought to be reciprocally related to team motivational–affective states (Cannon-Bowers & Salas, 2001), including cohesion and collective efficacy. Theoretical models of team effectiveness position both motivation and cognition as important emergent states that crystallize through repeated interaction, shape behavior, and sustain both performance and viability. While conceptually distinct, cognition and motivation ought to develop in tandem. Members of efficacious and cohesive teams would value and attend to one another's informational inputs more so than members of less efficacious or cohesive teams; such behavior would in turn promote the emergence of more functional team cognition. Similarly, teams with more functional cognition would perceive their teams as having greater task work capacity than would their less cognitively functional counterparts, thereby promoting cohesion and collective efficacy. Therefore, we expect:

> *Hypothesis 2:* Team cognition will be positively related to team motivational states.

Most important, team cognition is thought to impact team performance (Kang, Yang, & Rowley, 2006; Marks, Sabella, Burke, & Zaccaro, 2002; Mathieu et al., 2000; Webber, Chen, Payne, Marsh, & Zaccaro, 2000). Shared mental models provide a common framework for performance of individual task duties in a way that is ultimately compatible and serves as a valuable lens for interpreting changes in the performance environment (Marks, Zaccaro, & Mathieu, 2000). Similarly, transactive memory has been linked to team performance (Austin, 2003; Hollingshead, 1998; Lewis, 2004; Moreland & Myakovsky, 2000; Pearsall & Ellis, 2006). Social and organizational scientists have reasoned that over the course of interaction, team members develop a collective system for encoding, storing, and retrieving information (Hollingshead, 1998; Liang et al., 1995; Moreland & Myaskovsky, 2000), which then enables teams to efficiently use information and allocate tasks (Austin, 2003).

> *Hypothesis 3:* Team cognition will be positively related to team performance.

Performance Criterion as a Moderator

In considerations of the relation of team cognition to team performance, the operationalization of the performance criterion is a likely moderator. Team cognition has been examined in relation to both objective (e.g., Marks et al., 2002; Smith-Jentsch, Mathieu, & Kraiger, 2005) and subjective (e.g., Lewis, 2003; Lim & Klein, 2006) performance measures. Team cognition ought to show stronger effects on subjective than on objective measures for three reasons. First, subjective measures typically contain more performance-irrelevant variance (e.g., rater bias) than do objective measures. Second, performance raters may in part attend to indicators of cognition when making performance ratings (e.g., halo). And third, subjective indicators are typically more proximal to the behavior of the team and are therefore more controllable than are hard, objective indices; conversely, objective indicators are subject to greater influence by factors outside the direct control of the team than are subjective indicators (e.g., economic climate). Therefore, we expect:

[1] Only four of the 65 studies included in this database examined both transactive memory and shared mental models.

> *Hypothesis 4:* Performance criterion type will moderate the relationship between team cognition and team performance, such that team cognition will be more strongly related to subjective performance indicators than to objective indicators.

Triad of Emergent Processes & States

Major reviews of team effectiveness converge in representing a set of mediators that explain the core functioning of teams, linking inputs such as composition and levers such as leadership and training to team effectiveness (Ilgen et al., 2005; Kozlowski & Bell, 2003; Mathieu et al, 2008). The set contains a mix of processes and emergent states. Processes are typically classified using the Marks et al. (2001) integration, in which the behavioral synchronization of team members' efforts is described. This research was recently meta-analyzed by LePine, Piccolo, Jackson, Mathieu, and Saul (2008), and findings showed team behavioral processes have a moderate effect on team performance. The second major category of performance drivers are affective and motivational emergent states, including team cohesion and collective efficacy. Numerous meta-analyses have been conducted on these performance drivers, and they show similar moderate effects on performance (Beal, Cohen, Burke, & McLendon, 2003; Gully, Devine, & Whitney, 1995; Gully, Incalcaterra, Joshi, & Beaubien, 2002; Mullen & Copper, 1994).

Cognition is conceptually distinct from both behavioral process and motivational states. Behavioral process describes synchronization of joint actions, information sharing, and backup behavior—all of which impact team performance by aligning the unique contributions of team members (Marks et al., 2001; Salas et al., 2009). Motivational states describe emotional attraction to the team, beliefs about its capability to perform tasks, and the like. On the other hand, cognition describes the knowledge architecture of the team. Because cognition is conceptualized as a distinct, reciprocally related aspect of teamwork, we expect that cognition will evidence a unique contribution to team performance.

> *Hypothesis 5:* Emergent team cognition will explain unique variance in team performance after the effects of behavioral process and motivational states have been controlled.

Cognitive Moderators: Emergence, Form, and Content

While empirical research has begun to accumulate on the effects of transactive memory and various aspects of mental models, the relative importance of each conceptualization of cognition remains unclear. Thus, the second question is: Which aspects of cognition are most pivotal to team process and performance?

Nature of Emergence

Team cognition is a bottom–up emergent construct, originating in the cognition of individuals; the cognition of individuals present within a team manifests as a pattern, which ultimately constitutes the team cognition construct (Kozlowski & Klein, 2000). Kozlowski and Klein delineated a core dimension describing different forms of emergence ranging from compositional emergence (in which the individual-level building blocks are similar in form and function to their manifestation at the team level) to compilational emergence (whereby the construct manifested at the team level is different in form to the individual-level counterpart). The shared mental model literature is largely representative of compositional emergence. Both the similarity and accuracy of mental models are, in essence, examinations of the extent to which the cognitive content of individuals is the same; an index of the degree of similarity represents the team-level construct. Cognitive similarity–congruence refers to the extent to which teammates' cognitive structures match one another, whereas cognitive accuracy refers to the extent to which teammates' mental models match "correct" or target cognitive structures (Lim & Klein, 2006; Rentsch & Hall, 1994).

The transactive memory tradition is more consistent with compilational emergence, whereas a team-level memory system emerges that is composed of differentiated individual knowledge sets coupled with an awareness of who knows what. Rentsch, Small, and Hanges (2008) discussed this view of cognition as representing complementarity—the extent to which team members' cognitions are "complementary in structure and/or content fitting together like puzzle pieces" (Rentsch et al., 2008, p. 145). Transactive memory research explores the extent to which (a) the team's knowledge is distributed and retrieved in a coordinated fashion, (b) team members rely upon knowledge possessed by their teammates, and (c) team members' knowledge sets are differentiated within the team (Austin, 2003; Lewis, 2003).

Underlying differences in the nature of emergence ought to at least partly explain discrepant findings across studies. More specifically, cognition that emerges through compilation reflects a team-level construct that is nonisomorphic to the individual-level elemental cognitive content. Through this form of emergence, there is new substance arising from the *patterning* of knowledge which ought to better predict team-level outcomes than would be possible with compositionally emergent cognition. In essence, compilationally emergent cognition represents a greater degree of synergy, capturing new construct meaning at the team level than what can be observed solely based on its individual-level components (i.e., discontinuity). On the other hand, compositionally emergent cognition more closely resembles the individual-level cognitions on which the construct is comprised (i.e., isomorphic). Owing to differences in the degree of isomorphism versus the degree of discontinuity reflected by compilational and compositional emergence, we propose:

> *Hypothesis 6:* The nature of emergence will moderate the relationships between team cognition and team process (H6a) and between team cognition and team performance (H6b) such that relationships will be stronger for cognition arising through compilation than for cognition arising through composition.

Form of Cognition

A second underpinning of collective cognition is the form of cognition, which refers to the particular aspect of meaning that is investigated (or, more concretely, the way cognition is elicited and represented). Research on team cognition has focused on three different forms of cognition: (a) perceptual, (b) structured, and (c) interpretive, though most extant research fits within the first two categories (Rentsch et al., 2008). Perceptual cognition models team members' beliefs, attitudes, values, perceptions, prototypes, and expectations, but "does not provide a deep understanding of causal, relational, or explanatory links" (Rentsch et al., 2008, p. 146). Conversely, structured cognition attempts to capture the organization of a team's knowledge without modeling the content or amount of a given type of perception. Structured cognition focuses on the pattern of knowledge arrangement and then models the collection of knowledge patterns within a team. Often, structured cognition is assessed with Pathfinder, multidimensional scaling, or pairwise comparisons, whereas perceptual cognition is assessed with rating scales.

As both team behavioral process and team performance reflect a patterning or organization of effort, structured cognition is better aligned with process and performance than is perceptual cognition. Thus, we would expect to see stronger cognition-process and cognition-performance relationships when cognition has modeled structure. This logic is also consistent with the compatibility principle (e.g., Ajzen, 1988), which explains the strength of observed relationships between job attitudes and job behavior (Harrison, Newman, & Roth, 2006; Judge, Thoreson, Bono, & Patton, 2001), such that the more compatible and similar the operationalization or conceptualization of two constructs, the more strongly they relate. Because of the alignment in complexity of cognition–behavior and cognition–performance constructs, we expect:

> *Hypothesis 7:* Form of cognition will moderate the relationships between team cognition and team process (H7a) and between team cognition and team performance (H7b) such that structured cognition will show stronger effects on process and performance than will perceptual cognition.

Content of Cognition

The third underpinning of collective cognition is the content of knowledge represented. Although four content domains were originally proposed—technology or equipment, job or task, team interaction, and team (Cannon-Bowers et al., 1993)—Mathieu and colleagues (2000) suggested that these represent two overarching dimensions of cognition: (a) task-related cognition and (b) team-related cognition. These two facets have been explored in many subsequent investigations of mental models (Kang et al., 2006; Lim & Klein, 2006; Smith-Jentsch et al., 2005). *Task-related models* refer to features of the team's job, major task duties, equipment, and resources typically derived from a detailed task analysis. Task-related models are believed to enable effective teamwork; compatibility in cognitions enables members to interpret information similarly and anticipate the behaviors needed of them in response to that information (Klimoski & Mohammed, 1994). *Team-related models* include features of how team members interact and are interdependent with one another. Marks et al. (2000) used a team interaction mental model to represent team members' understanding of how they ought to sequence their tasks while performing a tank battle simulation task. Smith-Jentsch et al. (2005) examined a team mental model by capturing members' mental representations of positional-goal interdependencies. Team-related models are thought to underscore effective interactions among team members.

