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Mining for Solutions: How Expertise Distribution and Influence Structures Impact Team Improvisation

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by
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ABSTRACT OF THE DISSERTATION

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Organizations increasingly must operate in unpredictable, dynamic, and complex situations, and scholars in a wide variety of fields argue that flexibility and adaptation in these changing environments represent important capabilities for high performing groups. In response, teams in these challenging environments often require improvisation to help them react, plan, and execute in a short time frame. Despite widespread acknowledgement in the literature that preparation is essential for teams to be able to productively improvise, few have attempted to define what antecedents would promote and enable it. I develop and test a model of how team structure can influence improvisation. Deriving improvisational behaviors from the experiential learning process, I examine how teams modify these knowledge creation behaviors to perform in situations where planning and execution time are inhibited. I then explore how the distribution of expertise and influence shape the development of these improvisational behaviors and the subsequent ability to respond when the need for improvisation arises. I propose that by structuring teams with a moderate overlap of expertise distributed across team members and variable influence that allow teams to rotate decision-making to members with the most relevant expertise, teams can best perform the improvisational behaviors necessary to successfully respond to unanticipated problems or opportunities. I test this theory in a field study using mine rescue team competitions that finds mixed support for these propositions.

INTRODUCTION

Organizations increasingly must operate in unpredictable, dynamic, and complex situations, and scholars in a wide variety of fields argue that flexibility and adaptation in these changing environments represent important capabilities for high performing groups (Kozlowski, Gully, Nason, & Smith, 1999). Situations where fast learning and adaptation are required, which were previously considered atypical or occasional organizational conditions, are becoming more prevalent in today's complex and dynamic environments (Hutt, Reingen, & Ronchetto, 1988; Stacey, 1996). Responding effectively in these conditions can be crucial for survival; therefore, it is becoming increasingly important that teams are situated and designed to respond quickly and effectively, despite their inability to predict when such a situation may arise (Kao, 1996; Drucker, 1998). When faced with unpredictable conditions and time constraints, traditional patterns of planning and implementation may be ineffective or impossible to do (Chelariu, Johnston, & Young, 2002) Because teams are unable to simulate, anticipate, or prepare for every error or contingency in advance, teams in these challenging environments often use improvisation to help them react and execute in a short timeframe (Sundstrom, DeMeuse, & Futrell, 1990; Ishak & Ballard, 2012).

In attempting to understand how organizations can respond to and even exploit opportunities in these uncertain and unpredictable circumstances, scholars have investigated the role of improvisation both theoretically (e.g. Crossan, Cunha, Vera, & Cunha, 2005; Miner, Bassof, & Moorman, 2001; Weick, Sutcliffe, & Obstfeld, 1999) and empirically (e.g. Baker, Miner, & Esley, 2003; Vera & Crossan, 2005). In organizations, improvisation has emerged as "the deliberate and substantive fusion of the design and execution of a novel production" (Miner, et al., 2001: 314): a set of activities that generate novelty and require participants – without elaborate prior planning – to simultaneously create and enact new ideas, products, or routines. Improvisation can be evoked by emergent crises and unexpected opportunities (Fisher & Amabile, 2009). The critical element is often that teams use the process to balance the tensions between producing a unique creation while considering how to do it efficiently in an unplanned situation.

With a robust understanding of what defines improvisation in organizations, recent research has shifted focus to determine what factors increase the likelihood that improvisation will result in a successful outcome. Because of the idiosyncratic and unpredictable need for improvisation in organizations, research most prominently focused on identifying moderators that enhance the general capabilities of teams that help them produce positive outcomes. Factors identified as potential moderators span multiple levels of analysis, including organizational (e.g. information access, Akgun & Lynn, 2002; organizational memory, Moorman & Miner, 1998b), team (e.g. teamwork behaviors, Vera & Crossan, 2005; goals, Cunha, Cunha, & Kamoche, 1999), and individual factors (e.g. training, Crossan & Sorrenti, 1997) also may shape the effects of improvisation on outcomes.

However, this path obscures conclusions about the behaviors that teams undertake in any particular instance of improvisation. Because it is difficult to observe in advance the process of improvisation and to compare how different actions or trajectories may alter the results, prior empirical conclusions have been limited to the general, aggregate recollections of the team. Therefore, little is known about the actual behaviors that underlie successful or ineffective attempts. In addition, little has been done to disentangle the decision to improvise with the efficacy of the actual process. As a result, the process may seem to be ambiguously related to performance, when in fact teams are generalizing their outcomes or misapplying the process in unwarranted situations. This suggests that the direct effect of improvising on team performance, which has been previously viewed as equivocal (e.g. Vera & Crossan, 2005; Fisher & Amabile, 2009) is still unresolved.

Finally, despite widespread acknowledgement in the literature that preparation is essential for teams to be able to productively improvise, few have attempted to define what antecedents would promote and enable it. Work in high reliability organizations suggests that the highest performing teams anticipate abnormal situations by preparing for such situations in advance and structuring their team and activities to handle events when they occur (Waller, Gupta, & Giambatista, 2004). However, the research has primarily focused on approaches that emphasize command and control, rather than how to improve the adaptability and creativity required to respond in these improvised scenarios (Webb & Chevreau, 2006). Without a systematic understanding of the act of improvisation in organizations, there have been limited attempts to identify how factors like team structure can promote the development of improvisational behaviors and their utilization when time sensitive events occur. By closing these gaps in understanding how teams specifically develop and deploy improvisational behaviors, organizations will be better positioned to respond effectively when the opportunity for improvisation arises.

In order to address these gaps, I examine the underlying team improvisation process in more depth, comparing the design and behaviors of multiple teams as they improvise in response to the same stimuli in a crisis situation. I use surveys and recordings of actual mine rescue teams responding to simulated mine emergencies in order to determine what team characteristics facilitate successful improvisational behaviors. Mine rescue teams provide a unique setting in which to study this phenomena and have distinctive features that allow a new way to study both the act of improvisation and how teams prepare. These established teams train to develop their ability to respond in crisis; however, their preparation – particularly for behaviors during the process – is wholly determined by the individual team and their trainer. This provides variation among the teams in how they enact the underlying knowledge necessary to respond in these uncertain scenarios. In addition, mine rescue teams participate in competitions in order to obtain required government certification for emergency response. Mine rescue competitions include a field exercise that mirrors an unexpected, emergency event, where teams develop a solution that meets operational goals without prior knowledge of the intervening issues. The arrangement provides a unique opportunity to compare improvised responses to the same stimuli across multiple teams; further, the competition and certification format ensures that the teams take the consequences of their responses seriously despite being simulations of events.

In order to derive expectations for how these teams succeed, I draw from prior explorations of improvisation and learning. Despite the detailed exploration of what defines improvisation, studies have neglected to explicate the actual process by which teams improvise (Leone-Ludovica, 2010). However, the learning literature, with a mature and robust stream of research in knowledge creation as a process, has a well-developed understanding of the activities necessary to generate and enact new ideas. Based on prior definitions, improvisation can be considered a special case of a learning process where experience informs the simultaneous generation and execution of an unplanned *and* novel product (Miner et al., 2001). Thus, the experiential learning process provides a general framework for how teams collectively reflect on and react to experiences that require the creation of new knowledge and behaviors (Kolb, 1984; Argote, 1999). Because of the constraints that arise in situations that require improvisation, teams are unable to perform the traditional behaviors – e.g. systematic experimentation, reflection, and codification – in ways that would produce optimal outcomes (Edmondson, 1999; Gibson, 2001). Deriving behaviors from traditional learning processes (e.g. Edmondson, 1999; Savelsbergh, van der Heijden, & Poell, 2009; Gibson & Vermeleun, 2003), I examine how teams modify these knowledge creation behaviors to perform effectively in situations where planning and execution are inhibited and test them by unobtrusively recording the interactions of the mine rescue team members during their competition.

Based on a more detailed view of the improvisation process, I then identify what team structures enable these behaviors during the mine rescue competitions. Structure is one of the most important influences on both processes and outcomes in teams (Hackman, 1987; Campion, Medsker, & Higgs, 1993; Cohen & Ledford, 1994). Structure has been defined as the function and status of positions (Thompson, 1967), a system of constraints that define appropriate behavior (Buck, 1966), and the internal differentiation and patterning of relationships (Thompson, 1967). When evaluating team characteristics, scholars typically consider team structure as manifested in three core dimensions: specialization, hierarchy, and formalization (Bunderson & Boumgarden, 2010). Specialization is the horizontal division of labor (e.g., tasks and roles), hierarchy is the vertical division of labor (e.g., leaders and subordinates), and formalization is the explicit articulation of objectives, priorities, and procedures (Bresman & Zellmer-Bruhn, 2013).

Recent work highlights the importance of both knowledge and interaction structures for effective knowledge creation and improvisation **(e.g.** Ben-Menahem, von Krogh, Erden, & Schneider, 2016; Bunderson & Boumgarden, 2010); the structure of the team plays a prominent role in determining how well a team is prepared for improvisation when the need arises (McEntire, 2007). These works suggests that team structure is not only a central element of general team functioning and processes, but also has specific importance in encouraging learning and the processes that promote it (Bunderson & Boumgarden, 2010). Team structure creates stable team characteristics that help teams enact the behaviors necessary to improvise effectively during these unexpected events. Based on the importance of the different dimensions uncovered by these prior investigations, I examine the structure as distinct underlying features that vary in their effect on improvisation. Drawing on studies of teams in similar situations, I argue that teams with moderate overlap between members in domain-specific expertise, who have a strong understanding of what expertise each member has, and with interactions that allow for situationally-varying influence and decision-making, should be best positioned to perform improvisational behaviors productively and efficiently.

In the following sections, I provide a detailed derivation of improvisation behaviors based on research in improvisation and learning. Then, to develop a model of how structure enables improvisation, I review of the role of preparation in uncertain and unpredictable circumstances. I then test these ideas by collecting field data from mine rescue teams as they participate in competitions that require improvised solutions. Finally, I discuss the implications of my findings and how the outcomes suggest more targeted future studies.

THEORY AND HYPOTHESES

Improvisation Defined

Initial attempts to understand improvisation in organizations focused on understanding how improvisation in artistic fields like jazz or theater productions parallel management activities in organizational environments (e.g. Barrett, 1998; Crossan, 1998; Weick, 1998). However, even though these pieces attached managerial significance to many of the theatrical features, the idea of improvisation in organizations required more systematic attention to understand how and when it occurred. Anecdotally, improvisation seemed well-aligned to describe how organizations could cope with unplanned events, drawing parallels between the features of these short-lived performances and organizational concerns such as managing the costly tension between planning, developing rehearsed, efficient routines, and generating spontaneous responses (Weick, 1998). In order to move improvisation from an artistic metaphor to a utilizable concept, scholars called for more precise identification of what improvisation meant to organizations, not just as a parallel to jazz musicians and theater performers, but rather how the concept operated and coexisted in more traditional organizational settings (Cunha et al., 1999; Cornelissen, 2006). As a result, the next wave of organizational improvisational studies sought to validate the notion that "improvisation is more than a metaphor" (Crossan, 1998: 593), attempting to define a formal theoretical framework, initially through the construction of grounded theories (Miner et al., 2001) and subsequently through the identification and empirical testing of some of the consequences of improvisation (Moorman & Miner, 1998b; Vera & Crossan, 2005). The expansive search for contexts and reliance on inductive methods led theoretical consensus in the management literature on what can be considered improvisation, despite variation in domain-specific conceptualizations.

Based on this consensus, I also consider improvisation as the "deliberate and substantive fusion of the design and execution of a novel production" (Miner, et al., 2001, pg. 312). For actions to be considered improvisation, they must undertake a novel production, consist of simultaneous generation and execution of this outcome, and occur extemporaneously and intentionally (Moorman & Miner, 1998a). This definition acknowledges the inherent constraints within which teams operate in response to critical events. Teams are unable to plan their response prior to engaging in the process; they must deal with the situation as it unfolds and adjust as their actions consequently change the situation. Because improvisation occurs without foreknowledge of the outcome, and with restrictions that the execution must substantively converge with the design of the product, creation during improvisation must occur without a formal plan. Further, improvisation involves some degree of innovation, because it goes beyond automatically repeating a pre-existing routine (Crossan & Sorrenti, 1997; Weick, 1998). For example, in crisis situations this excludes scenarios where contingency plans and backup response routines may be directly applied as teams respond. Some improvisational actions may represent only modest shifts from prior behavior, whereas others may involve radical innovative activity (Weick, 1993). Teams must operate and execute without the opportunity to set and refine a specific course of action prior to engaging the process. As a result, improvisation is the process of producing a novel solution out of activities that necessarily depart from preexisting plans or routines.

Following this theoretical and inductive approach to defining improvisation, efforts shifted to expand the different managerial contexts in which improvisation plays a vital role, identifying specific instances of improvisation in empirical contexts (e.g. the Mann Gulch wildfire - Weick, 1993; the failure of a ship's navigational system - Hutchins, 1990; or the

Apollo 13 - Rerup, 2001 - and Columbia - Starbuck and Farjoun, 2005 space shuttle crises). This examination highlighted that improvisation particularly helps teams perform in crisis situations – those in which teams must maneuver in changing and hazardous working conditions characterized by situational unpredictability and high pressure, often dangerous, situations (Kendra & Wachtendorf, 2003; Weick, Sutcliffe, & Obstfeld, 1999). For example, in an examination of the Mann Gulch fire disaster, Weick (1993) notes that skills in improvisation can serve as a response mechanism for when routines break down. Improvisation allows the responders to invent a substitute or replacement routine in the moment, which can help "forestall the paralysis" that keeps them from acting effectively in these time critical situations (Weick, 1993, pg. 640).

Adaptive responses, like improvisation, allow teams to react to the environment in non-routine events (Waller et al., 2004; Waller, 1999). In fact, improvisation is considered central to the ability of these teams to perform. In a review of action teams, Ishak and Ballard (2012) highlight that these critical teams are unique in that they frequently work in life-and-death environments, and the timing of their actions is generally unplanned. Their ability to improvise is a critical dimension of their effectiveness. For instance, Bigley and Roberts (2001) show that improvisation is a key tool in the incident response of firefighter teams; this allows them alter their routines depending on the task requirements of the situation. Improvising allows teams to go beyond formal procedures and contingency plans to allow for flexible construction of solutions and routines in volatile and dynamic environments. The system allows these critical action teams to improvise by applying novel tactics to unexpected problems and implement more spontaneous and situationally-specific task activities.

Improvisation as a Learning Process

Despite this agreement on the existence and meaning of improvisation in organizations, and specifically crisis situations, there has been little research that ties these definitions to the underlying actions teams must take in order to successfully improvise. Team improvisation is a creative and spontaneous process; by defining it as a process, the focus is on how teams respond, not the outcome (Drazin, Glynn, & Kazanjian, 1999; Vera & Crossan, 2005). Other examinations of knowledge creation activities, like learning, have long recognized that the underlying processes that occur should be considered in addition to the outcome (Edmondson, Dillon, & Roloff, 2007; Argote, 1999). Experiential learning is "the process whereby knowledge is created through the transformation of experience. Knowledge results from the combination of grasping and transforming experience" (Kolb, 1984: 41). These observations are integrated into a shared understanding from which future actions can be deduced and utilized as guides in new situations (Kolb, 1984). Learning is conceptualized as a four-step process made up of experiencing, collecting information on experiences, reflecting on what has happened, and acting in response to the experience. New knowledge or actions are achieved through engagement of a concrete experience, reflective observation of that experience, abstract conceptualization of the insights, and experimentation which contributes to the subsequent creation of new experiences (Kolb, 1984; Kolb & Kolb, 2005).

