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TEAM COGNITION AT A CROSSROAD: TOWARD CONCEPTUAL INTEGRATION AND NETWORK CONFIGURATIONS

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A surprising and ironic lack of shared cognition currently exists about team cognition, including how to define the construct, organize the research, and integrate across multiple disjointed constructs. In response to team cognition at a critical crossroad, we provide a comprehensive on the concept of team cognition at a critical crossroad, we provide a comprehensive and cross-disciplinary review, highlighting similarities and differences between constructs and integrating across constructs. Specifically, we synthesize 10 disjointed team cognition constructs into three overarching dimensions. By establishing a common vocabulary to describe team cognition, the three-dimensional framework enhances our ability to evaluate accumulated research, recognize points of intersection, and identify key research gaps. Whereas the three-dimensional framework unites the team cognition literature conceptually, we see networks as a powerful tool to unite the team cognition literature methodologically. Networks neatly merge the structure and content of team cognition, multiple knowledge domains, the interrelationship between cognitive processes and cognitive representations, and the measurement capability to answer new and sophisticated research questions. By providing conceptual integration within a network configuration, we offer theoretical and measurement redirection to hasten the next frontier of team cognition research.

Understanding how teams collectively process and use information is critical to solving the volatile, uncertain, complex, and ambiguous problems that confront today's organizations. Unfortunately, teams' potential to develop innovative solutions often goes unrealized because members' diverse expertise and knowledge fail to be recognized, shared, and harnessed among team members (e.g., Hinsz, Tindale, & Vollrath, 1997). In response, a significant research stream on team cognition has developed over the past three decades. Reflecting how knowledge is collectively represented in a team (e.g., Cronin & Weingart, 2007; Kilduff, Angelmar, & Mehra, 2000), team cognition enables members to share or distribute information and has been used to explain how effective teams coordinate implicitly (Klimoski & Mohammed, 1994; Rico, Sánchez-Manzanares, Gil, & Gibson, 2008).

The importance of team cognition has been evidenced practically, theoretically, and empirically. Practically, notable team performance failures have been blamed on the lack of team cognition, including space mission breakdowns (Bearman, Paletz, Orasanu, & Thomas, 2010), surgical errors (e.g., Santos et al., 2013), airline accidents (e.g., Bell & Kozlowski, 2011), and fratricide (e.g., Rafferty, Stanton, & Walker, 2010). Theoretically, team cognition has commonly been identified as one of the "big three" team

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effectiveness drivers, in addition to motivational-affective states and behavioral processes (e.g., Mathieu, Hollenbeck, van Knippenberg, & Ilgen, 2017), and is therefore featured prominently in team theoretical frameworks (e.g., Burke, Stagl, Salas, Pierce, & Kendall, 2006; Rico et al., 2008).

Empirically, a meta-analysis of 65 studies concluded that team cognition uniquely and positively predicted team processes, motivational states, and team performance (DeChurch & Mesmer-Magnus, 2010a). Indeed, the empirically established team cognition–performance link has been noted as one of the most exciting developments in team research in recent decades (Salas, Cooke, & Rosen, 2008). Team cognition has also been regarded as an interdisciplinary success story (Salas, Kozlowski, & Chen, 2017), crossing disciplinary boundaries as diverse as medicine (e.g., Burtscher, Kolbe, Wacker, Manser, 2011), sports (e.g., Gershgoren, Filho, Tenenbaum, & Schinke, 2013), and engineering (e.g., Badke-Schaub, Neumann, Lauche, & Mohammed, 2007).

The notable progress made over the past 30 years might imply that the team cognition literature has attained a mature stage of theoretical development. Unfortunately, however, this is not the case. Team cognition comprises myriad specific constructs, 10 of which are featured in Table 1. Despite the commonality of representing teams' cognitive architecture, these 10 constructs derive from different literatures, capture unique aspects of team cognition, and have distinct methodologies (Cooke & Gorman, 2009; Mohammed, Ferzandi, & Hamilton, 2010). Table 1 summarizes each team cognition construct's disciplinary roots, definition, and representative citations, emphasizing systematic reviews and meta-analyses when available.

Because the literature consists of a loose collection of many constructs, what we know about team cognition is unclear, distributed, and fragmented. A careful evaluation of the research reveals a surprising and ironic lack of shared understanding of team cognition, including how to define the construct, organize the research, and integrate across the plethora of constructs. Few studies have examined how the 10 main team cognition constructs relate to each other or interact in complex ways to affect team processes and performance, despite calls for such research (e.g., Salas & Wildman, 2009). This piecemeal approach limits our capacity to generate a comprehensive picture, evaluate accumulated research, and delineate key research gaps. Furthermore, the answers to sophisticated questions demanded by contemporary work teams and the most promising avenues for future research lie not within each siloed form of team cognition but at their intersections. We therefore argue that team cognition is at a critical crossroad.

In response, the overall aim of this paper is to provide a comprehensive review of team cognition by highlighting similarities and differences *between* constructs and integrating *across* constructs. We have four specific objectives to push the science of team cognition toward more holistic evolution. First, we offer a clear definition of team cognition, addressing what team cognition is and is not, thereby moving beyond vague descriptions to distinguishing features. Second, we provide a cross-disciplinary and integrative review of 10 types of team cognition, offering a more comprehensive evaluation of the breadth of the literature and greater synthesis across constructs compared to prior reviews.

Third, from our review, we delineate three dimensions (knowledge domain, knowledge foci, and knowledge convergence) that underlie the 10 constructs featured in Table 1, allowing us to integrate the team cognition literature and move beyond the currently siloed approach. Fourth, we embed the three identified dimensions into a network-based framework to illustrate how networks unite the content and structure of team cognition. Networks not only conceptually integrate diverse constructs but also provide a set of measurement techniques that permit more expansive and nuanced research questions to be answered.

AN ORGANIZING DEFINITION OF TEAM COGNITION

Defining team cognition has been problematic from the start and has remained so over the decades. Klimoski and Mohammed (1994: **426–427**) were among the first to highlight the "surprising lack of definitional or conceptual clarity." Cannon-Bowers and Salas (2001: 200–201) later lamented that team cognition "has been used to mean so many different things, that it may be on its way to being meaningless." After almost a decade, DeChurch & Mesmer-Magnus (2010a: 32) reiterated that "team cognition is composed of an eclectic group of studies with different conceptual and operational definitions of cognition." Although we applaud recent empirical advances, our current review of the literature places us in the unfortunate position of having to repeat the same definitional lament.

Considerable dissensus exists as to what constitutes team cognition (Akkerman et al., 2007), as evidenced by prior qualitative reviews covering different numbers (ranging from 2–5) and types of

TABLE 1
Summary of Team Cognition Construct Academic Roots and Definitions

	Team Cognition Construct	Academic Roots	Definition	Key Sources
Team Cognitive Processes	*Process-based group learning*	Organizational behavior	Processes through which groups acquire, share, and combine new knowledge through experience	Argote, Gruenfeld, & Naquin, 2001; Bell, Kozlowski, & Blawath, 2012; Edmondson, Dillon, & Roloff, 2007; Wilson, Goodman, & Cronin, 2007
	Information sharing	Social psychology, communication	Collective sampling dynamics promote the discussion of shared information at the expense of pooling unshared information	Mesmer-Magnus & DeChurch, 2009; Mesmer-Magnus, DeChurch, Jimenez-Rodriguez, Wildman, & Shuffler, 2011; Sohrab, Waller, & Kaplan, 2015; Stasser & Titus, 1985, 1987
Team Cognitive Representations	*TMMs*	Industrial-organizational and cognitive psychology	Team members' shared, organized understanding of knowledge about key elements of the team's relevant environment	Cannon-Bowers, Salas, & Converse, 1993; DeChurch & Mesmer-Magnus, 2010b; Klimoski & Mohammed, 1994; Mohammed et al., 2010
	TSA	Aviation, human factors, cognitive psychology	Sharing among group members concerning the meaning and projected status of environmental events	Endsley, 1995a, 1995b, 2006, 2020, 2021; Salmon, Stanton, Walker, & Green, 2006; Salmon et al., 2008; Stanton et al., 2017; Wellens, 1993
	Cross-understanding	Organizational behavior	Team members' accurate comprehension of one another's mental models	Huber & Lewis, 2010
	Strategic consensus	Strategic management, decision-making	Shared understanding of organizational strategy and the strategic priorities among managers at the top, middle, or operating levels of the organization	Kellermanns, Walter, Floyd, Lechner, & Shaw, 2011; Kellermanns, Walter, Lechner, & Floyd, 2005
	Cognitive consensus	Decision making, leadership, negotiation, psychology, management	Similarity in the way that group members define and conceptualize and key issues	Combe & Carrington, 2015; Fiol, 1994; Kilduff et al., 2000; Markóczy, 2001; Mohammed & Ringseis, 2001; Walsh, Henderson, & Deighton, 1988
	Shared task representations	Decision making, information sharing, organizational behavior	Group members' shared understanding of the decision task	van Ginkel, & van Knippenberg, 2008, 2012
	TMSs	Social, cognitive, and industrial-organizational psychology; organizational behavior	Cognitively interdependent system for encoding, storing, and retrieving information that combines the knowledge possessed by each individual with a shared awareness of who knows what	Bachrach, Kim, Patel, Campion, & Thatcher, 2019; DeChurch & Mesmer-Magnus, 2010a; Lewis & Herndon, 2011; Ren & Argote, 2011; Wegner, 1987

TABLE 1
(Continued)

Team Cognition Construct	Academic Roots	Definition	Key Sources
rGaps	Information processing, psychology	Differences between team members' fundamental definitions of a given problem or task faced by the team	Cronin & Weingart, 2007; Firth, Hollenbeck, Miles, Ilgen, & Barnes, 2015; Weingart, Todorova, & Cronin, 2010

constructs (e.g., Cooke, Gorman, & Winner, 2007; DeChurch & Mesmer-Magnus, 2010a; Mesmer-Magnus, Niler, Plummer, Larson, & DeChurch, 2017; Mohammed & Dumville, 2001; Mohammed, Hamilton, Sánchez-Manzanares, & Rico, 2017; Niler, Mesmer-Magnus, Larson, Plummer, DeChurch, & Contractor, 2020; Uitdewilligen, Waller, & Zijlstra, 2010; Wildman, Thayer, Pavlas, Salas, Stewart, & Howse, 2012; Wildman, Salas, & Scott, 2014). As shown in Table 2, it is indeed striking that these team cognition review articles feature different constructs, even those by the same first author.

Because of this piecemeal approach, team cognition has routinely remained undefined and has often been used as a "catch-all" term to vaguely describe the collective cognitions of a group. Broad and encompassing definitions leave unspecified the question of what team cognition is not. Adding more complication, various terms have been used to describe team cognition, including shared cognition (e.g., Cannon-Bowers & Salas, 2001), distributed cognition (e.g., Hutchins, 1991), macrocognition (e.g., Fiore, Smith-Jentsch, Salas, Warner, & Letsky, 2010), and socially shared cognition (e.g., Levine, 2018).

Table 3 provides a sampling of various definitions of team cognition organized by emphasis, including functionality (e.g., Razzouk & Johnson, 2012), emergence (Wildman et al., 2012), cognitive processes (e.g., Cooke, Gorman, Myers, & Duran, 2013), and cognitive representations (Kozlowski & Ilgen, 2006). Although these emphases contribute to our understanding of the team cognition construct space, what is needed is synthesis across definitions and a clear description of what is fundamental to team cognition, which is the cognition itself. Providing this integration and core focus, we define team cognition as *the knowledge-building processes or the emergent mental representations characterizing the degree of convergence of team-relevant knowledge content and structure.* Below, we delineate several conceptual distinctions highlighted in this definition, concluding with a discussion of how team cognition differs from other team emergent states.

Definitional Elements of Team Cognition

First, the team cognition construct space includes both cognitive processes that are more transitory in nature (Cooke et al., 2013) and the resulting cognitive representations or outcomes that tend to persist over time (Fiore & Salas, 2004; Wildman et al., 2012). Whereas cognitive processes capture *how* information is encoded, stored, retrieved, and exchanged in the team, cognitive representations describe *what* knowledge structures emerge to organize the acquired collective knowledge (Mohammed, Klimoski, & Rentsch, 2000).

Group learning and information sharing are two fundamental cognitive processes describing how members acquire new knowledge from their environment and disseminate it to other members (Grand, Braun, Kuljanin, Kozlowski, & Chao, 2016). As such, cognitive processes help to explain how individual cognition is transformed into team cognition. Team cognitive processes produce emergent team cognitive representations, including team mental models (TMMs), team situation awareness (TSA), cross-understanding, strategic consensus, cognitive consensus, shared task representations, transactive memory systems (TMSs), and representational gaps (rGaps) (see Table 1). Thus, cognitive representations are emergent states or bottom-up constructs deriving from individual cognition and manifesting as an organized patterning of knowledge at the team level (Kozlowski & Klein, 2000; Marks, Mathieu, & Zaccaro, 2001).

This definitional distinction is substantiated in both the team cognition literature (e.g., Fiore & Salas, 2004; Wildman et al., 2012; Wildman et al., 2014) and broader team literature's popular distinction between team processes and emergent states (e.g., Ilgen, Hollenbeck, Johnson, & Jundt, 2005; Marks et al., 2001). According to Marks and colleagues (2001:

TABLE 2
Constructs Featured in Qualitative and Quantitative Reviews of Team Cognition

		Cooke, Gorman, & Winner, 2007	DeChurch & Mesmer-Magnus, 2010a[a]	Mesmer-Magnus et al., 2017[a]	Niler et al., 2020[a]	Mohammed & Dumville, 2001	Mohammed et al., 2017	Uitdewillige et al., 2010	Wildman et al., 2012	Wildman et al., 2014
Team Cognitive Processes	*Information sharing*					✓				
	Process-based group learning					✓				
	Team cognition as interaction	✓								✓
Team Cognitive Representations	*TMMs*	✓	✓	✓		✓	✓	✓	✓	✓
	TMSs	✓	✓	✓		✓		✓	✓	✓
	TSA	✓					✓	✓	✓	✓
	Cognitive consensus					✓				
	Strategic consensus								✓	✓

[a] Quantitative review.

357), team processes are defined as "members' interdependent acts that convert inputs to outcomes through *cognitive* [emphasis added], verbal, and behavioral activities directed toward organizing task work to achieve collective goals." In contrast, "emergent states describe *cognitive* [emphasis added], motivation, and affective states of teams, as opposed to the nature of their member interaction" (Marks et al., 2001: 357). By focusing on the subset of cognitive activities comprising team processes and emergent states, team cognition is solidly rooted in the heads of individual members.

Similar to the iterative relationship between team processes and emergent states described by Marks and colleagues (2001), team cognitive processes influence team cognitive representations that then alter team cognitive processes (Grand et al., 2016). Although both are dynamic, cognitive processes are more malleable, context-dependent, and "in the moment" (Cooke et al., 2013), whereas cognitive representations are more enduring over time (e.g., Fiore, Rosen, Smith-Jentsch, Salas, Letsky, & Warner, 2010). Despite the importance of cognitive processes, the bulk of the literature has featured team cognition as cognitive representations (Wildman et al., 2014), as illustrated in Table 1.

A second definitional element is the continuum of divergence to convergence, which refers to the degree of variability or similarity among team members' cognitive content and structure (Hinsz et al., 1997). On one end of the continuum, team members' mental models are completely distributed with zero overlap, and at the other end of the continuum, members' mental models are completely identical with 100% overlap (Cannon-Bowers & Salas, 2001). From the inception of the team cognition literature, it has been understood that the term "shared" holds multiple meanings, including having in common (share the vision) and dividing up (share the workload) (Klimoski & Mohammed, 1994). Synonyms for convergence include sharedness, similarity, overlapping, integration, and compositional, while synonyms for divergence include distributed, complementary, specialization, and compilational (e.g., Cannon-Bowers & Salas, 2001; DeChurch & Mesmer-Magnus, 2010a; Zajac, Gregory, Bedwell, Kramer, & Salas, 2014). Whereas some types of team cognition emphasize convergence (e.g., TMMs, shared task representations), others emphasize divergence (e.g., TMSs, rGaps) (e.g., Mohammed et al., 2010).