Although there are strong conceptual arguments and a recent stream of empirical support for the idea that both team and task mental models impact team process, performance, and motivation, Cannon-Bowers and Salas (2001) suggested that the particular manner in which shared cognition is conceptualized will affect what it impacts. In particular, task mental models are expected to drive task performance, whereas team mental models ought to improve team process. Therefore, we propose:

> *Hypothesis 8:* Content of cognition will moderate the relationships between team cognition and team process (H8a) and between team cognition and team performance (H8b) such that team-based cognition will be more predictive of team process than task-based cognition (H8a) and such that task-based cognition will be more predictive of team performance than team-oriented cognition (H8b).

Task Moderators

The third important question is: What types of teams most benefit from team cognition? The types of organizational tasks teams perform vary greatly, ranging from medical procedures to military missions to new product design teams. These tasks differ in meaningful ways in terms of the reason that the team exists, the type of goal that the team is tasked with, and the nature of member interaction required. We explored team interdependence and team task type as moderators in order to compare the relative predictive utility of cognition to team functioning.

Team Interdependence

Interdependence is a defining characteristic of teams, referring to the "extent to which team members cooperate and work interactively to complete tasks" (Stewart & Barrick, 2000, p. 137). Team interdependence increases as members are mutually reliant on one another for *resources* (e.g., equipment, information required for collective goal accomplishment; Wageman, 1995), *interaction* during the accomplishment of collective work (Van de Ven & Ferry, 1980), and desired *outcomes* (Alper, Tjosvold, & Law, 1998; Guzzo & Shea, 1992; Wageman, 1995).

Interdependence has been found to strengthen relations between team performance and team cohesion (Gully et al., 1995), collective efficacy (Gully et al., 2002), and team behavioral process (LePine et al., 2008). Synergistic emergent states and processes become more pivotal to team functioning when team members are mutually reliant upon one other.

Kozlowski and Ilgen (2006) specifically proposed team interdependence as an important moderator of cognition–team performance relationships, suggesting underlying distinctions in conceptualizations of cognition would render particular aspects differentially important, depending on task requirements. High interdependence ought to necessitate more distributed, compilational cognition, whereas lower interdependence would require the knowledge-sharing characteristic of compositional forms of cognition. Therefore, we expect:

> *Hypothesis 9:* Team interdependence will moderate the relationships between compositional cognition and team process (H9a) and team performance (H9b) such that compositional cognition will be a stronger predictor of team process and performance under lower, as compared with higher, team interdependence.

Hypothesis 10: Team interdependence will moderate the relationships between compilational cognition and team process (H10a) and team performance (H10b) such that compilational cognition will be a stronger predictor of team process and performance under higher, as compared with lower, team interdependence.

Team Type

Most taxonomies of team type distinguish team tasks that are largely informational from those with high behavioral components (Sundstrom, DeMeuse, & Futrell, 1990; Sundstrom, McIntyre, Halfhill, & Richards, 2000). Teams whose tasks involve processing information and making decisions (i.e., those who do knowledge work) are often referred to as *decision-making teams*. Teams performing time-sensitive tasks requiring members to coordinate actions and perform physical tasks such as those in medical operating rooms and manufacturing plants are described as *action teams*. A third type, the *project team*, is involved in both informational–knowledge work and behavioral action; examples of project teams abound in product design and consulting environments.

These three team types differ in terms of the behavioral and informational interdependence of team members, which delineates what team members are integrating: knowledge–information or physical–joint actions. Specifically, action teams generally possess high levels of *behavioral* interdependence; these include sports teams, assembly teams, and military combat teams. Decision-making teams possess high levels of *informational* interdependence; knowledge, expertise, opinions, and perspectives need to be integrated to make a decision or solve a problem. Decision-making teams include management teams involved in budgeting and joint planning decisions. Project teams have high levels of both behavioral and informational interdependence. These teams include engineering teams, research groups, and product design and development teams.

Because the nature of team tasks differ in the level of integration required of members' disparate knowledge, behavioral inputs, or both, we expected to find corresponding differences in the utility of different arrangements of knowledge. In particular, compositional knowledge (i.e., similar and accurate mental models) ought to be more important when behavioral integration needs are high, whereas compilational knowledge ought to be more pivotal when knowledge integration needs are high. As such, we expected the relationships between compositional emergent cognition and team process and performance would be strongest for action teams, then for project teams, and least important for decision-making teams. And, we expected compilationally emergent cognition would be most pivotal to the behavioral process and performance of decision-making teams, then for project teams, and least so for action teams.

Hypothesis 11: Team type will moderate the relationships between compositional cognition and team process (H11a) and team performance (H11b) such that compositional cognition will be most predictive of process and performance for action teams, then for project teams, and least predictive for decision-making teams.

Hypothesis 12: Team type will moderate the relationships between compilational cognition and team process (H12a) and team performance (H12b) such that compilational cognition will be most predictive of process and performance for decision-making teams, then for project teams, and least predictive for action teams.

Method

Database

This meta-analysis includes 231 correlations culled from 65 independent studies reported in 58 journal articles, dissertations, and conference presentations on team cognition; the total number of groups (*N*) was 3,738, and the total number of team members was approximately 18,240. To ensure a comprehensive search, we applied the following strategies: (a) conducting a computerized search of the PsycInfo (1887–2008), ABI/Inform (1971–2008), and ERIC (1966–2008) databases using appropriate key words and phrases,[2] (b) conducting a manual search for references cited in studies included in this meta-analysis, (c) soliciting relevant unpublished manuscripts from authors currently doing research in team cognition, and (d) obtaining related studies from recent conference presentations (i.e., Society for Industrial Organizational Psychology, Academy of Management). Our objective in examining unpublished manuscripts and studies from recent conferences was to incorporate relevant research results that had not yet been integrated into the extant literature.

Studies were included only if a relevant team cognition construct (e.g., transactive memory, shared cognition, shared mental models) was assessed, and sufficient information was reported to compute a correlation between team cognition and its relevant correlates (e.g., means and standard deviations, effect sizes, etc.).[3] When authors reported separate correlations for different samples, those correlations were examined separately. When authors reported multiple estimates of the same relationship from the same sample (e.g., between team cognition and more than one indicator of team process), those correlations were examined separately only as appropriate for subanalyses (e.g., team cognition and behavioral vs. motivational process), but an average correlation was computed for all global meta-analyses of those relationships (e.g., team cognition and team process) to maintain independence (Hunter & Schmidt, 2004). The articles included in this meta-analysis are listed in the references prefixed with an asterisk.

Coding Procedure

Each author undertook an independent effort to code the studies that met criteria for inclusion in this meta-analysis using a jointly developed coding scheme. Intercoder agreement was 94.2%. Coding disagreements were resolved through discussion. Data coded

[2] Sample keywords include *team* OR *group* AND *cognition*, *mental models*, *shared cognition*, *transactive memory*, *schemas*, *knowledge structure*, *cognitive structure*, *cognitive map*, *conceptual framework*, *shared situation awareness*, and *situation assessment*.

[3] Only correlations representing relationships at the team-level were included in the meta-analysis.

included study sample size, number of groups included, sample characteristics, study design characteristics, team type, task interdependence, conceptualization of team cognition construct (i.e., nature of emergence, form of cognition, cognitive content domain), and, when reported, reliability estimates of team cognition and its correlates. Further, we coded relationships between team cognition and (a) team process (i.e., behavioral, motivational) and (b) team performance.

Coding of team cognition. Team cognition constructs have been examined in a number of different ways (Cooke, Salas, Cannon-Bowers, & Stout, 2000; Mohammed, Klimoski, & Rentsch, 2000; Rentsch et al., 2008), posing a significant challenge in meta-analyses. Specifically, terms like *mental models*, *shared cognition*, and *transactive memory* are often used interchangeably but to represent different cognition constructs. Table 1 provides a summary of the various terms used in team cognition research. Table 2 provides an overview of the cognitive underpinnings examined in the current study with examples of how studies were coded.

For nature of emergence, team cognition was coded as (a) *composition* when either the *congruence* (degree of match among team members' mental models) or *accuracy* (degree of match between the team members' schemas and a "true score," usually an expert's mental model) was calculated or assessed and (b) *compilation* when authors assessed the extent to which team members possessed complementary task- or team-relevant knowledge (i.e., complementarity, transactive memory). All correlations that could be coded as compilation were from studies on transactive memory. Further, these studies either examined knowledge differentiation specifically or transactive memory globally. As such, compilational emergence was further subcoded as *complementarity/transactive memory–specialization* when team members' understanding of role specialization or memory differentiation was specifically assessed (e.g., Faraj & Sproull, 2000; He, Butler, & King, 2007), and as *complementarity/transactive memory–global* when a global measure of transactive memory was used (e.g., examining memory differentiation, task coordination, and task credibility aspects of transactive memory; Balkundi & Weinberg, 2008; Thomas, 2006).

For form of cognition, team cognition was coded as (a) *structured* when the organization of team knowledge was assessed (e.g., via Pathfinder, pairwise comparisons, multidimensional scaling) and (b) *perceptual* when shared cognition was assessed, but without any attempt to assess the structure of that cognition (e.g., via shared perceptions, Likert-type scales).[4]

For cognitive content domain, team cognition was coded as (a) *task* when cognition depicted the nature and components of the team's task(s) or (b) *team* when cognition included information related to team members' roles and responsibilities and facilitated members' expectations regarding how to interact with one another to accomplish team goals (e.g., Marks et al., 2000; Marks et al., 2002). Whereas task mental models depict what the team must do, teamwork mental models depict how the team should work together to do it (Marks et al., 2002).

Coding of team process. Two forms of team process were examined in the primary studies: behavioral and motivational. *Behavioral process* includes team actions that are primarily focused on task–goal accomplishment. In addition to coding behavioral process (overall), we further subdivided process to code transition process and action process (Marks et al., 2000). Process was coded as (a) *transition process* when it focused primarily on evaluating or planning activities (e.g., mission analysis, goal specification, strategy formulation, planning) and (b) *action process* when it focused primarily on actions contributing directly toward goal accomplishment (e.g., monitoring progress toward goals, systems monitoring, coordination). Studies were coded as *transition–action* when authors measured both transition and action process but reported only a global correlation with cognition. All estimates of behavioral process and cognition were included in the overall category, but only estimates in which processes clearly aligned with Marks et al.'s definitions of transition and action process were included in the transition, action, and transition–action subcategories.