In this light, improvisation, as a process, can be considered a type of learning (Miner et al., 2001; Vashdi, Bamberger, & Erez, 2013). Improvisation can be conceptualized at the group level as a collection of interaction activities through which individuals react in real-time to new experiences, focusing on the process and leaving the outcomes to be considered separately (Edmondson, 1999, pg. 353; Argote, Gruenfeld, Naquin, & Turner, 2001). In fact, prior definitional accounts acknowledge that improvisation may be classified as a special case of learning distinguished by the inability to enact prior plans or routines, the limited availability to gather external information or feedback, and the short-term or ephemeral intention of the solution (Miner et al., 2001).

There is a wealth of known actions by which teams generate new knowledge, categorizing learning as an action or process, rather than an outcome (see Edmondson et al., 2007 for a review). In previous studies, scholars have established various team learning behaviors that all appeared to refer to an ongoing process of collective reflection and action whereby knowledge was created through the transformation of experience (Argyris & Schön, 1978; Edmondson, 1999; Gibson & Vermeulen, 2003; Kasl, Marsick, & Dechant, 1997; Van der Vegt & Bunderson, 2005). Savelsbergh and colleagues (2009) draw from this rich literature to create a comprehensive framework that distinguishes among these various learning behaviors to shed more light on their separate effects on performance outcomes (Edmondson, Bohmer, & Pisano, 2001; Gibson & Vermeulen, 2003; Kasl et al., 1997). They categorize their comprehensive set of behaviors using Edmondson's (1999) framework where team learning is an ongoing process of collective reflection and action characterized by exploring, reflecting, discussing errors and unexpected outcomes of actions, seeking feedback, and experimentation within and as a team.

Savelsbergh and colleagues (2009) suggest that from this comprehensive set of behaviors, authors can focus on specific relevant behaviors to come up with more specific conceptualizations for their studies of learning in different contexts. This framework serves as the basis of my derivation of improvisational behaviors. Crisis situations limit the specific behaviors that these teams can take when they improvise. In translating this model to improvisation, I group the behaviors as identification, reflection, and experimentation which allow for expedient internal search and simultaneous implementation (See Table 1).

Identification behaviors are those which help the team create understanding among team members about the environment, resources, and objectives of the situation; these activities help position teams to create shared frameworks and boundaries within which to generate new responses (Bigley & Roberts, 2001; Bechky & Okhuysen, 2011; Harrison & Rouse, 2014). Identification behaviors enable the team to consider their internal response to the unplanned event. These behaviors specifically encompass conversations and actions that allow the team to assess the situation, modify or refine their existing understanding of the environment, and build consensus about the state of the team's resources or position. Researchers have provided descriptions of groups working under dynamic, time-pressured situations and suggested that teams' identification activities impact the likelihood of their recognizing and responding to unexpected events (Weick & Roberts, 1993).

For example, Bigley and Roberts (2001) show that the inclusion of mechanisms like creating understanding among team members about the incident, resources, and objectives of an emergency helped to coordinate fire responders in improvising reliable approaches. Similarly, Bechky and Okhuysen (2011) find that SWAT teams that initially draft agreement and develop immediate understanding of the situational demands are more likely to set a common, shared work flow for the members. Initial agreement creates boundaries that guide the generation of responses that help to achieve a cohesive final response (Harrison & Rouse, 2014).

Reflection behaviors are those which allow the team to conceptualize the situation and create a shared meaning in which to build a solution. Reflection behaviors encompass those conversations and actions that allow the team to explore only knowledge held within the team, refine and build on the meaning of the situation and its impact on their production, and to collectively discuss how the current actions and experiences align with the direction of response (Savelsbergh et al., 2009; Gibson & Veremeulen, 2003). These reflective activities encourage the team to continually develop their conceptualization of the situation and to promote collective interpretation, which facilitates idea generation and coordination of execution (Weick & Roberts, 1993; Bechky & Okhuysen, 2011; Hargadon & Bechky, 2006). By highlighting and creating consensus on instigating problems, the team spurs deliberate and mindful consideration of the issue, encouraging teams not to automatically use pre-existing or established ideas, products, and routines to respond (Weick & Sutcliffe, 2006; Crossan, 1998; Barrett, 1998). Further, these activities contribute to the reinforcement of boundaries and expectations in the team, helping to control the process as well as the final results (Harrison & Rouse, 2014). For example, Waller (1999) showed that airline flight crews that engaged in more information collection and sharing behavior exhibit higher levels of performance in responding to non-routine events in a flight simulator.

Identification and reflection behaviors, although related, represent distinct conceptual categories in improvisation. Identification behaviors, most notably, have an external focus on scanning the environment, identifying changes, and modifying team understanding jointly. In contrast, reflection behaviors are more internally focused, situating internally-held knowledge, conceptualizing how that knowledge may be used to plan a response in the moment, and then conceptualizing a response based on the shared understanding. There is overlap in some of the underlying actions that comprise identification or reflection in improvising teams. For example, conversational actions such as information sharing play a role in both updating the situation (identification) and exploring different perspectives (reflection); similarly, knowledge integration is necessary to update the situational schema using identification behaviors and the task expectations that builds upon the original goals in reflection (Savelsbergh et al., 2009). It is the intent and outcome of how the team uses that knowledge that distinguishes their effect on identification or reflection. Further, these sets of behaviors are linked in that changes to the situation, and thus identification of these modifications, may necessarily impact what knowledge and perspectives are relevant and necessary. Therefore, an update to the situation may necessarily coincide with additional reflection, even if they are theoretically distinct.

Experimentation behaviors are those which allow the team to generate and implement ideas, as simultaneously as materially possible; during experimentation, teams may also try to predict the results of their outcomes in order to ensure that their solutions fit within their conceptualized response (Fisher & Amabile, 2009). Although in improvisation, response generation and execution must happen in close proximity, teams may still exhibit these activities as a multi-stage process (Moorman & Miner, 1998a). However, in improvisation, contrary to typical experimentation in learning, successful teams are less likely to systematically perform iterations due to constraints. Instead, teams are more likely to participate in continual evaluation, which promotes continuous idea generation and increases the chances of identifying and retaining only productive ideas (Harvey & Kou, 2013).

Improvisation behaviors in practice – Illustration of behaviors in Apollo 13

To illuminate how behaviors underlie the improvisation process, consider a prominent example of organizational improvisation: the Apollo 13 mission to the moon. The Apollo 13 mission has been previously used in research as a model example of improvisation in a crisis situation (e.g. Rerup, 2001; King, 1996; Crossan, 1998) perpetually linked with improvisation because of the declaration by lead flight director for Mission Control, Gene Kranz, in which he ordered the crew to "Forget the flight plan. From this moment on we are improvising a new mission. How do we get our men home?" (Lovell & Kluger, 2006, pg. 174). This unplanned course of action required numerous instances of improvisation as changing circumstances created new, unforeseen issues that required immediate solutions in order to guarantee the astronauts' return.

Although there were multiple occasions that required improvisation over the course of the three days following the unexpected explosion that damaged an oxygen tank until their re-entry, I focus on the improvisation required as an engineering team worked to find a solution as they recognized an impending buildup of carbon dioxide in the lunar excursion module (LEM). During this time, engineers in mission control famously used materials such as plastic bags, cardboard, and duct tape to create a solution that would alleviate the problem (Rerup, 2001).

The astronauts had been transferred to the LEM in prior attempts to mitigate issues; however, the LEM was intended to hold only two crew members temporarily, instead of the three returning to Earth. The mission control was initially focused on correcting the re-entry trajectory; however, because of prior experience with life support systems, engineer Ed Smylie recognized that the carbon dioxide was going to be a problem:

> About one o'clock on the 14th, 1 AM on the 14th, we had realized that we had to do something about CO2. My first baseline solution, and I think the one that Mission Control was carrying, was to continue to operate the command module suit loop thing, had the hoses extended into the lunar module to absorb CO2. I don't really recall whether we decided the CO2 was a problem or we just looked at expendables in general at that point, but that's what we did probably from the time I got there around 10:30 until I went back to the division around 1 AM, and began to look at the problem in detail (Lovell & Kluger, 2006, pg. 251).

He was able to identify this change in the situation through mutual conversations with team members that helped them to both build information about the current conditions, as well as update their shared understanding of their resources. These key identification behaviors ensured that the mission control crew reprioritized their goals and actions, allowing this subgroup of engineers to drive an immediate solution.

Similar to reflection and conceptualization in the experiential learning process, this concrete knowledge allowed the team to use reflection behaviors to construct meaning in the moment; after making sense of the experience the engineers were able to conceptualize the actual problem to create a frame for how to form a response (Kolb, 2014). The team spent the next few hours not only updating their knowledge about the situation, but also reconciling that with their understanding of the systems and potential outcomes, finally arriving at the consensus that it was not simply that they needed to remove carbon dioxide, but specifically they needed to engineer a solution that allowed them to use the existing materials in a new way (Lovell & Kluger, 2006, pg. 253).

These reflection behaviors allowed the team to collaboratively construct the meaning and goals of their activities by refining and modifying their original intent given their shared understanding. In improvising, this focused conceptualization on the fly allowed the team to direct their responses (i.e. idea generation and implementation plans) to a bounded or specific framework helping them to efficiently produce effective solutions. They then aligned the appropriate experts with the situation – LEM specialists, life support system specialists, and engineers like Smylie who had worked on prior Apollo missions – and empowered them to drive the solution, As they gathered the core team, they were able to explore different perspectives and uncover what knowledge was held within the team in order to generate potential solutions and identify what work processes they needed to use.

However, as they engaged the problem and generated potential solutions, the team uncovered additional concerns and limitations. For example, Smylie (1999) remembers,

> Our first thought was to use the liquid-cooled garment and the tape, liquid-cooled garment bag, plastic bag and the tape, to tape the command module canister on the suit outlet hose in the LM, just blow the air through. That was what we were working towards…Somebody, I'm not sure who, suggested that it would be better to put it on the suit inlet hose because you get warmer air and moister air, which makes the chemical work better. That was a better solution, they said that would suck the bag down against the canister and block the flow, and that's when we came up with the EVA cue card from the flight plan to form an arch. So that's what we began to work toward. (para. 55).

These updates in their situation helped them refine, build, and modify their ideas as well as uncover new information and knowledge held by the team, including experiences and practices garnered from prior Apollo missions.

The crew ultimately engineered a solution that allowed the astronauts to use the available materials on board the LEM. When the engineers were able to identify with the situation, they were able to then find a way to use their prior experience to get inside the situation, control it, and make sense of it. The solution to the carbon dioxide problem was an extension and blend of the knowledge the team members already had. In order to solve the problem, the team exploited existing bits and pieces of knowledge and explored new combinations of their knowledge (Rerup, 2001). Within 24 hours of identifying the issue, they were implementing the solution on board the LEM, which aligns with improvisation as material convergence of generation and implementation (Miner et al., 2001).

Finally, because improvisation is not a discrete cycle of activities in practice, solutions generated by the team affected the on-going situation, creating new boundaries and constraints to be addressed in any future productions. As a result of the scrubbing solution deployed, the team introduced issues with runoff water in the command module which required additional identification behaviors and reflection in order to conceptualize these changes in solutions for their final re-entry (Apollo 13 PAO Mission Commentary Transcript, pg. 496).

Improvisation Behaviors and Performance

Although suggestive that increased success in improvisation will help teams be effective in these crisis situations, the direct relationship with improvisation has been equivocal across contexts. The more granular view of the behaviors of teams – derived from the learning behaviors – helps to clarify when improvisation will be done well or poorly; this allows for determinations of whether an instance of improvisation will be a success. The improvisational behaviors categorized by identification, reflection, and experimentation allow teams to simultaneously generate and implement ideas with the expediency and diligence necessary to respond to experiences. These behaviors impact the team's ability to quickly uncover information, create a shared understanding, avoid rework, and implement solutions quickly. These behaviors have been associated with team performance and effectiveness in situations that intersect with the different requirements of improvisation. Separate examinations demonstrate the performance benefits of reflective communication for generating novel solutions (e.g. Gibson & Vermeulen, 2003) and exploring different perspectives (e.g. West, 2000; Schippers, Den Hartog, Koopman, & Wienk, 2003); identification for creating shared understanding (e.g. Uitdewilligen, Waller, & Pitariu, 2013) and updating team members on situational changes (e.g. Moreland & McMinn, 2010); experimentation for generating solutions and evaluating options for simultaneous implementation (e.g. Harvey & Kou, 2013); and preventing mistakes in the future (e.g. Schippers, Den Hartog, & Koopman, 2007).

These behaviors all individually help teams to successfully manage the constraints occurring during improvisation, but taken together, they complement one another to help the teams tackle the different stages of the improvisational learning cycle. Because the stages are fluid and co-occurring, these behaviors are designed to reinforce each other when performed at the same time. Prior research has similarly suggested that, taken collectively, team learning behaviors relate to performance (Bunderson & Sutcliffe, 2002; Argote et al., 2001; Schippers et al., 2003; van der Vegt & Bunderson, 2005; Edmondson, 2002). In improvisation, the stages are more fluid than traditional learning patterns (Fisher & Amabile, 2009); the rhythms of improvisation require that teams continuously update their understanding of the situation and respond, making it almost impossible to fix the order of the processes as they are occurring. For instance, in the Apollo 13 mission, team members are continually updating the situation, reframing goals given these changes, reflecting upon available knowledge and resources, and producing solutions given these resources. Even as members generate potential ideas, they shift between phases of experimentation and reflection in order to continually update their understanding of the situation and create a mutual conceptualization of their intended outcomes and pathways to that outcome. Therefore, identification, reflection, and experimentation behaviors are frequently interwoven during the improvisation process, and the order and instances of these behaviors are completely dependent on the unpredictable and changing context in which the teams operate.

As a result, although the behaviors conceptually correspond with different categories, when hypothesizing the impact of preparation on improvisation I consider the categories in aggregate to constitute an indicator of improvisational behaviors. These behaviors are constitutive, and enhancing the quality of any one of these can impact the overall quality of improvisation. Positive increases in any one of these categories will positively increase improvisational output even if the antecedents or influencers do not impact each dimension equally. In addition, the behaviors are not mutually exclusive such that actions that underlie one dimension may also support another, making disentanglement difficult. In practice, these behaviors are fluid and continuous, and they may occur in simultaneity such that the different categories will then influence the others. Because of the fluidity and iterative nature of improvisation, at any point a team may adjust their focus as they strive to create a novel solution. Finally, empirical studies have shown overwhelmingly that behaviors in traditional learning cycles are highly correlated and reflect a higher order construct of learning behaviors (e.g. Gibson & Vermeulen, 2003; Edmondson, 1999). Because there is little theoretical rationale to support different relationships for the separate dimensions, in the next section I examine the relationship between preparation and improvisational behaviors as a whole. Thus, I consider that together these behaviors constitute improvisation.

