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Conditioning team cognition: A meta-analysis

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Abstract

Abundant research supports a cognitive foundation to teamwork. Team cognition describes the mental states that enable team members to anticipate and to coordinate. Having been examined in hundreds of studies conducted in board rooms, cockpits, nuclear power plants, and locker rooms, to name a few, we turn to the question of moderators: Under which conditions is team cognition more and less strongly related to team performance? Random effects meta-analytic moderator analysis of 107 independent studies ($N = 7{,}778$) reveals meaningful variation in effect sizes conditioned on team composition and boundary factors. The overall effect of team cognition on performance is $\rho = .35$, though examining this effect by these moderators finds the effect can meaningfully vary between $\rho = .22$ and $\rho = .42$. This meta-analysis advances team effectiveness theory by moving past the question of "what is important?" to explore the question of "when and why is it important?" Results indicate team cognition is most strongly related to performance for teams with social category heterogeneity ($\rho = .42$), high external interdependence ($\rho = .41$), as well

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as low authority differentiation ($\rho = .35$), temporal dispersion ($\rho = .36$), and geographic dispersion ($\rho = .35$). Functional homogeneity and temporal stability (compositional factors) were not meaningful moderators of this relationship. The key takeaway of these findings is that team cognition matters most for team performance when—either by virtue of composition, leadership, structure, or technology—there are few substitute enabling conditions to otherwise promote performance.

Keywords
team cognition, team composition attributes, team boundary attributes, team performance, meta-analysis

Grand feats of humankind are the province of teamwork. More than 100 years of team effectiveness research reveals a set of core enabling conditions that underpin the success or failure of teams (Mathieu et al., 2017), with team cognition emerging as one of the strongest predictors of team performance (DeChurch & Mesmer-Magnus, 2010; Mohammed et al., 2010). *Team cognition* describes the patterns of knowledge structures held among team members that enable them to anticipate one another's needs and coordinate their actions (Kozlowski & Ilgen, 2006). Decades of research support its positive relationship with team performance, and this has fueled many recommendations and interventions aimed at developing and enhancing team cognition (Cooke et al., 2000; Gurtner et al., 2007; Huber & Lewis, 2010; Liang et al., 1995; McNeese et al., 2017). Team cognition has now been investigated in a wide variety of teams working in the military (Cannon-Bowers et al., 1990), health care (D'Ambruoso et al., 2016), aviation (McFadden, 2009), athletics (McNeese et al., 2017), nuclear power plants (Waller et al., 2004), SWAT teams (Jones & Hinds, 2002), and space exploration teams (DeChurch et al., 2015), among others.

Given the sizable body of research exploring team cognition and the breadth of teams represented, we are in a solid position to meta-analytically address the question of moderators. Though certainly useful to know that team cognition is a robust predictor of team performance, it is even more useful to understand the particulars of when and for whom team cognition is *most* critical to performance. Toward that aim, this paper answers the question: *Under which conditions is team cognition more and less strongly related to team performance?*

Team cognition

Team cognition is an emergent state (i.e., a property of the team), describing how knowledge is mentally organized, represented, and/or distributed among team members (Cannon-Bowers et al., 1990; Grand et al., 2016; Kozlowski & Ilgen, 2006; Mohammed et al., 2010; Salas & Fiore, 2004). Two types of team cognition have been the subject of widespread research attention: team mental models (TMMs) and transactive memory systems (TMSs). TMMs capture the degree to which knowledge about teamwork and taskwork is shared and accurate (Cannon-Bowers et al., 1990). TMSs, on the other hand, involve a process where team members divide and encode the storage of information needed by the team, allowing each member to focus their attention on subsets of information, and then efficiently retrieve others' specialized information when needed (Lewis, 2004). Team cognition explains the observation that high performing expert teams can often coordinate with one another without the need for overt communication (Cannon-Bowers et al., 1990; Cooke et al., 2013; Salas et al., 2007). Indeed, research has documented the importance of team cognition for team performance (DeChurch & Mesmer-Magnus, 2010; Marks et al., 2001; Matheiu et al., 2000; Mesmer-Magnus et al., 2017; Stout et al., 1999), which has remained consistent across a variety of team contexts (Cannon-Bowers et al., 1990; D'Ambruoso et al., 2016; DeChurch et al., 2015; Jones & Hinds, 2002; McFadden, 2009; McNeese et al., 2017; Waller et al., 2004).

Furthermore, previous meta-analytic work has identified construct and methodological moderators of the cognition-performance relationship (DeChurch & Mesmer-Magnus, 2010). The first, nature of emergence, captures how individual cognitive elements form meaningful patterns at the team level. Whereas TMMs are functionally similar at the individual and team levels of analysis (Cannon-Bowers et al., 1990), TMSs are functionally different at the individual and team levels (Kozlowski & Klein, 2000). Although both patterns of cognition are positively related to performance, transactive memory (TMS), reflecting patterned emergence, is the stronger predictor (DeChurch & Mesmer-Magnus, 2010). The second construct moderator is the form of cognition, which describes how cognition is elicited/represented from team members. Team cognition can be perceptual, capturing the nature of individuals' beliefs, or structured, capturing the pattern of how members organize information (Rentsch et al., 2008). Structured cognition is more predictive of performance than is perceptual cognition (DeChurch & Mesmer-Magnus, 2010). Finally, the third cognition construct moderator is cognitive content. Team cognition may contain knowledge relevant to the task (e.g., goals, objectives, tools, timelines, etc.) and/or the team (e.g., who knows what, roles, responsibilities, etc.; Mathieu et al., 2000), and both content domains similarly predict team performance (DeChurch & Mesmer-Magnus, 2010). Lastly, team cognition has exhibited stronger relations to performance in field settings, and in non-experimental studies (DeChurch & Mesmer-Magnus, 2010).

To summarize, known moderators of the cognition-performance relationship include the nature of team cognition as a construct, how it manifests at the team level, and its form, as well as aspects of the research methodology. However, as the literature on team cognition has expanded, it is beneficial for theory and practice to expand the investigation of potential moderators. Doing so sharpens our theory, as we understand more about when team cognition is more and less strongly related to performance. Discovering boundary conditions is also useful for practical purposes; when designing team interventions, it is important to understand the kinds of teams who stand to benefit most from team development activities.

From both a theoretical and practical perspective, it is useful to understand the role of team compositional and boundary factors as potential moderators. Team compositional factors characterize aspects of team types and answer the question: "What kind of team is this?" (Hollenbeck et al., 2012, p. 84). Team composition factors include team homogeneity, authority differentiation, and temporal stability. These dimensions answer the questions: Is this a team whose members are similar or different (homogeneity), does the team have clear lines of authority (authority differentiation), and to what extent is membership stable over time (temporal stability)?

Team boundary factors stem from how team members work with each other and with outsiders, answering the question: How strong is the team's boundary? Strong boundaries support the formation and reinforcement of team norms and bolster members' identification with the team. Three attributes of team boundaries are external interdependence, temporal dispersion, and geographic dispersion. These attributes answer the questions: How closely do team members work with others not on the team (external interdependence), do team members do their work at the same time (temporal dispersion), and do team members work in close proximity to one another (geographic dispersion)? Both compositional and boundary factors allow us to answer the question: For which kinds of teams, either based on the characteristics of members or of the team's boundaries, is team cognition most strongly related to performance.

Across these two types of moderators, we posit that when a factor provides a substitute mechanism to support team productivity, team cognition will be less instrumental to performance than when the composition or boundary factor does not in and of itself provide such an alternative support system. Team composition and team boundaries are two aspects of team design that can support team performance independent of team cognition. Team composition can provide a degree of clarity among members in terms of what they expect from one another. Team boundary factors shape work patterns, norms, and provide opportunities for interaction that can support performance. In both cases, whether due to composition or boundaries, these factors may render team cognition more or less critical depending on the degree to which they constitute an alternative means of support for the team. The following proposition summarizes the core logic for the following moderator hypotheses:

> **Proposition:** The relationship between team cognition and performance is weaker when the team's composition or boundary structure promotes team performance than when these factors do not provide an alternative enabling condition.

Team composition moderators

Aspects of team composition, or the mix of member characteristics, are some of the strongest factors shaping member interactions. Three important compositional factors were detailed by Hollenbeck and colleagues' (2012) characterization of teams: member homogeneity, authority differentiation, and temporal stability. Team composition factors may affect the strength of the relationship between team cognition and performance because they determine the degree to which the team must rely on cognitive foundations in order to perform effectively. At one level of the factor are teams whose composition may act as a substitute for cognition. That is to say that the composition of the team, by design, supports performance. The team design provides conditions that support the team in a way that make cognition less critical. Consider member homogeneity. When teams are homogenous, members are similar to one another on some attribute. Similarity arises out of common background, experiences, or education, and can enable team members to perform effectively whether or not they have developed a shared mental model or transactive memory system with each other.