Motivational processes, which are broader in scope than behavioral processes, transcend the various phases of task or goal accomplishment (Kozlowski & Ilgen, 2006). Process was coded as *motivational* when it focused on actions associated with managing interpersonal relationships within the team (e.g., cohesion, conflict management, affect management, motivation, and confidence building; Marks et al., 2001). To examine the role of team cognition in team process, we first coded behavioral (transition, action) and motivational process individually whenever sufficient data were available. Then, we collapsed across process categories, computing average correlations as appropriate, to obtain an overall estimate of the role of team cognition in team process.

Coding of team performance. Team performance was typically operationalized as task performance, completion, or proficiency. We coded objective (e.g., simulation score, number of targets destroyed) and subjective indicators (e.g., supervisor evaluations, team evaluations) of team performance separately. We then collapsed across these categories, computing averages as appropriate, to examine team performance overall.

Coding of task and study characteristics moderators. We also coded aspects of the task and study characteristics that may moderate the cognition-process and cognition-performance relationships.[5] We coded *team interdependence* using Gully et al. (1995), Gully et al. (2002), and Campion, Medsker, and Higgs (1993) as guides. Interdependence was coded as (a) *low* when task performance was largely a function of individual effort; much of the team's work was performed individually; members generally did not rely on one another to accomplish their work; and feedback, rewards, and goals occurred mainly at the individual level, (b) *moderate* when members relied on one another for some information and resources but were able to complete a significant portion of the task individually and the goals, outcome, and feedback were mixed, and (c) *high* when there were mutual or reciprocal dependencies among all members; members' performance was dependent on information or resources provided by other members; and team goals, outcomes, and feedback were emphasized over those of individual members. No instances of low task interdependence were observed in the primary studies, and so

[4] Rentsch et al. (2008) recognized interpretive cognition as a third category of form of cognition, wherein cognitive similarity is inferred via qualitative analyses processes (e.g., sense making or using case studies, observations, interviews, or essays). However, interpretive cognition was infrequently used in the primary studies, and the category was not retained.

[5] A summary of study characteristics for the meta-analytic database is available from Leslie A. DeChurch upon request.

Table 1
Team Cognition Lexicon: Terms Used to Describe Team Cognition Constructs

Agreement about causes of performance	Perceptions of accurate cognitive map
Accuracy of knowledge identification	Perceptions of role specialization
Cognitive consensus	Presence of expertise
Cognitive diversity	Retrieval coordination
Cognitive elaboration	Shared task understanding
Collective cognition	Shared team declarative knowledge
Collective knowledge	Shared team interaction mental models
Collective mind	Shared team mental models
Cognitive spatial maps	Shared team procedural knowledge
Consensus about knowledge sources	Similarity of knowledge
Directory updating	Situated expertise
Distributed cognition	Specialization of expertise
Diversity in expertise	Strategic consensus
Expertise composition	Structure stability
Expertise coordination	Task coordination
Expertise location	Task credibility
Expertise schema	Team cognition
Group cognition	Team cognitive maps
Information allocation	Team declarative knowledge
Knowledge stock	Team procedural knowledge
Location of expertise	Teamwork schema agreement
Mastery of teamwork knowledge	Team mental models
Memory differentiation	Team role mental models
Shared cognition	Team task-related knowledge
Shared mental model development	Transactive information search
Shared mental models	Transactive memory
Shared strategic cognition	Transactive memory system

comparisons were made between teams exhibiting moderate and high levels of interdependence.

We coded team type into three categories (action, decision-making, and project teams) using Sundstrom, McIntyre, Halfhill, and Richards (2000) and Sundstrom, DeMeuse, and Futrell (1990) as guides. Teams were coded as (a) *action* when high levels of behavioral interdependence were required to effectively perform a task (e.g., sports teams, assembly teams, military combat teams), (b) *decision making* when high levels of informational interdependence were required to effectively make a decision or solve a problem (e.g., management teams involved in budgeting, joint planning), and (c) *project* when high levels of both behavioral and informational interdependence were required for successful task completion (e.g., engineering teams, research groups, development teams).

Analysis

To analyze this data, we used the meta-analytic methods outlined by Hunter and Schmidt (2004). Reliability estimates for team cognition and its relevant correlates were not reported in all studies. Therefore, corrections for unreliability were performed with artifact distribution meta-analysis. Corrections were made for unreliability in both team cognition and correlate measures.[6] Given the possibility of a file-drawer effect (wherein significant findings are more likely to be published; Rosenthal, 1979), we also conducted a file-drawer analysis (Hunter & Schmidt, 2004) to estimate the number of studies reporting null findings that would be required to reduce reliability-corrected correlations to a specified lower value (we used $\rho = .05$).

Results

Tables 3 through 14 present meta-analytic results for team cognition relations. In these tables, we report both the credibility (CV) and the confidence intervals (CI) around ρ (the reliability-corrected mean correlation, rho), as each provides unique information about the nature of ρ (Hunter & Schmidt, 2004; Whitener, 1990). Whereas the CV provides an estimate of the variability of corrected correlations across studies (wide CVs suggest the presence of a moderator, and CVs that do not include zero indicate that effects generalize across studies; Bobko & Roth, 2008; Kisamore, 2008; Kisamore & Brannick, 2008), the CI provides an estimate of the accuracy of our estimation of ρ (Whitener, 1990). As such, relationships were interpreted to generalize across situations in which the 80% CV did not include zero, and ρs were interpreted to

[6] As our objective was to generalize across both time and measures, we included estimates of both test–retest reliability (coefficient of stability) and internal consistency (coefficient of equivalence) in creating our artifact distributions (Hunter & Schmidt, 2004). However, as both forms of reliability estimates underestimate measurement error, full correction for measurement error was not possible. As such, the results reported here are conservative estimates. Although reliability estimates that simultaneously account for measurement stability and equivalence would be preferable for making artifact distribution corrections (i.e., coefficients of equivalence and stability; Cronbach, 1947; Schmidt, Le, & Illies, 2003), such data were not available in the primary studies. The incomplete correction for measurement error provided here gives in more accurate results than would be possible if we failed to make any correction for measurement error (Hunter & Schmidt, 2004).

Table 2
Overview of Cognitive Underpinnings Examined Within the Current Study

Underpinning	Definition	Exemplar study
Nature of emergence of cognition	Multilevel process whereby individual elemental cognitive content combines to constitute collective cognition (Kozlowski & Klein, 2000)	**Compilation**: "Members' meta knowledge of each other's areas of expertise was measured . . . by asking three, 5-point Likert scale questions about team members' knowledge of who knows what." (Kanawattanachai & Yoo, 2007, p. 792) **Composition**: "Shared task understanding was measured with a four-item instrument . . . [using] a five-point scale to rate the extent to which . . . teams shared a common understanding [of the task domain] . . . agreement within each team was assessed using . . . rwg." (He et al., 2007, pp. 275–276)
Form of cognition	Type of similar meaning, understanding, or interpretation among team members (Rentsch et al., 2008)	**Perceptual**: "[S]hared cognition [was] captured by three items: 'We understand each other,' 'I understand the other parties' problems and solutions,' and 'We know how to deal with each others' problems and solutions.'" (Swaab et al., 2007, p. 191) **Structured**: "Participants were provided with a matrix that listed [task-related] concepts. . . . They were asked to make judgments about the relatedness of each pair using a Likert-type scale. . . . These data were fed into . . . Pathfinder . . . which produced a similarity index . . . reflecting the overlap among each pair." (Marks et al., 2002, p. 7)
Content of cognition	Domain of knowledge contained in the team's collective cognition (Marks et al., 2002; Rentsch et al., 2008)	**Team**: "[T]eam members completed [concept] maps by placing concepts that best represented the actions of each team member on the map . . . [to] assess whether team members understood their teammates' roles and responsibilities. . . ." (Ellis, 2006, p. 576) **Task**: "[T]eam knowledge was indexed as members' average score on several individual course assignments . . . [which] collectively provided a good index of how well members knew the subject matter that underlay performance on the simulation." (Mathieu & Schulze, 2006, p. 609)

be meaningfully different from one another when one estimate was not included in the CI band of the other estimate.

Magnitude of Impact of Team Cognition

Table 3 presents meta-analytic evidence that bears on the broad relationships between team cognition and teamwork process and outcomes (H1–H4). Support was found for Hypothesis 1, which proposed a positive relationship between team cognition and team behavioral process; we found positive relationships between cognition and behavioral process overall (ρ = .43, CV = .18–.68), as well as between cognition and both transition and action processes (ρ = .43 and .29, respectively). Cognition shows a stronger relation to transition process than to action process. Hypothesis 2, which proposed a positive relationship between team cognition and team motivational states, was supported. We found positive relationships between cognition and motivational states overall (ρ = .37, CV = .03–.70), as well as more specifically between cognition and cohesion (ρ = .40, CV = .07–.73).

Support was found for Hypothesis 3, which proposed a positive relationship between team cognition and team performance (ρ = .38, CV = .17–.59). Support was also found for Hypothesis 4, which proposed that measurement of team performance would moderate the relationship between team cognition and performance such that team cognition would be more strongly related to subjective than to objective measures of performance. Indeed, the point estimate for team cognition and team performance assessed with subjective measures was greater than for performance assessed with objective measures (ρ = .44 and ρ = .31, respectively).