Despite the inherent uncertainty of successful outcomes in improvisation, teams that engage in improvisational behaviors are able to understand the environment, coordinate their actions, and simultaneously produce effective outcomes with efficiency and greater consistency. Therefore, I extend this reasoning that by enacting improvisational behaviors during situations that require improvisation, teams should similarly enhance their performance.

Hypothesis 1: *Improvisational behavior in teams is positively related to team performance.*

Preparation and Improvisation

With a better understanding of the underlying behaviors and actions taken during improvisation, I move to how teams can best prepare to perform them when the need arises. Research in both the traditional improvisation (e.g. Fisher & Amabile, 2009; Barrett, 1998) and crisis management literatures (e.g. McEntire, 2007; Webb & Chevreau, 2006) suggest that preparing to improvise represents an important function of these teams. To improvise, teams must simultaneously identify new challenges and generate responses with little or no time to prepare or activate relevant information. In fact, the process of improvising is one single step: a response is generated and executed as the task is presented. Therefore, preparation must happen previously, outside of the frame of action. Because improvisation is not a last-ditch effort, but a deliberate process, preparation plays a vital role in the ways teams build their repertoire and skills for use in the moment. However, preparation in improvisation is not simply the creation of stock response rules and routines, but rather the development of inventory that provides teams with both the knowledge and flexible routines to create deliberate and necessary variation (Cunha, Rego, & Kamoche, 2009). In its theatrical roots, researchers note that successful improvisation embodies both the design and practice prior to performance, not just the final composition. For example, Barrett (1998) highlights that jazz musicians prepare to be spontaneous by learning the musical theory and then building a stable of patterns and tunes that can be flexibly called upon and adjusted to the performance.

As noted, preparation is also essential for effective critical action teams, who must have the capability to recombine actions already in their repertoire into novel combinations (Weick et al., 1999). This situational recombination is one way in which teams address specific events, with the opportunity to also create new actions as an additional course (Callahan, 1986); when resources are limited, circumstances are changing rapidly and communication may be difficult, preparedness and improvisation serve as the foundations of crisis response (Drabek & McEntire, 2002; McEntire, 2007; Webb & Chevreau, 2006). However, there remains a gap in understanding preparedness for these teams which must simultaneously balance explicit, centralized protocols with the ability to create more emergent and diffuse accommodations to address the unforeseen tasks (Bigley & Roberts, 2001; Hadida, Tarvainen, & Rose, 2015).

The predominant perspective on preparation in the improvisation literature suggests that emergency situations force teams to reframe existing protocols in ways that take advantage of the knowledge and experience of the teams that emerge as a result of the unfolding situations (Drabek & McEntire, 2002). In this way, the evolving knowledge resources and coordination patterns allow for the flexible behaviors necessary to deviate from the strict, rigid planned response and foster effectiveness through learning and innovation (Lanzara, 1983; Britton, 1989; Neal & Phillips, 1995). For example, Wachtendorf and Kendra (2005) find in the disaster response to hurricane Katrina that the Coast Guard altered preexisting patterns of interaction and usage of resources in their search and rescue missions as different groups joined in the early stages of the response. This finding highlights the necessity for flexible routines that help teams build interaction practices as the situation unfolds, emphasizing the need for a dynamic understanding of emergent, adaptive coordination in teams (Okhuysen & Bechky, 2009).

However, another perspective on preparation in these circumstances suggests that teams must also build a certain amount of stability and order to allow members to engage in the iterative cycles of action and reflection needed to generate knowledge, solutions, and understanding of the dynamic situation (Vashdi et al., 2013; O'Leary, Wooley, & Mortensen, 2011). Recent work on the way that teams generate novel products when the outcome is uncertain suggests that teams must balance formal knowledge structures and informal coordination structures during these situations. For instance, Ben-Menahem and colleagues (2016) observe that these functions are mutually constitutive in pharmaceutical drug discovery teams, which enables teams to quickly coordinate specialized knowledge in uncertain and complex landscapes. They assert that "as task uncertainty increases and interdependencies among specialists become less predictable, structural designs with higher capacities for information processing based on more extensive interaction become more appropriate" (Ben-Menahem, von Krogh, Erden, & Schneider, 2016, pg. 1316).

While there have been examinations of the importance of structure for managing improvisation, studies do not explicitly tie together the relationship of the formal with the emergent. For instance, Bigley and Roberts (2001) describe the structuring activities – such as role switching or authority migration – that firefighting teams may use to respond in emergency situations, but they only touch on their implications for organizations trying to develop the routines and resources to implement these systems. Similarly, Miner and colleagues (Miner et al., 2001; Moorman & Miner, 1998b) show the benefits of knowledge resources such as organizational memory for enhancing improvisational action, but they do not explain how teams arrange and access that collective knowledge prior to its enactment. Unfortunately, there have been limited attempts to merge the dual perspectives regarding the role of formal knowledge and emergent interaction to understand how teams use stable systems that nonetheless allow them to engage in new behaviors and adapt responses necessary to thrive when improvising. Prior work suggests that the knowledge creation processes of critical teams cannot be explained optimally by static systems of interdependencies (Ben-Menahem et al., 2016). It is from this perspective that I build my model of team structure for improvisation such that formal knowledge structures must be examined in conjunction with dynamic and informal interaction structures to jointly enable the evolution of production to fit with the situation (Bigley & Roberts, 2001; Siggelkow, 2002).

Team Structure as Preparation

Studies focused on learning as a process typically adhere to a standard input-process-output model, illuminating a number of antecedents that help develop learning behavior (Edmondson et al., 2007). These antecedents include contextual factors (e.g. Edmondson, 1999; Zellmer-Bruhn & Gibson, 2006), as well as team-level variables (e.g. composition, Gibson &

Vermeleun, 2003; leader behavior, Nembhard & Edmondson, 2006; identity, van der Vegt & Bunderson, 2005). Recent work by Bunderson and Boumgarden (2010) has extended the critical antecedents to include the structure of the team, finding that the degree to which teams increase their specialization – with a clear leader and formal roles and procedures – creates productive learning in unconstrained organizational situations. By structuring their activities, teams are able to take advantage of the wealth of expertise distributed among members by coordinating behaviors centrally (Bigley & Roberts, 2001).

Thus, it follows that structure may be a critical driver in preparing teams to improvise as they must be able to tap into their existing resources and coordinate uncertain actions in these unpredictable situations. However, for improvisation, the ideal layout cannot simply be considered on a continuum, as an increasing aggregate of all the structural components. Improvising teams have an idiosyncratic need to continuously appraise and adjust in unforeseen events and changing situations. This means that teams must be structured to organize, access, and utilize their already-held resources (Moorman & Miner, 1998b) while coordinating through varying situational factors that any one person may be unequipped to handle (Burtscher et al., 2011). For example, recent work by Sander and colleagues (2015) finds that for unexpected changes in a laboratory game that require novel strategies to respond, team-shared knowledge and standardized communication alone do not predict success. Because of this, they propose knowledge should be arranged more strategically and interaction protocols should be flexible to allow for realignment after an unexpected event. The accuracy of team shared knowledge was helpful in recovering performance after a change, but may potentially only benefit teams when tasks can be done in multiple ways (Resick et al., 2010). Further, the recognition and perception of the knowledge affected the teams distinctly from the actual similarity of the knowledge held between members, despite both aiding in communication and recovery strategies. A shared understanding of the location of expertise allows teams to most effectively identify member expectations and leverage experts in generating new knowledge (Stasser, Stewart, & Wittenbaum, 1995; Gruenfeld et al., 1996).

As a practical effect of the preparation crisis response teams must undertake for unexpected problems, industries typically have a baseline agreement about the knowledge stock that is necessary to adequately respond (Wegner, 1987). Expertise is derived from having the knowledge necessary to respond in these situations. However, expertise is determined not simply from the content of the knowledge – the range or breadth of the skills and resources that members possess – but also from the depth of their knowledge – the extent or degree to which they know about the domain. From a response perspective, simply having a broad range of expertise internally increases the likelihood that teams will have the resources necessary to address the problem in real-time (Jackson, Joshi, & Erhardt, 2003), but teams can also derive distinct benefits by managing the depth of their knowledge across members.

Often, in critical action teams, the depth of different members' expertise is an indicator of the range of expertise held in a team; because industries have commonly-held beliefs about necessary knowledge in order to respond, the variation in expertise occurs because of differences in experience. These teams would not be able to even engage in these situations without a uniform base of skills. For instance, Weick (1993) emphasizes that all the firefighters in the Mann Gulch response were uniformly trained with the basic firefighting skills, but variations in their experiences with specific situations may have impacted the ability to improvise during critical failures. Prior research has indicated in critical teams that variations in depth can impact the mechanisms by which expertise is used to solve problems. Groups that have a better understanding of both who their experts were *and* the extent of their expertise are more effective in attaining goals and performing (Austin, 2003; Lewis & Herndon, 2011). For instance, Klein and colleagues (2006) find that in surgical teams, variations in depth aid both immediate response and training team members for future response. In this case, the differences in depth – reflective of an underlying hierarchy – allow coordinated deferral by senior members to promote team learning.

By architecting this variation in depth, rather than totally unique skills like a multifunctional team, critical teams gain an efficiency in response that allows them to capitalize on their expertise. They can maximize the gains from having a breadth of experts through varying degrees of expertise depth, while ensuring that this underlying core helps the teams use a common framework to effectively process the information from diverse experiences and perspectives (De Dreu, Nijstad, & van Knippenberg, 2008). Having both a breadth and depth of expertise in teams is crucial to improvisational behavior; expertise held within the team allows the team to both recognize quickly when and what problems occur and then mobilize the relevant knowledge and skills to address the problem. Therefore, in considering the underlying knowledge and how it is situated as expertise, I consider simultaneously the breadth and the depth of the knowledge held by team members. As such, in the model, I examine how teams choose to organize their coverage by having experts in uniform domains necessary for mine rescue, capturing the depth of the expertise across a broad set of skills.

Model Overview

Knowledge stock alone does not provide insight into what drives improvisational success. Instead, teams can only realize the benefits of knowledge held in the team if they can use and integrate the expertise of its members (Nonaka & Takeuchi, 1995). To use a team member's expertise effectively, the team must first recognize that expertise as valuable to its task (Stasser et al, 1995; Bunderson, 2003).

Expertise recognition is the correspondence between a team member's capabilities and other members' perceptions of those capabilities (Libby, Trotman, & Zimmer, 1987). The more accurate the perception, the more a team can allocate influence in accordance with true expertise (Bunderson, 2003). Expertise recognition improves improvisation as it facilitates "quick and coordinated access to specialized expertise" (Lewis & Herndon, 2011; p. 1254). During complex, unexpected situations, a team's ability to collect and assemble pieces of information into a conceptualization of the problem is critical in quickly and efficiently formulating a response (Waller et al., 2004).

Although having a good understanding, or high expertise recognition, provides one pathway for teams to effectively reflect and experiment, a parallel consideration is the way that knowledge is held within the team to provide teams with efficient retrieval necessary for reflection and experimentation. Typically, the distribution of expertise is considered as the extent to which team members are specialized in their roles; teams high in specialization have members with differentiated knowledge and skills (Pugh & Hickson, 1976). By uncovering and integrating these differences, teams can produce creative and effective solutions. However, in crisis situations, teams must improvise on the spot, which limits their ability to elaborate and integrate these differing perspectives. This creates a challenge as teams must be situated to contain enough relevant knowledge to address any situation they might encounter, but unlike other teams that operate in highly uncertain situations without real-time pressure to produce a response immediately, they cannot spend excess time uncovering, gathering, or building necessary skills.

To this end, in order to function in crisis situations, improvising teams must consider how the distribution of knowledge within the team not only can be used to provide diverse perspectives, but also how it can be harnessed for improvisation (Crossan et al., 2005). From this, in order to structure the team to most effectively improvise, prior research has highlighted how the ***expertise similarity*** of its members – the extent to which members of the team have expertise or knowledge that is similar or overlapping with other members of the team (Bunderson, 2003) – helps teams to respond in both unexpected or critical situations (e.g. Bechky & Okhuysen, 2011; Thomas-Hunt, Ogden, & Neale, 2003). Shared knowledge is necessary for adaptive team performance in unforeseen situations (Burke et al., 2006; Randall, Resick, & DeChurch, 2011; Rico, Sánchez-Manzanares, Gil, & Gibson, 2008), but teams with high similarity of knowledge may be unable to create essential, innovative structures if the new situation requires alternative strategies (Sander et al., 2015; Uitdewilligen et al., 2010).

During improvisation, the recognition and overlap of expertise is considered as a function of how the team members perceive their own and others' skills. Prior examinations of crisis response and team adaptation allow that these perceptions are mechanisms for mobilizing and using those skills (e.g. Marks, Zaccaro, & Mathieu, 2000). This means that teams operating in real-time during improvisation must make decisions and delegate authority based on their beliefs of what members hold knowledge and how they view their alignment of expertise. Perceptions are often implicit in discussions about expertise and how variations in these perceptions drive performance based on shared mental models (Brandon & Hollingshead, 2004). In the development and utilization of memory, the perceptions drive the behaviors and outcomes associated with the team (Wegner, 1987). These perceptions help to determine both the relevant domains for response, as well as what knowledge and experts should be used to complete the task; however, culture and the situation may modify the actual resource allocation and behaviors (Moreland, Argote, & Krishnan, 1996). As such, the actual interactions, coordination, and behaviors are based on individual and group judgments about the task and necessary resources situated in the environment and team member expectations (Brandon & Hollingshead, 2004). Therefore, both accurate recognition of the knowledge, as well as strategic access and placement of the knowledge, play vital roles in usage during improvisation.

By optimally configuring the knowledge within a team so that there exists some redundancy in what knowledge is held, teams are provided with critical information-processing mechanisms (e.g., unique knowledge sharing and transfer; targeted information processing). These mechanisms facilitate both the real-time creation of a novel solution and the team members' ability to gain insights from each other by increasing their mutual understanding and broadening their attention and exploration to different knowledge, particularly during reflection behaviors (Huang, Hseieh, & He, 2014; Tiwana & McLean, 2005). This moderate overlap allows teams to take advantage of broad perspectives – held internally to the team because they are unable to add to their repertoire after the situation occurs – while mitigating the negatives that arise from housing such diversity.

The necessity of expertise recognition and expertise similarity has been shown to be useful in dealing with unexpected situations, crises, and time pressure. However, in recognizing the utility of these team features, researchers tend to assume that the features simply make it *easier* to use the knowledge that is available. In so doing, they tend to overlook two important components. First, one cannot presume that the presence and recognition of expertise leads to the most productive and coordinated usage of that expertise; simply having the proper knowledge does not guarantee that teams will use it effectively (Lewis & Herndon, 2011). Second, the use of that expertise – the influence and interaction patterns – that would be most beneficial for teams in this specific context of improvisation has not been directly examined. Prior examinations have considered that the influence and interaction that occur when teams are in crisis situations must be flexible (e.g. Stachowski, Kaplan, & Waller, 2009; Waller et al., 2004), but they do not explicitly address how teams must respond when required to use their expertise in novel ways in unexpected, pressured situations. Therefore, the expectation that teams build a base of knowledge is not enough to explain *how* they should optimally unlock it.