TABLE 3
Sample of Team Cognition Definitions

Definitional Emphasis on	Definition	Citation
Generic Definitions	"Collaborative thinking activities."	Kiekel & Cooke, 2005: 738
	"A collaborative process that occurs between individuals."	Levine, 2018: 52
	"Processes at the intraindividual level that are dependent on and interact with process at the interindividual level."	Salas & Fiore, 2004: 138
	"The cognitive activity that occurs at a team level."	Cooke, Gorman, & Rowe, 2004: 158; Cook et al., 2007: 240
Functions Team Cognition Fulfills	"The knowledge that team members hold, which enables them to form accurate explanations and expectations for the task and in turn to coordinate their actions and adapt their behavior to demands of the task and other team members."	Razzouk & Johnson, 2012: 3056
	"Cognitive structures or knowledge representations that enable team members to organize and acquire information necessary to anticipate and execute actions."	Kozlowski & Ilgen, 2006: 83
Emergence	"The higher-level knowledge structures that emerge from the interactions of individual team members."	Wildman et al., 2012: 84
	"Team mental models (cognition) … represent emergent group properties that have their origins in the elemental content provided by individuals."	Kozlowski & Klein, 2000: **55–56**
Cognitive Processes	"Team cognition emerges from the interplay of the individual cognition of each team member and team process behaviors."	Cooke, Salas, Kiekel, & Bell, 2004: 85
	"Team member interaction, typically in the form of explicit communication (e.g., e-mail, phone, talking face-to-face), is team cognition … Team cognition is an activity, not a property or a product."	Cooke et al., 2013: **256–257**
	"Macrocognition in teams is the process of transforming internalized team knowledge into externalized team knowledge through individual and team knowledge building processes."	Fiore et al., 2010: 258
	Socially shared cognition is the process of "collaboration among members who seek to encode, interpret, and recall information together rather than apart."	Moreland, Argote & Krishnan, 1996: 58
Cognitive Representations	"Cognitive structures or knowledge representations that enable team members to organize and acquire information necessary to anticipate and execute actions."	Kozlowski & Ilgen, 2006: 83
	"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."	DeChurch & Mesmer-Magnus, 2010a: 33

Third, content and structure are key features of team cognitive representations, as acknowledged in prior research (e.g., DeChurch & Mesmer-Magnus, 2010a; Rentsch, Small, & Hanges, 2008). Content encompasses knowledge that is relevant to the team, including strategic priorities (e.g., Kellermanns et al., 2005), assumptions (e.g., Cronin & Weingart, 2007), task-related concepts (e.g., van Ginkel & van Knippenberg, 2008), interaction patterns and role interdependencies (e.g., Cannon-Bowers, Salas, & Converse, 1993), teammates' preferences (e.g., Huber & Lewis, 2010), and the temporal (Mohammed, Hamilton, Tesler, Mancuso, & McNeese, 2015) and situational (e.g., Endsley, 1995a) context. In contrast, team cognitive structure represents the pattern of relationships between concepts in team members' minds and has often been modeled via network analysis tools (Mohammed et al., 2000). Content and structure are closely intertwined in that the meaning of concepts depends on the connections between them (Seel, 2012).

What Is and Is not Team Cognition

Our review is bounded by the conceptualization of team cognition as knowledge-building activities (processes) or sharedness of knowledge content or structure (representations). This definition means that we exclude other emergent states that do not highlight as central how team knowledge emerges or is mentally represented and shared within the team. For example, according to a typology delineated by Fulmer and Ostroff (2016), noncognitive emergent properties include attitudes (e.g., team psychological safety, team efficacy), affect (e.g., compassion), and perceptions (e.g., climate). Whereas “climate is about *what* should be aimed for and, perhaps, *why*, TMMs and transactive memory are about *how* the knowledge is organized, represented, and distributed” (Kozlowski & Ilgen, 2006: 83). In addition to these conceptual distinctions, it should be noted that team cognition has been meta-analytically differentiated from, and has added unique variance beyond, motivational states and behavioral processes (DeChurch & Mesmer-Magnus, 2010a). Nevertheless, we hasten to add that the nomological network of team cognition includes other emergent states, such as psychological safety, collective efficacy, and team climate, that influence the development and representation of team knowledge.

A UNIFYING STRUCTURE FOR THE LITERATURE REVIEW

Having presented an organizing definition of team cognition, we now turn to the second goal of our article, which is to provide a cross-disciplinary and integrative review of 10 types of team cognition. What does the field of team cognition look like right now? Table 1 represents the current state of team cognition research, which can be characterized as a loose collection of 10 specific constructs, largely operating as independent entities (e.g., Bachrach et al., 2019; Mohammed et al., 2010; Salmon et al., 2008). Mirroring this disjointed state of affairs, most extant reviews have highlighted only one type of team cognition (e.g., Bachrach et al., 2019; Mesmer-Magnus & DeChurch, 2009; Mohammed et al., 2010; Ren & Argote, 2011; Salmon et al., 2008). Of the reviews shown in Table 2 that feature two or more team cognition constructs, most have summarized each form of cognition independently, with little cross integration. Parallel to conceptual research, rarely have empirical studies combined multiple forms of team cognition (Uitdewilligen et al., 2010). Although Salas and Wildman (2009) included the question of how various team cognition constructs integrate to influence team outcomes in the top 10 list of critical team research questions, it has largely gone unanswered.

On the positive side, the proliferation of constructs and the growth in research across disciplinary and international boundaries over the past 30 years illustrates the far-reaching interest in and impact of team cognition. On the negative side, however, the piecemeal nature of the proliferation significantly challenges the building of a cumulative knowledge base across domains and studies. Toward providing a more substantive and holistic picture, we extend existing reviews in two ways. First, we conduct a more comprehensive analysis of the team cognition literature, covering at least twice the number of constructs as prior reviews listed in Table 2. Second, rather than evaluating each in relative isolation from one another, we adopt a consolidative approach by comparing *between* constructs and integrating *across* constructs. In doing so, our aim is to facilitate collaboration and cross-fertilization across disconnected areas of the team cognition literature.

To achieve these goals, we utilize a unifying framework based on the definitional elements of team cognition described in the previous section. We use cognitive processes or representations, continuum of divergence–convergence, and content or structure to underpin our framework, for several reasons. First, the definitional elements are theoretically grounded and have been substantiated in prior team cognition reviews and meta-analyses (e.g., DeChurch & Mesmer-Magnus, 2010a, 2010b; Grand et al., 2016; Mohammed & Dumville, 2001; Wildman et al., 2014). Second, by highlighting common and distinguishing characteristics that underlie all team cognition constructs, a framework based on the definitional elements allows us to comprehensively review the breadth of the literature. Third, although familiar and comprehensive, these elements have not been fully leveraged for unifying purposes in prior work, allowing us the opportunity to clearly identify areas for cross-fertilization across team cognition constructs.

We utilize the first two definitional elements as superordinate categories to create a 2 (cognitive processes and representations) × 2 (convergence and divergence) underpinning framework. Although conceptually recognized as a continuum, we dichotomize convergence here because this depiction represents how team cognition constructs have been categorized in their respective literatures and by the prior reviews listed in Table 2 (e.g., DeChurch & Mesmer-Magnus, 2010a). As such, constructs were classified as either convergent or divergent based on the dominant emphasis in the literature as a whole. The third definitional element of content and structure is used later in the paper to scaffold our team cognition measurement review. As shown in Table 4, each of the 10 team cognition constructs was mapped to one

TABLE 4
Team Cognition Constructs Organized According to Knowledge Foci and Degree of Knowledge Sharing

		Knowledge Foci	
		Cognitive Processes	***Cognitive Representations***
Degree of Knowledge Convergence	***Convergent***	***Quadrant 1*** • Process-based group learning	***Quadrant 3*** • Team mental models • Team situation awareness • Cross-understanding • Strategic consensus • Cognitive consensus • Shared task representations
	Divergent	***Quadrant 2*** • Information sharing	***Quadrant 4*** • Transactive memory systems • Representational gaps

of the four quadrants resulting from the 2 × 2 overarching structure.

In the sections below, we first summarize the popularity and similarities across constructs included in each quadrant. We then provide a high-level review of the conceptualization and empirical evidence for each team cognition construct per quadrant. Table 5 outlines the key empirical findings for each of the 10 team cognition constructs reviewed. We then summarize the differences across constructs in each quadrant. Concluding the literature review, we encapsulate the state of the science and identify conceptual limitations across all quadrants. As such, we underscore the breadth of research across (rather than the depth within) team cognition constructs.

LITERATURE REVIEW: MAPPING TEAM COGNITIVE PROCESSES

Scholars have advocated different perspectives regarding team cognitive processes. For example, macrocognition describes how internalized knowledge (held in team members' minds) transforms into externalized team knowledge (facts, relationships, and concepts explicitly agreed upon by the team) by both individual and team knowledge-building processes (e.g., Fiore, Rosen, et al., 2010). The team collaborative stages of the macrocognition model include knowledge construction, problem model development, team consensus, and outcome evaluation and revision (Fiore, Wiltshire, Oglesby, O'Keefe, & Salas, 2014). Situation assessment, problem detection, communication, and coordination patterns are also key macrocognition functions enabling teams to cycle between internalized and externalized knowledge (e.g., Keyton & Beck, 2010; Roberts & Stanton, 2018). In addition to a process-based perspective, macrocognition is distinguished from the larger team cognition literature via a focus on naturalistic environments (cognition in the wild) rather than synthetic laboratory settings (Klein, Ross, Moon, Klein, Hoffman, & Hollnagel, 2003). Thus, macrocognition emphasizes knowledge-based performance in novel, complex, and dynamic contexts, rather than rule-based performance in familiar contexts (Fiore Smith-Jentsch, Salas, Warner, & Letsky, 2010). Utilizing a macrocognition framework, Grand and colleagues (2016) developed and found empirical support for a process-level theory of team knowledge emergence, detailing how internalized information transitions to externalized knowledge via learning (data selection, encoding, decoding, integration) and sharing (member selection, retrieval, transmission, acknowledgment) processes.

Also representing team cognition as a process-based approach, the interactive team cognition theory postulates that team cognition is not collective knowledge, but the joint interactivity by which members coordinate and communicate (Cooke et al., 2013). Thus, team cognition consists of observable team member interactions, including when team members communicate explicitly or when they distribute responsibility for accomplishing certain tasks (Perkin, 2019). According to Cooke and colleagues (2013), explicit communication exchanges between members are the enactment of team cognition itself, which changes over time and is situated in a certain context.[1] As such, cognitive processes capture the intersection of individual member cognition and team process behaviors (Cooke et al., 2004). According to this approach, the emphasis is on the global team-level, as opposed to aggregated individual-level, cognition, and on dynamic member exchanges over

TABLE 5
Summary of Team Cognition Constructs Empirical Findings

	Team Cognition Construct	Key Empirical Results	Representative Studies
Team Cognitive Processes	Process-based group learning	Process-based group learning positively predicted performance. Task- and person-focused leadership and psychological safety positively predicted group learning.	Edmondson, 1999; Koeslag-Kreunen, Van den Bossche, Hoven, Van der Klink, & Gijselaers, 2018; Wong, 2004; Zellmer-Bruhn & Gibson, 2006
	Information sharing	Groups mentioned disproportionate amounts of shared relative to unshared information, reaching suboptimal decisions. Information sharing positively predicted team performance and this relationship was stronger when studies emphasized information uniqueness rather than discussion openness. Task characteristics, leadership, size, time pressure, and communication technology were team-level inputs affecting information sharing.	Mesmer-Magnus & DeChurch, 2009; Mesmer-Magnus et al., 2011; Stasser, Taylor, & Hanna, 1989; Wittenbaum & Stasser, 1996
Team Cognitive Representations	TMMs	TMMs positively predicted team performance above and beyond team motivational states and team processes. Training, leadership, planning, and reflexivity fostered TMM emergence.	Fisher, Bell, Dierdorff, & Belohlav, 2012; Gorman & Cooke, 2011; Lim & Klein, 2006; Marks, Sabella, Burke, & Zaccaro, 2002; Mathieu, , Heffner, Goodwin, Cannon-Bowers, & Salas, 2005; Rentsch & Klimoski, 2001
	TSA	TSA positively predicted team performance in lab and field settings. Externalized knowledge devices, two-way informal team communication, and taskwork and teamwork training facilitated TSA formation.	Endsley, 2000, 2020, 2021; Hamilton, Mancuso, Mohammed, Tesler, & McNeese, 2017; Robertson, Dias, Yule, & Smink, 2017; Roth, Multer, & Raslear, 2006; Sorensen & Stanton, 2011; Valaker, Hærem, & Bakken, 2018
	Cross-understanding	Cross-understanding positively predicted team performance. Analogies, communication frequency, leadership, and openness to cognitive diversity promoted cross-understanding.	Furukawa, 2016; Graff & Clark, 2018; Hoandră, 2017; Meslec & Graff, 2015
	Strategic consensus	Strategic consensus promoted strategy implementation and performance.	Kellermanns et al., 2005, 2011; Knight et al., 1999; Porck, van Knippenberg, Tarakci, Ateş, Groenen, & de Haas, 2020
	Cognitive consensus	Cognitive consensus predicted team performance, decision satisfaction, and perceived implementation ease. A unanimity decision rule, the repertory grid cognitive mapping tool, and framing facilitated cognitive consensus.	Carrington, Combe, & Mumford, 2019; Combe & Carrington, 2015; Fiol, 1994; Kilduff, Angelmar, & Mehra, 2000; Markóczy, 2001; Mohammed & Ringseis, 2001
	Shared task representation	Shared task representations predicted information elaboration and decision-making performance. Team reflexivity promoted shared task representations.	Tindale, Smith, Thomas, Filkins, & Sheffey, 1996; van Ginkel & van Knippenberg, 2008, 2012.
	TMSs	TMSs positively predicted team performance above and beyond team motivational states and team processes. Interdependence, familiarity, training, and communication facilitated the development of TMSs.	Argote, Gruenfeld, & Naquin, 2018; Austin, 2003; Bachrach et al., 2019; Lewis, 2003; Liang, Moreland, & Argote, 1995; Mell, Van Knippenberg, & Van Ginkel, 2014; Mortensen, 2014; Pearsall, Ellis, & Bell, 2010

TABLE 5
(Continued)

Team Cognition Construct	Key Empirical Results	Representative Studies
rGaps	rGaps decreased information elaboration and increased conflict. rGaps positively predicted creativity and innovation.	Paletz, Schunn, & Kim, 2013; Wang, Mannix, & Cronin, 2016; Weingart, Todorova, & Cronin, 2008; Weingart et al., 2010

more stable knowledge representations (Cooke, 2015; Cooke et al., 2013).

As shown in Tables 1, 4, and 5, team cognition as cognitive processes represents a minority viewpoint in the team cognition literature, as most of the research has featured cognitive representations. Cognitive processes include information sharing, problem solving, learning, reasoning, remembering, assessing situations, designing, and decision-making (Cooke et al., 2013). However, in their monograph, Grand and colleagues (2016) identified information sharing and group learning as the two fundamental activities involved when individual cognition emerges into team cognition. Therefore, we focus on information sharing and group learning below.

Popularity and Similarities across Team Cognitive Process Constructs (Quadrants 1 and 2)

Although information sharing and group learning each have sizable literatures, they were only included in one (Mohammed & Dumville, 2001) of the nine team cognition reviews listed in Table 2, again demonstrating the prominence of cognitive representations over cognitive processes in team cognition research. Both constructs capture the importance of knowledge-building activities and have been found to positively predict team performance (e.g., Edmondson, 1999; Edmondson et al., 2007; Mesmer-Magnus & DeChurch, 2009; Mesmer-Magnus et al., 2011). Below, we provide a high-level review of the process-based group learning and information sharing literatures.

Quadrant 1: Cognitive Processes Emphasizing Convergence

Process-based group learning. Described as a “diverse, sprawling, and messy conceptual domain” (Bell et al., 2012: 902), group learning has been conceptualized as both a process (e.g., Edmondson, 1999; Wong, 2004) and an outcome (e.g., Edmondson, Dillon, & Roloff, 2007; Wilson et al., 2007). Focusing on the former in this section and the latter in a later section, process-based group learning captures how group members acquire and communicate new knowledge (Grand et al., 2016) across a group’s lifespan, including initial establishment, to task execution, to project modification, to the management of external resources (Argote et al., 2001). Specifically, process-based group learning has been characterized as “the activities through which individuals acquire, share, and combine knowledge through experience with one another” (Argote et al., 2001: 370) or “an ongoing process of reflection and action, characterized by asking questions, seeking feedback, experimenting, reflecting on results, and discussing errors” (Edmondson, 1999: 353). Team learning emergence has been theorized (with empirical support) to involve four sociocognitive processes (Kostopoulos, Spanos, & Prastacos, 2013), including intuition (preconscious individual insight), interpretation (explaining insights to oneself and other members), integration (developing a shared understanding and coordinated action through mutual adjustment), and codification (converting of tacit knowledge to explicit knowledge).