The first compositional factor is *team member homogeneity*, which refers to the degree to which members are interchangeable with one another (Hollenbeck et al., 2012). Homogeneity is conceptualized both in terms of social categories like gender and culture (i.e., social categories) as well as expertise and training differences (i.e., functional characteristics; Hollenbeck et al., 2012). Teams who are low on homogeneity have members who possess distinctive capabilities and are thus not easily substitutable with one another. Team diversity research explores the degree to which members are homogeneous or heterogeneous, and distinguishes differences that originate in social categories (e.g., gender, age) from those due to differences in members' functional characteristics (e.g., values, functions, disciplines; Bell, 2007; Harrison et al., 1998, 2002). Heterogeneity is thought to affect teams similarly by prompting social comparison processes and necessitating information elaboration (van Knippenberg et al., 2004).

The degree of homogeneity among team members may shift the importance of cognition to performance. Support for this idea comes from theories of team diversity that explain the effect of member differences on group information processing (van Knippenberg et al., 2004). In teams whose members are highly differentiated, team cognition may be especially critical by determining the extent to which diverse teams are able to benefit from the different experience, knowledge, and expertise members bring to the team. In their integrative model of work group diversity, van Knippenberg and colleagues (2004) explain that "transactive memory affects the team's ability for elaboration, because it helps determine which group members to consult on particular issues and provides a frame of reference for placing the individual's contribution in context" (p. 1018). On the other hand, when team members are homogenous in terms of background experiences and acquired expertise, they may have an easier time understanding one another's ideas, which reduces the need for elaboration and enables them to perform well regardless of team cognition. This is not to say that team cognition is not important in more homogeneous teams, but rather that it may be comparatively *more* critical and predictive of performance in heterogeneous teams. Accordingly:

> **Hypothesis 1:** Team homogeneity moderates the relationship between team cognition and team performance such that team cognition is more strongly related to performance in heterogeneous as compared to homogenous teams.

A second aspect of team composition stems from the degree to which team members differ in their ability to influence other team members and make decisions on behalf of the team. This feature is called *authority differentiation* which describes "the degree to which decision-making responsibility is vested in individual members, subgroups of the team, or the collective as a whole" (Hollenbeck et al., 2012, p. 84). At the high end of authority differentiation are judge-advisor systems, where certain individuals make decisions on behalf of the team. At the low end of authority differentiation are autonomous/self-managing teams, where members work collectively to lead themselves and each other.

Authority differentiation may shape the extent to which team cognition is instrumental to performance. As with diversity, authority differentiation can act as a substitute enabling condition for team performance. When differentiation is high, team members are clear on the expected lines of authority, who is responsible for resolving points of disagreement, and making decisions on behalf of the team. Because of this design feature, team cognition may not be as pivotal to performance as it is when teams lack these clear demarcations in authority. In teams with low authority differentiation, where leadership is rotated and/or shared by multiple team members, team cognition is critical for enabling the team to work together and integrate members' differing ideas and perspectives. Absent differentiation in authority, there is a premium on the team's ability to manage itself via its cognitive states. Stated differently, authority differentiation, when it is high, may act as a partial substitute for team cognition, making team cognition less critical for performance than when authority differentiation is low. Therefore, we posit:

> **Hypothesis 2:** Authority differentiation moderates the relationship between team cognition and team performance such that team cognition is more strongly related to performance when authority differentiation is low rather than when it is high.

The third team composition factor is *temporal stability*, defined as "the degree to which team members have a history of working together in the past and an expectation of working together in the future" (Hollenbeck et al., 2012, p. 84). Team cognition may be proportionally more important to performance in newly formed teams as they have little else upon which to base team processes, like information sharing and storage (processes that tend to come with increased experience in working together). Similarly, other emergent states known to be predictive of team performance, like team efficacy and potency, may not be as well-formed, leaving a greater proportion of the variance in team performance to be a function of the sharedness of team cognition. Teams with greater tenure have developed more efficient behavioral repertoires than teams with less time spent interacting (Klimoski & Mohammed, 1994; Salas et al., 1998), also providing a potential alternative pathway to performance besides team cognition. Hence, we would expect team cognition to be more strongly related to performance for newer teams as compared to teams with more experience together:

> **Hypothesis 3:** Temporal stability moderates the relationship between team cognition and team performance such that team cognition is more strongly related to performance when temporal stability is low rather than when it is high.

Team boundary moderators

A second set of factors affecting team interactions are boundary attributes. One attribute to receive extensive attention in the literature is team external interdependence. From Ancona and Caldwell's seminal work on boundary spanning processes, to more recent work on teams working in larger systems (i.e., multiteam systems; Luciano et al., 2018), there is abundant evidence that the degree of external coupling of a team affects internal functioning. Another boundary factor affecting teams is their degree of dispersion. Aspects of dispersion affecting team boundaries have been studied extensively in the virtual teams literature, like the degree to which members "work together separately" traversing temporal and/or spatial divides. Accordingly, we focus on three factors affecting the strength of team boundaries: external interdependence, temporal dispersion, and geographic dispersion.

Team boundary factors likely affect the strength of the relationship between team cognition and performance because they determine the strength or weakness of the team's boundary. Teams with high external interdependence, whose members are often reaching outside the team, have blurred boundaries that do little to regularize work patterns, reinforce internal team norms, and provide informal opportunities for members to interact with one another. Hence, when boundary factors are weaker, we would expect team cognition to be especially critical to performance. As with compositional factors, this is because substitutes or alternative pathways to performance are lacking, and cognition is critical. Consider geographic dispersion. At the low end, all team members are physically colocated, and any coordination errors due to misaligned mental models can be detected through frequent interaction. The contributions of team members would be more directly observable by others, making it possible (though less likely) for teams to perform effectively even without strong team cognitive states. In contrast, teams whose members are dispersed require a solid cognitive foundation to ensure their work is complementary. Properties of teams that serve to weaken their boundaries may positively moderate the relationship between team cognition and performance.

Starting with Ancona and Caldwell's seminal work on team boundary spanning (1988, 1992a, 1992b), to the more recent work on teams operating within multiteam systems (e.g., Luciano et al., 2018; Mathieu et al., 2001), there is a general recognition that teams are embedded in larger organizational systems. Indeed, teams can spend a considerable amount of time interacting with individuals outside the team in an effort to integrate external information internally, coordinate behaviors across the team boundary, and even exhibit reliance on external outputs. All of these activities describe the team's *external interdependence*, the degree to which a team is mutually reliant on outsiders to achieve either team goals or larger system goals (Choi, 2002), as is the case with multiteam systems. Research on teamwork and external interdependence has indicated that the quality of team external activities affects team performance (Ancona & Caldwell, 1992b; Marrone et al., 2007).

As such, team cognition may be comparatively more important for externally interdependent teams than those teams who are less engaged outside their team's boundary. As Choi (2002) noted, "teams may need to actively define their boundaries and integrate themselves with external actors ... however ... these activities often decrease the team's cohesiveness because 'external communication may signal an identification with outsiders' (Keller, 2001, p. 553)" (p. 182). Because external interdependence can weaken the entitativity of the team, team cognition is likely to be comparatively more important to performance in externally oriented teams. Reduced cohesion may also lead to decreases in explicit coordination, meaning there is less access within the team to explicit behavioral cues, lessening the role team process plays in performance. Shared cognition therefore provides the basis for implicit team coordination within externally interdependent teams, ultimately reinforcing team performance. Thus:

> **Hypothesis 4:** External interdependence moderates the relationship between team cognition and team performance such that team cognition is more strongly related to performance when external interdependence is high rather than when it is low.