Enhancing effects of rotational leadership

In structuring a team for improvisation, it is not enough to simply consider the distribution of resources that members bring to the team, but also the vertical structure that allows teams to take advantage of the resources available. Prior examinations of team structure have focused on the hierarchy of the team, considering most prevalently the extent to which there exists a clear team leader (Bunderson & Boumgarden, 2010). Although most teams have a formal authority structure, the informal hierarchy – which allows non-formally designated members to have influence regardless of assignation – also has an effect on team outcomes (Bunderson, 2003). Hierarchy in teams influences underlying factors that are critical to the success of improvisation. More centralized hierarchies in teams have been shown to be beneficial in coordinating team behaviors (DeChurch & Marks, 2006; Leenders, Van Engelen, & Kratzer, 2003; Hollenbeck et al., 2011). By restricting the opportunity to influence decisions to one or a few individuals, teams are able to streamline their decision-making and improve their coordination which is of benefit in time- sensitive situations. In contrast, in teams with less hierarchy, the opportunity to influence decisions is open to all or most members of the team, which can help teams recognize and broadly utilize expertise in groups, but can also slow the decision-making process (Bunderson, 2003; Shaw, 1964; Edmondson, 2002).

One problem with these conceptualizations is that they tend to assume that hierarchy or the distribution of influence is a static property. In contrast, many accounts of teams that operate in dynamic, uncertain, and unpredictable environments indicate that teams adjust their authority rigidity to meet changing goals during their response processes. The effectiveness of established and static interaction patterns decreases when the task context is unclear or unpredictable (Salas, Rosen, Held & Weissmuller, 2009; Stachowski et al., 2009). Team members must re-adjust their influence and interaction behavior to the new situation to respond (Sander et al., 2015). Various studies in the fields of military operations (Entin & Serfaty, 1999), aviation (e.g. Zala-Mezo et al., 2009), and heath care (Burtscher et al., 2011) have also shown that high-performing teams across contexts are able to dynamically adapt their processes in accordance with changing requirements as the situation unfolds (Schmutz et al., 2015, pg. 764). For example, Klein and colleagues (2006) describe dynamic delegation – a special case where active leadership of a trauma team shifted between team members depending on the nature of the situation that a team faced –as a response that fosters reliable performance and learning in teams.

Not much is known about the role of leadership specifically in the process of improvisation, but knowledge about authority in teams operating in similar environments provide insight into how its structure may influence success. First, it must facilitate the need for teams to coordinate their actions. Coordinated behaviors and centralized decision-making help move teams through their response more efficiently and with increased competence (Bechky & Okhuysen, 2011; Okhuysen & Bechky, 2009). Deference to experts, regardless of their formal place in the decision-making hierarchy, helps coordinate resource mobilization during crises and the rapid implementation of emergency plans (Roberts, Stout, & Halpern, 1994). For example, in investigating the response of teams to crisis (e.g. air craft crews, emergency responders), leadership has been shown to be critical in organizing activities that coordinate and economize emergency responses (e.g. Bigley & Roberts, 2001).

In addition, improvisation requires that the structure allows for flexibility to respond to the relevant issues. In improvisation, teams are unable to plan for the event or response; therefore, there must be enough flexibility in their decision-making structure to allow for relevant experts to bring their knowledge to the forefront when necessary. Because this cannot be determined in advance, the team behaviors must have leeway to instigate change within a team to generate a solution only after the problem is identified (Miner et al., 2001).

This style of alternating leadership, control, and decision making among team members over time has also been investigated as a form of shared leadership or as a power heterarchy structure. This type of shared leadership can influence a team's creativity and efficiency by actively and intentionally shifting the role of leader from one member to another as necessitated by the environment or circumstances in which the group is operating (Aime, Humphrey, DeRue, & Paul, 2014; Pearce, Hoch, Jeppesen, & Wegge, 2010). A power heterarchy is defined as "a relational system in which the relative power among team members shifts over time due to the resources of specific team members becoming more relevant (and the resources of other members becoming less relevant) because of changes in the situation or task" (Aime et al., 2014: 328).

In this study, I refer to this form of dynamic structuring as ***rotational leadership***, but acknowledge that the conceptualization encompasses these other concepts at the team level as well. Rotational leadership allows teams to explore more potential options in generating ideas, while maintaining the hierarchical benefits of having a dedicated leader to coordinate and implement effectively in a short timeframe (Davis & Eisenhardt, 2011). Rotating leadership gives relevant experts the possibility to exercise control over the process, allows the team members the freedom to contribute new ideas and build on those of others, and trains the team in how to implement these rotational patterns effectively under pressure.

Furthermore, the use of this flexible, rotational scheme enhances the effectiveness of the expertise configuration. By deferring to those with relevant expertise, teams establish even more utility in orchestrating their teams strategically. Through the use of rotational leadership, teams can best capitalize on the advantages of their expertise. Rotational leadership defines the process by which knowledge is utilized and the specific patterns of interaction by which team members can productively interact. The expectation is that given a strategically accessible configuration of expertise in the team, and given a good recognition of that layout, rotational leadership can enhance the retrieval and utilization of that knowledge in order to help teams perform the identification, reflection, and experimentation necessary to improvise (see Figure 1 for full model).

Expertise Recognition and Rotational Leadership

Expertise recognition is important throughout all phases of improvisation. Teams that share an understanding of the breadth and depth of other team members' knowledge are more likely to identify changes in their situation and modify their understanding of the goals and limitations this situation creates. Teams that are high in expertise recognition have been shown to quickly come to shared understanding of what the problem is, what the plan is for solving it, and the possible consequences of both the problem and the plan (Orasanu & Salas, 1993). Expertise recognition is also vitally important to the quality of reflection behaviors. As with traditional reflection, improvising teams benefit from uncovering and conceptualizing the knowledge held within their team; however, distinctly, improvising teams must be more targeted about what knowledge to surface and discuss in order to respond in real time. In this respect, greater recognition of what type of expertise team members hold can improve the relevancy and immediacy with which members share and integrate knowledge; this helps move teams through both a reflection on the instigating experience as well as the conceptualization of how the teams should respond.

In addition, recognition facilitates productive experimentation for teams, particularly in coordinating simultaneous implementation. Knowing the area of expertise of other team members allows them to anticipate when and how others will respond and behave in a more coordinated manner conducive to fast, effective execution (Faraj & Sproull, 2000). In this way teams are able to more easily and quickly converge on relevant solutions once the problem has been recognized (Ren & Argote, 2011). In improvisation, there is a need to put boundaries on the extent of generation during experimentation while still giving teams latitude to search for novel solutions or propose multiple potential solutions (Bechky & Hargadon, 2006). Expertise recognition enhances the simultaneity with which teams can undertake these processes by enabling efficient coordination once teams decide to activate these resources (e.g., Lewis, 2003; Liang, Moreland, & Argote, 1995). For example, Baker and Nelson (2005) show that entrepreneurial teams that have access to a library of pre-existing, comparable routines improved their real-time experimentation; recognition prior to the event improves the likelihood that the right knowledge is brought to the forefront effectively used.

The utilization of expertise recognition in improvisation is dependent on the leadership structure in improvising teams. Teams that have a well-formed and shared understanding of what each member can contribute will be able to identify situationally-relevant decision-makers during improvisation, making them well-positioned to take advantage of a dynamic structure (Lewis, 2003). In fact, in many examinations of expertise recognition, the ability to use and rely on different experts effectively is often implied in the definition (Lewis & Herndon, 2011; Lewis, 2003). However, merely recognizing relevant experts does not guarantee that the team is structured to take advantage of their specialized knowledge. Changing leaders helps teams to access the relevant capabilities that are held within the team given situational demands; when these changes are based on good understanding of the held expertise, this enables more effective use of the resources and more efficient and faster coordination (Aime et al., 2014).

In addition, rotational leadership encourages teams to uncover and encode expertise necessary for reflection behaviors and conceptualization of ideas (Maurer & Ebers, 2006). Rotational leadership helps create the understanding of the knowledge and skills held in the team, as well as an understanding of who the situationally-relevant expert would be in a given circumstance (Lewis, 2003). It can also enhance the likelihood that teams will engage in deep systematic processing of their different expertise, which increases the sharing of information and uncovering of novel trajectories (Stasser, 1999; Stewart & Stasser, 1995).

As situational demands change, the team members who perceive they have increased relevance of their resources should engage in more behaviors aimed at claiming or enacting their influence; those who possess less relevant resources should cede leadership to other members (Aime et al., 2014). In this way, the leadership structure helps enhance the reflection and integration behaviors that are established by the knowledge structure of the team. For example, SWAT teams that had a clear understanding of how the knowledge was situated in their team were more likely to use structured, coordinated interactions leading to more adaptive behaviors in uncertain situations (Marques-Quinteiro et al., 2013). When teams have a good understanding of what expertise lies in their group, rotational leadership helps create an efficient structure for how teams should coordinate their expertise.

Alternately, a rotational leadership scheme may impede improvisation in teams that have low expertise recognition. If teams are unsure or in disagreement about who holds situationally-relevant information, they may disrupt their improvisational process in two ways. First, if the team allows different members to influence the solution without having a justified rationale for their control, it risks being driven by a member with insufficient expertise or insight to respond to that situation. This could create solutions that are not effective in the problem space or require the team to do abundant rework after implementation. Second, when teams are low in expertise recognition, but inclined to share leadership, they may take the time within the improvisation to consider who has the appropriate experience and resources to contribute. Although this may be beneficial in encouraging participation in crafting a solution, it may also be detrimental for experimentation behaviors (Hollenbeck et al., 2011). Teams that spend time negotiating their process may be less likely to consider their options or reflect appropriately on the solutions and outcomes because of awareness of time constraints. In these situations, the team may be able to just as easily solve the problem by relying on one member, such as the formal authority structure.

Therefore, the benefits of expertise recognition on improvisational behaviors can be enhanced by rotational leadership when teams have a clear and shared understanding of expertise holders. Teams with high recognition will be able to take advantage of the dynamic leadership scheme to effectively allow experts to have greater influence in the solution at that point in time. However, enacting rotational leadership when expertise layout is not well understood can dampen the team's ability to improvise; without clear influencers the team risks incorrect conceptualization and unproductive idea generation and evaluation. Because of this, I propose that rotational leadership will positively affect the relationship between expertise recognition and improvisational behaviors, such that recognition of expertise is more strongly associated with exhibiting improvisational behaviors when rotational leadership in the team is high.

Hypothesis 2: *Rotational leadership will moderate the relationship between expertise recognition and improvisational behavior in teams.*

Expertise Similarity and Rotational Leadership

Evidence from prior research suggests that teams with both high and low expertise similarity may positively affect improvisation. Teams that are low in expertise similarity are highly differentiated, tending to be made up of specialists whose knowledge sets do not overlap. Alternately, teams with high expertise similarity are those in which there is complete redundancy on the knowledge, skills, and resources that each team member provides. The underlying distribution of expertise in teams provides the groundwork for productive team interactions and behaviors in improvisation. As with expertise recognition, rotational leadership is a key enabler to making the underlying expertise most effective for improvising. However, unlike expertise recognition, rotational leadership does not have uniformly beneficial effects as teams become more similar. Instead, rotational leadership enhances improvisation in those teams that have low and moderate expertise similarity while dampening the improvisation of those teams who have high expertise similarity (see Figure 2 for the proposed interaction between expertise similarity and rotational leadership).[1]

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[1] In crisis response teams, it is often considered costly to ensure that every team member has knowledge of all potentially necessary skills, but necessary that teams are cross-trained on at least the essentials of a breadth of skills (Bechky & Okhuysen, 2011; Majchrzak, Jarvenpaa, & Hollingshead, 2007; Wilson, Burke, Priest, & Salas, 2005). Therefore, it is practical to expect that rotational leadership will enhance the tendencies of crisis teams that rely on specialization to increase their base knowledge available during improvisation, despite the empirical relationship that dampens the effects on expertise similarity overall.

Teams that are dissimilar in expertise, or those with members whose skills and knowledge are highly differentiated or specialized, may benefit in selecting and combining information to produce outcomes that are necessary in these novel and unexpected situations. While teams that are high in similarity reap benefits of integrated mindsets and develop expectations that are particularly helpful for reflection, differentiated teams are more likely to enact behaviors that help them recognize and productively use disparate expertise. To come up with novel ideas, individuals and teams must be able to link and make use of ideas and information from multiple sources in order to broaden the scope of knowledge (Shalley & Zhou, 2008). However, if their expertise or depth of knowledge does not overlap, members may find it difficult to combine information or to evaluate potential outcomes of ideas – both key actions in experimentation during improvisation (Tortoriello, Reagans, & McEvily, 2012). For instance, Haas and Hansen (2005) show that a lack of shared understanding among consulting team members with dissimilar expertise renders explicit knowledge sharing ineffective within the team, as the members are too different to make use of each other's perspectives and insights to generate ideas for sales pitches. Therefore, highly differentiated teams may be forced to convey, integrate, and mobilize knowledge through effortful dialog and interaction (Majchrzak, Jarvenpaa, & Hollingshead, 2007). Existing research suggests that diverse teams take longer and encounter frequent difficulties in integrating their different knowledge stores to reach a consensus and solve problems because of misperceptions, poor mutual understanding, and inhibited information sharing (e.g., Gruenfeld et al., 1996; Jackson et al., 2003). Besides the potential negative effect this has on effective reflection behaviors for improvisation, these teams tend to focus on shared information about their past experiences or knowledge, which does not provide the team with additional knowledge with which to generate novel and useful ideas in uncertain or unknown situations (Huang et al., 2014).

Teams that are similar in expertise, those with members whose level and breadth of skills and knowledge are redundant or overlapping, are able to mitigate some of these drawbacks because they are likely to hold similar mental models that predispose them to select, codify, and retrieve information in a like manner (e.g. Rentsch & Klimoski, 2001). This facilitates the creation of shared situational models, which enhances the anticipation and adaptation of knowledge use in dynamic conditions (Rico et al., 2008; Hutchins, 1990). By building overlap in members' expertise, individuals could understand how the broader work process would proceed and how the group would achieve its objectives (Bechky & Okhuysen, 2011).

Therefore, expertise similarity is beneficial for both identification and reflection activities, especially for exploring different perspectives and integrating these perspectives into mutually-constructed conclusions and goals for implementation. When teams are high in expertise similarity, it increases the members' mutual understanding and ability to gain insights from others to broaden the scope and utilization of that knowledge (Tiwana & McLean, 2005; Huang et al., 2014). This overlap facilitates the development of shared expectations and task goals that are necessary to develop in response to changing situations; enhancing identification through mutual understanding of the situation and reflection by building on this understanding. For example, Bechky and Okhuysen (2011) observed that an increase in expertise overlap in SWAT teams directly enabled the development of task knowledge and work flow expectations in their response to surprise events; the similarity facilitated common understanding of both their tasks moving forward and their roles.