Using regression analysis, we sought to determine the independent contribution of emergent team cognition to the prediction of team performance after controlling for the effects of behavioral processes and motivational states (Hypothesis 5). Following the theory-testing method developed by Viswesvaran and Ones (1995), we conducted regression analyses on meta-analytically derived correlations between the variables (i.e., meta-analytic regression; Colquitt, Conlon, Wesson, Porter, & Ng, 2001; Zimmerman, 2008). We used the harmonic means of the total sample sizes on which each meta-analytic correlation from the input matrix was estimated to compute the standard errors associated with the regression coefficients (cf. Viswesvaran & Ones, 1995). In order to examine the joint impact of the three drivers of team performance specified in the literature (i.e., motivational, behavioral, and cognitive), we obtained six meta-analytic correlations. The three relationships involving cognition were estimated from the current database ($\rho_{\text{cognition-transition/action process}}$ = .35, $\rho_{\text{cognition-cohesion}}$ = .40, $\rho_{\text{cognition–performance}}$ = .38). Estimates of relationships between behavioral process and both performance and motivation were obtained from LePine et al.'s (2008) meta-analysis ($\rho_{\text{transition/action process–performance}}$ = .29, $\rho_{\text{transition/action process–cohesion}}$ = .61), and the relationship between motivation and performance was estimated from Gully et al.'s

Table 3
Overview of the Nomological Net of Team Cognition

Meta-analysis	k	N	r	SD_r	ρ	$SD_ρ$	80% CV	90% CI	% SEV	% ARTV	FDk
Emergent team process & states											
Team behavioral process											
Overall	37	1,934	.37	.21	.43	.19	.18, .68	.36, .50	33.90	35.13	281
Transition process	4	134	.37	.13	.43	.00	.43, .43	.31, .55	100.00	100.00	31
Action process	10	575	.27	.16	.29	.10	.16, .42	.20, .38	61.86	62.85	48
Transition/action process	20	976	.31	.19	.35	.15	.16, .54	.27, .43	49.32	50.55	120
Motivational states											
Overall	17	860	.31	.06	.37	.26	.03, .70	.25, .49	24.48	24.95	109
Cohesion	7	425	.34	.25	.40	.26	.07, .73	.22, .58	20.56	21.37	49
Team performance											
Overall	60	3,512	.33	.19	.38	.16	.17, .59	.33, .43	40.48	41.93	396
Measures											
Objective	39	2,243	.28	.18	.31	.15	.13, .50	.26, .36	47.18	48.33	203
Subjective	19	1,197	.38	.17	.44	.15	.25, .64	.37, .51	40.28	42.31	149

Note. k = number of correlations meta-analyzed; N = total number of groups; r = sample size weighted mean observed correlation; SD_r = sample size weighted standard deviation of the observed correlations; ρ = sample size weighted mean observed correlation corrected for unreliability in both measures; $SD_ρ$ = standard deviation of ρ; 80% CV = 80% credibility interval around ρ; 90% CI = 90% confidence interval around ρ; % SEV = percentage of variance due to sampling error; % ARTV = percentage of variance due to all corrected artifacts; FDk = file drawer k representing the number of "lost" studies reporting null findings necessary to reduce ρ to .05.

(1995) meta-analysis of team cohesion and performance ($ρ_{cohesion–performance}$ = .317).

First, we tested a model wherein team motivational states and behavioral process were used to predict team performance. Together these factors explained 11.6% of the variance in team performance. Then, we tested a model wherein team cognition was entered along with team motivational states and behavioral process. Together these factors explained 18.4% of the variance in team performance, accounting for a significant 6.8% change in R^2 due to team cognition.[7] The results are presented in Table 4. Notably, all three constructs explained significant unique variance in team performance, providing support for H5.

Cognitive Moderators

Hypotheses 6–8 dealt with the extent to which conceptualization and operationalization of cognition (nature of emergence, form of cognition, content of cognition) moderate the cognition–process and cognition–performance relationships. Support was found for Hypothesis 6 (nature of emergence moderator). Specifically, as can be seen in Table 5, a stronger positive point estimate was found for the relationship between compilational emergence and team behavioral process than between compositional emergence and team behavioral process (ρ = .62 vs. ρ = .29). Similarly, as can be seen in Table 6, stronger positive point estimates were found for the relationship between compilational emergence and team performance than between compositional emergence and team performance (ρ = .44 vs. ρ = .32). This pattern is consistent across both objective and subjective measures of performance.

Hypothesis 7 proposed that form of cognition moderates the relationships between team compositional cognition and team behavioral process (H7a) and between team compositional cognition and team performance (H7b). Support was found for Hypothesis 7a (see Table 7) but not 7b (see Table 8). Specifically, the positive relationship between team compositional cognition and team behavioral process was stronger for structured cognition than for perceptual cognition (ρ = .32 vs. ρ = .21). It is interesting that this relationship held for cognitive congruence but not cognitive accuracy. Accurate perceptual cognition predicted behavioral process more strongly than did accurate structured cognition (ρ = .35 vs. ρ = .22). Point estimates for the compositional cognition–performance relationship were similar regardless of whether the form of cognition was structured or perceptual (ρ = .33 vs. ρ = .34).

Hypothesis 8a proposed that content of cognition moderates the relationship between compositional cognition and behavioral process such that team-based cognition is more predictive of behavioral process than is task-based cognition. Support was found for this hypothesis but only with structured cognition. Specifically, as can be seen in Table 9, although structured team-based cognition was found to be more predictive of team process than structured task-based cognition (ρ = .36 vs. ρ = .23), perceptual task-based cognition and perceptual team-based cognition were similarly predictive of process (ρ = .31 vs. ρ = .30).

Table 4
Regression Analysis Examining Unique Contribution of Team Cognition to Team Performance

Construct	Team performance: Model 1	Team performance: Model 2
Team cohesion	.223	.138
Team behavioral process	.155	.106
Team cognition		.288
df	2, 883	3, 882
R^2	.116**	.184**
ΔR^2		.068**

Note. All coefficients are standardized and significant at $p < .01$.
** $p < .01$.

[7] We thank an anonymous reviewer for suggesting this analysis.

Table 5
Team Cognition–Team Behavioral Process Relationship: Nature of Emergence as a Moderator

Meta-analysis	*k*	*N*	*r*	SD_r	ρ	SD_ρ	80% CV	90% CI	% SEV	% ARTV	FD*k*
Compositional emergence	15	776	.26	.15	.29	.07	.20, .38	.22, .36	78.43	80.34	72
Congruence	11	632	.27	.16	.33	.12	.18, .48	.23, .43	62.56	63.43	62
Accuracy	10	547	.29	.16	.32	.08	.22, .42	.23, .41	74.91	77.36	54
Compilational emergence	10	525	.51	.17	.62	.16	.41, .82	.51, .73	35.57	38.68	114
TMS specialization	6	318	.45	.12	.55	.05	.49, .62	.45, .65	83.13	87.75	60
TMS global	8	467	.58	.22	.68	.23	.39, .97	.53, .83	16.81	18.74	101

Note. *k* = number of correlations meta-analyzed; *N* = total number of groups; *r* = sample size weighted mean observed correlation; SD_r = sample size weighted standard deviation of the observed correlations; ρ = sample size weighted mean observed correlation corrected for unreliability in both measures; SD_ρ = standard deviation of ρ; 80% CV = 80% credibility interval around ρ; 90% CI = 90% confidence interval around ρ; % SEV = percentage of variance due to sampling error; % ARTV = percentage of variance due to all corrected artifacts; FD*k* = file drawer *k* representing the number of "lost" studies reporting null findings necessary to reduce ρ to .05; TMS = transactive memory system.

Hypothesis 8b proposed that content of cognition moderates the compositional cognition–performance relationship such that task-based cognition is more predictive of performance than team-based cognition. As can be seen in Table 10, support was found for this hypothesis but only with subjective performance (ρ = .47 vs. ρ = .27). The proposed pattern was also found with the overall performance category (ρ = .31 vs. ρ = .27), but we could not conclude that the effects were different because the mean rho for task-based cognition fell within the confidence interval for team-based cognition (and vice versa).

Task Moderators

Hypothesis 9 proposed that team interdependence moderates the relationships between compositional cognition and team process (H9a) and performance (H9b) such that compositional cognition is more strongly predictive of team process and performance when team interdependence is moderate. As can be seen in Table 11, support was found for H9b but not for H9a. Opposite from our prediction, we found that the cognition-process relationship was stronger for compositional emergence under conditions of high team interdependence (ρ = .34 vs. ρ = .21). In support of H9b, the anticipated pattern was found with team performance; specifically, the cognition–performance relationship was stronger for compositional emergence under conditions of moderate, rather than high, interdependence (ρ = .38 vs. ρ = .28).

Hypothesis 10 proposed that team interdependence moderates the relationships between compilational cognition and team process (H10a) and performance (H10b), such that compilational

Table 6
Team Cognition–Team Performance Relationship: Nature of Emergence as a Moderator

Meta-analysis	*k*	*N*	*r*	SD_r	ρ	SD_ρ	80% CV	90% CI	% SEV	% ARTV	FD*k*
Team performance—Overall											
Compositional emergence	33	2,088	.28	.18	.32	.15	.13, .51	.25/.39	43.86	45.67	179
Congruence	28	1,852	.25	.20	.30	.20	.05, .54	.22/.38	32.92	33.93	140
Accuracy	15	872	.30	.16	.34	.10	.21, .47	.26/.42	60.81	63.67	87
Compilational emergence	26	1,510	.37	.17	.44	.15	.25, .63	.37/.51	44.25	45.92	203
TMS specialization	11	601	.30	.22	.35	.21	.09, .61	.22/.48	32.18	33.12	66
TMS global	21	1,310	.40	.18	.47	.17	.25, .69	.39/.55	34.06	35.52	177
Team performance—Objective											
Compositional emergence	24	1,403	.23	.16	.26	.10	.13, .39	.19/.33	62.48	63.73	101
Congruence	20	1,194	.21	.16	.25	.12	.10, .40	.18/.32	59.10	60.65	80
Accuracy	11	673	.28	.16	.30	.11	.16, .44	.21/.39	56.67	57.89	55
Compilational emergence	17	972	.35	.19	.42	.17	.20, .63	.33/.51	40.14	41.27	126
TMS Specialization	5	318	.24	.22	.29	.21	.01, .55	.09/.47	29.43	29.44	23
TMS Global	15	919	.39	.21	.47	.21	.21, .74	.36/.58	28.33	29.80	126
Team performance—Subjective											
Compositional emergence	9	685	.36	.18	.42	.17	.20, .64	.30/.54	30.44	32.13	67
Congruence	8	658	.31	.25	.37	.26	.03, .71	.19/.55	16.45	16.80	51
Accuracy	4	199	.37	.12	.43	.00	.43, .43	.32/.54	100.00	100.00	31
Compilational emergence	10	556	.42	.13	.50	.07	.42, .58	.42/.58	76.69	80.37	90
TMS specialization	7	301	.38	.19	.45	.15	.26, .65	.31/.59	49.94	51.77	56
TMS global	6	391	.43	.11	.50	.05	.43, .56	.41/.59	80.86	83.54	54

Note. *k* = number of correlations meta-analyzed; *N* = total number of groups; *r* = sample size weighted mean observed correlation; SD_r = sample size weighted standard deviation of the observed correlations; ρ = sample size weighted mean observed correlation corrected for unreliability in both measures; SD_ρ = standard deviation of ρ; 80% CV = 98% credibility interval around ρ; 90% CI = 90% confidence interval around ρ; % SEV = percentage of variance due to sampling error; % ARTV = percentage of variance due to all corrected artifacts; FD*k* = file drawer *k* representing the number of "lost" studies reporting null findings necessary to reduce ρ to .05; TMS = transactive memory system.