Another important boundary attribute of teams stems from their virtuality. With virtuality, all team members may not experience the same stimuli, or they may experience stimuli differently based on their patterns of dispersion (O'Leary & Mortensen, 2010). Though taxonomies differ in the particular aspects of virtuality (Gibson & Gibbs, 2006; Kirkman & Mathieu, 2005; O'Leary & Cummings, 2007) they converge in calling out the nature of dispersion among team members and the resulting reliance on virtual technologies as important factors affecting team members. Due to the heightened use of virtual technologies and other explicit forms of coordination, teams whose members are dispersed must rely more heavily on various modes of coordination. Implicit coordination occurs when "team members anticipate the actions and needs of their colleagues and task demands, and dynamically adjust their own behavior accordingly, without having to communicate directly with each other or plan the activity" (Rico et al., 2008, p. 164). In fact, implicit coordination theory offers implicit coordination as a behavioral mediating explanation for why team cognition predicts team performance (Rico et al., 2008). As teams converge in the ways they conceptualize task and teamwork, coordination continues to be crucial to team performance, though they likely require less explicit coordination as they are able to coordinate their actions more seamlessly and efficiently through tacit coordination. Rico and colleagues posit that implicit coordination, which is supported by team cognition, is more critical to performance for virtual teams (2008, Proposition 10, p. 176). This logic suggests the performance of teams whose members are more virtual and dispersed benefit more from team cognition than do teams whose members are more proximal to one another. We test this idea with two aspects of virtuality: members' degree of temporal dispersion and degree of geographic dispersion (O'Leary & Cummings, 2007).

Temporal dispersion reflects the degree to which team members are separated by time-related boundaries (e.g., operate in different time zones and/or on different schedules; O'Leary & Cummings, 2007). This form of dispersion often presents communication challenges for members—for example, working across different time zones can result in team members sending critical messages during other members' off-hours (Cramton, 2001). Similarly, by virtue of their temporal distribution, dispersed team members may struggle to maintain synergy and momentum during task completion (O'Leary & Mortensen, 2007). Unsurprisingly, temporal dispersion has been found to directly negatively impact team performance (Massey et al., 2003; O'Leary & Cummings, 2007). Thus, teams with high temporal dispersion may be particularly benefited by shared cognition among members, such that cognition may buffer the challenges and enable them to rely on the implicit coordination needed to work asynchronously (Rico et al., 2008). Accordingly, we hypothesize:

> **Hypothesis 5:** Temporal dispersion moderates the relationship between team cognition and team performance such that team cognition is more strongly related to performance when temporal dispersion is high rather than when it is low.

The third factor affecting the strength of team boundaries is *geographic dispersion*, which reflects the degree to which members are co-located versus spatially separated (O'Leary & Cummings, 2007). Boundaries of geographically dispersed teams tend to be less well-defined than those in more proximal teams, and as such, members are often more reliant on implicit coordination (Rico et al., 2008). When members are geographically dispersed, they encounter fewer chance interactions that can help align their activities and develop team cohesion and trust, all of which are known predictors of team performance. The performance of dispersed teams is therefore likely to hinge on cognitive foundations, that can ensure their individual work is coordinated and combinable. In teams with less dispersion, performance may remain high even if members lack shared cognitive states because they have other ways to coordinate their work via direct and frequent interactions. It follows then that team cognition would be comparatively more important for the performance of geographically dispersed teams that do not have the ability to interface directly with teammates, and we posit:

> **Hypothesis 6:** Geographic dispersion moderates the relationship between team cognition and team performance such that team cognition is more strongly related to performance when geographic dispersion is high rather than when it is low.

Method

We tested the hypothesized moderating role of team compositional and boundary moderators using meta-analysis. We compiled a meta-analytic database consisting of 107 independent studies (reporting results of 7,778 teams), which reported a bivariate relationship between team cognition and team performance. To construct the database, we first included all of the studies reported in the DeChurch and Mesmer-Magnus (2010) meta-analytic review of the team cognition construct. We then replicated their search strategy to locate the relevant published and unpublished studies conducted since their database was constructed. In particular, we conducted a search of the PsycInfo and ABI Inform databases using relevant keywords (i.e., group OR team AND cognition, mental models, team cognition, transactive memory, schemas, knowledge structure, cognitive structure, cognitive map, conceptual framework, and shared situation awareness). We also manually searched the references cited in studies that were identified as relevant to the constructs of interest. In an effort to ensure we captured relevant studies published in literatures outside those canvassed by these databases, we conducted a thorough search of the Google Scholar database. In an effort to ensure we captured unpublished studies, we searched relevant conference presentations (e.g., Academy of Management, Society for Industrial and Organizational Psychology, INGRoup, Science of Team Science) for the prior 2 years to find relevant studies that had not yet made it to the published domain and emailed the authors for a copy of their manuscript along with any other related manuscripts. To be included in the meta-analytic database, the study must have been published in English, though there were no other geographical or cultural restrictions applied. This search strategy resulted in nearly doubling the original DeChurch and Mesmer-Magnus (2010) database of 65 independent studies. We provide a supplement that includes (1) a list of the studies included in the meta-analytic database, (2) a table summarizing the coding of the compositional and boundary moderators for each study, and (3) additional details regarding study methodology to permit future replication.

Inclusion criteria

Consistent with previous meta-analyses of team cognition, we sought to include all studies of relevant team cognition constructs (e.g., team cognition, shared mental models, transactive memory). In order to be included in the meta-analytic database, studies must have examined team cognition in relation to team performance and reported sufficient information on which to compute a bivariate correlation between these two variables. Only correlations representing relationships at the team-level were included in the meta-analysis.

Coding content and procedure

Once the articles were identified as being relevant to the current meta-analysis, at least two authors coded each article for features that captured the focal moderators: diversity of social categories, diversity of functional characteristics, authority differentiation, temporal stability, external interdependence, temporal dispersion, and geographic dispersion. Due to the subjective nature of the majority of moderator variables examined in this study, coders first established exemplar studies to serve as baselines of "low" and "high" measures of each variable. Coders then engaged in a period of training to ensure consistency ratings for all variables and proceeded to code the entire database. Coder reliability was high ($\kappa = .9$), and instances of initial coder disagreement were resolved through discussion. In the next section, we detail how the moderators were coded. To complement this explanation, Table 1 provides exemplar features of articles in the database illustrating the different aspects and levels of all moderators.

Team composition moderators. Three study features were coded as evidence of ***team composition:*** (1) homogeneity, (2) authority differentiation, and (3) temporal stability. *Homogeneity* was coded as the extent to which teams were homogeneous versus heterogeneous in terms of (a) social categories, and (b) functional characteristics. We coded social category homogeneity when sufficient information was provided to determine the extent to which team composition varied with regard to race, gender, age, or other social category features. Teams with very similar social category characteristics were categorized as homogenous and those with mixed social category characteristics were categorized as heterogeneous. Similarly, we coded diversity of functional characteristics when sufficient information was provided to determine the extent to which members had specialized functional backgrounds. Teams comprised of members with similar functional backgrounds/expertise were coded as homogenous and those with more varied functional backgrounds/expertise were coded as heterogeneous. *Authority differentiation* was coded categorically as either low or high, based on the level of autonomy of focal team members. Teams who were largely self-managing with no clear line of authority were coded as "low" and those with a clear centralized formal leader were coded as "high." Finally, *temporal stability* (i.e., the time frame teams worked together) was coded as (a) hours (less than a day), (b) days (less than a week), (c) weeks (less than a month), (d) months (less than a year), or (e) years (a year or more). There were very few primary studies where this variable be categorized as "days" and so that category was often not possible for subsequent moderator analyses. See Table 1 for coding of exemplar studies exploring team composition factors.

Team boundary coding. We coded three factors affecting team boundary strength: (1) external interdependence, (2) temporal dispersion, and (3) geographic dispersion. *External interdependence*

Table 1. Team compositional and boundary moderators.

	Low	High
Team Composition Factors		
Social Category Homogeneity	**All-male** nuclear power plant control room crews (Waller et al., 2004)	**Mixed-gender** undergraduate radio assembly teams (Prichard & Ashleigh, 2007)
Functional Homogeneity	**Computer science** student teams participating in a team computing challenge (McIntyre & Foti, 2013)	Students assigned to **different functional roles** in a business simulation (Yoo, 2001)
Authority Differentiation	Disaster assistance and rescue teams with diverse and **decentralized command structure** (Burke, 2006)	Anesthesia teams in a **medical** simulation (Burtscher et al., 2011)
Temporal Stability	Students participating in a tank simulation for a **few hours** (Marks et al., 2002)	Air traffic control teams working together for an average of **over 5 years** (Smith-Jentsch et al., 2005)
Team Boundary Factors		
External Interdependence	Combat teams performing **military training simulation exercises** (Lim & Klein, 2006)	Product teams accountable to stakeholders, and had to make **decisions in line with other teams** (Austin, 2003)
Temporal Dispersion	Undergraduate students participating in a battle simulation together all **at the same time** (Minionis, 1995)	Teams participating in a management simulation challenge in which decisions were iterated and agreed upon **over the course of a week** (Santos et al., 2015)
Geographic Dispersion	Combat teams whose members are all performing **in the same place** (Ayoko & Chua, 2014)	Software development teams whose members are **distributed across multiple countries** (Mortensen, 2014)

was coded categorically as either low or high with respect to the degree to which members were interdependent with people or teams external to the focal team. Teams who operated fairly independently were coded as "low" whereas those who were more interdependent with individuals outside the team were coded as "high." *Temporal dispersion* refers to the extent to which members operate on different schedules or across different time zones (O'Leary & Cummings, 2007). This moderator was coded categorically as either low or high, with members who were working mostly synchronously coded as "low" and those working mostly asynchronously coded as "high." Finally, *geographic dispersion* refers to the extent to which team members are geographically separated during task work (O'Leary & Cummings, 2007), and this was coded categorically as (a) co-located, (b) co-located but with virtual communication, or (c) dispersed. See Table 1 for coding of exemplar studies.