Finally, there are benefits to experimentation behaviors when team members are similar in expertise. When team members have overlap in what they know, they are able to comprehend shared knowledge within the team (Tortoriello et al., 2012). This allows them to be capable of assessing and selecting useful viewpoints and perspectives from a large pool of information, which is necessary in order to respond to unknown stimuli (Carlile, 2004; Wegner, 1987). Teams with this overlap do not need to rely on extensive knowledge sharing and interaction to obtain ideas, information, and knowledge and can save effort and cognitive resources that are necessary to deal with unstable or changing situation rather than the distraction or conflict that may occur in understanding each other (Tortoriello et al., 2012; Majchrzak et al., 2007). In situations where the efficiency of response is inextricably linked with the effectiveness, the advantages of this shared mindset arising from similar knowledge and expertise may outweigh detailed elaboration in generating a novel response (Huang et al., 2014).

However, it is moderate expertise similarity that has been suggested in prior qualitative and case studies to be most effective for teams to respond to unexpected events, generate unknown outcomes, and enhance simultaneity of response. Those teams with moderate expertise similarity are able to capitalize on the coordination and information sharing, integration, and utilization that characterize high similarity teams and the evaluation and generation benefits of differentiated experiences and views that are characteristic of teams with low expertise similarity. However, teams with moderate expertise similarity may reap additional benefits than just information-processing.

In moderately heterogeneous teams, overlap may create subgroups or expertise cohorts within a team, which lends greater benefits to the moderate overlap setup. These subgroups may stimulate improvisational behavior during reflection and experimentation (Gibson & Vermeulen, 2003). The presence of a person who shares a similar background may stimulate an individual to explore and express his or her viewpoint, which could be useful in unexpected situations or where the outcome is uncertain such as in improvisation (Lau & Murnighan, 2005). When expertise is held individually by team members, and there is little overlap in knowledge between them, the broader group is likely to have difficulty efficiently and effectively integrating its knowledge because of unshared beliefs and information (Lau & Murnighan, 2005). Some homogeneity allows relevant members of the team to band together, communicate, and quickly converge on ideas to implement solutions (Gibson & Vermeulen, 2003). Subgroups that form when teams have moderate overlap in expertise are positioned to open communication, adaptation, and convergence of ideas between members, which enhances their ability to reflect on held knowledge, update team schemas and goals, and integrate information for implementation.

Expertise and coordination are mutually constitutive, jointly enabling improvising teams to coordinate their efforts under the constrained circumstances. Teams need clear direction to coordinate the integration of members' knowledge inputs (Hackman, 2002). People are most likely to take direction from those they perceive as having legitimate task knowledge (Lewis, 2004), and expertise is an important source of legitimacy in most task settings. Therefore, having relevant knowledge concentrated within a few team members will provide a team with a more streamlined set of directions and thereby enhance the efficiency of their communications (Gardner, Gino, & Staats, 2012). Teams with moderate overlap are already positioned to benefit in improvisation by using rotational leadership. When expertise is separated, it is clear who should lead; the few prior empirical examinations of rotational leadership in teams, in fact, have almost exclusively focused on differentiated and highly specialized teams (Aime et al., 2014).

Therefore, the effects of rotational leadership are made possible by having an available, distinguishable range of expertise. By imposing a coordinated interaction scheme, rotational leadership ameliorates the issues that distributed resources create in acknowledging and integration information.

Further, greater resource distribution typically inhibits the collaboration and validity of team communications, particularly in situations of high uncertainty like those requiring improvisation (Gardner et al., 2012). Rotational leadership, therefore, should be beneficial for both reflection and experimentation when teams have low expertise similarity – providing an improvement over static hierarchy or teams that do not rotate when differentiated in expertise. This extends to groups that have moderate expertise, particularly those that tend to form subgroups; these subgroups still allow enough differentiation that teams can capitalize on the clear and distinguishable expertise. In addition, moderate expertise similarity still provides the background for shared conceptualizations and frameworks that teams with high similarity have in improvising (albeit with more restricted team members). Even when overlap only occurs between a few members, or is concentrated in subgroups, the teams will benefit from this mutual understanding and approach.

To clarify this reasoning, consider an example from an observation of a mine rescue team during a training exercise. A commonly observed configuration in the mine rescue teams was a team structure based on role that allowed two members to specialize in ventilation issues while another two were specialized in first aid. Although everyone on the team had familiarity with the knowledge required to deal with both ventilation and first aid problems, when they would encounter one of those, the subgroup members would branch off to come up with a solution. This allowed two benefits. First, the subgroup was able to capitalize on the benefits of focusing on in-depth knowledge, having others to cross-check their solutions and evaluate them prior to implementation, and then coordinating the implementation of the plans of the concentrated groups. Second, this allowed the teams to anticipate or work in parallel on different challenges, alternating control depending on situational relevance of expertise. The mutual understanding of the task and situation derived from having a cohort allows teammates to develop adequate expectations regarding their teammates' actions and decisions and enables team members to adapt quickly to changes and demands in the environment (Blickensderfer, Cannon Bowers, Salas, & Baker, 2000). However, the team simultaneously used the specialization to their benefit, allowing those with the correct prior experience to drive the solution, increasing the likelihood that their actions would resolve the issue.

However, when teams have high expertise similarity, rotational leadership can create issues for improvisation. In this case, these teams have difficulty in effectively reflecting and implementing during improvisation. When teams have high similarity and attempt to use a rotational interaction pattern, they will be less able to efficiently explore different perspectives; often, their interactions during reflection are of lower quality because they cannot distinguish relevant insights and therefore must explore more broadly than necessary to meet the demands of the situation. In addition, this hampers their ability to capitalize on centralization because there is not clear consensus on the relevant expert. Moving towards common goals, selecting ideas, and implementing them may be derailed as the team needs to negotiate the right approach or simply defer to a formal leader. Therefore, I propose that when rotational leadership is high, the relationship between expertise similarity and improvisation is strongest at low and moderate levels of expertise similarity. When rotational leadership is low, the curvilinear relationship between expertise similarity and improvisation is dampened (see Figure 2).

Hypothesis 3: *Rotational leadership will moderate the curvilinear relationship between expertise similarity and improvisational behavior in teams.*

DESIGN AND METHODS

Research Setting and Sample

In order to systematically track and compare team responses during improvisational learning, rather than retroactively as is the norm in the current literature, I collected data at simulated mine emergency events. Simulations are necessary because it is impossible to predict the existence of actual mine emergencies; this context allows a natural control for the improvisational situation so that the behaviors of the teams can be compared for the same unexpected event. I use a field study of mine rescue teams during simulated mine emergency competitions to test whether these team characteristics influence the success of a team during improvisational learning.

Mine emergencies are sudden and unforeseen situations or incidents that endanger human life or cause significant injury, result in damage to property, or result in environmental damage. These are inherently improvisational situations: the events are unexpected and unpredictable, the response to the event cannot be predetermined as the issues must be uncovered and solved simultaneously as the team traverses the distressed mine, and teams are unable to step back and formulate a formal response plan once uncovering the problems.

Following recent disasters in mines (e.g. Upper Big Bend, Sago), governmental oversight in preparing teams to be a first line of response and recovery has tightened. The Mining Safety and Health Administration (MSHA) regulates the rules for team availability and training requirements necessary for each mine, in order to ensure that in the event of emergency resources are available to rescue personnel and stabilize hazardous situations. These mine rescue teams are cross-functional teams consisting of six members, each responsible for one of the following roles: team captain, co-captain, mapping, briefing officer (also referred to as fresh air base or FAB personnel), first aid or medical response, and gas detection. This does not mean that other members of the teams do not have skills in these areas, these are simply the persons responsible for ensuring the protocols associated with these situations.

One of the most common methods for mine rescue teams to maintain and certify their skills is for teams to participate in mine rescue contests. Mine rescue contests serve as a training tool to improve the skills required to respond to a mine emergency. During contests, teams are exposed to a stressful situation where they are required to respond as they would in an unplanned crisis or emergency situation, while following safe practices. Contest field exercises are designed to be reflective of real-life situations, providing a medium fidelity approximation of what a team would encounter during an unplanned emergency. Each team must compete in at least two contests per year following MSHA governmental regulations. MSHA established these requirements to build skills in key areas of mine rescue expertise like mine gases, mine ventilation, exploration, fires, firefighting and explosions, the rescue of survivors and the recovery of the mine, but also to build inter- and intra-team dynamics like bonding, comradery, and idea sharing for successful rescue operations.

Although the layouts of the mines and the field exercises that the teams solve may vary between contests, the National Contest Rule Book (released annually by MSHA for all regional contest organizers to follow) establishes procedures and rules that serve to guide the rescue teams in actual situations. Although the rule book governs procedures, it does not provide any communication or leadership regulations; instead, it focuses on how to address technical responses like monitoring gases or checking for roof stability. These procedures and rules allow for organizers to develop comparable improvisational scenarios between events without duplication, so that teams will not be able to directly apply any previously used routines to directly solve future contests. Following National Mine Rescue Contests Rules, teams train for and compete in several events; mine rescue field exercise, first aid contest, and self-contained breathing apparatus testing and repair contest. This study gathered data on the mine rescue field exercise, which simulates a mine disaster scenario.

The mine rescue field exercise is where each team is required to safely and systematically explore through a simulated mine, looking for trapped miners and stabilizing hazardous conditions. Each team is timed and in their search the teams may encounter issues like fires, cave-ins, floods, and poisonous or explosive atmospheres. The teams are required to achieve predetermined goals such as to properly ventilate the mine to clear the hazardous atmospheres, provide first aid to rescue patients, or buttress shafts for systematic recovery following their first line rescue. As they traverse the simulated mine, they encounter problems that they must use improvisational learning to resolve. Examples of types of conditions that teams may find include (but are not limited to) inundation with liquids or gases, fires or explosions, unsafe roof falls, cave-ins, and hazardous atmospheres. As the teams work to solve the field exercise they are judged on certain procedures receiving deductions when they fail to work properly according to the set of predetermined National Mine Rescue Contest Rules.

Data Collection

In order to collect data at mine rescue competitions, I did a series of preliminary observations and interviews during training exercises across multiple types of mine rescue teams that would participate in the competitions. Every mine rescue team is mandated by MSHA to train 8 hours per month; during these trainings, I observed teams complete mine rescue exercises comparable to ones that would be used in competition (often these exercises in training were modifications of prior competition situations). I conducted observations and interviews at four mine rescue team trainings, which were regularly scheduled sessions to comply with MSHA regulations, speaking with 12 individuals across these sessions. During these training exercises, I interviewed the team members and their trainers to understand their behaviors and rationales during these improvised situation; I also used non-exercise times to speak with key members about their preparation and their experiences outside of training. Through this I was able to validate and refine the theoretical model, as well as modify previously validated measures for learning behaviors, expertise, and leadership to fit with the context and constructs. In order to ensure that my theories were not biased to one type of team, I observed multiple types of teams including two mine-site teams who were wholly owned by large companies and whose members all worked at one mine site, one composite team that was run by the state and recruited members from different small mine sites (including one retired person), and one collegiate team composed of mining engineering students who were learning mine rescue tenets prior to entering the workforce.

After these preliminary observations, I then observed unjudged competitions that emulated actual competitions in exercises, but allowed teams to be collaborative and interact before and after their performance. The unjudged competitions allowed me to test my recording protocol and speak with trainers and experts in the field about the operationalization of my constructs, verifying that these constructs were likely to vary significantly between teams, identifying the parameters for the sample of teams to participate in both studies, and understanding relevant contextual factors to include in my final surveys. While these interviews and observations were not expansive enough for an in-depth qualitative study, they were used to clarify the model of interest and to confirm that teams vary in the extent to which the members held expertise and in how they responded to unexpected problems during the course of a rescue, making these situations appropriate in which to study these processes.

Finally, I coordinated with multiple regional mine rescue competition organizers to gain access to the teams for my study. Although MSHA oversees the rules and judging criteria at a national level, each competition is run separately in conjunction with state-level MSHA offices and regional mining boards. The competitions are available to the public; however, in order to gain access to survey the teams prior to the competition and to place recording devices on the teams, I gained approval from the organizers to access the restricted areas and recruit. Although I attempted to participate in every competition, the final competitions depended on agreement from the organizers and maximizing the number of distinct teams in the sample (e.g. teams who participated in Virginia are most likely different from those who participated in Missouri because of travel restrictions, despite some regional overlap).

The selection of these teams and competitions was done as systematically as possible, with the sole goal of testing this study. Prior to this study, I did not have any access to or knowledge about mine rescue, the government organizations, or the individual teams. Initial contact was made by reaching out to multiple companies through publicly available channels (e.g. corporate emails, company phone lines) to understand the industry and how mine rescue training was established. Access was granted to the observed teams from their safety managers, who were typically not involved in the day to day training of the teams; however, these safety managers felt that additional insight on the training of their teams could be beneficial for the industry overall.

In order to interview and observe in depth, I drew on my status as a neutral, outside party to encourage honest responses from the team members. Although I was an outsider to the mining industry, my position as a non-industry, academic researcher seemed to reassure the participants that I was not judging or grading their specific performance, but to apply the knowledge broadly to management of crisis response. Although I had no specific knowledge about the methods of mine rescue teams, I theoretically identified a preliminary model based on prior research in order to address and test the research question prior to the engagement of companies; I refined the expectations and hypotheses after the initial interviews and observations. In these initial interviews and observations, I attempted to let the team members guide the open ended conversations about how they approached their work. However, my position, interests, and knowledge may have guided the teams towards certain behavioral rather than technical aspects of their performance. The teams in the quantitative data collection – during the mine rescue competitions – were not informed of the research question, hypotheses, or expected outcomes of the study, in order to try and mitigate any influence.

I was also informed during my initial contact that MSHA had dedicated behavioral and social science groups collecting data in the mining industry. Despite this, no prior studies had attempted to record the mine rescue competition process, except to use for promotional material, and the mine rescue organizations and MSHA welcomed this analysis. Therefore, the regional organizers were motivated to allow access for both their learning and training, as well as to promote interest in their industry. They were not provided with any other payment. Despite this interest they did not, however, provide any input into the design or reporting of the study outside of reviewing the collection procedures and survey items to ensure that they met with their regulations. The teams were provided with copies of their recordings and a summary of their survey results in compensation for their participation.

Study procedures

All mine rescue competitions are scheduled the same way. At the outset of the competition, competing mine rescue teams are placed into an isolation space where they are kept from having any contact with personnel who have access to the field exercise. This guarantees that the problems faced are unknown to the team, regardless of what order they compete. Teams stay in isolation until it is their turn to perform the mine rescue field exercise. Upon completion of the field exercise, judges tabulate the final deductions based on their individual observations and score cards. During this time, teams are kept separate from the isolation space. After the judges tabulate the scores, teams are taken to a debriefing room where the judges walk the members and their coaches through their scores and discuss any developmental points for training.