Table 7
Compositional Team Cognition–Team Behavioral Process Relationship: Form of Cognition as a Moderator

Meta-analysis	*k*	*N*	*r*	SD_r	ρ	SD_ρ	80% CV	90% CI	% SEV	% ARTV	FD*k*
Perceptual	6	245	.19	.13	.21	.00	.21/.21	.11/.31	100.00	100.00	19
Congruence	3	175	.16	.12	.20	.00	.20/.20	.06/.34	100.00	100.00	9
Accuracy	8	398	.32	.15	.35	.08	.25/.45	.25/.45	74.29	76.77	48
Structured	10	555	.26	.16	.32	.11	.18/.45	.22/.42	67.19	67.42	54
Congruence	10	555	.27	.16	.33	.12	.18/.49	.23/.43	61.62	61.86	56
Accuracy	3	173	.18	.09	.22	.00	.22/.22	.12/.32	100.00	100.00	10

Note. *k* = number of correlations meta-analyzed; *N* = total number of groups; *r* = sample size weighted mean observed correlation; SD_r = sample size weighted standard deviation of the observed correlations; ρ = sample size weighted mean observed correlation corrected for unreliability in both measures; SD_ρ = standard deviation of ρ; 80% CV = 80% credibility interval around ρ; 90% CI = 90% confidence interval around ρ; % SEV = percentage of variance due to sampling error; % ARTV = percentage of variance due to all corrected artifacts; FD*k* = file drawer *k* representing the number of "lost" studies reporting null findings necessary to reduce ρ to .05.

cognition is more strongly predictive of process and performance when interdependence is high rather than when interdependence is moderate. This hypothesis was not supported (see Table 11); opposite our prediction, the cognition–process relationship was stronger for compilational emergence under conditions of moderate interdependence (ρ = .75 vs. ρ = .62), and there was no observed difference in the performance for compilational cognition across levels of team interdependence (ρ = .44 vs. ρ = .44).

Hypothesis 11 proposed that team type moderates the relationships between compositional cognition and process (H11a) and performance (H11b) such that compositional cognition is most predictive of process and performance in action teams. As can be seen in Table 12, support was found for H11a but not for H11b. Specifically, compositional cognition was found to be more predictive of team process in action teams than in decision-making teams (ρ = .33 vs. ρ = .15); however, compositional cognition was more predictive of performance in project and decision-making teams than in action teams (ρ = .52 vs. ρ = .25, and ρ = .40 vs. ρ = .25, respectively).

Hypothesis 12 proposed that team type moderates the relationships between compilational cognition and process (H12a) and performance (H12b) such that compilational cognition is more predictive of process and performance in decision-making teams. Partial support was found for H12a; H12b was not supported. Specifically, compilational cognition was more predictive of team process in decision-making and project teams than in action teams (ρ = .78 vs. ρ = .55, and ρ = .77 vs. ρ = .55, respectively). However, compilational cognition was more predictive of team performance in action and project teams than in decision-making teams (ρ = .47 vs. ρ = .30, and ρ = .54 vs. ρ = .30, respectively).

Study Characteristics Moderators

Although no specific hypotheses were proposed, we explored study setting (laboratory vs. field) and design (experiment vs. nonexperiment) as potential moderators of the cognition–process and cognition–performance relationships (see Table 13 and Table 14). Setting and design were found to moderate the relationship between compilational cognition and team process such that the cognition–process relationship was stronger in field than in

Table 8
Compositional Team Cognition–Team Performance Relationship: Form of Cognition as a Moderator

Meta-analysis	*k*	*N*	*r*	SD_r	ρ	SD_ρ	80% CV	90% CI	% SEV	% ARTV	FD*k*
Team performance—Overall											
Perceptual	19	1,227	.29	.20	.34	.18	.11, .57	.26, .42	34.88	35.95	110
Congruence	13	967	.25	.25	.29	.26	−.05, .62	.16, .42	18.93	19.51	62
Accuracy	10	472	.29	.13	.32	.00	.32, .32	.25, .39	100.00	100.00	54
Structured	16	912	.26	.15	.33	.09	.21, .45	.25, .41	74.01	74.39	90
Congruence	16	912	.24	.13	.31	.04	.26, .37	.24, .38	93.16	93.60	83
Accuracy	6	424	.31	.18	.35	.15	.16, .55	.21, .49	37.90	37.98	36
Team performance—Objective											
Perceptual	13	683	.22	.17	.23	.12	.08, .38	.15, .31	58.47	59.02	47
Structured	13	777	.25	.14	.29	.09	.19, .40	.22, .36	74.17	74.54	63
Team performance—Subjective											
Perceptual	6	544	.38	.19	.44	.18	.21, .67	.29, .59	24.03	26.28	47
Structured	3	141	.29	.15	.32	.08	.22, .42	.16, .48	78.01	78.01	16

Note. *k* = number of correlations meta-analyzed; *N* = total number of groups; *r* = sample size weighted mean observed correlation; SD_r = sample size weighted standard deviation of the observed correlations; ρ = sample size weighted mean observed correlation corrected for unreliability in both measures; SD_ρ = standard deviation of ρ; 80% CV = 80% credibility interval around ρ; 90% CI = 90% confidence interval around ρ; % SEV = percentage of variance due to sampling error; % ARTV = percentage of variance due to all corrected artifacts; FD*k* = file drawer *k* representing the number of "lost" studies reporting null findings necessary to reduce ρ to .05.

Table 9
Compositional Team Cognition–Team Behavioral Process Relationship: Content of Cognition as a Moderator

Meta-analysis	*k*	*N*	*r*	SD_r	ρ	SD_ρ	80% CV	90% CI	% SEV	% ARTV	FD*k*
Task	11	557	.25	.13	.27	.00	.27, .27	.20, .34	100.00	100.00	49
Perceptual	5	178	.28	.14	.31	.00	.31, .31	.20, .42	100.00	100.00	26
Structured	8	427	.21	.13	.23	.02	.20, .25	.15, .31	98.44	98.68	29
Team	8	475	.26	.14	.30	.07	.20, .39	.20, .40	75.58	78.38	40
Perceptual	5	320	.28	.14	.30	.07	.21, .39	.19, .41	72.89	74.47	25
Structured	6	345	.30	.14	.36	.09	.24, .47	.25, .47	72.89	73.16	37

Note. *k* = number of correlations meta-analyzed; *N* = total number of groups; *r* = sample size weighted mean observed correlation; SD_r = sample size weighted standard deviation of the observed correlations; ρ = sample size weighted mean observed correlation corrected for unreliability in both measures; SD_ρ = standard deviation of ρ; 80% CV = 80% credibility interval around ρ; 90% CI = 90% confidence interval around ρ; % SEV = percentage of variance due to sampling error; % ARTV = percentage of variance due to all corrected artifacts; FD*k* = file drawer *k* representing the number of "lost" studies reporting null findings necessary to reduce ρ to .05.

laboratory studies (ρ = .85 vs. ρ = .60) and in nonexperiments than in experiments (ρ = .78 vs. ρ = .49).

Discussion

The current findings empirically support an emerging consensus in the team effectiveness literature: Three classes of emergent collective constructs (behavioral process, motivational states, and cognitive states) are uniquely important drivers of team effectiveness (Ilgen et al., 2005; Kozlowski & Bell, 2003; Kozlowski & Ilgen, 2006; Mathieu et al., 2008). The first two—behavioral process and motivational states—have been the subject of prior meta-analytic integration (Gully et al., 1995; 2002; LePine et al., 2008; Mullen & Copper, 1994). The aim of the current study was to provide a comprehensive synthesis of the team cognition literature that would enable a unified, coherent body of research to follow. The current pattern of findings (a) clarify several meaningful conclusions about the value of the team cognition construct supported by the existing empirical knowledge base, (b) suggest a number of revisions to the way in which team cognition should be studied, and (c) point out empirical blind spots in need of closer examination.