By uncovering unexpected implications and permitting the team to shift directions as situations change, process-based group learning has been found to promote increased group performance (e.g., Edmondson, 1999; Edmondson et al., 2007; Schaubroeck, Carmeli, Bhatia, & Paz, 2016; Van der Vegt & Bunderson, 2005; Wong, 2004). Although performance has been the dominant outcome examined, process-based group learning has also positively predicted team satisfaction and viability (Ortega, Sánchez-Manzanares, Gil, & Rico, 2010), team task knowledge and team coordination quality (Wiedow, Konradt, Ellwart, & Steenfatt, 2013), mutually-shared cognition (Van den Bossche, Gijselaers, Segers, & Kirschner, 2006), and the quality of team interpersonal relations (Zellmer-Bruhn & Gibson, 2006).

Regarding antecedents, a recent meta-analysis supported the positive relationship between group learning and task- and person-focused leadership behaviors, finding person-focused leadership behaviors to be particularly effective for increasing team learning on both adaptive and developmental tasks (Koeslag-Kreunen et al., 2018). Other factors found to promote team learning include psychological safety (e.g., Ashauer & Macan, 2013; Edmondson, 1999, 2003; Edmondson et al., 2007; Ortega, Sanchez-Manzanares, Gil, & Rico, 2013), teams' cooperative (vs. competitive or independent) learning goals (Tjosvold, Yu, & Hui, 2004), task autonomy (Bresman & Zellmer-Bruhn, 2013; Zellmer-Bruhn & Gibson, 2006), collective efficacy (Edmondson, 1999; Ortega et al., 2010), task interdependence (Ortega et al., 2010; Van den Bossche et al., 2006), organizational and team structure (Bresman & Zellmer-Bruhn, 2013), justice climate (Walumbwa, Hartnell, & Misati, 2017), and peer justice (Walumbwa et al.,2017). Regarding team composition, higher cognitive ability and lower agreeableness were associated with greater team learning (Ellis, Hollenbeck, Ilgen, Porter, West, & Moon, 2003).

Quadrant 2: Cognitive Processes Emphasizing Divergence

Information sharing. According to the biased sampling model of group discussion theorized by Stasser and Titus in 1985, unshared information is less likely to be mentioned in discussion and is therefore less likely to influence decisions. Consequently, many teams never realize the potential benefit of pooling expertise because already shared information is rehashed at the expense of discussing unique member information (e.g., Stasser et al., 1989). This literature has therefore warned of the danger of focusing exclusively on shared information and the advantages of discussing uniquely held information. Despite numerous calls for conceptual expansion (e.g., Mohammed & Dumville, 2001; Wittenbaum, Hollingshead, & Botero, 2004), the collective information sampling model has dominated the information sharing literature (Stasser & Titus, 1985, 1987), with little theoretical development beyond the original model.

Three meta-analyses (Lu, Yuan, & McLeod, 2012; Mesmer-Magnus & DeChurch, 2009; Reimer, Reimer, & Czienskowski, 2010) confirmed Stasser and Titus' (1985) original finding that groups mention, repeat, and recall disproportionate amounts of shared relative to unshared information, thereby reaching suboptimal decisions. Also supportive of Stasser and Titus (1985), teams favor shared information when they stand to gain the least rather than the most from pooling knowledge, including when members already know the information and decision structure is high, when they can make accurate decisions by themselves, when members are similar and cooperative, and when they are instructed to find a correct answer (rather than a consensus) (Mesmer-Magnus & DeChurch, 2009).

A meta-analysis summarizing 22 years of research across 72 independent studies concluded that information sharing positively predicted team performance across all moderators, and this relationship was stronger when studies emphasized information uniqueness rather than discussion breadth or openness (Mesmer-Magnus & DeChurch, 2009). A follow-up meta-analysis of 94 studies found that teams with high levels of virtuality shared more unique information and exhibited less open information sharing than was the case either face-to-face or in teams with low levels of virtuality (Mesmer-Magnus, DeChurch, Jimenez-Rodriguez, Wildman, & Shuffler, 2011). Moreover, unique information sharing was more strongly related to team performance in face-to-face teams, whereas open information sharing was more strongly related to team performance in teams with high levels of virtuality (Mesmer-Magnus et al., 2011).

Given the level of support for the biased sampling model of group discussion, numerous studies have sought to increase the probability that unshared information will be mentioned by investigating various individual- and team-level antecedents (Sohrab et al., 2015). For example, information dissemination and decision quality improve under conditions of reduced shared information (Cruz, Boster, & Rodriguez, 1997), a solve set (demonstrably correct answer) instead of a judge set (where there may be insufficient information to determine the correct answer) (Stasser & Stewart, 1992), and when information is partially shared among more than one member (Sohrab et al., 2015). Moreover, members who were directive leaders (e.g., Larson, Foster-Fishman, & Franz, 1998), had higher status (Hollingshead, 1996a), or had expert roles publicly assigned on the team (e.g., Stasser, Vaughan, & Stewart, 2000) were more likely to mention unshared items compared to their novice companions. In contrast, increasing group size (e.g., Lu et al., 2012), time pressure (e.g., Reimer et al., 2010), and accountability to outside parties (Stewart, Billings, & Stasser, 1998) exacerbated the shared information bias.

Differences and Summary across Team Cognitive Process Constructs (Quadrants 1 and 2)

The group learning and information sharing literatures differ in important ways. Regarding what is shared, information sharing features revealing information and facts, while group learning covers a broader array of content, including seeking corrective feedback, addressing differences of opinion, asking for help, reflecting on work processes and results, and discussing errors in addition to seeking out and communicating information. Whereas information sharing has been dominated by lab studies that are variations of hidden profile tasks (e.g., Sohrab et al., 2015), most process-based group learning research has been conducted in the field (Edmondson et al., 2007) using a mixture of quantitative (e.g., Schaubroeck et al., 2016; Walumbwa et al., 2017; Wong, 2004) and qualitative (e.g., Edmondson, 1996, 2002; Edmondson, Bohmer, & Pisano, 2001; Tucker, Nembhard, & Edmondson, 2006) methods. Interestingly, while the information sharing literature has been criticized for its theoretical and methodological homogeneity (Sohrab et al., 2015), group learning has been faulted for its eclectic nature and lack of theoretical and methodological cohesion (Bell et al., 2012; Mohammed & Dumville, 2001). As highlighted in Table 4, whereas group learning has emphasized convergence, information sharing has underlined divergence via the value of uniquely held information.

Although information sharing and group learning have rarely been empirically combined, a recent study by Grand and colleagues (2016) measured both, demonstrating that efficient information processing by individuals and equal rates of information sharing across members increased knowledge internalization in an agent-based simulation and human team study. Extending beyond previous research emphasizing what information is shared, these results indicated that what information members share, and how often, are equally or more essential to knowledge building (Grand et al., 2016). We hope that future research follows in the footsteps of Grand and colleagues (2016: 1376) by continuing to unpack the black box of "how, when, and why team knowledge manifests."

As highlighted above and in Table 4, whereas group learning has emphasized convergence, information sharing has underlined divergence via value of uniquely held information. That is, the information sharing literature has lauded distributed expertise that is disseminated as a hallmark of effective teamwork and cautioned on the liabilities of a convergence-only approach (Stasser & Titus, 1985, 1987). Applying this perspective to group learning would raise questions that have not been explicitly discussed. For example, does the learning of a few, the majority, or all team members constitute group learning? What are the potential benefits of only a subset of members acquiring certain information? An interesting synergy of group learning and information sharing would be to consider the optimum mix of convergence and divergence in knowledge building activities regarding how knowledge is acquired and communicated across the team's life cycle.

LITERATURE REVIEW: MAPPING TEAM COGNITIVE REPRESENTATIONS

Whereas cognitive processes describe the "how" of information exchange in teams, cognitive representations capture the "what" of the resulting collective knowledge structures (Mohammed, Klimoski, & Rentsch, 2000). In addition, while information sharing and process-based group learning describe dynamic exchanges between members, the emergent knowledge representations have been viewed as comparatively more persistent. As Table 4 clearly illustrates, most of the literature has featured team cognition as cognitive representations. A major differentiator across the eight constructs reviewed below is whether they emphasize knowledge convergence or divergence.

Quadrant 3: Cognitive Representations Emphasizing Convergence

Across-construct popularity and similarities for Quadrant 3. Of the constructs listed in Quadrant 3, TMMs have been the most commonly researched, followed by TSA, as evidenced by a trend analysis (Wildman et al., 2012). In addition, prior qualitative and quantitative team cognition reviews all included TMMs, and five of the nine reviews in Table 2 included TSA (e.g., Cooke et al., 2007; DeChurch & Mesmer-Magnus, 2010a; Mesmer-Magnus et al., 2017; Mohammed & Dumville, 2001; Mohammed et al., 2017; Uitdewilligen et al., 2010; Wildman et al., 2012; Wildman et al., 2014). Cognitive consensus (Mohammed & Dumville, 2001) and strategic consensus (Wildman et al., 2012; Wildman et al., 2014) were included once and twice in prior literature reviews, respectively. Cross-understanding and shared task representations have the smallest literatures.

As Table 4 depicts, most constructs in the team cognition literature have emphasized knowledge representation convergence. Although deriving from distinct literatures that largely operate as silos, each of the six constructs reviewed in Quadrant 3 are conceptually united in assuming that "getting on the same page" improves team processes and outcomes.

Moreover, they empirically coincide in demonstrating that similar cognitive representations positively predict team performance. Each of the six constructs is briefly reviewed below.

Team mental models. TMMs are "team members' shared, organized understanding and mental representation of knowledge about key elements of the team's relevant environment" (Mohammed & Dumville, 2001: 90). The central assumption underlying this research is that when team members develop similar team-relevant knowledge, they anticipate the needs and actions of other members, thereby increasing coordination and effectiveness (Cannon-Bowers et al., 1993). TMMs are conceptually distinct from other types of team cognition in that they include a broader range of cognitive content, encompassing taskwork (what needs to be accomplished, such as work goals and performance requirements), teamwork (how members should work together to accomplish tasks, including interpersonal interaction requirements of members), and "timework" (when work should be accomplished, such as deadlines, schedules, and pacing) domains (Mohammed et al., 2015; Santos, Passos, & Uitdewilligen, 2016). TMMs have two primary properties: similarity (the degree to which members' mental models overlap with one another) and accuracy (the degree to which members' and experts' mental models overlap).

Across diverse settings, the most consistent and strongest empirical finding is that TMMs similarity positively predicts team performance, as supported by three meta-analyses (DeChurch & Mesmer-Magnus, 2010a, 2010b; Mesmer-Magnus et al., 2017). Higher taskwork (e.g., Cooke, Kiekel, & Helm, 2001), teamwork (e.g., Rentsch & Klimoski, 2001), and "timework" (Mohammed et al., 2015; Santos, Uitdewilligen, & Passos, 2015) TMM similarity have been associated with higher performance. Results for taskwork tend to be stronger than for teamwork in studies measuring both types of content (e.g., Lim & Klein, 2006; Mathieu et al., 2005; Mathieu, Rapp, Maynard, & Mangos, 2009).

Although team performance has been the most popular criteria by far, adaptation (Randall, Resick, & DeChurch, 2011; Uitdewilligen, Rico, & Waller, 2018), viability (members' willingness to work together in the future) (Resick, Dickson, Mitchelson, Allison, & Clark, 2010; Santos & Passos, 2013), and innovation (content only) (Dao, Strobl, Bauer, & Tarba, 2017; Reuveni & Vashdi, 2015) have also been positively predicted by TMM similarity. TMM similarity has been associated with several team processes (DeChurch & Mesmer-Magnus, 2010a, 2010b), including higher back-up behaviors (Marks et al., 2002), higher coordination (Fisher et al., 2012; Marks et al., 2002), and higher communication (e.g., Gorman & Cooke, 2011; Waller, Gupta, & Giambatista, 2004). Team processes have frequently been found to mediate the relationship between TMM sharedness and team performance (e.g., Fisher et al., 2012; Gorman & Cooke, 2011).

Because members may share erroneous mental models, similar and accurate TMMs are expected to produce the highest team performance (e.g., Edwards, Day, Arthur, & Bell, 2006; Mathieu et al., 2005). However, TMM studies have emphasized similarity over accuracy, and research findings have been more consistent for similarity than for accuracy (e.g., Mohammed et al., 2010). Parallel to the findings for TMM similarity, most studies have reported that greater TMM accuracy is associated with higher performance (e.g., Edwards et al., 2006; Ellis, 2006; Pearsall et al., 2010); however, others have failed to find such a relationship (e.g., Mathieu et al., 2005; Webber, Chen, Payne, Marsh, & Zaccaro, 2000). Unlike TMM similarity, TMM accuracy has not been positively associated with team processes (e.g., Marks, Zaccaro, & Mathieu, 2000; Resick et al., 2010).

In terms of antecedents, various types of training have had positive effects on TMM similarity or accuracy, including cross-training (Cooke et al., 2003; Marks et al., 2002) and guided team self-correction (Smith-Jentsch, Cannon-Bowers, Tannenbaum, & Salas, 2008). In addition to training, other team interventions, such as planning (Stout, Cannon-Bowers, Salas, & Milanovich, 1999), reflexivity (Gurtner, Tschan, Semmer, & Nägele, 2007; Konradt, Schippers, Garbers, & Steenfatt, 2015), and storytelling (Tesler, Mohammed, Hamilton, Mancuso, & McNeese, 2018), foster TMM development. Different types of leadership, including empowering (Lorinkova, Pearsall, & Sims, 2013), distributed-coordinated (McIntyre & Foti, 2013), and transformational (Ayoko & Chua, 2014), have positively predicted TMM similarity or accuracy. Receiving less emphasis than team interventions, compositional determinants of TMMs include higher cognitive ability (e.g., Edwards et al., 2006; Randall et al., 2011), lower racial diversity and higher mean agreeableness (Fisher et al., 2012), as well as higher tenure (Smith-Jentsch, Campbell, Milanovich, & Reynolds, 2001), and experience and educational similarity (Rentsch & Klimoski, 2001). Regarding contextual antecedents, acute stress (Ellis, 2006) is negatively predictive of TMM similarity and accuracy.

Team situation awareness. TSA refers to "the sharing of a common perspective between two or more individuals regarding current environmental events, their meaning, and projected future states" (Wellens, 1993: 6). That is, TSA captures the extent to which team members hold similar representations regarding how their task context is currently characterized. Paralleling the individual level, TSA has three hierarchical levels. Level one refers to perception or awareness of elements in the task environment, and level two describes comprehension or understanding the meaning of the elements' interrelationships. Level three denotes projection or anticipation of how elements in the task environment will change in the future (Endsley, 2000). TSA has generally been considered isomorphic to individual situation awareness as a compositional team level construct, assuming overlapping situational knowledge between team members (e.g., Endsley, 1995a; Salas, Prince, Baker, & Shrestha, 1995).

TSA's main assumption is that when team members accurately perceive, comprehend, and project what is occurring in their task environment they can more effectively and efficiently fulfill common goals and adapt to evolving and changing situations (Burke et al., 2006; Uitdewilligen et al., 2010; Valaker et al., 2018). In this regard, TSA has been proposed to facilitate team adaptation processes such as communication, coordination, and the search and elaboration of task-relevant information. Accordingly, TSA helps teams to integrate their perceptions so that teams will avoid mistakes and react more quickly to task environment volatility.

Similar to TMM research, studies have consistently shown that high TSA predicts higher team performance due to faster response rates and fewer mistakes, in both simulated (e.g., Cooke et al., 2001; Sulistyawati, Wickens, & Chui, 2009) and field (e.g., Prince, Ellis, Brannick, & Salas, 2007; Soraji et al., 2012) settings. Antecedents of TSA can be divided into three main categories: technological artifacts, team communication, and team training. Regarding technological artifacts, externalized knowledge devices (e.g., shared boards or other intelligent agents) facilitate a common perception of the situation between team members (e.g., Chen & Barnes, 2012; She & Li, 2017). However, recent research revealed that the use of robots compromised communication (Randell et al., 2016) and using synthetic agents in key roles made coordination processes more rigid than using humans, reducing TSA and effectiveness (Demir, Likens, Cooke, Amazeen, & McNeese, 2019). Team communication is especially important for building TSA (e.g., Valaker et al., 2018), with information gaps (Seppänen, Mäkelä, Luokkala, & Virrantaus, 2013), one-way communication (e.g., Bleakley, Allard, & Hobbs, 2013), and reliance on formal communication (e.g., Roth et al., 2006) detracting from TSA formation. Both task- (e.g., Proctor, Panko, & Donovan, 2004) and team-based (e.g., Jankouskas, 2010; Robertson et al., 2017) training improved TSA.

Cross-understanding. Cross-understanding describes the extent to which team members accurately understand one another's mental models (Huber & Lewis, 2010). As a compositional construct, cross-understanding exists at the group level and emerges from individuals' understanding of each other's mental models through member interactions (Huber & Lewis, 2010). Cross-understanding is applicable to interdependent group tasks relying on different bases of expertise, and has been assumed to exert positive effects on team processes and outcomes by augmenting communication and coordination effectiveness, in addition to increasing TMM comprehensiveness (Huber & Lewis, 2010).