Surveys were distributed at two points of time during the competition. During the initial isolation prior to their field exercise, team members took an initial survey where they provided ratings of the independent and moderating variables in the model of expertise structure, expertise recognition, and rotational leadership. In addition, in the initial survey team members provided information on demographics, experience, familiarity and general team functioning like conflict, trust, psychological safety, and identification. At the conclusion of the team's competition attempt, all members completed a final survey. Final surveys were distributed immediately following the conclusion of the attempt, prior to receiving their scores from the judges in debriefing. In the final survey, team members provided ratings about their specific team behaviors and cognitions during the prior solution attempt, including measures of rotational leadership materialization, information processing, improvisational behaviors, perceived effectiveness, and conflict handling.

During their field exercise, team members were recorded to capture their verbal interactions. Recording devices were unobtrusive; I provided each team member with a two inch microphone worn on a lanyard that could be covered by their required safety gear and communication devices. Audio recordings began at the start of the team's turn and was stopped when the team captain indicated that they had concluded their solution. These recordings are coded for team improvisational behaviors by independent coders. Judges ratings were collected following the event; official score cards were used to assess the team effectiveness and speed of completion.

Measures

Descriptions have been provided only for those measures that were used to test the hypotheses. Appendix A includes a full listing of the scales and items included in the data collection.

Expertise similarity

In line with other studies that used expertise ratings, I adapted Austin's (2003) measure of expertise recognition for these field-based teams. On the initial survey, using a 5-point scale (very little expertise to great expertise), team members rated themselves and each team member on dimensions of expertise recognized by the MSHA guidelines (CFR 30 Part 75 – Safety Standards for Mines) as the core skills necessary for mine rescue teams. The ratings reflect each members' perceptions of their own and other team members' skills. These skills include: ventilation, gas detection, roof support, combustible materials, electrical, fire protection and suppression (fire brigade experience), maps, explosives and blasting, hoisting and ropes, emergency evacuation procedures, shaft exploration procedures, communication, shaft sealing and surface structures, mine recovery, and first aid and medical assistance. These skills correspond with guidelines from MSHA and should be familiar to members of the mine rescue team, regardless of their personal depth and experience in the area.

Expertise similarity is calculated using this expertise data to determine the amount of similarity in the expertise held by the members. Prior studies suggest that expertise similarity can be calculated by comparing the overlap between an individual's skills to every other member of the team on each skill dimension (Bunderson, 2003; Reagans & McEvily, 2003). To calculate the similarity, the individual's difference score is divided by the maximum score in the sample and the result subtracted from one. This individual similarity measure is aggregated to calculate the average amount of overlap or similarity between the team members for a team-level score. Difference scores are calculated with the following formula:

$$\sum_{j=1}^{m}[\sum_{k=1}^{c}(x_{ik} - x_{jk})^2] \ /(m-1)$$

Where i is the focal team member, j is each other member of team, x is the rating on skill area k, c is the number of skills, and m is the number of team members. To test the curvilinear effect of expertise similarity, I centered the aggregated (mean) value of expertise similarity for each team and squared it.

Expertise recognition

I adapted Austin's (2003) measure of expertise recognition for the mine rescue teams. Using the same 5-point (very little expertise to great expertise) of the handbook skills, team members provided ratings of their own skills, which was used as the indicator of the level of skill that member actually had. To calculate the accuracy of teams' expertise recognition, I followed procedures detailed by Gardner (2012).[2] First, each individual's own expertise score was

[2] Previous studies (e.g. Austin, 2003; Gardner, 2012) tend to use an objective measure of expertise rating such as certifications or examination scores in order to compare the accuracy of the team's perceptions. However, in this setting the use of the own rating as indicator is justified for two reasons. First, in this setting these subjective ratings of skills provided the best picture of how the teams conceptualize their experts and the most proximate indicator of how teams determine situationally relevant decision-makers, which in turn informs how influence patterns are designed. Second, both team trainers and MSHA officials informed me that there were no objective tests of skill

regressed on the mean expertise rating provided by their team. The residuals from this model are the deviation between a person's expertise and their teammates' perceptions of that expertise. For each team, the average of the squared residuals across all team members represents the overall deviation in recognizing the team members' expertise. The scores were multiplied by negative one so that higher scores (closer to zero) indicated more accurate recognition.

Rotational Leadership

Rotational leadership is measured by eight items developed based on the existing literature (e.g. Davis & Eisenhardt, 2011; Aime et al., 2014) to reflect the extent that team members felt their team demonstrated the characteristics of a rotating leadership team. Team members will rate these items using a 7-point scale (strongly disagree to strongly agree). These measures include: "Our team allows members to alternate who provides input on the problem solution," "Our team allows members who have the most relevant expertise to influence the solution," "Our team changes who has influence on the solution and activities depending on the needs of the situation," "We allow different members to take the lead when they have the most relevant insights and experiences," and "Our team identifies who has relevant expertise when a situation changes." The same items were used in the final survey, but modified to ask about the specific competition event.

Improvisational behaviors

Items were developed based on the extant literature by modifying existing scales of learning behaviors (e.g. Edmondson, 1999; Savelsbergh et al., 2009) with relevant actions that define improvisational learning in the categories of Identification, Reflection, and

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capacity currently in place. However, future research could consider how well these types of perceptions align with more objective measures of expertise and whether it is actual expertise or the perceptions of expertise that facilitates the team coordination necessary to improvise.

Experimentation. Items were derived and developed in two stages. First, Savelsbergh and colleagues (2009) created a systematic list of learning behavior categories across empirical studies. These items were grouped by subdimensions that represent aspects of the traditional learning process (see concepts and definitions in Table 3 and how they align with the categories of identification, reflection, and experimentation). From this, I theoretically selected relevant subdimensions of these behaviors and items for improvisation, modifying existing items from the source scales (e.g. Edmondson, 1999; Gibson & Vermeulen, 2003) to make sense in the mining context. For example, I eliminated items in traditional learning reflection like "We stop and take time to reflect on how we can improve our working methods" because it is in theoretical contradiction to productive improvisation. Next, I validated the items with mining experts who also have extensive behavioral research experience to ensure their relevance. Finally, I validated the items in a pilot competition, which allowed me to modify any that were ambiguous or were not related to other items. The final scale included 15 items across the three categories of improvisational behaviors.

Coders rated whether the subset of improvisational learning behaviors occurred for each team. The coders were undergraduate mining engineering students who are also participants on their collegiate mine rescue team. Collegiate mine rescue teams often compete in local mine rescue competitions for exhibition; they are not eligible for any MSHA regulations or certification. Typically, these students may have actual mining experience in the form of internships and summer work. Their goals often are to be familiar with all roles of the mine rescue team to bolster their marketability to future employers, as well as gain the skills necessary to contribute in a real mining emergency. This allows them to have a baseline understanding of all the actions and roles the team undertake. The coders employed for this study both had 3 years of mine rescue experience, participating in practices and drills. They had on average 1.5 years of experience participating in the competitions.

Coders rated (on a scale of 1 – strongly disagree to 7 – strongly agree) of the quality with which the team performed the underlying learning behavior at the end of the field exercise. These measures included items such as: “The members of this team made sure everyone had the same understanding of the situation,” “The team transferred and combined information between members,” “The team used questions and discussion to understand issues,” and “The team worked together to evaluate potential outcomes before choosing one.” See Table 2 for listing of all items by behavioral category and Table 3 for examples of conversation segments in each improvisational behavior category. In addition, teams rated their own improvisational behaviors immediately following the competition in the final survey. The same items were used as those the coders rated. Following previous conceptualizations of learning behaviors from which these behaviors were derived, the total improvisational behavior score is then determined by aggregating the ratings of improvisational behaviors for the entire field exercise (Edmondson, 1999; Savelsbergh et al., 2009).

Performance

Team performance is measured as the number of deductions given to the team by a team of judges based on a standard scoring sheet distributed nationally each year by MSHA. Judges are trained personnel who have deep experience in mining and mine rescue; many of the judges are MSHA personnel or former mine rescue team members and many have actual mine emergency response experience. The same set of judges watches each team as they solve the field exercise monitoring for team safety, how well the task was completed and how much time it took to complete the task. Judges ratings must be provided in the following categories per

MSHA contest guidelines: communication protocols, time taken to solve the field exercise, accuracy of recording activities on maps, team effectiveness in identifying and solving problems, and team effectiveness in handling first responder activities.

The final team performance consists of a total rating for each team that reflects their ability to respond to the initial performance goals, with deductions taken for mistakes and failures to follow protocols. Deductions range from 0 (indicating the team was effective in solving the field exercise to meet all the criteria and they incurred no penalties while implementing their solution) to 250 (indicating they reach a maximum number of penalties or their solution was so ineffective that they created a terminal situation from which they could no longer respond). Team performance scores have been multiplied by negative one so that higher scores represent better performance.

Control variables

Because the data was collected across multiple competitions, where the problems were similar but not exactly the same, I also included a control variable for the difficulty of the competition problem. The two experienced coders rated the level of difficulty of each competition on a scale from 0 to 100. The raters were given the field exercise layouts, maps of the problems, and notes provided to the judges to inform their rating; they did not have any information about the performance ratings of the teams in that competition.[3] In addition, because some field exercises may be similar to others that teams have encountered before, I included as a control a rating that each team member provided about their level of experience with the specific situation and the routine nature of the task given their experience, labelled situational experience

[3] I also ran the regressions with fixed effects for each competition, instead of the competition difficulty score. Because there was no substantive difference in the estimate or significance inferences using those fixed effects, I opted to use the difficulty rating to preserve degrees of freedom.

(Withey, Daft, & Cooper, 1983). Examples of these items include “This situation was unlike any other we had faced before,” and “The tasks required to solve the problem were very routine.”

RESULTS

Data was collected at six competitions in four states; six competitions were comprised of coal teams; one competition featured metal/non-metal teams. Overall, 59 teams participated in the study out of 79 total teams in competition for a team response rate of 74%. Initial surveys were filled out by 332 individuals out of 354 on the participating teams (94%); no individuals were asked to respond if their team did not first agree to participate. Final surveys were not returned by eight teams; returned final surveys were filled out by 333 individuals out of a possible 378 responses (63 observations across all teams).

Teams were included in the sample if they had at least three members of their team (50% of the mine rescue team) responding to the survey. One team was excluded for not meeting this minimum criteria for a final sample of 58 teams. I examined whether there was any difference in the performance for the teams who did not participate in the study to verify that there was not systematic exclusion of teams based on their outcomes. The teams who participated in the study had an average performance score of 51.45 (standard deviation = 37.96); the teams who did not participate had an average performance score of 41.57 (standard deviation = 48.68). An analysis of variance showed that the differences between the groups were not significant ($F = 0.71$, n.s.).

The descriptive statistics and correlations among all modeled variables are shown in Table 4. Of the 58 teams included in the sample, 40 were dedicated, mine-site teams (68%). The average age of the mine rescue team members is 37.2 years, with an average of 1.9 years of post-high school education. The team members have an average of 13.9 years of experience working in the mining industry, with participants working in diverse job functions such as production, maintenance, engineering, health and safety, and administration. The teams on average have 77.8 months of experience working as dedicated mine rescue team personnel.

Examination of Data Structure

Several of the survey measures used were either adapted from prior measures or developed specifically for this study. To provide evidence of the validity of these measures, I conducted confirmatory factor analysis. Specifically, I fit a measurement model to the data in which survey items for rotational leadership and self-reported improvisational behaviors loaded on their respective factors and all factors were allowed to covary with one another. [4] The measurement model provided an acceptable fit for the data (χ_{134} = 434.59, CFI = .90, TLI = .88, RMSEA = .082, SRMR = .06), lending evidence to the validity of the survey measures used. The observer-rated improvisational behaviors were significantly correlated to the self-reported ones ($r = .50$, $p < .05$), although the observers tended to rate the mean quality of the behaviors as lower than the teams themselves did (see Table 4 with descriptive statistics).[5]

All analyses are performed on team-level constructs. To validate this data structure, I examined whether the data empirically justified aggregation of the individually rated items for rotational leadership and self-reported improvisational behaviors. According to one-way analysis variance, both the self-reported improvisational behaviors (F=3.711, $p < .05$) and rotational leadership (F=2.339, $p < .05$) ratings differed between teams. Intraclass correlation coefficients were comparable to aggregate constructs reported in the literature (e.g. Edmondson, 1999; Hirst,

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[4] I also examined the factor structure for the improvisational behaviors. First, I fit a model that let the improvisational behaviors load onto three factors: identification, reflection, and experimentation. This model had acceptable fit (χ_{32} = 109.66, CFI = .96, TLI = .93, RMSEA = .085, SRMR = .04). I then collapsed into two factors, combining the identification and reflection factors; this model (χ_{34} = 113.29, CFI = .95, TLI = .94, RMSEA = .083, SRMR = .04). Finally, I examined the one factor model, which provided a similar fit for the data (χ_{35} = 118.72, CFI = .95, TLI = .94, RMSEA = .083, SRMR = .04), lending evidence to the validity of the survey measures used. Although all models provided reasonable fit, because there was no significant improvement in the fit ($\Delta\chi_3$ = 9.06 p = n.s.), I used the most parsimonious model where all the improvisational items loaded on one factor.

[5] I calculated the interrater reliability for the improvisational behaviors rated by the coders. Because of the length of time to code each recording, both coders rated only one competition with which to calculate the reliability; 7 teams participated in that competition. The ICC(2,k) of the overall improvisation rating was 0.94. Prior to rating separately, the coders also jointly completed 5 ratings together that were used in hypothesis tests.

Van Knippenberg, & Zhou, 2009). For the improvisational behaviors (ICC1 = .276, ICC2 = .730, $r_{wg(j)}$ = .835) and for the rotational leadership (ICC1 = .158, ICC2 = .572, $r_{wg(j)}$ = .858), suggesting adequate within-team agreement as well as aggregation. These results justify the aggregation of team improvisational behavior. To calculate nonlinear terms, I centered the variables (Aiken & West, 1991) and calculated quadratic terms based on these.

Hypothesis Testing

To test hypothesis 1 (Table 5), I use a tobit model, also called a censored regression model. The tobit model is designed to estimate linear relationships when there is censoring in the dependent variable. When the dependent variable is censored, OLS can provide inconsistent estimates of the parameters (Woolridge, 2002). A tobit model is also appropriate when the dependent variable has a cluster of observations at the constraint. In this sample, the performance scores provided by the judges cannot be greater than 0 and the distribution of the scores are skewed so that a significant portion of the data has a value approaching this zero boundary, making a tobit model appropriate for testing the relationships. With tobit models, a log likelihood-ratio (LL) test is used to compare whether the models are significantly different. A drop in LL indicates a better fit; the significance is assessed by model comparison with ANOVA, a chi-squared test (Akaike, 1974).

In hypothesis 1, I propose that the improvisational behaviors would be positively related to the team performance. Consistent with this hypothesis, the coefficient for the self-report improvisational behaviors is statistically significant (Table 5, Model 2, B = 22.95, $p < .01$) and corresponds with a significant decrease in the LL in (ΔLL = 200.48, $p < .01$). Also consistent with this hypothesis, the coefficient for the observer-rated improvisational behaviors is statistically significant (Table 5, Model 3, B = 31.16, $p < .01$) and corresponds with a significant decrease in LL in (ΔLL = 5.53, $p < .05$). Thus, hypothesis 1 is not rejected. Figures 3-4 provide additional graphical examination of the relationships with performance. Figure 3 shows the relationship between improvisational behaviors and performance, grouped by the different competitions; Figure 4 shows the relationship grouped by the average experience of the team.