The Value of Team Cognition

In response to our first question, there is clearly a cognitive foundation to teamwork. Cannon-Bowers and Salas made an important observation in their applied work with military teams: Patterns in the combinations of individuals' cognitive sets are strongly related to team behavioral process (transition and action), team motivational

Table 10
Compositional Team Cognition–Team Performance Relationship: Content of Cognition as a Moderator

Meta-analysis	*k*	*N*	*r*	SD_r	ρ	SD_ρ	80% CV	90% CI	% SEV	% ARTV	FD*k*
Team performance–Overall											
Task	22	1,419	.28	.17	.31	.13	.15, .48	.24, .38	49.06	50.65	115
Perceptual	12	824	.32	.19	.35	.17	.14, .57	.25, .45	32.18	33.79	72
Structured	13	717	.24	.14	.25	.06	.17, .34	.18, .32	80.11	80.58	52
Team	20	1,137	.23	.18	.27	.15	.08, .47	.19, .35	48.26	49.78	88
Perceptual	12	630	.21	.21	.22	.17	.01, .44	.12, .32	40.70	41.26	41
Structured	10	581	.25	.16	.33	.13	.16, .49	.22, .44	59.98	60.30	56
Team performance—Objective											
Task	17	903	.21	.14	.22	.05	.16, .28	.15, .29	88.88	89.63	58
Perceptual	9	408	.19	.19	.21	.13	.04, .37	.09, .33	56.87	57.22	29
Structured	10	546	.22	.13	.22	.03	.17, .26	.15, .29	94.08	94.08	34
Team	12	735	.25	.16	.28	.12	.13, .43	.20, .36	56.81	58.64	55
Perceptual	7	412	.23	.17	.24	.12	.09, .38	.12, .36	53.69	53.70	27
Structured	8	469	.24	.16	.28	.13	.12, .45	.16, .40	57.53	57.80	37
Team performance—Subjective											
Task	5	516	.41	.12	.47	.09	.35, .58	.37, .57	48.94	50.79	42
Perceptual	3	416	.45	.08	.51	.03	.47, .55	.43, .59	78.61	86.21	28
Structured	—	—	—	—	—	—	—	—	—	—	—
Team	6	283	.23	.22	.27	.20	.01, .52	.09, .45	38.97	39.51	27
Perceptual	4	171	.17	.25	.20	.23	−.10, .49	−.05, .45	35.23	35.49	12
Structured	—	—	—	—	—	—	—	—	—	—	—

Note. *k* = number of correlations meta-analyzed; *N* = total number of groups; *r* = sample size weighted mean observed correlation; SD_r = sample size weighted standard deviation of the observed correlations; ρ = sample size weighted mean observed correlation corrected for unreliability in both measures; SD_ρ = standard deviation of ρ; 80% CV = 80% credibility interval around ρ; 90% CI = 90% confidence interval around ρ; % SEV = percentage of variance due to sampling error; % ARTV = percentage of variance due to all corrected artifacts; FD*k* = file drawer *k* representing the number of "lost" studies reporting null findings necessary to reduce ρ to .05. Dashes indicate no data.

Table 11
Team Interdependence as a Moderator of the Cognition–Process and Cognition–Performance Relationships

Meta-analysis	*k*	*N*	*r*	SD_r	ρ	$SD_ρ$	80% CV	90% CI	% SEV	% ARTV	FD*k*
Cognition–process relationship											
High interdependence	27	1,500	.37	.20	.44	.18	.21, .67	.36, .52	36.05	37.48	211
Compositional emergence	19	975	.29	.16	.34	.10	.21, .47	.27, .41	66.61	68.96	110
Compilational emergence	8	525	.52	.17	.62	.17	.41, .83	.50, .74	28.96	31.05	91
Moderate interdependence	10	434	.35	.25	.42	.24	.11, .73	.26, .58	29.69	30.86	74
Compositional emergence	5	267	.19	.15	.21	.06	.13, .29	.09, .33	84.15	84.99	16
Compilational emergence	5	167	.61	.14	.75	.09	.64, .86	.62, .88	67.10	72.80	70
Cognition–performance relationship											
High interdependence	37	2,069	.29	.18	.33	.14	.15, .52	.27, .39	49.36	51.11	207
Compositional emergence	25	1,379	.25	.16	.28	.10	.16, .41	.21, .35	65.62	68.26	115
Compilational emergence	13	787	.37	.18	.44	.16	.24, .65	.34, .54	40.25	41.65	101
Moderate interdependence	20	1,353	.33	.21	.39	.21	.12, .65	.30, .48	27.49	28.57	136
Compositional emergence	10	743	.33	.22	.38	.22	.10, .66	.25, .51	23.32	24.53	66
Compilational emergence	13	723	.38	.17	.44	.13	.27, .62	.36, .52	49.22	51.15	101

Note. *k* = number of correlations meta-analyzed; *N* = total number of groups; *r* = sample size weighted mean observed correlation; SD_r = sample size weighted standard deviation of the observed correlations; ρ = sample size weighted mean observed correlation corrected for unreliability in both measures; $SD_ρ$ = standard deviation of ρ; 80% CV = 80% credibility interval around ρ; 90% CI = 90% confidence interval around ρ; % SEV = percentage of variance due to sampling error; % ARTV = percentage of variance due to all corrected artifacts; FD*k* = file drawer *k* representing the number of "lost" studies reporting null findings necessary to reduce ρ to .05.

states, and team performance (Cannon-Bowers & Salas, 1990, 2001; Cannon-Bowers et al., 1993). The cognitive architecture of teams is reciprocally related to both their behavioral synchronization and their motivational states. Furthermore, collective cognition is a unique contributor to team performance. While cognition, process, and motivation are interrelated, the meta-analytic regression results provided here offer the first big-picture view of the determinants of team functioning considered jointly. Team cohesion and team behavioral processes together explain nearly 12% of the variance in team performance; adding team cognition to the equation offers nearly an additional 7% incremental explained variance in team performance over and above cohesion and process.

Although team cognition was found to be positively related to team process and performance, the current findings highlight the importance of three classes of moderators of these relationships: (a) cognitive underpinnings (nature of emergence, form of cognition, content of cognition), (b) task features (team interdependence and type), and (c) study characteristics (performance criterion, study setting and design).

Table 12
Team Type as a Moderator of the Cognition–Process and Cognition–Performance Relationships

Meta-analysis	*k*	*N*	*r*	SD_r	ρ	$SD_ρ$	80% CV	90% CI	% SEV	% ARTV	FD*k*
Cognition–process relationship											
Action teams	20	1,148	.34	.17	.40	.14	.23, .58	.33, .47	48.71	50.93	140
Compositional emergence	15	788	.29	.16	.33	.10	.21, .45	.25, .41	67.83	70.41	84
Compilational emergence	5	360	.45	.15	.55	.14	.38, .73	.42, .68	41.42	43.69	50
Decision-making teams	9	433	.34	.29	.39	.29	.02, .76	.21, .57	20.29	20.79	61
Compositional emergence	6	268	.13	.12	.15	.00	.15, .15	.06, .24	100.00	100.00	12
Compilational emergence	3	165	.68	.09	.78	.05	.72, .84	.68, .88	73.98	76.77	44
Project teams	5	174	.58	.17	.72	.14	.54, .90	.56, .88	48.00	52.42	67
Compositional emergence	—	—	—	—	—	—	—	—	—	—	—
Compilational emergence	4	154	.62	.13	.77	.10	.64, .90	.64, .90	56.26	63.78	58
Cognition–performance relationship											
Action teams	29	1,656	.27	.17	.32	.13	.15, .49	.26, .38	53.26	55.52	157
Compositional emergence	20	1,120	.23	.13	.25	.02	.22, .28	.20, .30	95.39	97.81	80
Compilational emergence	10	617	.38	.19	.47	.19	.23, .71	.35, .59	34.57	36.66	84
Decision-making teams	13	960	.32	.19	.36	.18	.13, .59	.26, .46	30.62	31.70	81
Compositional emergence	9	679	.35	.20	.40	.20	.14, .65	.27, .53	25.21	26.89	63
Compilational emergence	6	343	.26	.14	.30	.08	.20, .41	.19, .41	74.89	75.63	30
Project teams	9	387	.44	.18	.51	.15	.32, .71	.40, .62	46.55	48.51	83
Compositional emergence	3	100	.47	.28	.52	.26	.19, .86	.23, .81	24.59	24.71	28
Compilational emergence	7	338	.46	.15	.54	.11	.40, .68	.43, .65	58.07	61.57	69

Note. *k* = number of correlations meta-analyzed; *N* = total number of groups; *r* = sample size weighted mean observed correlation; SD_r = sample size weighted standard deviation of the observed correlations; ρ = sample size weighted mean observed correlation corrected for unreliability in both measures; $SD_ρ$ = standard deviation of ρ; 80% CV = 80% credibility interval around ρ; 90% CI = 90% confidence interval around ρ; % SEV = percentage of variance due to sampling error; % ARTV = percentage of variance due to all corrected artifacts; FD*k* = file drawer *k* representing the number of "lost" studies reporting null findings necessary to reduce ρ to .05.

Table 13
Study Setting as a Moderator of the Cognition–Process and Cognition–Performance Relationships

Meta-analysis	k	N	r	SD_r	ρ	$SD_ρ$	80% CV	90% CI	% SEV	% ARTV	FDk
Cognition–process relationship											
Laboratory studies	27	1,502	.36	.18	.44	.16	.23, .65	.37, .51	42.23	43.48	211
Compositional emergence	19	970	.29	.16	.35	.10	.22, .48	.28, .42	69.94	70.91	114
Compilational emergence	8	532	.49	.15	.60	.14	.42, .78	.49, .71	39.01	41.86	88
Field studies	10	432	.39	.28	.45	.28	.09, .81	.28, .62	21.79	22.87	80
Compositional emergence	5	272	.21	.17	.23	.11	.09, .37	.09, .37	61.43	62.19	18
Compilational emergence	5	160	.71	.09	.85	.00	.85, .85	.77, .93	100.00	100.00	80
Cognition–performance relationship											
Laboratory studies	37	2,063	.31	.19	.37	.17	.15, .58	.31, .43	42.27	43.58	237
Compositional emergence	23	1,258	.27	.19	.32	.15	.12, .51	.24, .40	46.99	48.12	124
Compilational emergence	17	988	.38	.18	.45	.17	.24, .67	.36, .54	38.35	40.21	136
Field studies	20	1,359	.31	.18	.35	.15	.16, .55	.28, .42	39.54	41.02	120
Compositional emergence	12	864	.28	.19	.32	.16	.11, .53	.22, .42	35.32	36.85	65
Compilational emergence	9	522	.36	.15	.42	.10	.29, .55	.30, .54	62.59	64.03	67

Note. k = number of correlations meta-analyzed; N = total number of groups; r = sample size weighted mean observed correlation; SD_r = sample size weighted standard deviation of the observed correlations; ρ = sample size weighted mean observed correlation corrected for unreliability in both measures; $SD_ρ$ = standard deviation of ρ; 80% CV = 80% credibility interval around ρ; 90% CI = 90% confidence interval around ρ; % SEV = percentage of variance due to sampling error; % ARTV = percentage of variance due to all corrected artifacts; FDk = file drawer k representing the number of "lost" studies reporting null findings necessary to reduce ρ to .05.