According to Huber and Lewis (2010), both cross-understanding and TMMs allow members to better predict each other's behaviors, and thereby increasing coordination. However, the contribution of cross-understanding is that it helps to explain inconsistencies in the team cognition literature, such as when low TMM similarity does not lower coordination as hypothesized because cross-understanding may be high (Huber & Lewis, 2010). In contrast to TMSs, cross-understanding does not necessarily result in a division of cognitive labor or become progressively differentiated over time (Huber & Lewis, 2010). Moreover, cross-understanding extends beyond "who knows what" to capture "who believes what, who is sensitive to what issues, and who prefers what" (Huber & Lewis, 2010: 9).

Studies testing the propositions derived by Huber and Lewis (2010) are limited. Regarding outcomes, cross-understanding has been found to positively predict team performance (Meslec & Graff, 2015), in addition to TMM flexibility (Guiette & Vandenbempt, 2013). In terms of antecedents, the use of analogies, communication frequency (Graff & Clark, 2018), and openness to cognitive diversity (Meslec & Graff, 2015) have been associated with increased cross-understanding. Specifically, cross-understanding partially mediates the analogy-knowledge application relationship. Cross-understanding also positively mediates the relationship between openness to cognitive diversity and team performance, as well as the relationship between reflective communication cognition and team performance (Meslec & Graff, 2015). Another mediational study of organizational teams found that the relationship between transactive leadership and adaptive team performance was serially mediated by task conflict and cross-understanding (Hoandră, 2017).

Strategic consensus. Strategic consensus refers to group members' shared understanding of the high-level organizational strategy. The content of the consensus is strategic priorities (relative importance of initiatives such as innovation and cost reduction) or strategic means and ends of a decision-making process (Wooldridge & Floyd, 1989). Strategic consensus has generally been studied within the context of management and top management teams (Floyd & Wooldridge, 1992; Kellermanns et al., 2005; Wildman et al., 2014). However, it has been recognized that "all teams in the organization, at all levels of the hierarchy, are responsible for putting the organization's strategy into action" (Porck et al., 2020: 2).

Because of the focus on the extent to which group members share an understanding of the strategic vision, group or organizational performance has been the focal outcome. Spanning nearly five decades, research has suggested that greater strategic consensus improves coordination and cooperation for strategy implementation, and in doing so promotes organizational performance (Kellermanns, Walter, Floyd, Lechner, & Shaw, 2011). Although some empirical studies have found a lack of support for the relationship between strategic consensus and organizational performance (e.g., Menon, Bharadwaj, & Howell, 1996; Ramos-Garza, 2009; West & Schwenk, 1996), a meta-analysis examining a total of 23 independent studies (2,089 management teams) supported a positive relationship between the two constructs, and identified key moderators (Kellermanns et al., 2011). Specifically, the strategic consensus–performance relationship was stronger for organizations competing in stable environments compared to dynamic environments, stronger for middle- and lower-level groups as compared to top management groups, and stronger when the content to be agreed upon was strategic priorities instead of means and ends (Kellermanns et al., 2011).

Moreover, empirical work has established several antecedents of strategic consensus, including greater top management team homogeneity (e.g., Knight et al., 1999), increased planning (e.g., St. John & Rue, 1991), more agreement-seeking behaviors (e.g., Knight et al., 1999), and increased communication (e.g., Rapert, Velliquette, & Garretson, 2002). Although a positive association has been found between employment tenure diversity and strategic consensus, functional and educational diversity are negatively related to strategic consensus (Knight et al., 1999).

Cognitive consensus. Cognitive consensus has been defined as "similarity among group members regarding how key issues are defined and conceptualized" (Mohammed, 2001: 408). Teams whose members develop high cognitive consensus attend to, interpret, and communicate about issues more similarly than do teams with low cognitive consensus. Scattered throughout the decision-making, leadership, negotiation, management and psychology literatures, different terminologies and operationalizations have captured the notion of cognitive consensus, including shared or collective sensemaking (e.g., Balogun & Johnson, 2004; Brown, Stacey, & Nandhakumar, 2008), negotiated belief structures (e.g., Walsh et al., 1988), group-level framing (e.g., Tindale, Sheffey, & Scott, 1993), interpretive (dis)ambiguity (Kilduff et al., 2000), consensus of interpretive frames or content (Fiol, 1994), and agreement on causal beliefs (Markóczy, 2001). Mohammed (2001) integrated this fragmented collection of studies under the term "cognitive consensus," which continues to be the most commonly used terminology across various subdisciplines (e.g., Combe & Carrington, 2015; Fiol, 1994). What unites these papers is an emphasis on sharedness regarding the fundamental interpretation of issues underlying decisions to be made. For example, to what extent do team members hold similar beliefs about the causes of organizational success and failure (Carrington et al., 2019)?

The cognition that is shared includes the assumptions ("natural set of givens" involved in the perception of a situation, Mitroff & Emshoff, 1979: 10), category frames (e.g., threat, opportunity, problem, crisis [Jackson & Dutton, 1988]), content domains (e.g., political, economic, social, strategic, technical [Thomas, Shankster, & Mathieu, 1994]), dimensions (e.g., urgency, feasibility, controllability [Dutton, Stumpf, & Wagner, 1990]) or causal maps (causal links between concepts [Carrington et al., 2019]) supporting team members in assigning meaning to the issues (Mohammed, 2001). Mohammed (2001) argued that, at a minimum, teams must share a common conception of the assumptions underlying key issues to qualify as having shared consensus. Conceptually, it has been assumed that an optimal level of cognitive consensus will depend upon factors such as the team environment, members' interdependence, the nature of the task, and where the team is in the decision-making process (Mohammed, 2001).

Outcomes of cognitive consensus include higher performance (e.g., Kilduff et al., 2000; Walsh et al., 1988), perceived ease of implementation, and satisfaction with decisions reached (Mohammed & Ringseis, 2001). Research has supported the conceptual notion that team members may agree on certain assumptions, categories, content domains, dimensions, or causal maps, but disagree on others (e.g., Combe & Carrington, 2015; Fiol, 1994). Several longitudinal studies have concluded that cognitive diversity decreases, and cognitive consensus increases, over time (e.g., Carrington et al., 2019; Fiol, 1994; Kilduff et al., 2000). For example, Kilduff and colleagues (2000) found that manager teams performing well on a simulation started with high interpretive ambiguity but developed agreement about the causes of market share results later in the game. In contrast, poorly performing teams exhibited the opposite pattern. Therefore, early in the decision-making process it may be advisable to maximize the number of viewpoints represented to aid in defining the issues comprehensively (Kilduff et al., 2000; Walsh et al., 1988). However, high cognitive consensus later in a team's life cycle enhances performance (Kilduff et al., 2000) and eases decision implementation (Mohammed & Ringseis, 2001).

Regarding antecedents, cognitive consensus is facilitated by unanimity decision rule (Mohammed & Ringseis, 2001), the Delphi technique in the short-term, and the repertory grid cognitive mapping tool in the long-term (Chiravuri, Nazareth, & Ramamurthy, 2011). From the psychology literature, variations in gain or loss frames of reference among team members have been shown to influence cognitive consensus (e.g., Paese, Bieser, & Tubbs, 1993; Tindale et al., 1993), and cognitive change is not necessary for preference change to occur (Tindale et al., 1993).

Shared task representations. Shared task representations refer to group members' shared understanding of the task (van Ginkel, Tindale, & van Knippenberg, 2009; van Ginkel & van Knippenberg, 2012). Specifically, the content held in common by group members includes task-related concepts, norms, perspectives, and processes (Tindale et al., 1996; van Ginkel & van Knippenberg, 2008). Groups are expected to make better use of distributed information if there is a common understanding about task requirements via the exchange, discussion, and integration of decision-relevant information (van Ginkel & van Knippenberg, 2008). As such, group members' shared task representations have been proposed to help groups use informational resources effectively.

Regarding outcomes, empirical research has demonstrated that shared task representations improve group decision-making performance by promoting information elaboration (van Ginkel et al., 2009; van Ginkel & van Knippenberg, 2008, 2012). Furthermore, psychological safety has been found to partially mediate the relationship between shared task representations and information elaboration (van Ginkel & van Knippenberg, 2008).

Regarding antecedents, leader behaviors have been empirically established as precursors of shared task representations (van Ginkel & van Knippenberg, 2012). That is, leaders who advocate for information elaboration, as opposed to focusing on common ground, are more likely to have their group members develop task representations emphasizing information elaboration (van Ginkel & van Knippenberg, 2012). Team reflexivity (i.e., reflecting on the group task, goals, and strategies) has also been found to increase the extent to which groups develop a shared task representation emphasizing information elaboration (van Ginkel et al., 2009).

Across-construct differences for Quadrant 3. Several differences underlie these six constructs emphasizing knowledge representation convergence. For example, TMMs, TSA, and cross-understanding tend to have been empirically investigated in action teams. In contrast, decision-making teams have been sampled in studies examining strategic consensus, cognitive consensus, and shared task representations. Whereas strategic consensus research has tended to be conducted in field settings (e.g., Porck et al., 2020; Tarakci, Ates, Porck, van Knippenberg, Groenen, & de Haas, 2014), shared task representation studies have exclusively sampled university students in the laboratory (van Ginkel et al., 2009; van Ginkel & van Knippenberg, 2008, 2012).

Because of its emphasis on top management teams, organizational (in addition to team) performance is a key outcome variable for strategic consensus, which therefore offers a more macro focus than the other constructs listed in Quadrant 3. In addition, TSA concentrates more on technological artifacts (e.g., intelligent aids, human–robot teaming, synthetic agents) compared to other forms of team cognition due to its human factor origins (e.g., Demir et al., 2019; Randell et al., 2016). Moreover, TSA has been theorized to capture dynamic knowledge that needs to be updated to accurately characterize changing situations (Patrick & Morgan, 2010). In comparison, the other constructs in this quadrant represent more stable cognition.

The most substantial conceptual difference between Quadrant 3 constructs lies in the content held in common across team members. TMMs represent the broadest range of what is shared, including taskwork, teamwork, and timework categories. In contrast, TSA and shared task representations focus more narrowly on the situational context and task-related concepts, respectively. The content of strategic consensus is strategic priorities or strategic means and ends, whereas the content of cognitive consensus includes assumptions, category frames, or causal maps underlying decisions. Cross-understanding captures teamwork content via teammates' factual knowledge, cause–effect beliefs, sensitivities, and preferences.

On top of the content represented by the six constructs in Quadrant 3, team cognition scholars have proposed other types of knowledge domains that are important for team members to hold in common. For example, Van Knippenberg, van Ginkel, and Homan (2013) conceptually advocated that diversity mindsets (team members' mental representations of diversity) be shared and that team members recognize that their mindsets are shared. The content of diversity mindsets includes team members' knowledge about their team diversity, the way in which team processes and performance will be affected by diversity, and how diversity needs to be approached (Van Knippenberg et al., 2013). In addition, outcome-based group learning has been defined as a change in the group's shared understanding of potential behavior (Goodman & Dabbish, 2011). The content held in common among teammates that constitutes group learning is the group's repertoire of potential behavior, based on the sharing, storage, and retrieval of group knowledge (Wilson et al., 2007). Because diversity mindset propositions have not been empirically tested (Van Knippenberg et al., 2013), and because outcome-based learning measurement has often been redundant within TMSs or empirically confounded with team performance (e.g., Edmondson et al., 2007; Wilson et al., 2007), they have not been formally represented as one of the 10 team cognition constructs we feature. However, they are worthy of mention because they highlight unique content not captured by other cognitive representations.

Quadrant 4: Cognitive Representations Emphasizing Divergence

Across-construct popularity and similarities for Quadrant 4. A trend analysis identified TMSs as the second most commonly researched form of team cognition (behind TMMs) (Wildman et al., 2012). Consistent with that finding, all but one of the prior qualitative and quantitative team cognition reviews in Table 2 covered TMSs (Cooke et al., 2007; DeChurch & Mesmer-Magnus, 2010a; Mesmer-Magnus et al., 2017; Mohammed & Dumville, 2001; Mohammed et al., 2017; Uitdewilligen et al., 2010; Wildman et al., 2012; Wildman et al., 2014). In contrast, the literature base for rGaps is much smaller, consisting of a handful of studies.

TMSs and rGaps unite conceptually in their emphasis on cognitive divergence and unite empirically in their positive prediction of creativity or innovation. Each construct is briefly reviewed below.

Transactive memory systems. TMSs capture the notion that memory is a social phenomenon in which people serve as external memory aids (Wegner, 1987). Incorporating meta-knowledge (Mell et al., 2014), TMSs describe "what you know, what I know, what we know, and how we get that knowledge from one another" (Hollingshead, Gupta, Yoon, & Brandon, 2012: 423). As such, TMSs combine the unique knowledge held by individual members with a collective awareness of who knows what in a team (Lewis & Herndon, 2011; Wegner, 1987). The cognitive content of a TMS comprises knowledge of members' diverse expertise and skills (Moreland & Myaskovsky, 2000). Therefore, the emphasis of this literature has been on specialization or the unique proficiencies of team members (DeChurch & Mesmer-Magnus, 2010a). By enabling access to a larger breadth of knowledge than any single member possesses, TMSs are a property of the team (Lewis & Herndon, 2011).

In addition to a structure of unique and shared knowledge, the definition of TMSs also incorporate the three-stage process of encoding, storage, and retrieval (Hollingshead et al., 2012; Lewis & Herndon, 2011). A complete TMS occurs when each member stays current on who knows what, channels incoming information to the appropriate person, and has a strategy for accessing the information (Wegner, 1995). Communication is the primary updating mechanism of TMSs (Lewis, 2004).

On the positive side, TMSs help to decrease member cognitive workload, increase the quality and quantity of available information, hasten information search, and decrease the chance that important information will fall through the cracks (Bachrach et al., 2019; Wegner, 1987). On the negative side, members may overestimate TMS capabilities, thereby experiencing difficulties when knowledgeable team members leave or are not available (Lewis, Belliveau, Herndon, & Keller, 2007).

Paralleling many other team cognition constructs, the most reliable and robust finding for TMSs is that they are positively related to higher team performance, as supported by three meta-analyses (Bachrach et al., 2019; DeChurch & Mesmer-Magnus, 2010a; Mesmer-Magnus et al., 2017). Specifically, a compilation of 76 empirical studies with 174 effect sizes found that each of the transactive memory system's behavioral indicators (specialization, credibility, and coordination) independently and positively predicted higher performance (Bachrach et al., 2019). In addition, TMSs were positively predictive of both task (e.g., efficiency, quality) and creative and innovation performance, confirming that TMSs expedite ready access to task-critical knowledge, and foster the divergent thinking processes needed for creativity (Bachrach et al., 2019). Bachrach and colleagues (2019) also revealed the positive effects of TMSs on affective outcomes, including team satisfaction, cohesion, and viability. In addition, studies have found that TMSs are positively associated with behavioral processes such as reflexivity (e.g., Dayan & Basarir, 2010) and cognitive processes such as group learning (e.g., Akgun, Byrne, Keskin, & Lynn, 2006).

TMS antecedents can be divided into three general categories: team composition, team-level inputs, and contextual factors, with the most empirical attention devoted to team-level inputs (Ren & Argote, 2011). Regarding team composition, TMSs are facilitated by mean dispositional assertiveness (Pearsall & Ellis, 2006) and team human capital (Bachrach et al., 2019), but impeded by informational and gender diversity (Bachrach et al., 2019) and changes in group composition (e.g., Lewis et al., 2007), especially when a member holding a central role leaves (Siegel Christian, Pearsall, Christian, & Ellis, 2014).

Interdependence, familiarity, training, and communication have been investigated as team-level inputs. Task and cooperative goal interdependence (Zhang, Hempel, Han, & Tjosvold, 2007), member familiarity, and prior experience working together (e.g., Akgun, Byrne, Keskin, Lynn, & Imamoglu, 2005; Littlepage, Robison, & Reddington, 1997) generally facilitate TMS emergence. Moreover, several studies have shown that in comparison to members who train individually, team members who train together evidence stronger TMSs (e.g., Lewis, Lange, & Gillis, 2005; Liang, Moreland, & Argote, 1995; Moreland et al., 1996). Face-to-face interactions (He, Butler, & King, 2007; Lewis, 2004) facilitate TMS emergence, and the beneficial effects of communication appear early in the team life cycle but diminish over time (e.g., Kanawattanachai & Yoo, 2007). A centralized social network (certain team members hold more connections than others) enables TMS emergence when turnover occurs (Argote, Aven, & Kush, 2018). Also demonstrating the positive effects of centralization, Mell and colleagues (2014) found that having one member who possesses all the meta-knowledge enhances performance over a decentralized TMS structure on high-coordination tasks because central members serve as catalysts for team information exchange.