To test hypotheses 2 and 3, I use a three-step ordinary least squares (OLS) regression, entering the control variables, then the main effects of expertise recognition, rotational leadership, squared term for expertise similarity, and then the interactions between them as shown in Tables 6. I introduced the control variables (Table 6, Models 1-2)[6], the main effects of expertise similarity, expertise recognition, and rotational leadership (Table 6, Models 3-5), the linear two-way interactions (Table 6, Models 6-9), the non-linear term for expertise similarity (Table 6, Model 10), and the squared two-way interactions (Table 6, Model 11). These steps were duplicated for the observer-rated data in Table 7. All hypothesis tests for the interactions are based on the final model, including all linear and nonlinear terms (i.e., simultaneous tests of interactions in the same model).

In the cases of the self-reported improvisational behavior, there were some instances in which teams participated in multiple competitions. Therefore, they have different improvisational outcomes and team performance depending on the competition, but their team characteristics do not change. This creates a non-independence between observations, such that the error varies systematically due to the grouping; because these observations are not independent, the regular OLS standard errors are biased which can lead to incorrect inference particularly in small samples. In order to correct this bias, I use clustered standard errors to

[6] Appendix B includes tests with average expertise included as a control variable for comparison.

account for the observations within teams and test the hypotheses (Rogers, 1994).[7,8] Therefore, the significances reported for the self-reported improvisational behaviors are adjusted. For the observer-rated data, I use unadjusted standard errors to test the hypotheses because the current dataset contains only one observed recording per team.

In hypothesis 2, I propose that rotational leadership positively moderates the effect of expertise recognition on improvisation. Despite the significance main effect of rotational leadership in the main effect model (Table 6, Model 5, B = .20, $p < .01$), the main effect of expertise recognition is not significant (Table 6, Model 5, B = .06, n.s.). Despite expectations from prior research, increasing expertise recognition does not have an effect on the team's self-reported improvisational behaviors. Moreover, there is no support for the expected interaction that rotational leadership will enhance the effects of expertise recognition in improvisational behavior. The interaction between expertise recognition and rotational leadership does not significantly predict self-reported improvisational behaviors when added to the main effects (Table 6, Model 8, B = -.03, n.s.) or when considering all interactive effects simultaneously (Table 6, Model 9, B = -.02, n.s.). Additionally, the inclusion of these interactions does not significantly improve the model fit beyond the main effects – in fact it worsens the fit when considering the additional complexity of the model (Table 6, Model 9, $\Delta R^2 = .03$, n.s.). The relationships were also not significant for the observer-rated improvisation behavior: neither the main effect of expertise recognition (Table 7, Model 5, B = .04, n.s.) nor the interaction between expertise recognition and rotational leadership (Table 7, Model 9, B = .26, n.s.). The addition of the interaction between expertise recognition and rotational leadership also fails to improve

[7] In order to calculate these adjusted values, I used the r package "multiwayvcov" to find a cluster-adjusted variance-covariance matrix which can be used to test the significance of the coefficients for the regressions.
[8] In comparison, I used HLM to account for the clustering of observations within teams. The estimates and significance inferences were unchanged. The results of these are included for comparison in Appendix B.

model fit beyond the main effects (Table 7, Model 8, $\Delta R^2 = .05$, n.s). Therefore, hypothesis 2 is rejected.

In hypothesis 3, I propose that rotational leadership moderates the quadratic relationship between expertise similarity and improvisation, such that improvisation would be higher when teams with low or moderate expertise similarity had high rotational leadership. For the self-reported improvisational behaviors, the main effect of expertise similarity is marginally significant (Table 6, Model 5, B = .11, $p < .10$); increasing the overlap in expertise does increase the team's self-reported improvisational behaviors. There is no support, though, that rotational leadership enhances the effects of expertise similarity in self-reported improvisational behavior. The interaction between expertise similarity and rotational leadership does not significantly predict self-reported improvisational behaviors when added to the main effects (Table 6, Model 7, B = .01, n.s.) or when considering all interactive effects simultaneously (Table 6, Model 9, B = .01, n.s.). However, it is the quadratic of expertise similarity that tests the curvilinear relationship of hypothesis 3. In the self-reported improvisational behavior neither the squared expertise similarity main effect (Table 6, Model 10, B = -.02, n.s.), nor the interaction between the squared term and rotational leadership (Table 6, Model 11, B = -.08, n.s.) predicts improvisation. The addition of the interaction also fails to improve model fit beyond the main effects, again worsening fit because of the additional complexity of the model (Table 6, Model 11, $\Delta R^2 = .02$, n.s).

However, the relationships vary slightly when testing the effects on the observer-rated improvisation. Despite a lack of main effect on improvisation for both expertise similarity (Table 7, Model 5, B = .28, n.s.) and expertise similarity squared (Table 7, Model 10, B = -.21, n.s.), there is a relationship between the interactions and improvisation. The interaction between expertise similarity and rotational leadership does significantly predict observer-rated improvisational behaviors when added to the main effects (Table 7, Model 7, B = -1.08, $p < .05$) and when considering all interactive effects simultaneously (Table 7, Model 9, B = -1.39, $p < .05$), explaining significant additional variance (Table 7, Model 7, $\Delta R^2 = .23$, $p < .01$). However, the interaction between the squared term and rotational leadership is only marginally significant in predicting observer-rated improvisation (Table 7, Model 11, B = -1.22, $p < .10$), with the inclusion significantly improving fit (Table 7, Model 11, $\Delta R^2 = .36$, $p < .01$). Despite this marginally significant result, overall hypothesis 3 is rejected. I discuss in the following section how this result may provide guidance for additional examination of the hypothesis that rotational leadership moderates the quadratic relationship of expertise similarity with improvisation.

DISCUSSION

I set out to uncover how the formal knowledge structures of expertise overlap and the recognition of that expertise in the team are enhanced by the utilization of the dynamic coordination provided by rotational leadership. Unfortunately, the hypothesis testing suggests that further investigation is needed to understand the relationship between the structural features and their impact on improvisation. Although the interactions between rotational leadership and recognition were robustly insignificant for both the self-report and observer-rated improvisational behaviors, the observer-rated improvisational behaviors offer some insight for the hypothesis that rotational leadership moderates the relationship between expertise similarity and rotational leadership. However, there was support using both self-reported and observer-rated behaviors for the direct relationship between improvisational behaviors and team performance.

The interaction coefficient between expertise similarity and rotational leadership was only significant for the observer-rated improvisational behavior models; therefore, despite the hypothesis being rejected, I examine the relationship in more depth as a basis for future investigation in how teams strategically situate and use their knowledge stock. At moderate levels, expertise similarity is expected to be more strongly related to improvisation when rotational leadership was high rather than low. For the observer-rated data, the quadratic interaction of expertise similarity and rotational leadership is marginally significant ($B = -1.36$, $p < .10$). I plotted the association between expertise similarity and improvisation, comparing the two leadership levels (one s.d. above or below the mean, see Figure 5). From this it is clear that the trajectory of the curves does vary depending on whether teams used rotational leadership, albeit not completely as expected. For teams that were high in rotational leadership, the relationship matched predictions, which is that those teams that have low and moderate expertise similarity were rated to have improvised better than those teams with high expertise similarity. This is in-line with the hypothesized predictions that low and moderate similarity allows the team to distinguish between experts clearly which allows them to identify and reflect on relevant experts and information without sacrificing quality. Further, this differentiation allows them to distinguish who should be at the forefront when dealing with new problems or changes to the situation. And, as expected, the curvilinear relationship suggests teams with moderate expertise similarity in the high rotational leadership condition were rated the highest. In line with prior work, this supports the notion that having some redundancy helps relevant team members reflect on the knowledge held and generate and evaluate ideas better than teams lacking this slight overlap.

However for teams that were low in rotational leadership, the trajectory was not as expected. It was predicted that these teams would limit their ability to capitalize on any differences in the team productively if they did not rotate, dampening the quality of improvisation when expertise similarity was low or moderate, but not when teams were high in similarity. As Figure 5 depicts, it is the extremes of the functions that deviate from the predictions. At both low and high expertise similarity, teams have an improved improvisation rating when teams are low in rotational leadership. This suggests that for this sample, teams are able to capitalize without alternating influence based on the situation. However, in the limited data sample, there were only two teams that fell into the category of low rotational leadership and low expertise similarity, which may not provide enough evidence to conclude that prior expectations do not hold. In fact, it is likely that teams in the field who are low in expertise similarity recognize that rotating leadership helps them to capitalize on their differences and adjust their interactions accordingly.

For the teams with high expertise similarity, this finding is not fully counter to the prior expectations. The case for bounding the expertise similarity, such that low and moderate levels of similarity would benefit most through rotational leadership, was built on the idea that improvising teams must possess diverse knowledge and resources internally to create new solutions or routines to address these unexpected events and that total overlap may limit search (Moorman & Miner, 1998a). However, increasing the overlap of the core skills increases the chances that the mine rescue teams would have the right knowledge to solve the problem; with more team members having expertise in the areas they are most likely to encounter in a mine disaster, they increase the likelihood that they can apply prior knowledge and routines to come up with a new solution. It is possible that this finding extends only to those environments where the creativity must simply satisfy a minimal threshold to solve the unexpected problem, rather than allow the team to increase the degree of their creativity. For instance, because of the detailed regulations for response in mines, teams have a solid foundation of what types of skills are necessary to hold within the team (and these are the skills that I specifically measured). Therefore, there is no downside in this context in having multiple members with the same skillset.

Instead, this unbounded building of cross-member expertise strengthens assertions by prior work in responding to unexpected events. Overlapping expertise helps to develop shared expectations for tasks, roles, and problem-solving that are necessary to respond to surprises (Bechky & Okhuysen, 2011; Hutchins, 1990). These teams benefitted from the coordination that results from these shared expectations. This suggests that in teams that are improvising in response to these types of crisis events benefit substantially from increasing their overlapping knowledge when they do not rotate leadership. Contrary to prior expectations, when team members' expertise sets were highly similar they were still able to efficiently converge and implement solutions; these teams were not encumbered by the predicted need to carve out roles and task expectations, but rather this overlapping knowledge structure helped them to coordinate their responses optimally. This redundancy helped the team know about their counterparts jobs, which helped them predict each member's response patterns necessary to communicate for these collaborative activities (Grant, 1996).

Prior investigation of expertise overlap and learning suggested that moderate levels allowed teams to optimally band together subgroups to respond (Gibson & Vermeulen, 2003). The tendency for subgroup formation, which is particularly common in when teams have moderate expertise overlap, provides insight into how the teams that are high in rotational leadership take advantage of the strategic expertise layout to improvise. I ran a model to see whether subgroup formation was enhanced by rotational leadership in enacting improvisational behaviors. Subgroups exist when some members share an overlap in terms of expertise that is not shared with others. I computed this subgroup strength by taking the standard deviation of the pairwise skill overlap in teams; this pairwise skill overlap was calculated using the difference score from the expertise similarity profile (Gibson & Vermeulen, 2003). Therefore, subgroups are high or strong when there are pairs with a lot of overlap in skill and pairs with very little overlap. For instance, in mine rescue, a common distribution of skills was to have the fresh air base person and co-captain specialize in ventilation, while the gas person and medic were certified for EMT responsibilities necessary for first aid. Neither pair was then well-trained in the alternate skills. This setup created strong subgroups in the teams.

I ran the regressions substituting this subgroup formation for the expertise similarity. The interaction between subgroup strength and rotational leadership is significant ($B = 1.26$, $p < .05$). I further analyzed this interaction by evaluating the simple slopes (Aiken & West, 1991). Figure 6 depicts the effects of rotational leadership and subgroup strength on improvisation. Results show that the slope is significant and positive when teams were high in rotational leadership ($b = 1.10$, $t = 2.90$, $p < .05$), and is negative but not significant for teams who were one standard deviation below the mean in rotational leadership ($b = -0.16$, $t = -0.29$, n.s.). Therefore, this suggests that it is the presence of these strategic subgroups that drives the benefits of moderate expertise similarity and rotational leadership in improvisation. Relevant expertise subgroups can take the forefront in responding when the situation demands it. By dividing skills, teams are able to reap the benefits of specialization, where there are clear experts to respond to situational demands. Simultaneously, the overlap in skills that subgroups denote enhances the ability for these groups to retrieve and adapt knowledge. Therefore, subgroups allow teams to maintain the ability to explore different perspectives for generating and evaluating ideas during improvisation, while reducing the likelihood that the teams will be hampered by coordination issues when every member has the same expertise.

Despite these findings, the crux of my model was based on the fact that teams needed rotational leadership to fully unlock the benefits of their expertise and most of the tests were rejected. Rotational leadership was hypothesized to provide a coordination mechanism that enacts the strategic knowledge structures in the team. Contrary to expectations, rotational leadership only served to moderate the impact of expertise similarity for the observer-rated improvisational behaviors and for no other relationships. In trying to understand the general non-significance, I look to two potential avenues (1) that the context overly prioritizes efficiency over novel recombination or (2) that my model insufficiently describes the complex relationships between the team structures.

Because these are actual mine rescue teams, there is a baseline amount of knowledge that is necessary to even participate; teams are already certified to respond in emergency situations and therefore, it is assumed that the members have a base understanding of the core skills necessary to respond to a disaster. Therefore, any variations in expertise is relative to a baseline amount of knowledge that is sufficient to solve these training problems. In real mine disasters, the unexpected events may draw from more unique or idiosyncratic combinations of problems where the layout and presence of expertise may be more valuable in orchestrating a response. In these emergencies the breadth of expertise available to the team and the recognition of these infrequently used skills may contribute prominently to the team's ability to respond. However, the competitions may tend to draw on similar patterns of problems, allowing all teams to build those necessary core skills and reducing the importance of *strategically* developing and distributing unique knowledge.

And to that effect, this competition setting may disproportionately value the coordination relative to knowledge in more unpredictable mine disaster situations. Because these are simulations that are designed to test training, teams may use their experiences from prior competitions and trainings on similar problems to predict the way that their previous routines will be applied. In this way, the coordination quality of moving between experts becomes the most important driver of how teams behave, rather than a moderator of how they use the knowledge. Perhaps inherent in the conceptualization of rotational leadership is the fact that teams have the necessary knowledge to rotate and with this restriction in the variance of expertise, the differences are attributed to their ability to rotate effectively to capitalize on this knowledge instead of the knowledge stock itself.

The second avenue may be that the model misspecified the complex relationship between the structural components and their impact on improvisation. Because prior empirical examinations of these complex relationships have been primarily qualitative, and the quantitative tended to focus on only one aspect of the situational constraints (e.g. required novelty or time pressure on solution), it may be that the influence of these effects are not as separable as hypothesized. Instead, the power of the structure on improvisation may emerge from a confluence of having the knowledge strategically situated, understanding how it is situated, and then using it effectively.