Cognitive Underpinnings

In response to our second question, not all cognition has the same impact on teamwork. The nature of cognitive emergence was found to moderate the cognition–process and cognition–performance relationships. Specifically, studies were classified according to their representation of team cognition as a single convergence point (compositional emergence) versus a patterned estimate (compilational emergence; Kozlowski & Klein, 2000). Results show the effects of cognition on both behavioral process and team performance are stronger when emergence is represented through compilation (patterned emergence) than composition (congruent or accurate isomorphic emergence). As compilational emergence represents a team-level construct that is nonisomorphic with the individual-level construct, it ought to relate more strongly to team-level performance indicators. Further, in cross-functional teams, for example, it is likely less relevant to team process and performance that team members know everything similarly (congruence) than that team members know their own areas of expertise as well as whom to consult for everything else (compilation). In other words, patterned knowledge is more intuitively related to process and performance than is its isomorphic counterpart. This finding emphasizes the important role the nature of emergence plays in the resulting predictive capacity of multilevel constructs (Kozlowski & Klein, 2000). In future work on team cognition, the formative multilevel process underlying emergent cognition should be addressed.

Table 14
Study Design as a Moderator of the Cognition–Process and Cognition–Performance Relationships

Meta-analysis	k	N	r	SD_r	ρ	$SD_ρ$	80% CV	90% CI	% SEV	% ARTV	FDk
Cognition–process relationship											
Experiments	14	871	.32	.16	.39	.13	.22, .56	.30, .48	52.34	53.57	95
Compositional emergence	10	578	.28	.16	.34	.13	.18, .50	.24, .44	57.70	58.61	58
Compilational emergence	4	293	.40	.12	.49	.08	.39, .59	.37, .61	69.66	73.41	35
Nonexperiments	23	1,063	.41	.23	.47	.22	.19, .76	.38, .56	28.42	29.90	193
Compositional emergence	14	664	.26	.16	.29	.09	.17, .40	.21, .37	72.22	73.26	67
Compilational emergence	9	399	.65	.11	.78	.06	.70, .86	.71, .85	67.35	76.71	131
Cognition–performance relationship											
Experiments	20	1,248	.30	.18	.35	.16	.14, .55	.27, .43	39.88	40.86	120
Compositional emergence	12	717	.26	.17	.31	.14	.13, .50	.21, .41	50.37	50.65	62
Compilational emergence	9	628	.37	.17	.40	.15	.21, .59	.30, .50	36.30	37.16	63
Nonexperiments	37	2,174	.31	.18	.36	.16	.16, .57	.30, .42	42.09	43.54	229
Compositional emergence	23	1,405	.28	.19	.32	.16	.11, .53	.25, .39	39.06	40.37	124
Compilational emergence	17	882	.38	.17	.45	.14	.27, .63	.37, .53	50.10	51.79	136

Note. k = number of correlations meta-analyzed; N = total number of groups; r = sample size weighted mean observed correlation; SD_r = sample size weighted standard deviation of the observed correlations; ρ = sample size weighted mean observed correlation corrected for unreliability in both measures; $SD_ρ$ = standard deviation of ρ; 80% CV = 80% credibility interval around ρ; 90% CI = 90% confidence interval around ρ; % SEV = percentage of variance due to sampling error; % ARTV = percentage of variance due to all corrected artifacts; FDk = file drawer k representing the number of "lost" studies reporting null findings necessary to reduce ρ to .05.

The second underpinning of cognition that we examined was form of cognition (structured vs. perceptual; Mohammed et al., 2000; Rentsch et al., 2008). Here we found evidence of a complex relationship whereby the form of cognition matters for the prediction of behavioral process but not for the prediction of team performance. Specifically, structured cognition was more predictive of process than perceptual cognition, but there was no difference between structured and perceptual representation in the prediction of team performance. This finding extends the application of the compatibility principle (Ajzen, 1988) from individual attitude–behavior linkages (Harrison et al., 2006), to team-level cognition–behavior relationships as well; notably, patterned (structured) cognition shows a stronger relation to patterned process than does nonpatterned (perceptual) cognition.

Furthermore, cognitive congruence was more predictive of team process when the structure of cognition was represented than when cognition was merely perceptual; conversely, cognitive accuracy was more predictive of process when cognition was represented as perceptions rather than structured knowledge. While overlapping confidence intervals warrant caution, this pattern in point estimates raises an interesting idea requiring future research: Perhaps cognitive perceptions need to be accurate, whereas cognitive structures need to be congruent, in order for teams to realize process gains.

The third underpinning of cognition, cognitive content, has been a focal classificatory variable in the team cognition literature since its inception (Cannon-Bowers & Salas, 1990). The content of cognition, examined here as team- versus task-based cognition, did not moderate the cognition–performance relationship; collective cognition regarding either key elements of the team's task or teamwork showed similar positive effects on performance. Cognitive content did, however, moderate the cognition–process relationship. It is interesting that when cognition is focused on the team, the effect on process is stronger than when cognition is focused on the task.

Taken together, these findings lend some support to Cannon-Bowers and Salas' (2001) proposition that the prediction of outcomes would differ by content domain; particularly that task-related cognition would be most predictive of performance and team-related cognition most related to process. Indeed, task-related cognition was more related to (subjective) performance than was team-related content, likely because knowledge of the task more directly permits the sort of task accomplishment assessed in team performance indicators. Further, current findings suggest an interplay between cognitive form and content domain when predicting process: Structured team-related cognition is most predictive of team behavioral process.

Task Moderators

In response to our third question, some teams need functional cognition more than others. We examined the impact of two task moderators on the cognition–process and cognition–performance relationships: team interdependence (Van de Ven & Ferry, 1980; Wageman, 1995) and team type (Sundstrom et al., 1990, 2000). Regardless of the level of interdependence, compilational emergence was more strongly predictive of process and performance than compositional emergence.

With the compositional cognition–process and the compositional cognition–performance relationships, task interdependence had opposite moderating effects (positive versus negative moderator). Task interdependence has been found to positively moderate the cohesion–performance (Barrick, Bradley, Kristof-Brown, & Colbert, 2007; Gully et al., 1995) and process–performance (LePine et al., 2008) relationships. When considering compositional emergence (e.g., shared mental models), cognition was more predictive of team behavioral process for highly interdependent than for moderately interdependent teams, which is consistent with the expectation that as the interdependence of the task increases, overlap in members' understanding of important aspects of the task and team will enable smoother synchronization of joint actions, and permit members to better anticipate one another's needs (Marks et al., 2000, 2002; Mathieu et al., 2000). However, in support of Kozlowski and Ilgen's (2006) prediction, we found compositional cognition was more predictive of team performance for moderately interdependent teams than for highly interdependent teams.

A possible explanation for this difference could be that cognition has comparable effects on performance on both moderate and highly interdependent tasks, but that the manner in which cognition impacts performance differs across interdependence levels. On highly interdependent tasks, cognition affects performance both directly and through improved behavioral process, whereas on less interdependent tasks, cognition has less of an impact on behavioral process, and thus affects performance either directly or through an alternative mediator-like individual-task performance. Future research is needed on the cognition–process–performance relationships wherein task interdependence is directly manipulated.

The opposite pattern was found for compilational emergence (e.g., transactive memory). Compilational cognition was more related to behavioral process when interdependence was moderate rather than high, and there was no difference in performance based on interdependence (compilationally emergent cognition was similarly predictive of team performance for both moderately and highly interdependent teams). This finding fails to support the expectation of Kozlowski and Ilgen (2006) that compilational forms of cognition would be more important under high than under moderate interdependence. It should be noted that Kozlowski and Ilgen based their prediction on differences between additive (low-interdependence) versus intensive (high-interdependence) tasks. As the literature currently only affords an examination of this relationship at moderate and high levels of interdependence, we advance this as a particularly interesting avenue for future research.

We also found meaningful differences in the role of different aspects of cognition based on the types of tasks teams perform. Compositional cognition is most predictive of process for action and decision-making teams and most predictive of performance in project and decision-making teams, suggesting that cognition is important to performance in more than just action teams. Further, the compositional cognition–process relationship was stronger for action than for decision-making teams, whereas the compositional cognition–performance relationship was stronger for decision-making than for action teams. Clearly, cognition affects different teams differently. While the majority of cognition research to date has been conducted on action teams, the effects of cognition on performance are actually stronger for project teams.

Study Design Moderators

We also examined three methodological moderators of the cognition–process and cognition–performance relationships: (a) performance operationalization, (b) study setting, and (c) study design, which have important implications for understanding the appropriateness of inferences drawn from cognition research. The finding that operationalization of team performance is an important moderator—specifically, the finding that cognition was more strongly related to subjective than to objective performance measures—has important implications for construct validity. There are two interpretations of this finding, which yield different implications. First, to the extent that subjective metrics show stronger relationships due to their reflection of extraneous variance including rater, halo, and same-source bias, future researchers would be well served to incorporate objective performance indicators whenever possible. An alternative view is that subjective metrics are more proximal performance indicators less influenced by factors outside a team's control. In this view, objective measures would be less desirable as diagnostic tools, suggesting future research use subjective performance indicators. Neither study setting nor design moderated effect sizes with performance, supporting the idea that relationships between cognition and team performance obtained in laboratory settings generalize to field settings and that experimentally versus correlationally derived effect size estimates are comparable.

Study characteristics were found to moderate relationships between cognition and process. In particular, compilational cognition has a stronger effect on process in the field and in nonexperiments. Laboratory and experimental findings may actually underestimate the true effects of compilational cognition on behavioral process in intact teams. While laboratory settings enable a high degree of control and experimentation allows cognition to be represented at potentially artificial extremes (e.g., no transactive memory vs. complete transactive memory), this finding suggests the value of transactive memory manifests over time, in repeated interactions, and in the course of meaningful consequences. The dynamic nature of transactive memory should be considered when designing future research investigating the compilational cognition–team process relationship.