Team performance coding. We coded *team performance* as evidence of team goal attainment. Examples include team members' self-report of team performance (Mathieu et al., 2006), supervisor evaluations of team performance (Austin, 2003), dollars earned (Yoo & Kanawattanachai, 2001), and the number of targets eliminated (Mathieu et al., 2000).

Analytic approach

The meta-analytic methods for random effects models as outlined by Schmidt and Hunter

Table 2. Team cognition–team performance relationship: Team composition moderators.

Meta-Analysis	k	N	r	SD_r	ρ	SD_ρ	80%CV	95%CI	%ARTV	FDk
Social Category Homogeneity										
Homogeneous	12	882	.27	.19	.32	.19	.08/.56	.19/.45	31.64	65
Heterogeneous	8	431	.35	.10	.42	.00	.42/.42	.34/.50	100	59
Functional Homogeneity										
Homogeneous	7	301	.32	.36	.36	.21	.10/.63	.17/.56	37.53	43
Heterogeneous	19	1166	.25	.29	.29	.18	.06/.52	.18/.39	35.83	86
Authority Differentiation										
Low	74	4961	.29	.17	.35	.16	.15/.55	.30/.39	41.00	438
High	13	664	.24	.19	.28	.16	.07/.49	.16/.40	46.85	57
Temporal Stability										
Hours	30	1786	.27	.17	.31	.14	.13/.49	.25/.38	48.89	172
Weeks	9	586	.26	.22	.30	.22	.03/.58	.15/.45	25.70	55
Months	18	1089	.32	.17	.38	.14	.20/.56	.29/.47	48.33	112
Years	9	463	.25	.13	.30	.07	.21/.39	.21/.39	78.78	62

Note. k = number of correlations meta-analyzed; N = total number of groups; r = sample size weighted mean observed correlation; SD_r = sample size weighted standard deviation of the observed correlations; ρ = sample size weighted mean observed correlation corrected for unreliability in both measures; SD_ρ = standard deviation of ρ; *80%CV* = 80 percent credibility interval around ρ; *95%CI* = 95% confidence interval around ρ; *%SEV* = percent variance due to sampling error; *%ARTV* = percent variance due to all corrected artifacts; *FDk* = the file drawer analysis calculating the number of missing studies averaging null results needed to reduce the observed ρ to .05.

(2014) were used to analyze this data. A random effects model was chosen as it permits effect sizes to vary as a function of random error as well as by study design details and other relevant moderators. Further, the Schmidt and Hunter (2014) methods of meta-analysis advocates that a random-effects model is more consistent with real-world data. Effects reported in the primary articles were corrected for sampling error and measure reliability in both cognition and performance. Because reliability information was not consistently reported across all studies, corrections to unreliability were made using artifact distribution meta-analysis as articulated by Schmidt and Hunter. When authors reported separate correlations for independent samples, those correlations were examined separately. When authors reported multiple estimates of the same relationship from the same sample, an average correlation was computed for all global meta-analyses of those relationships to maintain independence (Hunter & Schmidt, 2004). Meta-analyses were conducted using Schmidt and Le's (2014) software for the Hunter-Schmidt Meta-Analysis Methods. The weight of primary effect sizes was a function of the study sample size, thus decreasing the potential outliers might affect the conclusions.

Results

We first replicated the results of the DeChurch and Mesmer-Magnus (2010) meta-analysis using an expanded database of 107 independent studies. Results from 7,778 teams indicate an overall rho (ρ) for the team cognition-team performance relationship of .35 with a standard deviation around rho (SDρ) of .15. The overall rho estimate reported in 2010 was .38 (SDρ = .16; k = 60, N = 3,512 teams). The 80% credibility interval of .16/.54 surrounding rho reinforces that the cognition-performance relationship is generalizable across teams, as 90% of the effects fall above a correlation of .16 (since 10% of those effects are above the upper end of the interval).

The relationships between team cognition and team performance by the focal moderators—team compositional and team boundary factors—are summarized in Tables 2 and 3,

Table 3. Team cognition–team performance relationship: Team boundary moderators.

Meta-Analysis	*k*	*N*	*r*	SD_r	ρ	SD_ρ	*80%CV*	*95%CI*	*%ARTV*	*FDk*
External Interdependence										
Low	66	4600	.27	.19	.32	.17	.10/.54	.27/.38	36.78	346
High	17	861	.34	.13	.41	.05	.35/.47	.33/.49	91.27	115
Temporal Dispersion										
Low	70	4350	.30	.18	.36	.16	.15/.57	.31/.41	42.80	434
High	6	315	.18	.18	.22	.14	.04/.40	.05/.39	55.82	20
Geographic Dispersion										
Co-located	62	3918	.30	.18	.35	.17	.14/.57	.30/.41	40.34	372
Co-located but Virtual	10	672	.20	.19	.23	.18	.01/.46	.09/.38	36.00	32
Dispersed	3	136	.23	.13	.27	.00	.27/.27	.09/.46	100	13

Note. k = number of correlations meta-analyzed; N = total number of groups; r = sample size weighted mean observed correlation; SD_r = sample size weighted standard deviation of the observed correlations; ρ = sample size weighted mean observed correlation corrected for unreliability in both measures; SD_ρ = standard deviation of ρ; *80%CV* = 80 percent credibility interval around ρ; *95%CI* = 95% confidence interval around ρ; *%SEV* = percent variance due to sampling error; *%ARTV* = percent variance due to all corrected artifacts; *FDk* = the file drawer analysis calculating the number of missing studies averaging null results needed to reduce the observed ρ to .05.

respectively. We report the number of effect sizes meta-analyzed (*k*), number of teams (*N*), the sample size weighted mean observed correlation (*r*), the standard deviation of *r* (*SDr*), the sample size mean observed correlation corrected for unreliability in the predictor and criterion (ρ), the standard deviation of rho ($SD\rho$), the 80% credibility value around rho (*80%CV*), the 95% confidence interval around rho (*95%CI*), and the percent variance due to corrected artifacts (*%ARTV*). Credibility intervals can be used to judge the significance of mean rho. The credibility interval reflects our confidence in the "true" distribution of effect sizes within the primary literature. When the credibility interval does not include zero, we have confidence that the relationship is different from zero across sample types. When the credibility interval includes zero or is fairly wide, there is reason to believe there may be a moderator present.

Per the meta-analytic guidelines proffered by Hunter and Schmidt (2004), confidence intervals are used to examine whether two effects are meaningfully different from one another (i.e., if a moderator exists). In particular, rhos may be interpreted as being meaningfully different from one another when one rho is not included in the confidence interval of the comparison rho (Bobko & Roth, 2008; Kisamore, 2008; Kisamore & Brannick, 2008). Confidence intervals report our confidence in the estimate of mean rho for each level of a moderator. To assess the extent to which the moderator may explain variability in the main effect, we compare the confidence intervals for each level of the moderator. Although a rigorous interpretation of the presence of a moderator would require the confidence intervals to not overlap at all, this interpretation is likely to result in false negatives, as typically only the strongest moderators will produce such a difference. Therefore, we follow the rule of thumb within the extant literature, comparing the rho of each moderator level to the confidence interval of comparison rho. When the rho is not included within the comparison group's confidence interval, then it can be said to be sufficiently different from comparison rho (Bobko & Roth, 2008; Kisamore, 2008; Kisamore & Brannick, 2008).

Lastly, in an effort to address potential publication bias, we report a file-drawer analysis (Rosenthal, 1979) wherein we report the number of unpublished studies averaging null results that would be required to reduce the observed effect to .05. As can be seen in Tables 2 and 3, dozens if not hundreds of missing studies would be required to substantially alter our conclusions for most of the moderators considered in this meta-analysis.