Regarding contextual antecedents, challenge stressors (Pearsall, Ellis, & Stein, 2009), leadership effectiveness, and environmental volatility (Bachrach et al., 2019) positively influence TMSs. Acute stress (Ellis, 2006) and hindrance stressors (Pearsall et al., 2009) negatively influence TMSs. A meta-analysis also found moderating effects for national cultural context, with a stronger TMS–performance relationship for higher power distance and collectivism (Bachrach et al., 2019).

Representational gaps. Deriving from psychological research on information processing (e.g., Newell & Simon, 1972), rGaps are "inconsistencies between individuals' definitions of the team's problem" (Cronin & Weingart, 2007: 761). Due to knowledge, belief, and value dissimilarities resulting from deep-level diversity, team members encode team problems differently, yielding conflicting representations that are difficult to reconcile (Srikanth, Harvey, & Peterson, 2016). As such, rGaps emphasize divergence rather than convergence. Mismatches in team members' problem definitions (e.g., What is quality and why is it important?) have been theorized to underlie many team decision-making difficulties because they result in derailed communication, information processing, coordination, and conflict management (Cronin & Weingart, 2007; Firth et al., 2015).

Cronin and Weingart (2007) described incompatibilities within joint representations in terms of "GAEO," or goal hierarchies (the goals to be achieved to solve the problem), assumptions (operative restrictions and preferences that are taken for granted), elements (interchangeable constituents of the problem), and operators (rules to transform the elements). They proposed that goal hierarchies and assumptions should be shared, and that elements and operators may remain unshared without impairing team performance.

On the positive side, research has shown that rGaps positively predict creativity by raising task conflict and easing coordination among team members (Weingart et al., 2008). Similarly, team product innovation in MBA student teams was highest when rGap heterogeneity was high (Weingart et al., 2010). On the negative side, research has evidenced that rGaps generally impair team processes, including decreasing information elaboration and increasing conflict (Paletz et al., 2013; Wang et al., 2016).

Across-construct differences for Quadrant 4. Whereas TMSs have been studied in a variety of lab and field settings (e.g., Argote et al., 2018; Austin, 2003; Mortensen, 2014), rGaps have been primarily investigated in student samples (e.g., Pearsall & Venkataramani, 2015; Weingart, Cronin, & Goh, 2007; Weingart et al., 2010). Cognitive content is another key difference between the two constructs, with TMSs characterized by members' expertise and rGaps highlighting goal hierarchies, assumptions, elements, and operators underlying problem definitions.

Summary Across Team Cognitive Representation Constructs (Quadrants 3 and 4)

As illustrated by the six constructs in Quadrant 3 and the two constructs in Quadrant 4, team cognitive representations have primarily emphasized convergence. Whereas some forms of team cognition assess evaluative beliefs (e.g., cognitive consensus, strategic consensus, rGaps), others describe forms of knowledge that can be verified as (in)accurate (e.g., TMMs, TMSs, TSA, cross-understanding).

Similar to cognitive processes, team cognitive representations also positively predict team performance (DeChurch & Mesmer-Magnus, 2010a). DeChurch & Mesmer-Magnus's (2010a) meta-analysis from 3,738 teams in 65 studies concluded that team cognition explained approximately 14 and 18% of team performance and team behavioral processes variance, respectively. Notably, this meta-analysis also found that team cognition explained 7% of unique variance in team performance beyond team cohesion and team processes. A follow-up and more inclusive meta-analysis (128 studies from 4,943 teams) confirmed the positive correlation of team cognition with team processes and performance, with team cognition accounting for 5% of unique variance in team performance beyond cohesion and team processes (Mesmer-Magnus et al., 2017).

Paralleling their popularity, TMMs and TMSs have been regarded as more developed constructs, with more mature literatures compared to other types of team cognition (e.g., DeChurch & Mesmer-Magnus, 2010a; Mathieu, Maynard, Rapp, & Gilson, 2008). Theoretically, they oppose each other in that TMMs focus on the similarity in knowledge between team members whereas TMSs focus on the unique specializations that make members distinct. For example, TMMs are characterized as a form of compositional emergence (the extent to which knowledge is similar across team members) and TMSs as a form of compilational emergence (the extent to which knowledge is complementary across team members [DeChurch & Mesmer-Magnus, 2010a; Mesmer-Magnus et al., 2017]). However, multiple meta-analyses have confirmed that both convergent and divergent approaches to team cognition positively predict team performance (DeChurch & Mesmer-Magnus, 2010a; Mesmer-Magnus et al., 2017; Niler et al., 2020). Specifically, two meta-analyses converged in that the cognition–process relationship was stronger for compilational than for compositional emergence (DeChurch & Mesmer-Magnus, 2010a; Mesmer-Magnus et al., 2017). However, opposing results occurred for the cognition–performance relationship in that the original meta-analysis found stronger effects for compilational emergence (DeChurch & Mesmer-Magnus, 2010a), but the updated meta-analysis found stronger effects for compositional emergence (Mesmer-Magnus et al., 2017). Although both convergent and divergent forms of cognitive representations positively predict performance, we lack understanding of their combined or differential impact on team processes and outcomes because they have rarely been blended empirically.

A third meta-analysis (107 studies from 7,778 teams) again confirmed the positive relationship between team cognition and performance (Niler et al., 2020). This relationship was strongest for teams whose members were heterogeneous on social categories, lacked formal authority, depended heavily on people outside the team, and worked at the same time and in the same place as their teammates (Niler et al., 2020).

A CRITICAL AND INTEGRATIVE VIEW OF TEAM COGNITION

The Big Picture: The State of Team Cognition Science

To summarize, the team cognition literature is composed of a lengthy and eclectic list of team cognition types. Although all have referenced some degree of shared cognition, each has captured unique content and has its own subliterature (see Table 1). The team cognition literature includes both cognitive processes that describe team knowledge building and the emergent cognitive representations resulting from information sharing and learning. Whereas some team cognition constructs emphasize knowledge convergence ("getting on the same page"), others focus on knowledge divergence (unique information held by team members; see Table 4). While some constructs highlight dynamic knowledge (e.g., situation awareness, group learning, or information sharing), other capture more persistent knowledge (e.g., TMSs, or TMMs). Moreover, some team cognition constructs, such as TSA, feature taskwork knowledge (what needs to be accomplished), whereas others, including process-driven group learning, feature teamwork knowledge (how work needs to be accomplished). As a whole, the team cognition literature has emphasized cognitive representations over cognitive processes, knowledge convergence over knowledge divergence, and more stable forms of knowledge over dynamic ones.

Condensing nearly 30 years of research, the best-supported finding and most-researched effect is that team cognition positively predicts team performance (DeChurch & Mesmer-Magnus, 2010a; Mesmer-Magnus et al., 2017). The team cognition–team performance link has been sufficiently demonstrated for both cognitive processes (e.g., Edmondson et al., 2007; Mesmer-Magnus & DeChurch, 2009) and cognitive representations (e.g., DeChurch & Mesmer-Magnus, 2010a; Mesmer-Magnus et al., 2017), as well as for constructs emphasizing knowledge convergence and divergence (Bachrach et al., 2019; DeChurch & Mesmer-Magnus, 2010a; Mesmer-Magnus et al., 2017).

We applaud the noteworthy progress made by team cognition research, which demonstrates the widespread interest and cross-disciplinary reach across the fields of decision-making, strategy, psychology (industrial-organizational, social, cognitive), information processing, organizational behavior, and human factors (see Table 1). Such interest has yielded a burgeoning literature stream with a steady increase in the number of studies over the years (Wildman et al., 2012), which has made available a range of conceptual and methodological options to examine team cognition within specific areas of study. Clearly, team cognition has earned a place at the team table via the clear empirical demonstration of its positive effects on team processes and performance (e.g., DeChurch & Mesmer-Magnus, 2010a; Mesmer-Magnus et al., 2017).

Conceptual Limitations of Team Cognition

Despite these strengths, however, several deficiencies offer substantial opportunities for further conceptual development. First, the lack of synthesis across the 10 siloed constructs has rendered a scattered research landscape that is increasingly confusing to navigate. Consequently, new researchers have difficulty answering rudimentary questions such as "How do I identify what type of team cognition to study?" Because each specific type of team cognition has been framed by its perspective of origin and represents benefits and liabilities, integrating across constructs has proven difficult. Specifically, the literature's lack of integration, and its piecemeal approach, have precluded a holistic evaluation of its empirical results. That is, without simultaneously considering these generally siloed approaches, the weight of accumulated scientific evidence is easily obscured and lost. Furthermore, the current state of the literature and its limited capacity to generate a clear and comprehensive picture may be off-putting to consumers of team cognition research. We argue that, if this continues, the disjointed and fragmented state of the literature will do more harm than good.

Second, conceptual distinctions across the 10 team cognition constructs may be more artificial than substantive. Thus far, the various literatures have defined constructs as distinct from other team cognition forms and have underscored differences instead of similarities (e.g., Huber & Lewis, 2010; Mohammed et al., 2010). However, the distinguishing criteria between team cognition constructs are increasingly blurring. To illustrate, the recognition, comprehension, and prediction of changing situational demands has been a differentiating feature of TSA from other types of team cognition (e.g., Salmon et al., 2008). Nonetheless, research has increasingly highlighted the importance of team situation models (e.g., Waller et al., 2004), defined as "the mental representation associated with a dynamic understanding of the current situation that is developed by team members moment by moment" (Rico, Gibson, Sánchez-Manzanares, & Clark, 2019: 167). Therefore, although considered two separate constructs, it is unclear how TSA and team situation models are conceptually distinct. Similarly, what has differentiated strategic consensus from other cognitive constructs has been its content emphasis on strategic priorities and vision (Kellermanns et al., 2011). However, TMM studies have also begun to examine strategic priorities, trade-offs, and implications (Randall et al., 2011; Resick, Murase, Randall, & DeChurch, 2014), making previous distinctions fuzzy. Moreover, cognitive consensus (Mohammed, 2001) and rGaps (Cronin & Weingart, 2007) both feature assumptions as key cognitive content, but are separate literatures with minimal crossover.

These blurred boundaries raise the question, "Are all 10 constructs necessary?" Team cognition scholars have suggested that the answer may be no. For example, reviews of team cognition have signified that other constructs, such as cognitive consensus and team situational awareness, could be subsumed under the broader TMM framework (e.g., Mohammed & Dumville, 2001; Mohammed et al., 2010). Concurring, Wildman and colleagues (2012: 107) acknowledged that

> with a small amount of reframing, nearly every team knowledge construct studied in the literature to date could be reconceptualized based on the mental model paradigm … we are not suggesting that all team knowledge research should focus on team mental models as the sole construct of interest but, rather, that researchers should begin to think about the various constructs as related categories, or types, of knowledge organization structures within teams.

According to a recent meta-analysis, TMSs, information sharing, and group learning are likely confounded (Bachrach et al., 2019). Likewise, the group mastery approach to outcome-based group learning has often been empirically equated with TMSs (Edmondson et al., 2007). As distinctions become less clear, integration is a natural consequence of the blurring of the lines that previously justified separate constructs.

A third conceptual limitation is that the lack of synthesis across the 10 team cognition literatures has fostered a limited "either–or" mentality rather than inclusive "both–and" thinking. As illustrated in Table 4, cognitive constructs capture *either* cognitive processes *or* representations, and tend to be categorized according to whether they characterize divergence *or* convergence (e.g., DeChurch & Mesmer-Magnus, 2010a). However, comprehending how team cognition develops over time is a key need in the team cognition literature (Grand et al., 2016). Specifically, future research must address how team members move from divergent views to convergent views and then back to divergent views in iterative fashion (Grand et al., 2016). This cycle can only be explored when cognitive processes and representations, as well as cognitive convergence and divergence, are explored simultaneously rather than separately.

Fourth, little cross-fertilization, artificial boundaries, and either–or thinking has favored the pursuit of basic research questions within constructs instead of more sophisticated explorations across constructs. Answering questions such as, "Does team cognition improve team performance?" and "What antecedents predict team cognition?" were key to establishing the importance of team cognition in team science over the past 30 years. However, we are convinced that the most promising avenues for future research lie not within each siloed literature stream but at the intersection of team cognition constructs. For example, what are the differential effects of the 10 cognitive constructs on team processes and performance? How do they interact to predict outcomes? Moreover, it has been repeatedly noted that TMSs may be positively predictive of unique (as opposed to commonly held) information sharing in the hidden profile paradigm (e.g., Bachrach et al., 2019; Mohammed & Dumville, 2001; Sohrab et al., 2015); however, empirical research combining the two is strikingly absent. It is likely that unique information sharing also contributes to the generation of TMSs.

In summary, the current lengthy list of team cognition constructs has become more of a hindrance than a help. The piecemeal approach limits our ability to evaluate accumulated research, recognize points of intersection, and identify key research gaps. As such, whereas the emphasis of the past three decades has been on building the nomological network of independent forms of team cognition, we argue that the agenda of the next decade should be on exploring intersections across constructs and integrating team cognition as a holistic entity. Building on the findings and momentum of prior research, team cognition is ripe for integration but needs a new framework to move the literature forward.

A DIMENSIONAL FRAMEWORK FOR DESCRIBING TEAM COGNITION

To address the conceptual limitations listed above, we propose describing and differentiating team cognition according to a set of dimensions underlying all 10 team cognition constructs. Dimensional scaling approaches have been successfully utilized in previous team research, including condensing the dizzying number of categorical team typologies into the dimensions of skill differentiation, authority differentiation, and temporal stability (Hollenbeck, Beersma, & Schouten, 2012). Similarly, as an alternative to the 10 team cognition constructs, we propose three dimensions to serve as fundamental differentiators of team cognition: knowledge domain, knowledge foci, and knowledge convergence. Knowledge domain answers the question, "What cognitive content is focal?" Knowledge foci answers the question, "Is the focus on the sharing process, the shared outcome, or both?" Finally, knowledge convergence answers the question, "What is the degree of sharedness or distribution across team members on the focal cognitive content?"

Building on each other, these three dimensions were selected because they are common denominators in prior team cognition research. Knowledge domain, foci, and convergence parsimoniously, yet comprehensively, highlight the major conceptual and empirical distinctions underlying the 10 constructs, and two out of the three dimensions were already featured in Table 4. Furthermore, each dimension has been repeatedly referenced in prior team cognition reviews and research (e.g., Cannon-Bowers & Salas, 2001; DeChurch & Mesmer-Magnus, 2010a; Espinosa & Clark, 2014; Mohammed et al., 2000; Rentsch et al., 2008). As such, these three dimensions are deeply ingrained in the historical development of the field and thereby formed the basis of our organizing definition of team cognition. Described below, the dimensional approach addresses the conceptual weaknesses of the current team cognition literature delineated in the previous section.

Knowledge Domain (What Is Shared?)

The study of team cognition begins with the question of what the focal knowledge content is, which should be guided by the domain of interest, theoretical considerations, and the team context. Taskwork (What needs to be accomplished?) versus teamwork (How should members work together to accomplish tasks?) has been a popular content dichotomy in the team cognition literature (e.g., DeChurch & Mesmer-Magnus, 2010a; Mohammed et al., 2010), but these broad categories are too generic and too limited to adequately capture the variety of content reviewed across the 10 constructs. For example, cognitive content not only encompasses knowledge of what (declarative) but also knowledge of how (procedural), or knowledge of context and application (strategic) (Mohammed et al., 2010). Moreover, in addition to factual knowledge that is believed to be true, team cognitive content includes evaluative belief structures or desired states that are preferred or expected (Mohammed et al., 2000). Table 6 delineates many types of cognitive content represented in team cognition research.

Rather than following the traditional approach of selecting a team cognition construct to study (e.g., TSA, rGaps, cross-understanding), we advocate that researchers begin by identifying the knowledge domain(s) of focus (e.g., team member expertise, strategic priorities, team member interaction patterns). Doing so bypasses the increasingly fuzzy boundaries and artificial distinctions between the 10 cognition constructs, allowing researchers to directly hone in on the content that is shared or distributed among team members.

Moreover, adopting a "content instead of construct" approach encourages researchers to broaden beyond the boundaries of siloed literatures to examine multiple types of content in new combinations that better reflect the complexity of team cognition. For example, instead of a TSA scholar focusing exclusively on environmental context, a dimensional approach encourages expanding the knowledge domain across constructs (e.g., incorporating member interaction patterns from TMMs or strategic priorities from strategic consensus). By simultaneously measuring multiple knowledge domains that have never before been combined, more sophisticated research questions can be addressed, including how different forms of content interact and differentially predict team processes and outcomes. Moreover, what is the sequencing by which knowledge domains should be shared to maximize team performance? For example, should teams get on the same page regarding objectives and strategies before team interaction patterns? Should teams invest the effort to converge on assumptions underlying strategic issues before building knowledge about team member preferences, strengths, and weaknesses?