Contribution 1: Estimating the Impact of Team Cognition

Taken together, these findings make several important contributions to the literature on team cognition. First, team cognition is indeed an important emergent property of teams. Across the various ways cognition has been conceptualized in the literature, our findings show team cognition positively predicts team task-related processes, motivational states, and performance. Meta-analytic examinations estimate team performance validity coefficients for team cohesion ranging from .17 to .31 (Beal et al., 2003), for efficacy and potency of .35 (Gully et al., 2002), and for team behavioral process of .29 (LePine et al., 2008). We can now compare these effects to the predictive validity of cognition, which is .38.

Second, on the basis of the current study, we can make not only an estimation of the predictive power of cognition in isolation but also an estimation of the unique contribution of cognition to team performance independent of the effects of behavior and motivation, confirming Cannon-Bowers and Salas' intuitive hypothesis: There is a cognitive foundation for team performance.

Contribution 2: Integrating Team Cognition Research on the Basis of Common Underlying Dimensions

The three underlying dimensions of cognition examined here—nature of emergence (composition vs. compilation), form of cognition (perceptual vs. structured), and content of cognition (task vs. team)—show promise in truly moving this area of research forward. First and foremost, this typology provides a common vocabulary that, if adopted, would enable future investigators to accumulate with more forward momentum than has been the case thus far. Second, this framework provides a meaningful way to capture the complexity of multiple aspects of cognitive configuration in teams. Using this lens to examine prior work has enabled us to look at combinations of emergence (Kozlowski & Klein, 2001), forms of cognition (Rentsch et al., 2008), and content domains (Cannon-Bowers et al., 1993). Doing so integrates work that has been previously viewed as somewhat disparate (e.g., those conducted within the mental model, transactive memory, and strategic consensus traditions), permitting broader conclusions and specific qualifications regarding the role of collective cognition in team effectiveness.

Contribution 3: The Importance of Cognitive Complementarity and Emergent Processes

Kozlowski and Ilgen (2007, 2006) drew an important distinction in team cognition constructs, noting that the mental model tradition has tended to explore aspects of the compatibility or similarity of mental representations across team members, whereas the transactive memory approach has emphasized the distribution of information across team members. This distinction is reflective of underlying differences in the multilevel processes through which individual cognition forms an emergent team-level construct (Kozlowski & Klein, 2000), and results show compilational representations of cognition are more predictive of process than are compositional representations (either congruence or accuracy); whereas compilational cognition showed large effect sizes with process and performance, compositional emergence showed similar moderate effects. The effect sizes were closer together when predicting team performance, though the pattern was generally similar. Clearly, knowledge compatibility is an important determinant of team functioning. Effective systems for storing and retrieving information, that is, transactive memory systems, seem particularly critical. A ripe area for future research is to conceptualize and empirically study the impact of unstudied forms of compilationally emergent cognition, in particular, structured assessment of transactive memory.

Limitations

Although the current study makes an important contribution to the study of team cognition, it has several important limitations.

The first two stem from limitations in the availability of primary studies. First, as with any meta-analysis, this study is limited by the availability of reported effect size estimates. Some relationships had very little data available for cumulation, resulting in meta-analyses of a small number of primary studies. We recognize that such meta-analyses are prone to second-order sampling error (Hunter & Schmidt, 2004). However, questions regarding the dimensions and operationalizations of cognition are important to the team cognition literature; thus, we reported on them even when limited data were available. Second, we explored an ambitious list of meaningful moderators, though the number of moderators relative to the availability of studies representing each variant of each moderator prevented us from conducting a fully hierarchical moderator analysis. As a result, we were not able to discern the relative impact of each moderator, nor could we examine complex interactions. It should be noted that examining moderators separately can be particularly problematic when moderators are likely to be correlated (e.g., laboratory/field and experiment/nonexperiment). As such, these results should be interpreted with caution.

Third, caution is warranted when interpreting differences based on the nature of emergence. The conceptual distinction between composition and compilation largely tracks the distinction between examining mental models versus examining transactive memory. Thus, although differences in the nature of emergence of cognitive constructs are conceptually meaningful, the current empirical record largely confounds this distinction with other study features such as measurement methods, samples, and settings. Recognizing these potential confounds and designing careful studies for systematic examinations of both forms of collective cognition are critical next steps toward building an integrated literature on team cognition, a point we will return to in the future research directions.

Two additional limitations stem from design features of the primary studies. First, although team processes feature prominently in current theoretical elaborations of teamwork (Kozlowski & Ilgen, 2006; Marks et al., 2001), primary studies show very little consistency in the labeling and measurement of team processes. We were able to reliably code many studies' conceptualizations of process into the transition and action dimensions, but some could only be coded as global processes. Team process measurement could benefit both from conceptual uniformity in defining the process being investigated (LePine et al., 2008) and from additional psychometric work (Salas et al., 2009). Second, as many of the estimates reported in our results are based on nonexperimental designs, we did not address the causal nature of these relationships.

Future Directions in Team Cognition Research

The current findings highlight a number of areas in need of future research. First, in most studies, one aspect of cognition or another is examined; very few provide information on the interrelation of various aspects of cognitive structures or on potential interactions among multiple aspects of cognition on important outcomes (Smith-Jentsch, 2009). Smith-Jentsch et al. (2005) found meaningful interactions between team and task mental models in predicting safety and efficiency outcomes in air traffic control teams. In the future, investigators should take this idea even further and examine more complex interactions between compositional and compilational forms of emergent cognition. Perhaps compilational cognition (which enables teams to efficiently retrieve and utilize expertise) is even more impactful to the extent that teams also possess congruent compositional cognition (which enables teams to implicitly coordinate actions).

A second fruitful area for future work relates to how collective cognition develops within teams. Relatively little is known about how team cognition forms. This is a critical issue for those designing and using teams in applied settings. Given the important role emergent cognitive structures play, more research is needed to identify factors that promote the formation of functional cognitive structures. Prior work has identified antecedents like cross training (Marks et al., 2001), team demography (Rentsch & Klimoski, 2001), and leader behavior (DeChurch, 2003) that may be profitable springboards for future research. Recently, Rico, Sanchez-Manzanares, Gil, and Gibson (2008) suggested four key factors impacting the formation of team cognition (longevity, knowledge diversity, trust, and group efficacy) and developed conceptually grounded propositions about the manner in which these factors enable emergent cognition in teams which are ripe for empirical testing.

Third, the earliest formulations of team cognition alluded to the value of the construct in substituting for overt communicative processes (Cannon-Bowers et al., 1993). In essence, this view posits that cognition enables teams to switch from a reliance on explicit processes (which require direct communication) to implicit modes of coordination that take place "when team members anticipate the actions and needs of their colleagues and task demands and dynamically adjust their own behavior accordingly, without having to communicate directly with each other or plan the activity" (Rico et al., 2008, p. 164). The vast majority of research on team cognition has focused on relations to explicit team process. Future researchers should capture multiple forms of coordination in order to enable a deeper understanding of the complex relationships that likely exist between configurations of multiple dimensions of cognition and multiple forms of team process.

Fourth, research on team cognition would benefit tremendously from an expanded incorporation of the role of time (Mohammed, Hamilton, & Lim, 2008). Important temporal considerations include performance episodes (Marks et al., 2001), dynamic cognition (Rico et al., 2008), and adaptive team performance outcomes (Burke, Stagl, Salas, Pierce, & Kendall, 2006; Kozlowski, Gully, Nason, & Smith, 1999). The current findings show cognition is more strongly related to transition process than to action process. Transition processes include mission analysis, goal setting, and strategy formulation, and this finding implies a strong connection such that cognition enables these essential actions and that these processes are formative of functional cognitive structures. Future research is required for exploration of the directionality in this relationship and also of the malleability of cognition over time in teams. In essence, cognition is shaped over time, in response to salient internal and external factors, and so researchers need to take a more fine-grained look into the manner in which particular team processes shape cognition, the manner in which cognitive configurations then shape processes, and the factors that prompt functional revisions in cognitive configurations as dictated by the performance environment. Furthermore, adaptation is an important part of the team performance criterion space, and future research into the role of cognitive configurations, particularly modeling changes in team cognition over time, would be especially insightful.

Lastly, future research should focus on additional aspects of compilational cognition in teams, moving beyond cognition as a "shared" or convergent construct to also consider how more complex arrangements of knowledge are complementary. The transactive memory literature clearly underscores the impact of patterned emergence on behavior and performance, while the mental model literature shows the importance of modeling the structured arrangement of knowledge in predicting behavior and performance. Thus, an exciting challenge for future research on collective cognition is to explore the impact of structured compilational cognition.

Practical Applications

While the current findings raise many new directions for team cognition research, and there is much to be learned, several recommendations for applied teaming seem warranted. Cognition positively and meaningfully impacts team performance regardless of how performance is tracked and how cognition is conceptualized. There are clearly differences in prediction based on these underpinnings, but the effects are nonetheless positive across moderator levels. Thus, managers using teams need to consider the congruence, accuracy, and complementarity of cognition in teams. We suggest that team task analyses (Arthur, Edwards, Bell, Villado, & Bennett, 2005) be performed to identify specifically the team-cognitive demands of tasks and then to structure important support systems (e.g., measurement, performance appraisal, and reward structures) to develop and shape the collective cognition needed for successful teamwork. Two levers likely to be most instrumental in shaping cognition are training and leadership, and research examining both sets of interventions would be well served to consider the role of these interventions in shaping functional forms of cognition in teams.

Conclusion

One need not look far to see the prevalence and importance of team functioning to endeavors as varied as medical procedures, military missions, and even knowledge creation. A recent *Science* article called attention to the shift in how knowledge is produced; "solo authors did produce the papers of singular distinction . . . in the 1950s, but the mantle of extraordinarily cited work has passed to teams by 2000" (Wuchty, Jones, & Uzzi, 2007, p. 1038). Teams increasingly perform complex information-processing-intensive tasks, placing a premium on functional forms of collective cognition. Using a unifying theoretical framework, we cumulated extant literature on team cognition and found team cognition is an important driver of team effectiveness. In sum, our findings suggest emergent cognition that enables team members both to predict and anticipate one another's actions and to fully utilize the often diverse array of expertise present in the team are essential underpinnings of team functioning.

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