Team composition

Hypotheses 1–3 posited the moderating effects of team composition factors on the cognition-performance relationship, and these results are presented in Table 2. Hypothesis 1 postulated that team homogeneity would weaken the relationship between team cognition and team performance such that the team cognition-performance relationship would be stronger for heterogeneous than homogenous teams. Examining Table 2 shows H1 was supported for social category homogeneity, but not for functional homogeneity. Social category homogeneity is a significant moderator of the cognition-performance relationship such that the effect of team cognition on team performance is .42 ($k = 8$) for heterogeneous teams as compared to .32 ($k = 12$) for homogeneous teams. Moderation is supported since the rho for homogeneous social categories falls outside the corresponding confidence interval for heterogeneous social categories (.34/.50) and are in the hypothesized direction.

On the other hand, the rho for functionally homogeneous teams ($\rho = .36$, $k = 7$) is included in the confidence interval for functionally heterogeneous teams (.18/.39), and the rho for functionally heterogeneous teams ($\rho = .29$, $k = 19$) is also included in the confidence interval for functionally homogeneous teams (.17/.56). This overlap suggests that functional homogeneity is not a significant moderator of the team cognition-performance relationship. Thus, Hypothesis 1 was supported with social category but not functional homogeneity. We note that the direction of the functional homogeneity effect is opposite that of social category diversity (and opposite H1): Cognition is somewhat more strongly related to performance in functionally homogeneous teams as compared to functionally heterogeneous teams.

Hypothesis 2 posited authority differentiation would moderate the relationship between team cognition and team performance such that team cognition would be more strongly related to performance when authority differentiation was low rather than when it was high. H2 was supported. Meta-analytic estimates show the relationship between team cognition and performance is strongest for teams with low authority differentiation ($\rho = .35$, $k = 74$) as compared to those high in authority differentiation ($\rho = .28$, $k = 13$), and the rho for high authority differentiation falls outside the confidence interval associated with low authority differentiation (.30/.39).

Hypothesis 3 posited temporal stability would moderate the relationship between team cognition and team performance, such that team cognition would be more strongly related to performance when temporal stability is low rather than when it is high. H3 was not supported. Examining Table 2 shows the relationship between team cognition and performance was not significantly different for teams with different levels of temporal stability. In contrast to H3, our results suggest the cognition-performance relationship is fairly consistent for teams working together for hours, weeks, months, or years.

Team boundary factors

Turning to the moderating effect of team boundary factors, Hypothesis 4 posited external interdependence would moderate the relationship between team cognition and team performance such that cognition would be more strongly related to performance when external interdependence was high, as compared to when it was low. H4 was supported. As reported in Table 3, the relationship between team cognition and team performance is stronger for teams high on external interdependence ($\rho = .41$, $k = 17$) as compared to teams low on external interdependence ($\rho = .32$, $k = 66$). The rho for low external interdependence falls outside the confidence interval for high external interdependence (.33/.49) and the rho for high external interdependence falls outside the confidence interval for low external interdependence (.27/.38).

Lastly, we hypothesized that temporal (H5) and geographic (H6) dispersion would moderate the team cognition-performance relationship, such that team cognition would be more strongly related to performance when dispersion was high rather than when it was low. H5 and H6 were not supported as the pattern of effects runs counter to these hypotheses. The relationship between team cognition and team performance was *weaker* when teams were more temporally or geographically dispersed than when they were less dispersed. Examining Table 3 shows the rho for high temporal dispersion was not contained within the confidence interval for low temporal dispersion (.31/.41), and the relationship between team cognition and team performance is weaker when teams have more temporal dispersion ($\rho = .22$, $k = 6$) than less ($\rho = .36$, $k = 70$). For geographic dispersion, the relationship between cognition and performance is stronger when teams are co-located ($\rho = .35$, $k = 62$) as compared to when they are either dispersed ($\rho = .27$, $k = 3$) or co-located with virtual communication ($\rho = .23$, $k = 10$). Though opposite H6, this moderator was significant. The rhos for co-located virtual teams and dispersed teams were not contained in the confidence interval for co-located teams (.30/.41).

Supplemental analyses. We conducted a series of supplemental analyses to address the issue of moderator intercorrelation, and also to examine the extent to which the current compositional and boundary moderators account for additional variation in effect sizes after accounting for existing cognition construct moderators: nature of emergence, form of cognition, and content of cognition (DeChurch & Mesmer-Magnus, 2010).

Moderator intercorrelations. As Lipsey (2003) notes, meta-analyses that examine moderating variables are prone to confounded results. In particular, moderating variables are typically related to one another, and thus, results regarding any single moderator variable can be misleading. As such—in line with Lipsey's (2003) logic—the co-occurrence may confound our understanding of the role of isolated moderators in the cognition-performance relationship. For example, it is likely that the focal teams in primary studies that experienced temporal dispersion also experienced geographic dispersion (i.e., it may be more difficult to find samples of teams that operated in high temporal dispersion but not high geographic dispersion, or vice versa; Gibson & Gibbs, 2006; O'Leary & Cummings, 2007). Therefore, these conditions would be highly related to one another within our meta-analytic database (Schmidt & Hunter, 2014).

In order to examine the relatedness/co-occurrence of moderators included in this meta-analysis, we calculated moderator intercorrelation matrices by computing the correlation between each set of moderators as they appeared in the teams that were sampled within the meta-analytic database (e.g., we ran a correlation between the coding of levels of team homogeneity and levels of authority differentiation, between levels of team homogeneity and temporal stability, and so on). The strength of the correlation coefficient indicates the degree to which a given combination of moderators was likely to appear together within the teams examined in the primary studies. Moderator intercorrelations are presented in Table 4. While most of the moderator variables were weakly intercorrelated (e.g., below $r = .20$; Cohen, 1992), there were some that had moderate intercorrelations (e.g., as great as $r = 0.57$), meaning we are unable to isolate the extent to

Table 4. Team cognition–team performance relationship: Intercorrelations among moderating variables.

	1	2	3	4	5	6	7	8	9	10
Cognition Construct Moderators										
1. Nature of Emergence	—	201	201	37	51	171	147	160	161	148
2. Form of Cognition	−.56***	—	201	37	51	171	147	160	161	148
3. Content of Cognition	.56***	−.37***	—	37	51	171	147	160	161	148
Team Compositional Moderators										
4. Social Category Homogeneity	.17	−.07	.03	—	22	36	27	35	35	34
5. Functional Homogeneity	.20	−.42**	.21	.28	—	50	44	50	50	48
6. Authority Differentiation	.03	−.19*	.09	−.12	.16	—	142	159	154	143
7. Temporal Stability	.24**	−.37***	.14	−.20	−.18	−.03	—	132	135	125
Team Boundary Moderators										
8. External Interdependence	.24**	−.23**	.16*	.47**	.21	−.33***	.47***	—	148	138
9. Temporal Dispersion	.06	−.03	.01	.25	.18	−.13	.30***	.17*	—	145
10. Geographic Dispersion	.03	.03	.13	.22	.02	.11	.00	−.15	.57***	—

Note. Numbers below the diagonal represent the correlations among moderating variables and numbers above the diagonal represent the N on which each correlation is based. The *N* for a given correlation is the number of studies which could be coded on both variables.
*$p < .05$. **$p < .01$. ***$p < .001$.

which one or the other moderator affected the team cognition-performance relationship.

The meta-analytic estimates presented in Tables 2 and 3 indicate five factors as being significant moderators of the cognition-performance relationship. However, the degree to which previously supported construct moderators are correlated with compositional and boundary moderators needs to be considered. To the extent that they are correlated, meaning primary studies tended to couple levels of multiple possible moderators, it is important to consider the degree to which each moderator is accounting for distinct variation in effect sizes. Further, we examine the degree of intercorrelation of the previously supported cognition construct moderators (nature of emergence, form of cognition, and content of cognition; DeChurch & Mesmer-Magnus, 2010) with the compositional and boundary moderators supported by the current findings.

Coding supported cognition construct moderators. Based on the meta-analytic review by DeChurch and Mesmer-Magnus (2010), we examined the extent to which cognition constructs may interact with the compositional and boundary moderators we explored herein. Three features were coded as the cognition construct moderators, using the approach outlined by DeChurch and Mesmer-Magnus (2010), though only two of these were supported and thus retained for further analysis. The first supported moderator of the cognition-performance relationship we coded was nature of emergence. *Nature of emergence* refers to how the cognitive elements form (i.e., at the individual or team level; DeChurch & Mesmer-Magnus, 2010). This construct was coded categorically as "congruent" (Cannon-Bowers et al., 1990) or "complimentary" (Kozlowski & Klein, 2000). The second cognition construct moderator was *form of cognition*, which captures how cognition is elicited and represented by team members (DeChurch & Mesmer-Magnus, 2010). We coded this categorically as either "perceptual," where the cognitive elements are derived from the individual beliefs of team members, or "structured," meaning the cognitive elements are derived from the pattern of how the members organize their information (Rentsch et al., 2008). Lastly, we coded *content of cognition*, which describes whether the cognitive elements pertain to the task or team (DeChurch & Mesmer-Magnus, 2010; Mathieu et al., 2000); because this cognition construct moderator was not correlated with the moderators in our study, it was dropped from subsequent analyses.