Knowledge Foci (Is the Focus on the Sharing Process, the Shared Outcome, or Both?)

In addition to identifying the type of cognitive content to study, researchers should determine whether they will emphasize cognitive processes, cognitive representations, or both. Merely mentioning the sharing process and the shared outcome in the same research question promotes both–and thinking, reducing the sharp artificial divide between literatures by helping cognition scholars to consider the alternative of their traditional orientation. Moreover, investigating the black box of how and why team cognition emerges in tandem with what knowledge emerges allows for more advanced research questions to be asked. For example, to what extent do variables such as how members internalize information, who speaks in a team, and how members signal agreement influence team-level cognitive representations (Grand et al., 2016)? How can learning and information sharing be temporally synchronized to predict superior knowledge outcomes (Grand et al., 2016)? Especially coveted are studies that

TABLE 6
Content Shared in Team Cognition

Content	Examples
Objectives, Goals, Strategy	• Organizational strategic vision, strategic priorities, means and ends of a decision-making process (Kellermanns et al., 2011) • Strategic priorities, strategic trade-offs, and implications of strategic decisions (Randall et al., 2011) • Goals and performance requirements (Cronin & Weingart, 2007)
Information	• Verifiable facts and data relevant to team decisions (Stasser & Titus, 1985, 1987)
Evaluative Beliefs Underlying Decision-Making Issues and Problem Definitions	• Assumptions, categories, content domains, dimensions, and causal maps underlying how key issues are defined and conceptualized (e.g., Mohammed, 2001) • Goal hierarchies, assumptions, elements, and operators underlying problem definitions (Cronin & Weingart, 2007)
Technology	• Equipment (Cannon-Bowers et al., 1993) • Operating procedures (Cannon-Bowers et al., 1993) • System limitations and likely failures (Cannon-Bowers et al., 1993)
Job or Task	• Task procedures and sequences (Cannon-Bowers & Salas, 2001) • Task-related concepts, norms, perspectives, and processes (van Ginkel & van Knippenberg, 2008)
Team Interaction	• Member roles and responsibilities (Cannon-Bowers et al., 1993) • Interaction patterns, communication channels, and role interdependencies (Cannon-Bowers et al., 1993)
Process-Based Knowledge	• Process-based knowledge-building activities through which members acquire and share knowledge, seek feedback, discuss errors, and reflect on results (Edmondson et al., 2007) • Group's repertoire of potential behavior based on the sharing, storage, and retrieval of group knowledge (Wilson et al., 2007)
Diversity Mindsets	• Knowledge about team diversity, the way team processes and performance will be affected by diversity, and how diversity needs to be approached (Van Knippenberg, van Ginkel, & Homan, 2013)
Team Member Knowledge	• Who is considered a team member (Mortensen, 2014) • Expertise and skills of team members (Ren & Argote, 2011) • Expertise and skills of individuals external to the team (Austin, 2003) • Teammate's factual knowledge, cause-effect beliefs, sensitivities, and preferences (Huber & Lewis, 2010) • Member preferences (Cannon-Bowers et al., 1993) • Member strengths and weaknesses (Cannon-Bowers & Salas, 2001)
Situational Context or Task Environment	• Perception, meaning, and projection of how events will change in the future (Endsley, 1995a) • Understanding of how the current situation changes moment by moment (Rico et al., 2019)
Temporal Context	• Deadlines, scheduling, sequencing (Mohammed et al., 2015) • When expertise is needed in the team (Mohammed & Nadkarni, 2014)

longitudinally track how knowledge comes to be shared and how the emergent shared outcome is then updated in an iterative cycle.

Although empirically combining cognitive processes and representations has been rare, recent studies have begun to illustrate how both can be incorporated (Leonardi, 2018). Specifically, Leonardi (2018) first quantitatively examined the change in the similarity of team members' cognitive knowledge structures (who knows what) and social knowledge structures (who knows whom) before and after a company's intranet implementation (Leonardi, 2018). The second part of the study then qualitatively examined how employees used social media to develop more shared knowledge and social structures by expanding their networks and using exogenous events to trigger the integration of diverse content into a coherent whole (Leonardi, 2018). We are hopeful that this recent exemplar will pave the way for the simultaneous investigation of the sharing process and the shared outcome becoming normative rather than rare.

Knowledge Convergence (What Is the Degree of Sharing?)

Dominating the team cognition literature (see Table 4), convergence is a powerful concept underlying the need for team members to operate as a unified collective. However, without cognitive divergence there is no need for team formation in the first place. On the one hand, too much knowledge convergence may foster groupthink (e.g., Cannon-Bowers et al., 1993), reducing creativity (e.g., Kilduff et al., 2000) and giving rise to biases and judgment errors (e.g., Carrington et al., 2019). On the other hand, too much knowledge divergence risks diminished cohesion and coordination (e.g., Rico et al., 2008). A certain level of commonality is often necessary to take advantage of differences, and differences underlie the need for commonality (Antino, Rico, & Thatcher, 2019; Gibson & Vermeulen, 2003). Indeed, unity and diversity naturally coexist in teams, and managing the paradox between the two is key to team effectiveness (Fiol, 1994).

Despite the necessity and value of a both–and perspective, team cognition constructs tend to be categorized as either convergent or divergent, as illustrated in Table 4 (e.g., DeChurch & Mesmer-Magnus, 2010a; Mohammed et al., 2010). However, a fine-grained analysis of various cognitive constructs yields a more nuanced picture than the oversimplified bifurcation reveals. To illustrate, although commonly characterized as divergent or compilational (DeChurch & Mesmer-Magnus, 2010a), scholars have acknowledged that TMSs unite differentiation and specialization, and integration and coordination, conceptually (Hollingshead et al., 2012; Lewis & Herndon, 2011) and operationally (Lewis, 2003). Whereas the TMM literature has widely assumed that more sharing is better, one of the earliest published chapters challenged, "at what point do team members' knowledge and expectations overlap so much that the uniqueness of their individual contributions is lost?" (Cannon-Bowers et al., 1993: 236). Moreover, although TSA has emphasized overlapping situational knowledge between team members (e.g., Endsley, 1995a), some researchers have viewed TSA as distributed or complementary situated knowledge among team members (e.g., Hutchins, 1995; Stanton et al., 2006). As its name implies, consensus is core to cognitive consensus; however, studies have illustrated the value of diverse member perspectives (e.g., Fiol, 1994; Kilduff et al., 2000).

Together, this research has suggested that the bifurcation of convergence and divergence across the 10 cognitive constructs is more artificial than substantive. Not only is a both–and perspective essential, but divergence and convergence should be viewed as a continuum, not a dichotomy. Therefore, the dimensional approach asks, "What is the degree of sharing?" Doing so allows research to more precisely pinpoint where teams are located on a continuum rather than in one of two broad convergent or divergent categories.

A continuum as well as a both–and perspective permits more sophisticated research questions to be explored. For example, what are the team process and performance implications of members converging on one type of cognitive content (e.g., strategy), while diverging on another type of cognitive content (e.g., deadlines and scheduling)? How do teams manage the inherent tension between simultaneously converging on some types of cognitive content and diverging on other types of cognitive content? How do teams facilitate knowledge-building activities to stimulate divergence (e.g., devil's advocacy and dialectical inquiry [Schweiger, Sandberg, & Ragan, 1986]) and convergence (e.g., integration, assimilation), or both (e.g., constructive controversy [Johnson, Johnson, & Tjosvold, 2000]). What temporal sequencing (e.g., diverging on *X* cognitive content first, converging on *X* cognitive content first) best supports team decision-making? Team processes? Team innovative performance?

Using the Three-Dimensional Model to Build Theory and Empirical Research

Moving toward a dimensional approach and away from a construct-driven approach may seem somewhat unsettling when the team cognition literature has been so deeply rooted in the latter since its inception. However, we believe that the advantages of adopting a dimensional framework outweigh the advantages of maintaining the status quo, as delineated below.

First, a dimensional approach simplifies how team cognition is described. "What kind of team cognition is this?" has traditionally been answered using the lengthy list of 10 team cognition constructs from siloed and fragmented literatures. Using the dimensional approach, however, the key distinctions across the 10 constructs are encapsulated in three dimensions that are well-grounded in extant team cognition literature (DeChurch & Mesmer-Magnus, 2010a; Rentsch et al., 2008): knowledge domain, knowledge foci, and knowledge convergence.

Second, in addition to concision, the three dimensions improve the precision of conceptually describing the nature of team cognition. With a common vocabulary (knowledge domain, knowledge foci, and knowledge convergence), new and existing team cognition researchers will have fresh and clearer guidance in identifying the similarities and differences of underlying cognitive properties. Because dissensus and inconsistency within a field have historically been regarded as indicators of disciplinary immaturity (Kuhn, 1963), the greater consensus forged around the three-dimensional model can launch a new way of thinking about team cognition to strengthen theory building and add momentum to theory testing for years to come.

Third, the dimensional approach promotes more flexible and sophisticated theorizing by favoring: (a) an across-construct rather than a within-construct analysis, (b) substantive distinctions rather than artificial divides, and (c) inclusive both–and thinking rather than a limited either–or mentality. As such, the proposed dimensions not only simplify and add a greater level of precision in describing team cognition but have the potential to substantively expand the range of cognitive variables considered in theoretical and empirical research.

For example, a traditional TMM researcher would typically assess knowledge representation convergence on taskwork (what needs to be accomplished) or teamwork (how work needs to be accomplished) (Mathieu, Heffner, Goodwin, Salas, & Cannon-Bowers, 2000). However, rather than assuming that more sharing is uniformly better, the dimensional approach acknowledges that teams may need a distribution of knowledge across team members, as well as shared understanding to leverage member expertise and talents (e.g., Lewis & Herndon, 2011). Therefore, the dimensional approach challenges TMM scholars to consider research questions such as: "Under what conditions is taskwork knowledge convergence optimal and under what conditions is taskwork knowledge divergence optimal?" Moreover, the dimensional approach broadens the knowledge domain to include content that has not been frequently investigated within the TMM literature, such as evaluative beliefs, diversity mindsets, and strategic priorities. By taking cognitive processes into account, TMM researchers could expand to consider how representations may differ depending on the range and types of knowledge-building activities in teams.

Likewise, a TMS researcher traditionally examining the distribution of member expertise in teams would be challenged by the dimensional approach to expand the knowledge domain. After all, the practical reality is that work goals, performance, and interaction requirements, and the situational and temporal context, occur in tandem with members' knowledge proficiency. By considering the continuum of divergence–convergence, TMS scholars could broaden research questions to include considerations of which team content should be overlapping and which should be distributed among team members for increased team performance. Furthermore, as the TMS literature has emphasized representations, the dimensional approach would draw increased attention to the important role that information sharing and group learning play in the development of cognitive outcomes.

Although our illustrations featured TMMs and TMSs, since these have been the most popular constructs in the team cognition literature, a similar rationale can be applied to any of the other 10 cognition constructs. Thus, the dimensional approach can both broaden and deepen their research scope.

Potential Extensions of the Three-Dimensional Model

Although knowledge domain, knowledge foci, and knowledge convergence were theoretically derived as common denominators underlying the 10 team cognition constructs, we readily acknowledge the flexibility of the dimensional approach to make additions as needed. For example, a fourth dimension could be temporal stability or the extent to which knowledge endures over time or is more short-lived (Espinosa & Clark, 2014). Cognitive processes have generally been considered more transitory in nature and the resulting cognitive representations as more enduring over time (Fiore & Salas, 2004; Wildman et al., 2012). However, TSA and team situational models have been considered as more momentary, since the underlying situational context is more dynamic compared to other forms of content (Espinosa & Clark, 2014; Rico et al., 2019).

In addition to time, the three-dimensional framework could be expanded to include accuracy, or the "true state of the world" (Edwards et al., 2006: 728). Although the team cognition literature has emphasized sharedness, team knowledge scholars have recognized that shared, but erroneous, cognition may yield undesirable outcomes (e.g., Austin, 2003; Brandon & Hollingshead, 2004; Smith-Jentsch, Kraiger, Cannon-Bowers, & Salas, 2009). However, accuracy is not equally applicable across team cognition constructs. Whereas accuracy is a key concern for knowledge structures that one knows to be true (e.g., TMMs, TMSs, TSA, cross-understanding), it is not pertinent for belief structures that capture preferred or desired states because of their subjective and evaluative nature (e.g., cognitive consensus, strategic consensus).

Thus far, our treatment of team cognition has been primarily theoretical; we now turn to the critical issue of measurement.

MEASUREMENT

Moving the team cognition literature forward necessitates not only an integrative dimensional framework but also an integrative measurement framework that enables interrelationships between cognitive processes and representations, knowledge convergence and divergence, and multiple forms of content. Regrettably, extant team cognition measurement has been fragmented, featuring singular forms of content, and separating processes and representations as well as convergence and divergence. From its inception, the proverbial "Achilles heel" of team cognition has been its operationalization, which has been fraught with challenges (e.g., Cooke, Salas, Cannon-Bowers, & Stout, 2000; Mohammed et al., 2000).

Table 7 highlights samples and tasks that have typically been investigated in team cognition studies, as well as commonly used measures. As illustrated, the range of assessments is broad, including qualitative (e.g., Guiette & Vandenbempt, 2013), quantitative (e.g., Weingart et al., 2010), and nonobtrusive (e.g., Cooke & Gorman, 2009) techniques.

As illustrated in Table 7, perceptual and structured are two primary categories of knowledge elicitation commonly referenced in prior team cognition reviews and research (e.g., DeChurch & Mesmer-Magnus, 2010a; Espinosa & Clark, 2014; Rentsch et al., 2008). As such, content (most commonly measured via perceptual measures) and structure were included in our organizing definition of team cognition. Perceptual measures assess team members' attitudes, beliefs, values, and expectations (Rentsch et al., 2008). As their name implies, perceptual measures describe subjective assessments of the extent to which team members perceive they converge on cognitive content via Likert scale items (e.g., Ellwart, Konradt, & Rack, 2014; Lewis, 2003) that are analyzed with mean-based (e.g., Lewis, 2003) or variance-based (e.g., Kilduff et al., 2000; Mohammed & Ringseis, 2001) statistics. Because they do not "provide a deep understanding of causal, relational, or explanatory links" (Rentsch et al., 2008: 146), perceptual measures assess only cognitive content and not structure.

In contrast, structured measures capture the organization, arrangement, or pattern of team knowledge in members' heads in addition to cognitive content. As such, structured techniques provide objective assessments of the extent to which team members converge on cognitive content, as calculated by measures independent of member perceptions. Structured measures include concept mapping (e.g., Burtscher et al., 2011), causal maps (Combe & Carrington, 2015), multidimensional scaling (Combe & Carrington, 2015), repertory grids (Chiravuri et al., 2011), and team knowledge stock (team member combinations of unique and shared knowledge) and accuracy of identified experts (Austin, 2003). The most popular structured measure is pairwise ratings (ratings of the similarity of pairs of various concepts [Randall et al., 2011]), the structure of which is captured by correlating the resulting networks through a quadratic assignment procedure (e.g., UCINET Quadratic Assignment Procedure [Mathieu et al., 2005]) or Pathfinder analysis (e.g., McIntyre & Foti, 2013).

As Table 7 reveals, most team cognition measures are perceptual. This is not surprising given the relative ease of administering Likert-scale measures in comparison to structured assessments, which not only have the added burden of capturing knowledge organization but also typically tailor cognitive content to specific team contexts via a team task analysis (Mohammed & Hamilton, 2012). In their meta-analytic review, DeChurch and Mesmer-Magnus (2010a) found that structured cognition measures had stronger positive effects on team processes than did perceptual cognition measures, but no difference between the two resulted for team performance.