Results of supplemental analyses. Table 4 reports the intercorrelations among the cognition construct moderators and compositional/boundary moderators of the cognition-performance relationship. Social category homogeneity is weakly correlated with nature of emergence ($r = .17$, *ns*), and not correlated with form of emergence ($r = -.07$, *ns*). Authority differentiation is not correlated with nature of emergence ($r = .03$, *ns*), and weakly correlated with form of emergence ($r = -.19$, $p < .05$). External interdependence is correlated with both the nature of emergence ($r = .24$, $p < .01$) and form of emergence ($r = -.23$, $p < .01$). Temporal dispersion is not correlated with either nature of emergence ($r = .06$, *ns*) or form of emergence ($r = -.03$, *ns*). Similarly, geographic dispersion is not correlated with either nature of emergence ($r = .03$, *ns*) or form of emergence ($r = .03$, *ns*). Given this, we next conducted WLS regressions including the correlated moderators.

Weighted least squares regression. We conducted weighted least squares (WLS) regression to assess the extent to which each of the five supported moderators added unique predictive value in explaining the variation in effect sizes, beyond two established moderators of the cognition-performance relationship (i.e., nature of emergence, form of cognition; DeChurch & Mesmer-Magnus, 2010). Effect sizes were regressed on vectors capturing the moderator variables. In each regression, vectors for the two construct variables and either a compositional or boundary moderator were examined, and effects were weighted by the number of teams included in the estimate. Examining the change in R-squared when the compositional/boundary moderator is added to a base model including only the two supported construct moderators allows us to evaluate the degree to which the new moderator is explaining significant variance in the effect sizes while controlling the two construct moderators. Table 5 reports the models including construct and compositional and boundary moderators.

Examining Table 5 shows neither social category homogeneity (Model 1; $\Delta R^2 = .00$, *ns*) nor authority differentiation (Model 2; $\Delta R^2 = .00$, *ns*) explained additional variance in effect sizes after controlling for nature and form moderators. With social category homogeneity, none of the moderators were significant, which was likely due to the small number of studies ($k = 37$). Regarding authority differentiation, the form of cognition was a significant moderator ($b = -.18$, $p < .05$) and this analysis included a substantially larger sample ($k = 107$), so statistical power was an unlikely explanation for the lack of support for authority differentiation as a moderator.

Two of the three team boundary moderators explained significant additional variation in effect sizes after accounting for the nature of emergence and form of cognition moderators: temporal dispersion (Model 4; $\Delta R^2 = .07$, $p < .001$) and geographic dispersion (Model 5; $\Delta R^2 = .05$, $p < .01$). Although external interdependence did not meet the standards of statistical significance, the results were in the predicted direction (Model 3; $\Delta R^2 = .02$, $p < .10$). Together, these results support the boundary moderators as explaining unique variance in effect sizes beyond that explained by the nature of emergence or form of cognition.

Importantly, we note that the findings for the team composition moderators of social category homogeneity and authority differentiation need to be interpreted cautiously, in light of regression results. For social category homogeneity, the small sample size makes this analysis inconclusive. Social category homogeneity is not significantly correlated with the cognition construct

Table 5. Weighted least squares regression: Comparison of cognition construct moderators and team compositional and boundary moderators.

	Model 1 Social Category	**Model 2** Authority Differentiation	**Model 3** External Interdependence	**Model 4** Temporal Dispersion	**Model 5** Geographic Dispersion	**Model 6** Interaction
Step 1: Construct Moderators						
Nature of Emergence	.20	.17†	.13	.17†	.15	—
Form of Cognition	.19	−.18*	−.22*	−.16†	−.17†	—
R-squared	.04	.10**	.10**	.09**	.08**	
Step 2: Construct & Compositional and Boundary Moderators						
Nature of Emergence	.21	.17†	.11	.22*	.19*	—
Form of Cognition	.19	−.18*	−.21*	−.15†	−.15	.27**
Social Category Homogeneity	.20					
Authority Differentiation		.01				.05
External Interdependence			.15†			
Temporal Dispersion				−.27**		
Geographic Dispersion					−.23**	
Δ*R*-squared	.00	.00	.02†	.07**	.05**	.08**
Step 3: Construct & Compositional and Boundary Moderators & Interaction						
Form of Cognition						.19**
Authority Differentiation						.11
Authority × Form of Cognition						−.15†
Δ*R*-squared						.02†
k	37	107	160	161	148	107

Note. All coefficients are standardized. Weights computed using team level sample sizes of primary studies from which each effect estimate was obtained. Authority × Form of Cognition is a multiplicative interaction term.
†$p < .10$. *$p < .05$. **$p < .01$.

Table 6. Team cognition–team performance relationship: Moderated by authority differentiation and form of cognition.

Meta-Analysis	*k*	*N*	*r*	SD_r	ρ	SD_ρ	*80%CV*	*95%CI*	*%ARTV*
Authority Differentiation									
Perceptual Cognition									
Low Authority Differentiation	17	912	.42	.17	.50	.14	.32/.68	.41/.60	49.10
High Authority Differentiation	40	3164	.30	.16	.35	.14	.29/.40	.17/.52	43.76
Structured Cognition									
Low Authority Differentiation	13	636	.20	.19	.22	.13	.05/.39	.11/.33	56.93
High Authority Differentiation	19	1130	.22	.16	.26	.12	.17/.34	.11/.40	61.91

Note. k = number of correlations meta-analyzed; N = total number of groups; r = sample size weighted mean observed correlation; SD_r = sample size weighted standard deviation of the observed correlations; ρ = sample size weighted mean observed correlation corrected for unreliability in both measures; SD_ρ = standard deviation of ρ; *80%CV* = 80 percent credibility interval around ρ; *95%CI* = 95% confidence interval around ρ; *%SEV* = percent variance due to sampling error; *%ARTV* = percent variance due to all corrected artifacts.

moderators, but with only 37 effect sizes, none are supported by the WLS analysis. With authority differentiation, there is a significant correlation with the form of cognition moderator. Given the appreciably larger subset of studies available, we conducted an additional set of regressions to test for an interaction (see Model 6 in Table 5). Since authority differentiation was correlated with form of cognition but not with nature of emergence, a hierarchical WLS regression was used to test for an interaction. The interaction term between authority differentiation and form of cognition was significant (Model 6; b = .08, $p < .01$, using a Bonferroni correction for multiple comparisons). To examine this interaction, we conducted an additional subgroup analysis crossing authority differentiation with form of cognition, which is presented in Table 6.

Table 6 shows the pattern of the interaction between authority differentiation and form of cognition. The moderating effect of authority differentiation holds for perceptual cognition, but not for structured cognition. For perceptual cognition, the relationship between team cognition and team performance is stronger for low authority differentiation teams ($\rho = .50, k = 17$) than for high authority differentiation teams ($\rho = .35$, $k = 40$). With structured cognition, authority differentiation is not a moderator. The team cognition-performance relationship does not differ for teams with low ($\rho = .22$, $k = 13$) or high ($\rho = .26$, $k = 19$) levels of authority differentiation.

Research setting as a moderator. Last, we explored the effect of research setting. We conducted subgroup analyses according to the methods outlined by Schmidt and Hunter (2014) and examined the extent to which the nature of the moderated relationships changed as a function of team setting (whether the research was conducted in a lab versus field setting). We did not find evidence of an interaction between the research setting and the team composition/boundary moderators examined here.[1]

Discussion

Substantial research evidence supports the positive relationship between team cognition and team performance (DeChurch & Mesmer-Magnus, 2010; Mathieu et al., 2000; Mesmer-Magnus et al., 2017; Mohammed et al., 2010; Stout et al., 1999). These findings have fueled many interventions aimed at developing and maintaining cognition in a variety of team types and settings (e.g., boardrooms, hospitals, the military, and space exploration, to name a few).