Measurement Limitations of Team Cognition

We now enumerate several limitations of the current state of measurement that unsurprisingly mirror the aforementioned conceptual limitations. First, team cognition measurement has been marked by fragmentation, a natural consequence of definitional and ambiguity. Not only does Table 7 reveal a scattered measurement picture *across* the 10 constructs, but *within* constructs there has been limited agreement among researchers regarding how constructs should be measured, including group learning (e.g., Edmondson et al., 2007), TSA (e.g., Endsley, 2021), TMMs (e.g., Mohammed et al., 2010), strategic consensus (e.g., Tarakci et al., 2014), and TMSs (e.g., Kush, 2019). Such discordance is not only

TABLE 7
Summary of Team Cognition Construct Measurements & Methods

	Team Cognition Construct	Samples and Tasks Typically Investigated	Knowledge Elicitation	Commonly Used Measures
Team Cognitive Processes	Process-based group learning	Qualitative and quantitative field research on a variety of team types	Perceptual	Surveys (e.g., Aragón, Jiménez, & Valle, 2014; Edmondson, 1999); qualitative techniques such as interviews and observation (e.g., Edmondson, 1996; Edmondson et al., 2001; Ely & Thomas, 2001)
	Information sharing	Laboratory-based research; intellective hidden profile task (e.g., murder mystery, candidate selection)	Perceptual	Extent to which unique and common information was shared and discussed among members and whether the team made the correct decision (e.g., Stasser, Stewart, & Wittenbaum, 1995; Stasser et al., 1989)
Team Cognitive Representations	TMMs	Laboratory student teams performing computer simulations and action teams in a variety of field settings including military, air traffic control, medical, and software teams	Structured	Team task analysis to tailor measures (Mohammed & Hamilton, 2012); pairwise ratings analyzed via Pathfinder (e.g., McIntyre & Foti, 2013) or UCINET (e.g., Mathieu et al., 2005); concept mapping (Pearsall et al., 2010)
	TSA	Action teams in dynamic and complex settings performing simulations in lab or in field contexts (e.g., military, aviation, emergency response)	Perceptual	Situation Awareness Global Assessment Technique (Endsley, 1995b), the Crew Awareness Rating Scale (McGuinness & Foy, 2000), the Mission Awareness Rating Scale (Matthews & Beal, 2002), process-based measures such as observations, interviews, or video recordings (e.g., Cooke & Gorman, 2009)
	Cross-understanding	Qualitative and quantitative field studies and student samples	Perceptual	Interviews (e.g., Guiette & Vandenbempt, 2013); surveys reported on teammates' communication effectiveness, knowledge elaboration, and collaboration (e.g., Meslec & Graff, 2015)
	Strategic consensus	Top management teams, middle-level and lower-level management groups, management decision-making teams	Perceptual	Surveys about organizational strategy or agreement on strategic goals that were analyzed with variance-based metrics including $r_{wg(j)}$ (e.g., Vissa & Chacar, 2009) and Euclidean distance (e.g., Walter, Kellermanns, Floyd, Veiga, & Matherne, 2013)
	Cognitive consensus	Laboratory and field research designs; quantitative and qualitative methodologies	Mainly perceptual, but some structured	Survey questions assessing perceived overlap between members assessed with variance-based statistics (e.g., Kilduff et al., 2000); causal maps (Combe & Carrington, 2015); multidimensional scaling (Combe & Carrington, 2015); repertory grids (Chiravuri et al., 2011)
	Shared task representation	Decision-making or problem-solving tasks sampling undergraduates in lab settings	Perceptual	Various surveys measuring the extent to which participants developed specific task representations that were analyzed via awg(1) values (e.g., van Ginkel et al., 2009; van Ginkel & van Knippenberg, 2008)

TABLE 7
(Continued)

Team Cognition Construct	Samples and Tasks Typically Investigated	Knowledge Elicitation	Commonly Used Measures
TMSs	Laboratory student teams performing assembly tasks; MBA project teams, industry teams	Mainly perceptual, but some structured	Survey assessing the behavioral indicators of specialization, credibility, and coordination (Lewis, 2003); structural components of team knowledge stock (unique and shared knowledge) and meta-knowledge (shared understanding of who knows what (Austin, 2003)
rGaps	Engineering, industrial design, and MBA students working on a product development process; multidisciplinary science teams	Mainly perceptual, but some structured	*Q*-sort methodology comparing perceptions of task process via averaged pairwise correlations (Weingart et al., 2010); self-report scale about incompatibilities in team members' conceptions of the team task (Wang et al., 2016); Euclidean distance between nodes in a multidimensional space (Weingart et al., 2007)

increasingly difficult for team cognition scholars to navigate but is also off-putting to research newcomers in search of clear measurement guidance. How many researchers have wanted to include team cognition as a substantive variable in their studies, only to be discouraged from doing so by having to navigate a messy array of metrics with little standardization?

Second, measurement distinctions across the 10 team cognition constructs are becoming more artificial than substantial. For example, structural assessment has been identified as a key factor distinguishing TMMs from other forms of team cognition (Mohammed et al., 2010). However, other constructs, such as cognitive consensus (e.g., Combe & Carrington, 2015), TMSs (e.g., Argote et al., 2018), and rGaps (e.g., Weingart et al., 2007), have begun to assess structure more (albeit at lower frequency), blurring prior distinctions. In addition, whereas the hallmark of TSA measures has been capturing the situational context as perceptual cognitive representations (Endsley, 1995a), CAST (Coordinated Awareness of Situation by Teams) assesses the situation as a structural measure featuring cognitive processes (Gorman, Cooke, Pederson, & DeJoode, 2005).

As a result of the lack of cross-fertilization and cross-referencing across literatures, many subliteratures of team cognition appear to have reinvented the proverbial wheel, despite measures being potentially applicable across different types of content to assess the underlying dimensions of knowledge domain, foci, and convergence. For example, Table 7 reveals that many perceptual measures rely on similar variance-based statistics (e.g., rwg, Euclidean distance). Moreover, several team cognition constructs assess accuracy, but operationalize it differently (e.g., Austin, 2003; Endsley, 1995b; Huber & Lewis, 2010; Mathieu et al., 2005). Because multiple accuracy measures are not typically administered in the same study, comparisons across measures are unknown. Rather than continuing to only assess main effects with processes and performance, we need to test differential and interactive influences of multiple team cognition measures on outcomes. Doing so would help to elucidate which measures provide unique utility in predicting team outcomes.

Third, the lack of synthesis across literatures has facilitated a limited either–or measurement mentality rather than inclusive both–and thinking. Within constructs, most empirical research has employed a single team cognition measure. Of the limited number of within-construct studies simultaneously including multiple measures, results have consistently indicated that measures are not interchangeable (e.g., TMSs [Kush, 2019], TSA [Endsley, 2021], strategic consensus [Kellermanns et al., 2011]), necessitating a both–and measurement approach to explore why. Across-construct team cognition studies are rare (Wildman et al., 2014). In the few cases in which two types of team cognition constructs have been measured, results have typically concluded that each independently predicts performance, rather than examining interactive or differential effects (e.g., Ellis, 2006; Pearsall et al., 2010).

Moreover, despite the fact that cognitive structure is needed to properly interpret cognitive content (Seel, 2012), perceptual measures separate the two by only capturing content. Because perceptual measures dominate team cognition measurement, more direct empirical demonstration is needed regarding how structural differences affect the meaning and sharedness of knowledge content. In addition, rarely have empirical papers combined measures assessing perceptions of sharedness with measures assessing actual sharedness of knowledge content (Mohammed et al., 2010). However, if perceptual and structural measures were combined, we could assess the consequences of team members thinking they are on the same page when they are not, or thinking they not are on the same page when they are (e.g., Marhefka, Mohammed, Hamilton, Tesler, Mancuso, & McNeese, 2018).

Not only is there an artificial bifurcation between content and structure, but cognitive process measures are generally divorced from cognitive representation measures. This separation has created a superficial view of how antecedents shape the development of improved or deteriorated cognitive representations over time. Yet, our ability to answer both–and questions is crucial to representing the complexity of contemporary teams.

Fourth, the combination of the first three limitations has facilitated basic measurement and analyses, precluding the exploration of more advanced research questions. To illustrate, both perceptual and structured measures of team cognition rely on team-level aggregation approaches that grossly oversimplify knowledge representations (Cooke et al., 2013; Grand et al., 2016; Mohammed et al., 2010). Specifically, perceptual scale items generally utilize a team-based referent and are aggregated to the team level, which assumes that all team members contributed the same amount to team cognition process measures (e.g., Van der Vegt, De Jong, Bunderson, & Molleman, 2010) or that all content should be equally weighted in team cognition representation measures (e.g., Lewis, 2003). Structured measures, such as pairwise ratings (analyzed using programs such as UCINET or Pathfinder) are typically compared dyadically (Member *A* compared to Member *B*, Member *B* compared to Member *C*) and then aggregated to the team level to provide an overall index of team cognition (e.g., Lim & Klein, 2006).

Clearly, team-level aggregation has provided a solid foundation for team cognition measurement by allowing us to demonstrate its positive prediction of team-level performance. However, by simplistically assuming that all team members make similar contributions to their team, aggregated team cognition measures fail to sufficiently capture the variability of knowledge-building activities and their resulting representations. Moreover, aggregated approaches obscure multilevel complexities such as individual, dyadic, or subgroup interactions, thereby limiting our potential to generate new knowledge.

Which team members should be "on the same page," and which team members should not be? Which content domains (e.g., expertise, task representations, equipment, time, member interactions) should be convergent and which should be divergent? Who should share what knowledge? How do information-sharing patterns affect resulting cognitive representations? How should teams manage the inherent tension between knowledge convergence and divergence? Despite the foundational nature of these questions for both theory and practice, the extant team cognition literature has provided few answers because either–or assumptions of siloed literatures still hold. To answer these questions, we advocate network-based metrics, which address the conceptual and measurement limitations discussed above and have been increasingly gaining traction in the study of teams (e.g., Park, Grosser, Roebuck, & Mathieu, 2020). Whereas the three-dimensional framework unites the team cognition literature *conceptually*, we see networks as a powerful tool to integrate the team cognition literature *methodologically*. In the next section, we explain how.

MOVING TEAM COGNITION RESEARCH FORWARD THROUGH NETWORK CONFIGURATIONS

We join many other scholars who have preceded us in the advocacy of a network-based approach to study and understand team cognition (e.g., Espinosa & Clark, 2014; Mathieu, Gallagher, Domingo, & Klock, 2019). In fact, a recent review of the broader team literature recognized that "researchers have increasingly adopted network approaches to enrich our understanding of work teams as dynamic and complex systems" (Park et al., 2020: 21). Networks are also no stranger to cognition. From its roots in schemata theory and cognitive psychology (e.g., Tversky & Kahneman, 1980), team cognition has tacitly assumed that the meaning of elements in a cognitive system requires consideration of their interrelationships (Cannon-Bowers & Salas, 2001; Cannon-Bowers et al., 1993). Making this assumption explicit conceptually and methodologically, Espinosa and Clark (2014) emphasized the capacity of networks to bring additional explanatory power to team cognition by preserving both the content and the structural detail at the individual and dyadic levels that comprise team knowledge. Thus, networks can accommodate both perceptual and structured knowledge elicitation, although they are particularly well-suited to capture team knowledge organization. As the meaning of cognitive content ultimately depends on its structure (Graves, Wayne, & Danihelka, 2014), eliciting team knowledge through structured measures expands our capacity to capture critical aspects of team cognition via multilevel, multilayer, longitudinal networks.

Empirically, several team cognition studies have incorporated network approaches (e.g., Zappa & Lomi, 2016), including TMSs (Argote et al., 2018), TSA (e.g., Roberts & Stanton, 2018), cognitive consensus (Combe & Carrington, 2015), rGaps (Weingart et al., 2007), and process-based approaches (Cooke et al., 2013). Of the team cognition constructs reviewed, TMMs have utilized network-based measures with the highest frequency to assess both knowledge similarity and accuracy (e.g., Mathieu et al., 2005). Although extant research has started to reveal the promise of a network-based approach, the few studies have only begun to "scratch the surface" of integrating networks and team cognition, especially since network analytic tools are rapidly evolving (Kivelä, Arenas, Barthelemy, Gleeson, Moreno, & Porter, 2014; Wang, Robins, Pattison, & Lazega, 2016).

Networks can advance team cognition research by addressing the pressing conceptual and methodological limitations reviewed above. Not only do networks have the capability to combine multiple knowledge domains but they can also simultaneously incorporate cognitive processes and representations, knowledge convergence and divergence, as well as content and structure. Applying networks to team cognition therefore offers representational and analytical procedures to operationalize both–and thinking. As such, network-based approaches have the potential to bring unity to team cognition's artificial divides and scattered measurement landscape.

Networks also surpass traditional team-aggregated approaches by accommodating the multilevel nature of team cognition emergence from individual to dyadic to subgroup to overall team to multiteam systems and beyond (Espinosa & Clark, 2014), accounting for reciprocal cross-level effects (i.e., top down and bottom up). Specifically, cross-level statistics can be computed for each network level (upper and lower), the meso-level network (i.e., the network that contains the ties between nodes across levels), and the combination of all networks (i.e., upper, lower, and meso-level network) (Wang, Robins, Pattison, & Lazega, 2013; Wang, Robins, et al., 2016). By preserving the richness of multiple levels operating simultaneously, networks capture the inherent multilevel characterization of teams, thereby offering unique, predictive information over aggregate team cognition measures. For example, instead of assuming that all members need to share all knowledge at all times, as aggregate measures imply, more nuanced research questions, such as "Who should share what knowledge?" can be pursued.

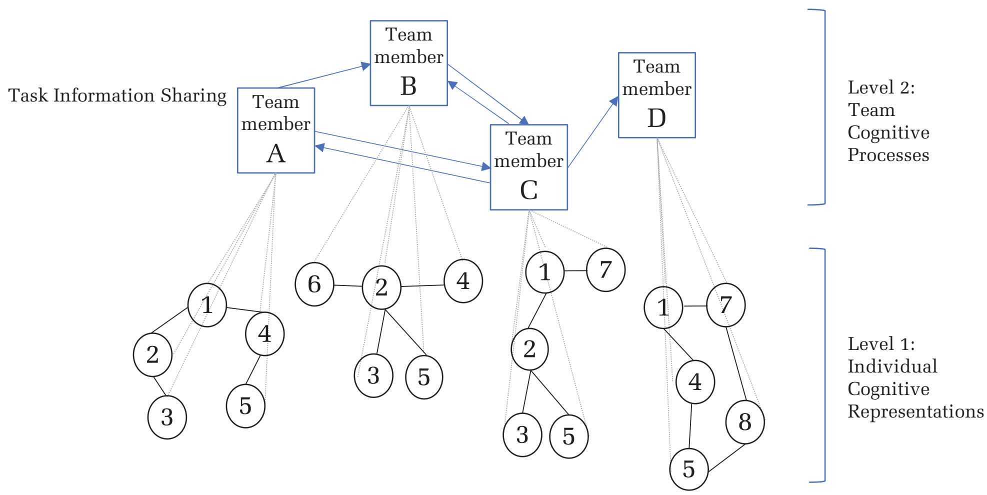
Building on prior calls for greater incorporation of networks into the study of team cognition (e.g., Phelps, Heidl, & Wadhwa, 2012; Wildman et al., 2014), we use the three-dimensional team cognition framework to pose and answer three questions addressing how network approaches can move the study of team cognition forward. First, how do networks accommodate the multifaceted nature of team cognition by simultaneously modeling cognitive processes and cognitive representations? Second, how do networks accommodate the multilayer nature of team cognition by simultaneously capturing several knowledge domains? Third, how do networks accommodate the complexity of both convergence on some knowledge domains and divergence on other knowledge domains?

How do Networks Accommodate the Multifaceted Nature of Team Cognition by Simultaneously Modeling both Cognitive Processes and Cognitive Representations?

Although siloed in different literatures and not normally combined in empirical research, cognitive processes (Cooke et al., 2013; Grand et al., 2016) and cognitive representations (e.g., Uitdewilligen et al., 2010) are neatly interconnected in networks, more accurately modeling team dynamics. Following multilevel network analysis developments (Snijders & Lazega, 2016), we consider team cognitive processes and team representations as two levels that are not nested in the traditional sense of individual, dyadic, team, and organizational levels, but fit multilevel logic.

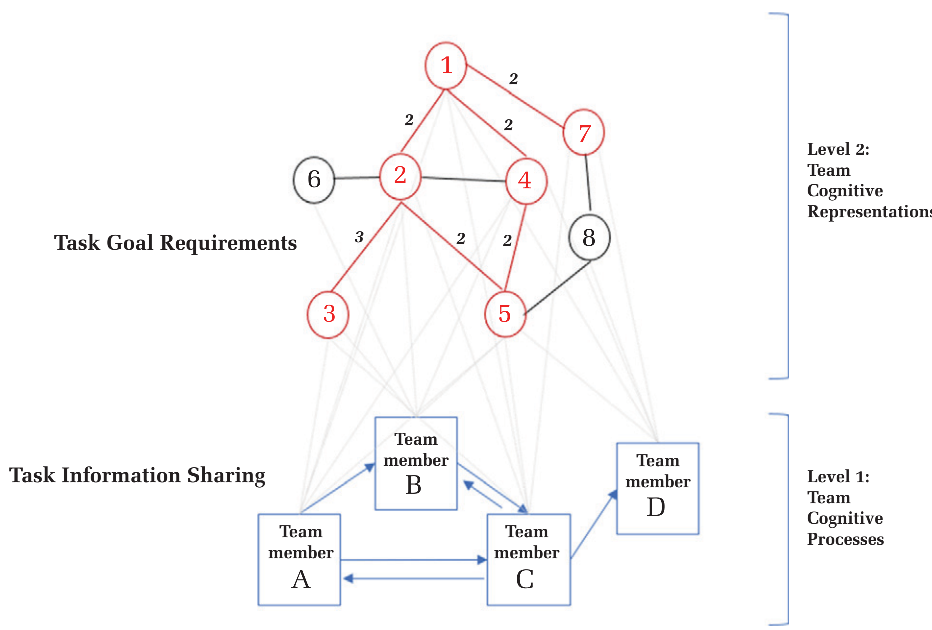
Figure 1 illustrates that team cognition can be portrayed as a set of two interdependent network levels: (a) an individual level capturing internalized knowledge held by individuals represented as nodes linked to other nodes in members' minds, and (b) a team level representing team cognitive processes in

FIGURE 1
Individual Cognitive Representations and Team Cognitive Processes as Multilevel Interdependent Networks



Note: Numbers inside circles represent independent knowledge.