This study furthers that evidence. Team cognition indeed lays the groundwork for effective team performance. At the same time, the current findings extend knowledge to highlight the role of team composition and boundary factors as conditions. This work makes two contributions to research on team cognition. The first is to answer the question of *when*: When is team cognition most strongly related to team performance? The second contribution is to answer the question of *why*: Why is team cognition sometimes more or less strongly related to team performance?

Contribution #1: When is team cognition most related to team performance? The global estimate suggests that team cognition is never negatively associated with performance (i.e., the effect estimate is positive with a credibility interval that excludes zero), though this is not to say that the relationship is always strong. In fact, one contribution of this paper is to identify conditions where the cognition-performance relationship is quite strong versus where it may be more modest. To summarize, the current results support the conclusion that team cognition is most strongly related to the performance for teams: (1) whose members are heterogenous on social categories, (2) who lack formal lines of authority, (3) who are highly reliant on people outside the team, and (4) whose members work at the same time and in the same place as their teammates. Identifying these conditions advances theory on team cognition and serves as a useful guide for those developing interventions to support teams of one kind or another. We now consider the implications of each moderator.

Regarding team compositional factors, we found team social category heterogeneity and leadership (authority differentiation) moderate the cognition-performance relationship. Both factors create uncertainty (Hogg, 2000), and require team cognition in order for team members to gain the advantages of varied backgrounds or shared leadership. In the case of social category heterogeneity, having members with different backgrounds and experiences stands to benefit teams in terms of idea generation, evaluation, and creativity/innovation (Hülsheger et al., 2009). But, as noted in the categorization-elaboration model of team diversity, differences trigger social categorization processes that may negatively affect group information processing (van Knippenberg & van Ginkel, 2010). The current findings are consistent with this model, indicating that team cognition is more strongly related to team performance for teams whose members represent different social categories. Given the restricted information processing triggered by social category differences, having team cognitive structures to support information processing offsets this potential drawback to diversity.

The uncertainty created by a team compositional attribute also explains the authority differentiation moderator. Whereas low authority differentiation, or decentralized leadership, is positively related to team performance (D'Innocenzo et al., 2016), it can also create uncertainty as members informally negotiate their leader-follower relationships (DeRue & Ashford, 2010) and resolve differing ideas and perspectives in the absence of a clear authority structure. The uncertainty created by decentralized leadership offers a possible explanation for the finding that team cognition is more strongly related to performance when authority differentiation is low rather than when it is high. Because primary studies do not typically measure and report correlations of this uncertainty mechanism, we do not test it, but offer it as a potential explanation for these findings and a profitable direction for future research. We note the authority differentiation moderator is strongly supported for perceptual cognition, but not for structured cognition. Perceptual cognition refers to shared or compatible beliefs, attitudes, values, perceptions, or expectations among team members, whereas structured cognition captures how members' beliefs are causally or otherwise related. Team cognition is most strongly related to team performance for teams with decentralized authority structures and when the measured form of cognition is perceptual. For decentralized/self-managing teams, the more members perceive they are cognitively aligned, the more strongly they perform. Indeed, our results suggest as much as 25% of the performance of decentralized teams is a function of the perceived sharedness of their cognition, which suggests interventions aimed at developing perceptual forms of cognition may be particularly beneficial for decentralized/self-managing teams. Though temporal stability was not supported as a moderator, it would seem to operate in the same manner as the other forms of team composition, as a property of the team that reduces uncertainty since team members can rely on established and familiar relationships (Shah & Jehn, 1993). We consider the implications of this non-finding in the discussion of the study's second contribution.

It is important to note that, just as we have proposed and tested these elements of team composition as moderators of the cognition-performance relationship, they are also subject to complex interplay with other variables. For example, research on team diversity and social categorization has found that national diversity had a curvilinear relationship with information use (Dahlin et al., 2005). Additionally, other work has found evidence that task routineness and group longevity moderate the relationship between functional diversity and team conflict (Pelled et al., 1999). Therefore, although we find evidence for social category homogeneity and authority differentiation as moderators of the team cognition-performance relationship, we acknowledge the complexity of the moderating variables studied in this meta-analysis. This interplay may explain the non-significant findings that resulted from the WLS analysis, which tested the role of these moderators in light of the cognition construct moderators offered by DeChurch and Mesmer-Magnus (2010). As such, future research is needed to tease apart the independent roles played by social category diversity and authority differentiation in relation to cognition construct moderators.

Finally, the non-findings with respect to functional homogeneity and temporal stability are nonetheless informative, in that we can conclude that the effect of team cognition on performance is similar for teams who are homogeneous and heterogeneous, as well as for teams with different levels of stability. It may be that functional homogeneity does not trigger the same uncertainty as does social category homogeneity, and the same may be true with temporal stability. In effect, functional homogeneity may create "predictable" uncertainty (e.g., "I may not know how to work with these people yet on this task, but I know the stages of team formation and can adjust accordingly"). Social categories and decentralized leadership may trigger "unpredictable" uncertainty as there isn't an enduring script for how to collaborate across social category differences or absent a hierarchy.

Furthermore, examining the boundary attributes provides insight into other moderators. Team cognition was more strongly related to team performance when external interdependence was high. Team external interdependence is becoming increasingly important to explore as organizations reorganize into teams (Mathieu et al., 2017) and teams of teams (Davison et al., 2012; Luciano et al., 2018; Shuffler & Carter, 2018). It is likely that repeated interaction with external entities makes teamwork more challenging, and requires predictable interactions *within* the team boundary in order to (1) effectively transfer that information outside the team boundary to the larger system and (2) adapt team processes to efficiently respond to demands external to the team boundary. Thus, teams who are nested in and interdependent with larger systems may rely more heavily on intra-team cognition during task performance than teams whose tasks and outcomes do not rely on people outside the team.

The final two moderators (temporal and geographic dispersion) also relate to team boundaries. We found team cognition was more strongly related to performance in less dispersed teams. This was unexpected. Based on implicit coordination theory (Rico et al., 2008), we expected the opposite: The more virtual the team, the more pivotal team cognition would be to the team's performance. It is important to note that even in virtual teams, the cognition-performance relationship was always positive. That said, the effect size was greater for teams whose members were less dispersed than for teams whose members were more dispersed. We consider the implications of this finding in detail in relation to the second contribution.

Contribution #2: Why is team cognition sometimes more and less strongly related to team performance? In hypothesizing moderators, we focused on conditions where there were other enabling conditions for performance besides team cognition. In particular, we focused on two sets of factors—one based on the composition of the team, and the other on boundary features of the team—and the logic of substitute enabling conditions provides a common interpretive thread for our findings. Teams with homogeneous members may perform effectively based on the many bases for their similarity in backgrounds before they came together as a team. Teams with clear formal leaders know to "follow the leader" and can rely on this leadership schema to regulate their processes and performance. Teams who are tightly bound, whose work does not rely on externals, have strong boundaries that support coordination and reinforce norms. We explored temporal stability along these same lines, but this was not a significant moderator.

With temporal and geographic dispersion, we found significant moderators, but the pattern was opposite our hypotheses. We originally posited that teams whose members work at the same time and place have other enabling conditions to support performance (i.e., a strong team boundary). Accordingly, we expected their performance hinges less on cognitive states than does that of teams whose members are dispersed and do not have as strong a boundary to support their performance. However, we found the opposite. Team cognition was more strongly related to performance for teams whose members worked in the same time and/or place. With geographic dispersion, we found team cognition is more important to team cognition when the team is face to face and not relying on virtual tools, than when it relies on virtual tools (whether collocated or not). In considering the explanation for this finding that is opposite our hypotheses, we wonder whether the core logic of substitute enabling conditions may in fact hold, but that our theorizing incorrectly viewed co-location as the needed support for the team. A possible explanation is that the use of the virtual technologies is in fact the support mechanism, and not, as we originally thought, the co-presence afforded by working face-to-face. Hence, we offer two possible explanations for the findings with temporal and geographic dispersion, that run counter to Hypotheses 5 and 6.

The first possibility is that the logic of substitute enabling conditions may in fact hold, but that we hypothesized the wrong direction by focusing on boundedness as the enabler. It could be that virtual teams have these enablers not by virtue of their boundaries but from their reliance on technology to work together while apart. We theorized that for more virtual teams, the team boundary would be weakened, potentially undermining performance and enhancing the importance of cognition. Instead, it may be the case that the structure of these teams provides an alternative enabling condition: technology. Dispersion requires team members to use technologies to coordinate (e.g., knowledge databases and other technology; Martins et al., 2004). Technologies may be digital or not. Hospital teams who work in shifts are temporally but not geographically dispersed. They use technologies like patient records and white boards to document their thinking and enable smooth handoffs with team members who will resume the work later on. Geographically dispersed teams often use digital technologies, relying on technologies like Slack, Basecamp, Microsoft Teams, or email to document their thinking, send files, or otherwise interact with teammates. In this way, technologies may provide structural support for these teams, making team cognition less critical to performance as they have technology affordances serving as an alternative enabling structure. Research on technology affordances has suggested that dispersed teams use digital technologies to enact and reinforce social practices that enable performance. For example, the digital traces left in many chat logs and other forms of electronic communication provide a useful way to associate people to ideas (i.e., association affordance; Leonardi & Treem, 2012), or to directly build on one another's ideas using shared documents (i.e., editability affordance; Leonardi & Treem, 2012). The current findings are consistent with this logic.

There is also another plausible explanation for this finding. Perhaps the teams who are not dispersed do work that differs fundamentally from the teams who work remotely, and that team cognition is more strongly associated with the performance of this type of work. Many teams who are not dispersed include action teams, such as those doing urgent tasks in the military, aviation, or medicine. It may be that the same factors that force these teams to work together at the same time and place, also necessitate team cognition more so than teams who do work that allows them to be either geographically or temporally distributed from one another.

All things considered, the five team conditions we find as moderators are all consistent with the core logic of alternative enabling conditions: social category homogeneity, authority differentiation, external interdependence, geographic dispersion, and temporal dispersion. Taken together, these findings suggest the reason why team cognition is sometimes more and less strongly related to team performance is because of the presence or absence of substitute support mechanisms in the team. Team composition, leadership, structure, and technology reflect conditions that shape how strongly related team cognitive states are to team performance. In light of the findings with boundary attributes, it seems more useful to consider the specific enabling support when considering potential moderators.

Future research directions. The current work suggests three directions for future research. The first applies generally to work on team cognition, as well as other team processes and states. Given the importance of substitute enabling conditions for team performance, it will be useful for future research on teams to holistically consider compositional, leadership, structural, and technological factors as they interpret and generalize findings. Globalization and technological sophistication are introducing variance in such factors within what were previously comparatively more "static" or predictable workplace dynamics. It is important to understand the complex interplay of team cognition within these dynamics so team performance can be supported.

The second direction for future research is in the area of technology. Elements of virtual collaboration played an important moderating role in the cognition-performance relationship, even when controlling for previous moderators. As noted earlier, the findings for virtuality run counter to what we predicted. The cognition-performance relationship was weaker as team dispersion increased. It may be the case that virtual teams rely on aspects of cognition not well captured by current constructs or measures. Future research should begin to explore the aspects of cognition that are most pivotal in virtual teams. Some of the constructs found to be important in virtual teams include shared context (Hinds & Mortensen, 2005), boundary objects (Iorio & Taylor, 2014), and scaffolding and offloading (Wiese et al., 2011), among others. Exploring cognitive foundations that enable teams to collaborate remotely represents a particularly exciting area for future research, given the prevalence of these teams and the interest in designing social media technologies to connect them. Indeed, the availability of collaborative technologies has grown and there are platforms for everything from project management (ProofHub) and communication (Troop Messenger), to design (Viewflux) and documentation (Google Docs), to file sharing (Dropbox) and organization (Evernote; Kashyap, 2019). Future research is needed to explore the ways in which these tools can be designed to enable teams to develop and maintain team mental models and transactive memory.

The third area for future research is to explore compositional and/or boundary-specific interventions for improving team cognition. Research has shown the benefits of interventions to promoting team cognition, including cross-training (Cooke et al., 2000; Marks et al., 2001), group training (Liang et al., 1995; Moreland & Myaskovsky, 2000), planning (Fiore & Salas, 2004; Stout et al., 1999), debriefs (Smith-Jentsch et al., 2008), reflexivity training (Gurtner et al., 2007), and leadership briefings (Marks et al., 2002; Smith-Jentsch et al., 2008). Depending on compositional and boundary factors, different interventions may be more or less valuable in developing team cognition and improving team performance (Schulze et al., 2017). For example, the finding that team cognition is most strongly related to team performance under conditions of external interdependence suggests interventions are especially critical for these types of teams. Also related to interventions, more work is needed providing causal evidence for factors that shape team cognition. There is far more research on consequences than on antecedents. Given the consequences of team cognition established in this and in previous meta-analyses, a shift in focus toward antecedents would be useful in designing interventions to support teams.

Limitations

Though the current findings contribute to the literature on team cognition, there are a number of important limitations that need to be considered. The first limitation, as with any meta-analysis, is that the quality of inferences that can be drawn is inherently constrained by the content and quality of the primary studies included in the meta-analytic database. For example, the content and quality of our coding of team composition and boundary moderators is contingent upon the detail provided by the primary authors. Another example relates to the limited availability of primary studies examining some of the effects. According to Schmidt and Hunter (2014), such meta-analyses are prone to second-order sampling error. In this meta-analysis, there are a few instances where low *k* may be of particular concern when interpreting results. For example, there were dozens of studies that examined the correlation between cognition and performance in conditions of low temporal dispersion, but very few examined this relationship under conditions of high temporal dispersion. Thus, while the relationship between cognition and performance in scenarios of low temporal dispersion is unlikely to change dramatically with the addition of a few studies, the same level of stability may not be seen with the inclusion of additional studies conducted under conditions of high temporal dispersion. A similar issue is relevant to the results on geographic dispersion. Thus, we caution readers to cautiously interpret the results of low-*k* meta-analyses. To identify meta-analyzed relationships most in jeopardy of changing significantly with the introduction of new data, we conducted Rosenthal's (1979) file-drawer analysis. The file-drawer analysis estimates the number of missing studies (e.g., those that may be in someone's metaphorical file-drawer because they weren't published due likely to nonsignificant findings) averaging null results that would be needed to reduce the reported rho to a non-significant level; we used .05. As reported in Tables 2 and 3, for the majority of analyses, dozens if not hundreds of studies averaging null results would be needed to reduce the reported rho to a less meaningful level. Those analyses with smaller file-drawer *k* estimates are prime examples where future research would be most beneficial to assessing the stability of the reported effects.

A second limitation relates to the nature of causality between team cognition and team performance. An open question is the degree to which cognition improves performance, or alternatively, whether teams who perform well in turn develop better team cognition. A proportion of the included studies were cross-sectional in nature, limiting the ability to draw causal conclusions. Many of the focal studies did employ either experimental or longitudinal research, suggesting we may have some degree of confidence in the conclusions regarding the directionality of the team cognition-performance relationship, though future research is needed to confirm causal directionality and/or reciprocity.

A third limitation concerns the social category homogeneity moderator. This analysis was based on a relatively small subsample of studies, and so there was insufficient statistical power needed for WLS regression. At the same time, the social category moderator was not significantly correlated with the cognition construct moderators. All things considered, the finding with social category homogeneity should be interpreted with caution based on the number of studies representing each level of the social category moderator (12 and 8).

Fourth, although we considered moderators that spanned conceptual domains of the team compositional and boundary conditions, the co-occurrence of moderators included in our meta-analytic database did not allow us to completely tease apart moderating effects. As can be seen in Table 4, there are several instances where the presence of our focal moderators co-occurred in the primary studies. While most of the correlations suggest low co-occurrence, there were three that stand out as high. Two involve external interdependence, with social category homogeneity (these categories correlate .47) and with temporal stability (these categories correlate .47). The association between external interdependence and social category homogeneity affects these conclusions since we cannot rule out that one moderator or the other is accounting for this effect. The WLS regressions lend some support to external interdependence as the stronger moderator, as its effects are in addition to the moderating effects of construct moderators found in prior meta-analyses. The third is temporal and geographic dispersion (these categories correlate .57). The association between temporal and geographic dispersion suggests these two aspects of dispersion cannot be cleanly separated (i.e., teams with one type of dispersion often had the other). Together, they depict the extent of virtuality in a team and collectively have a significant moderating effect on the cognition-performance relationship that is independent of the previous construct moderators.

Conclusion

One of the most pivotal factors in team success is largely invisible—the pattern of cognitive processes represented in the minds of team members about each other and their work. There is a strong cognitive foundation to teamwork, though the relationship is even stronger for some teams than for others. This meta-analysis advances team effectiveness theory by following up questions of “what is important?” with the question of “when and why is it most important?” The key takeaway being that team cognition is most strongly related to performance when, either by virtue of composition, leadership, structure, or technology, there are few substitute enabling conditions to otherwise promote team performance. It is under these conditions that team cognition matters most.

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Supplemental material

Supplemental material for this article is available online.

Note

1. Tables reporting these results are available from the first author upon request.

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