FIGURE 2
Team Cognitive Processes and Team Cognitive Representations as Multilevel Interdependent Networks



Notes: Red circles and links depict shared, externalized cognitive content. Black circles and links depict unshared, internalized cognitive content. Numbers inside circles represent concepts, while numbers by the links indicate the number of team members sharing that externalized cognitive content.

which nodes are team members and links between nodes capture team members' interactions (e.g., task-information sharing).

As the emergence of individual to team cognition has been detailed in other articles (e.g., Grand et al., 2016; Kozlowski & Chao, 2012a, 2012b) and our focus is on the team level, we emphasize the interplay between team cognitive processes and the resulting team representations. Therefore, Figure 2 illustrates the team cognitive processes depicted in Figure 1 and cognitive representations in which nodes are externalized knowledge collectively acknowledged by team members (Grand et al., 2016). Each level and their interaction are detailed below.

Team cognitive processes are characterized by a network of interdependent team members also known as a social network. Indicative of traditional social network analysis, nodes represent team members and links capture team members' knowledge-dissemination activities (e.g., Grand et al., 2016). This characterization of team cognitive processes has already been accounted for in the literature in the form of situation awareness updating (Stanton, Salmon, Walker, Salas, & Hancock, 2017) and interactive team cognition (Cooke et al., 2013). As depicted in Figure 2, team member *D* only shares information with team member *C* and therefore has low centrality, being the least connected individual in the team.

Team cognitive representations are characterized by a network of externalized knowledge that is shared and acknowledged by at least two team members (Fiore, Rosen, et al., 2010), and that has emerged from individually acquired internalized knowledge (Level 1 in Figure 1) via team cognitive processes (Level 2 in Figure 1). The nodes represent knowledge in a certain domain (e.g., task concepts, problem definitions), and the links represent how team members connect pieces of knowledge (e.g., Koponen & Nousiainen, 2018)

Team cognitive process and representation interactions capture the most important feature of the multilevel network approach—interdependent nodes and network ties can interact within and across levels (Contractor, Wasserman, & Faust, 2006; Wang, Robins, & Matous, 2016). As shown across Figures 1 and 2, the links between externalized knowledge nodes depend on team members' information-sharing patterns and on the internalized knowledge held by individual members. For example, team member *D* individually holds concept 8, as part of the team knowledge pool (Grand et al., 2016) depicted as Level 2 in Figure 2. However, given the task information-sharing patterns and the marginal interrelationship of member *D* with the rest of team, we can understand why that knowledge has not yet been externalized in the team. Over time, member *D* may develop more information-sharing ties with other members, which may cause concept 8 to become actionable team knowledge.

The capacity to model interacting social and knowledge networks captures the reciprocal cross-level effects between both networks (Wang, Robins, Pattison, & Lazega, 2016; Zappa & Lomi, 2016). As such, network measures not only reduce fragmentation and artificial distinctions between cognitive processes and representations but also foster the both–and thinking that encourages team cognition scholars to pursue more advanced research questions. For example, who is communicating with whom, and what knowledge domains converge across team members? Specifically, do central team members in the information-sharing network also hold central knowledge about task goals in the externalized cognitive representation network? Such questions may be addressed through exponential random graph measures accounting for cross-level centrality (e.g., Wang et al., 2016), which report the extent to which central task goal concept interconnections are sustained through central team members' interactions in the information-sharing network. As we illustrate, measures that jointly model team cognitive processes and representations open new avenues to better understand team knowledge emergence, development, maintenance, and change over time.

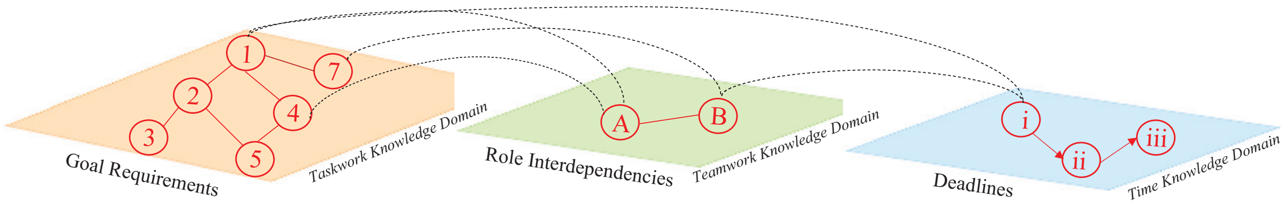
How do Networks Accommodate the Multilayer Nature of Team Cognition by Simultaneously Capturing Several Knowledge Domains?

In addition to fitting multilevel logic, networks accommodate the multilayer nature of team cognition by simultaneously capturing several knowledge domains and interrelationships within and between knowledge domains. Specifically, multilayer networks (i.e., meta-networks) result from combining different knowledge domains (i.e., layers) and account for the interaction of nodes (e.g., concepts) belonging to each layer (Carley, 2019; Kivelä et al., 2014; Snijders & Lazega, 2016). Multilayer network measures can connect two, three or even more nodes (Carley, 2019).

Figure 3 exemplifies a multilayer network featuring three specific concepts (goal requirements, role interdependencies, and deadlines) within three respective layers (taskwork knowledge, teamwork knowledge, and temporal knowledge). Concepts (nodes) are interconnected both within (solid) lines) and across (dashed lines) the three knowledge domains. Therefore, rather than three separate measures found across literatures, as has been the case to date (Cronin & Weingart, 2007; Mathieu et al., 2000; Mohammed et al., 2015), a single multilayer network reduces fragmentation by concurrently modeling goal requirements, role interdependencies, and deadlines.

Figure 2 could similarly be enhanced by adding multiple layers representing additional knowledge domains (Espinosa & Clark, 2014).

FIGURE 3
Team-Level Multilayer Network: Interrelationships Within and Between Multiple Knowledge Domains



Notes: Red circles and links represented in each knowledge domain depict shared, externalized cognitive content. Numbers inside the circles represent concepts within each knowledge domain. Solid links connect concepts within each knowledge domain, while dashed links connect concepts across knowledge domains.

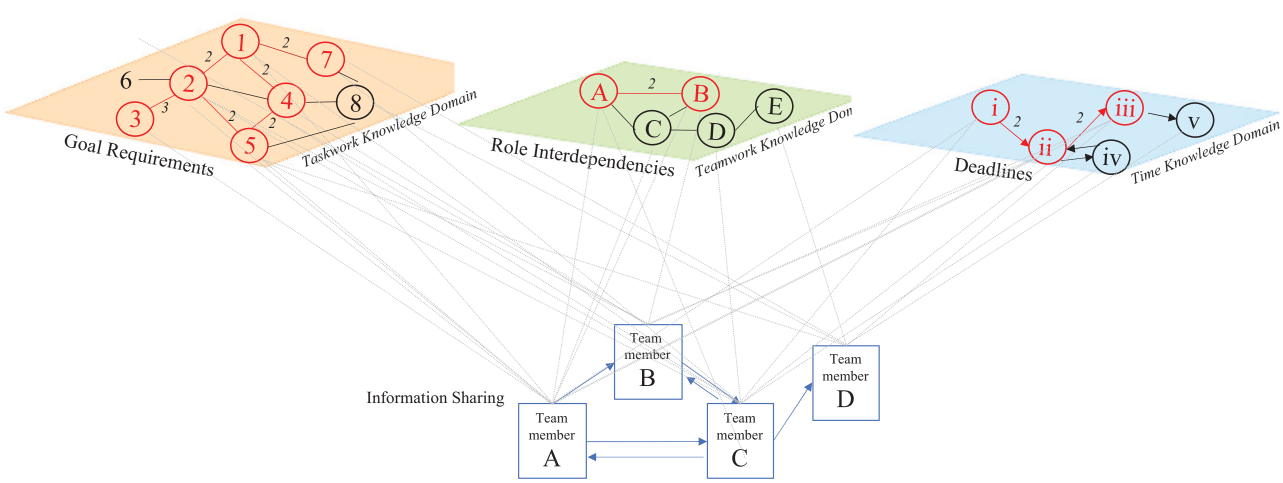
Multilayer networks allow for central, but previously unanswered, questions to be tested. For example, to what extent are teams' taskwork, teamwork, and temporal representations aligned? Specifically, what team goals are connected to member roles to ensure adequate staffing to fulfill team objectives (Goals 1, 4, and 7 in Figure 3)? Furthermore, what team goals are connected to both member roles and deadlines to increase the probability that deliverables will be finished in time (Goal 7)? What team goals are at risk of not being completed because they lack associated role interdependencies and assigned deadlines (Goals 2, 3, and 5)? What deadlines may be unmet because they are not connected to either goals nor member roles (Deadlines ii and iii)?

These questions can be addressed through multimode measures from the group of the coherence measures that Carley (2019) identified as performance-based, which report the likeliness of completing team task goals. The performance measure captures the percentage of goals that cannot be completed because they lack associated member interactions and needed deadlines (for details and supporting software, see Carley, 2019).

How do Networks Incorporate the Complexity of Both Convergence on Some Knowledge Domains and Divergence on Other Knowledge Domains?

Networks can also assess degrees of team members' convergence or divergence across multiple

FIGURE 4
Multilevel, Multilayer Network: Team Members Knowledge Convergence Across Multiple Knowledge Domains



Notes: Red circles and links depict shared, externalized cognitive content. Black circles and links depict unshared, internalized cognitive content. Characters inside circles represent concepts in different knowledge domains, while numbers by the links indicate the number of team members sharing that externalized cognitive content.

knowledge domains, in which some nodes may be empty (members do not share externalized cognitive content), other nodes may be sparse (a few members hold in common externalized knowledge), while other nodes may be dense (most members share externalized knowledge) (Zajac et al., 2014). As shown in Figure 4, team members have the highest convergence or most dense network layer for goal requirements and the lowest convergence for role interdependencies, with deadlines in between.

Network approaches have already been used to capture the convergence and divergence ends of the team cognition continuum, albeit not with the sophistication that they could have. For example, TMM convergence has been estimated through a quadratic assignment procedure index that correlates two matrixes (or networks) to quantitatively assess the degree of similarity in cognitive content across pairs of team members (e.g., Mathieu et al., 2005). However, this method can be extended to simultaneously compare more than two networks using the multiple regression quadratic assignment procedure (Dekker, Krackhardt, & Snijders, 2007). Similarly, cognitive divergence capturing “which team members know what” has already been represented and analyzed as two-node networks by calculating standard deviations to estimate transactive memory consensus (Austin, 2003). However, dynamic network analytical procedures allow for finer-grained assessments combining two or more layers (Carley, 2019).

Advances in network measures allow us to address complex and relevant research questions, including: Which team members can diverge, and on what knowledge? To what extent does knowledge convergence depend on team members’ interaction patterns under different levels of task interdependence (Bachrach et al., 2019)? For example, the question of which team members need to converge and on what knowledge domains could be approached using a negotiation measure pertaining to multimode network coherence measures (Carley, 2019). A negotiation measure, to illustrate, can identify the proportion of task goals that need negotiation (i.e., information sharing) between team members because teammates lack convergence on role interdependencies and deadlines to accomplish task goals (Carley, 2002).

We acknowledge that the network logic we advocate increases the theoretical, methodological, and statistical complexity of team cognition research, which is already challenging. However, to move forward we must “embrace the complexity,” as advocated in a recent review of team science by Mathieu and colleagues (2019). We are convinced that multilevel, multilayer, longitudinal networks capturing multiple knowledge domains, content and structure, cognitive processes and representations, and knowledge convergence and divergence are and will continue to be a game changer for the study of team cognition in current and future work settings.

THE FUTURE OF TEAM COGNITION RESEARCH

In our opinion, some of the most pressing issues for team cognition moving forward center around team complexity, adaptation, time, and accuracy. Each will be briefly discussed below. Team cognition should be researched in the increasingly complex, distributed, and specialized contexts faced by contemporary teams, in which boundaries are becoming more permeable and difficult to identify (Mathieu et al., 2019; Rico, Gibson, Sánchez-Manzanares, & Clark, 2020). Many employees are members of multiple teams simultaneously, may join or leave intact teams midstream, work in multiple time zones, and may interact with robot teammates (e.g., Fiore & Wiltshire, 2016; Tannenbaum, Mathieu, Salas, & Cohen, 2012). As such, the assumptions underlying team cognition research need to be reconsidered to ensure alignment between modern-day teaming and scholars’ investigations. For example, Mortensen (2014) reported that 84% of teams disagreed on who was a member of their team, and this membership model divergence negatively influenced interaction levels in teams. Therefore, patterns of knowledge convergence and divergence should be examined amid the reality of multiple team affiliations, geographically dispersed teammates, changing team members, and human–robot teaming. Toward this end, the network approach provides the logic and the analytical tools to interrelate sets of interdependent nodes and network ties within and across multilayer networks (e.g., members with different affiliations included in alternative layers in one multilayer network and cognitive content in different knowledge domains included as alternative layers in another multilayer network).

Relatedly, team adaptation is at the core of how teams and organizations effectively respond to the complexity and accelerated unpredictability that current and future work settings entail (Baard, Rench, & Kozlowski, 2014). Team cognition plays a critical role in the adaptive process, such as when team members shift their mental models to match changing situations and task changes (Rico et al., 2019; Zajac et al., 2014). How do changes in team cognitive representations coevolve with changes in cognitive processes to support adaption over time? Which team knowledge-building patterns enable convergence between the situational knowledge domain and the current situation so that teams can coordinate and satisfactorily adapt to unexpected changes (Rico et al., 2019)? We can begin to address these research questions by applying multilayer, multilevel network logic and metrics (Wang, Robins, Pattison, & Lazega, 2016).

Adaptation, by nature, involves change over time, which must be studied if we wish to truly understand team cognitive processes and representations. Adopting a temporal perspective acknowledges that not all cognitive representations are used all the time; rather, they are activated at different moments, with cycles of convergence and divergence (Rico et al., 2019). Similarly, member information sharing occurs in certain patterns and different latencies across time. In what temporal sequence are knowledge domains activated during transition and action phases? How do cognitive processes change cognitive representations over time? Fortunately, networks incorporate time by accounting for *when* the links between nodes occur (Holme & Saramäki, 2012), and whether and when change occurs in a network over time (McCulloh & Carley, 2011).

In addition to time, we proposed accuracy as an extension of the three-dimensional model. Given how strongly the team cognition literature has attended to getting team members on the same page, it is striking how little comparative emphasis has been given to whether the page is the right one. Assessing accuracy is complicated and has been defined and measured differently across team cognition constructs (e.g., Austin, 2003; Edwards et al., 2006; Huber & Lewis, 2010). However, traditional measures can now be complemented by more flexible multilevel network measures (Koponen & Nousiainen, 2018), which offer the capacity to answer key unaddressed questions. For example, how do team cognitive processes help to reconcile multiple inaccurate cognitive representations of team members (Rico, Hinsz, Davison, & Salas, 2018)? How do team members' expertise during information sharing influence the accuracy of knowledge representation (e.g., Mathieu et al., 2005; Palazzolo, Serb, She, Su, & Contractor, 2006)?

CONCLUSION

What we currently know about team cognition is distributed and fragmented because the literature consists of a loose collection of many constructs with little cross-fertilization and cross-referencing. By continuing this traditional, siloed lens, team cognition research risks becoming stagnant and increasingly irrelevant. In response, we provided a comprehensive and cross-disciplinary review that integrates 10 disjointed team cognition constructs into three overarching dimensions. We embed the three dimensions into a network-based framework that unites the content and structure of team cognition and provides a set of measurement techniques that permit more expansive and nuanced research questions to be answered. We remain convinced that the most promising avenues for future research lie not within each siloed form of team cognition but at their intersections.

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