In order to take into consideration that it is the confluence of the entire structure that affects improvisation, I examined the overall interaction between expertise similarity, expertise recognition, and rotational leadership using the self-reported improvisational behaviors[9]. Previous research highlights the combinative effect of specialization, recognition, and coordination on team performance and call for emphasis on understanding the differential impact of these components (Austin, 2003). Therefore, I examined whether the relationship was instead dependent on the interaction between the three variables, rather than simply the two-way effects considered. I modeled multiple regressions with improvisational behaviors as the dependent variable. First, I added the linear three-way interactions to the model including all the two-way interactions (Table 8, Model 1). In order to examine the three-way interaction of the team structural variables – the aggregation of the hypothesized two-way interactions – I entered the

[9] The decision to only report this analysis for the self-reported improvisational behaviors is due to the limitations of the sample size of observer-rated improvisational behaviors at the time of publication. With only 31 observations ratings, there are not enough degrees of freedom to test three-way interactions in this sample at this time.

quadratic three-way interaction in the Model 2 in Table 8. In Model 2, the quadratic three-way interaction is significant (B = -.85, $p < .01$). The interaction between the curvilinear distribution of expertise (expertise similarity squared), the expertise recognition, and the rotational leadership capability is significant for this sample.

In order to probe the three-way interaction, I examined the difference between the simple curves in the three-way interaction. As shown in Figure 7, the relation between expertise similarity and improvisational behaviors depend on whether teams have a good understanding of the expertise held by team members and on whether the team employs a rotational leadership structure. The graphs suggest that improvisational behaviors are most likely to be expressed when teams have high expertise recognition and high rotational leadership.

Using methods described by Dawson (2014) to unpack the curvilinear three-way effects, I further examined whether similarity has a different impact on teams with high rotational leadership that vary in their expertise recognition. It is possible to examine the "curve differences" (analogous to slope difference in the linear moderation case) by holding constant one variable along with the quadratic component (Dawson, 2014). I compared models that examine the effect of expertise similarity on those teams that have high expertise recognition (i.e. for teams with high expertise recognition, expertise similarity has a differential effect for teams with more or less rotational leadership). The differential effect of recognition at high expertise recognition is marginally significant, determined by comparing through a log-likelihood test models that exclude and include the differential recognition term ($\Delta LL = 2.27$, $p < .10$). Despite the low number of teams for the complexity of the model, this may provide preliminary explanation of the effect.

Further, the primary driver between the curve differences in this three-way interaction was between the conditions when teams have high expertise recognition. In examining, then, what drives the differences in these interactions, I focused on understanding what differed between the teams that had high expertise recognition. Figure 7 shows the relationship between expertise similarity and improvisation moderated by the joint effects of high expertise recognition and varying rotational leadership. The relationships behave similarly to those in the observer-rated improvisation in Figure 5, mirroring how rotational leadership makes a difference in improvisation, even when the behaviors are self-reported. However, in this case the teams needed to not only rotate accordingly, but also recognize who the experts are in order to fully capitalize on these relationships.

Unfortunately, the sample in this study, designed only to have the power to detect two-way interactions, has a low number of teams to provide generalizable implications for this interaction (Snijders, 2005). A post-hoc power analysis was conducted using the software package, G*Power (Faul, Erdfelder, Buchner, & Lang, 2009). The sample size of 58 was used for the statistical power analysis and a 5 predictor variable equation was used as a baseline. The recommended effect sizes used for this assessment were as follows: small ($\rho^2 = .02$), medium ($\rho^2 = .15$), and large ($\rho^2 = .26$) (Cohen, 1988). The alpha level used for this analysis was $p < .05$. The post-hoc analyses revealed the statistical power was .11 for detecting a small effect, .62 for a medium effect, and .92 for the detection of a large effect size. Thus, there was more than adequate power (i.e. power > .80) at the large effect size, but insufficient at the smaller effect levels. With the actual effect sizes being small ($\rho^2 = .09 - .16$), the post-hoc analysis reveals low power for finding the effects in this sample; I believe that there may be a stronger level of significance given more statistical power.

In addition, it is possible that the selection or creation of the teams, which influences who is on the team and potentially their choices of how to interact, may also affect the relationship with performance (Hamilton & Nickerson, 2003). In this case, endogeneity arises from the fact that the teams are formed on some basis prior to my observing and measuring the teams and their responses; most likely, the teams are formed with the expectation that the alignment will yield higher performance. For example, there was only one team that was low in recognition that also utilized high rotational leadership when they had low expertise similarity, suggesting that the teams recognized their limitation in their ability to coordinate efficiently when they were not sure of their differences and thus employed a strategy that maintained a static hierarchy. Therefore, it may be that the teams self-select their personnel and coordination strategies to best maximize their improvisational effectiveness. In order to adequately rule out the effect of endogenous self-selection, I need additional information on the formation of these teams (e.g. the decision rules that the trainer uses to assign members, the subject pool from which members are drawn) or additional variables that would correlate with formation but not performance. Unfortunately, given the data I am unable to account for the bias that may result from this correlation and which limits examination of their effects on the outcome.

In sum, the data provides some support to the notion that the theory was too simple resulting in a test that failed to capture necessary complexities. More precisely, the theory neglected the interdependencies of the different components resulting in small effects. Therefore, I consider this as an indicator for future work to verify the complex relationship between these structural features in a larger population or more systematic test.

Qualitative Examination of a Competition

Because I suggest that the theory may be too simple, I examined the different interactions between teams more closely to gain a better understanding of the complexity of the improvisational process during these mine rescue competition field exercises. An alternate way that the model be too simple is through the underlying improvisational process. To that effect, I looked more closely at one competition in order to understand how the improvisation process unfolded to guide future directions for examination. By examining the specific improvisation process for multiple teams, I attempt to understand with more nuance how the behaviors are actually enacted, as well as validate the most important behaviors in order to set up future work on preparation.

Competition exercise

The field exercise at this competition included multiple types of issues that needed to be addressed in order to meet the objectives. The setup of this exercise was that there was a gas problem during an overnight clean up in the mine, resulting in seven maintenance workers being reported missing. The teams are warned of caved roofs and water accumulation, although they were not specific where these hazards occurred, and they also are apprised of potential electrical issues. Their objectives are to retrieve or locate the missing men, given a number of constraints with the ventilation and electrical systems.

This field exercise was similar to those at other competitions, but featured a longer mine shaft than other competitions, resulting in a longer average time needed to solve the problem (see Figure 8 for layout of the exercise – there are three corridors through which they can travel deeper into the mine and the field is six coal blocks deep). Although there was no one correct way to solve the problems, the exercise tended to be solved by the teams in three phases that corresponded with the removal of the three remaining live miners. The teams, prior to going into the problems, did not have any idea of this layout, but using traditional exploration patterns would lead the teams to approach these areas in this fashion. I use this idea of phases to aid in describing the actions of the teams at different points in the narrative because the way the teams solve the problem can vary so drastically.

All teams enter at the south end of the mine. The first phase incorporates their preliminary exploration as the teams do an initial pass through the mine to understand the situation. Generally, MSHA provides guidelines for safe traversal of a mine rescue team, but these guidelines have open decision points that allow the teams to autonomously recognize and decide how they should traverse the different shafts (as long as they do not violate any regulations in doing so). Following exploration through the first three segments of the mine, the teams must implement a first ventilation plan that eliminates areas of explosive gas, as well as water interference, in order to safely remove the first miner.

In the second phase, the teams must then do an additional exploration to uncover the state of the last two segments of the mine. Following this additional exploration, the teams must perform a series of builds and fan changes that address multiple roof cave-ins, explosive gas mixtures, and unstable power sources. Typically, this phase requires a multi-stage solution where the teams must perform an implementation, ventilate, and then perform additional builds that remove or change previous layouts. At the conclusion of this phase, teams are typically able to retrieve a miner from a blockaded section.

Finally, in the third phase, the team must primarily implement structural changes in order to approach the remaining missing miners, both living and dead. The second phase ensures that the team has cleared the mine of any explosive areas; in the third phase the teams need to erect structures that allow them to pump water out in order to reach the final two miners. As they are doing this, they must simultaneously consider how to gather the materials to build around caved areas in order to identify the remaining missing miners who are dead. At the conclusion of this phase, teams are able to retrieve the final living miner and complete the field exercise. It should be noted that teams are not bound to complete these phases discretely, and often do not.

Teams in competition

Table 9 provides a summary of the background of the teams in competition, including their member demographics, their experience in the mining industry, and their experience in mine rescue. Team A is wholly owned by one company, but includes members from neighboring mines owned by the same company; because of this, the team members still work in relatively close proximity and have worked together on different shifts before. The team had on average about 12.5 years of experience working in the industry; however, most of their members had worked over 12 years, with only their captain and co-captain working in mining for only five years. Despite only having an average of 4.7 years of experience in mine rescue specifically, the team members had experience in a range of positions, with all members except the gas person having served in at least two other non-gas positions.

Team B is also a dedicated mine-site team, with all team members working at the same mine. Although the team had an average of 12.8 years working in the mining industry, there was a wide variation between the members. The captain, map person, and fresh air base person (FAB) having an average of 17 years and the others having an average of only 4.5. Similarly, the team members had a range of mine rescue experience; despite averaging 4.6 years of service on the team, the gas person had only been involved for 8 months, while the FAB was on the team longest for 7 years. Again, most team members were limited in experience to their current position and that of the gas person. The map person and FAB, the two longest tenured members, had served in competition in most of the positions.

Team C is a mine-site team that is wholly owned by one company, with all team members working in the same mine. Although the team had only 7.3 years of experience in the mining industry, the team members perform a range of jobs at the mine. The team members all joined the mine rescue team at approximately the same time, having an average of 40.5 months of experience in mine rescue; however, all members had been on the team for 4 years except the co-captain who started mine rescue the previous year. As a result of starting together on the team, the members all indicated an equal familiarity across team members, with none of the members having known or worked with each other prior to joining. As a result of their newness, the team members did not have much experience outside of their current roles on the team. The only exception was that most had served some time working as the gas person.

Team D is a state owned team, comprised of team members from multiple mines and including two retired persons. Because of this the team members have very little interaction outside of their mine rescue training, having only been familiar with each other as long as they have been on the team. Despite having two retired persons, the team was only 41.5 years old on average, with their gas person and co-captain being only 26 years old. Similarly, they had a wide range in the working and mine rescue experience driven by these members. The map person and the FAB, the two retired personnel, and the captain all had decades of experience in both the industry and mine rescue, while the others were relatively new, particularly to mine rescue with about 3 years of experience. In Team D, almost every team member had experience working as the gas person (they averaged 2.5 years of experience at that position for each member). However, outside of the gas position, members typically only had experience in their current position, with the exception of the FAB and the map person who in their 28 years of working in mine rescue had served in competition in all roles except for captain.

Team E is also a mine-site team, where all the members work in the same mine. Despite having an average of 6.3 years of mine rescue experience, the team members were mostly familiar with each other outside their mining jobs. Some members of the teams were brothers, neighbors, and in-laws, having known each other on average 15 years and working together in mine rescue for 4.5 years. The experience of the team in different positions varied widely across members. The captain, for example, had over 3 years of experience working as the captain, map person, and gas person. However, the gas person participated in competitions for 10 years solely in that position. In general, the members were primarily experienced in their current positions.

Team F is a mine-site team that is wholly owned by one company, with all team members working in the same mine. The team members are actually very familiar with each other, despite having only 3.5 years of experience working together in mine rescue, the team members knew and worked with each other an average of 8 years. Despite their limited experience in mine rescue, the team members typically rotated between many different positions over the years. Most team members spent approximately one year in a position during their time on the team such that each person had competition experience in at least 3 positions, with almost everyone serving time as the gas person or medic. Despite their youth, most have extensive industry experience, on average 16.3 years, with medic being the lowest with only 10 years of mining experience.

The three teams that were high performing were Team A, Team B, and Team C; the low performers were Team D, Team E, and Team F. Although all teams completed the exercise, the low performing teams received the majority of their penalties for creating an inappropriate solution during the competition. When this happens, the team receives a large penalty, but is allowed to continue solving the field exercise using the conditions they created. For example, Team F performed a ventilation that inadvertently blew explosive gas through an area where the team members were exposed. As a result, they were deducted points for endangering their team, but the team was not stopped during the exercise and allowed to continue with the exercise. They eventually cleared the dangerous area in a future ventilation, receiving no further deductions for the oversight. Because of this structure, all teams were able to meet the objectives laid out for the exercise. However, Team B completed all of their tasks beyond the time limit set by the regional organizers. Again, they were not interrupted in their problem-solving – although they were aware of the time penalty during the exercise – and were assessed a minor penalty at the completion.

Approaches for problem-solving

Overall, the way that teams attempted to solve the field exercise generally fell into two categories. Teams either attempted to centralize their problem-solving and interaction efforts through one team member, typically the captain or fresh air base member (FAB), or they attempted to divide the effort between subgroups, typically between idea generation and execution, allowing the units to work in parallel. I should note that my labelling these strategies does not imply that the teams themselves entered with the mindset of approaching the problem in this way. Rather these represent the interaction patterns and typical problem-solving approaches the team used based on my post-hoc observation of how they attempted to solve the field exercise.

Although I categorize these teams in these two high-level approaches, there was variation in the way they undertook these approaches and assigned duties, as well as variation in the success of their efforts. Therefore, it warrants explaining how each team went through the problem to help understand how these strategies pointed to some key activities that corresponded with success during this competition. See Table 10 for summary of team approaches and examples of how the teams used them in competition.

Centralized approach. The first approach used primarily by Team B and Team F was to rely heavily on a single person, or at most two people, to both formulate a plan, evaluate the outcomes, and then tell the rest of the field how to execute it precisely. Having a centralized approach allowed the teams to be more focused, particularly when executing a plan. However, the effectiveness of this strategy is often limited by the skill of their central planner.

Team B primarily relied on their FAB to drive their procedural and task approaches; when needed their co-captain served as a conduit of information between the FAB and the other members. In general, the only verbal involvement from the other members occurred when it was necessary to relay information to these members or judges or when they needed to announce regulated procedural tasks (e.g. verifying that they initialed entries prior to exploration). Team B leaned heavily on their FAB to come up with a plan throughout the exercise, and their recordings were marked with long silences while the FAB brainstormed and chose a plan on his own without additional input. After choosing a plan, the FAB would relay an execution plan to the rest of the team to complete, providing explicit direction on exactly how to carry it out; the rest of the team served to implement these ideas directly.

Even from the beginning of exploration, Team B uses a very centralized communication strategy. During exploration, the co-captain and FAB primarily discuss the items to record on their map – indicating the state of the mine – but there is hardly any input from the captain and gas person who are responsible for procedural checks. Unlike some teams, Team B even tends to stay physically together as they explore, waiting until the FAB indicates he’s completely ready to move forward. Their interactions were very centralized throughout the completion; the only exceptions occurring after they explicitly acknowledge that it took them longer to retrieve the first miner than expected. During the subsequent exploration the captain and map person briefly generate ideas on how they should move forward more efficiently before deferring to the FAB.

The team operates by having the FAB lay out an entire plan all at once, along with execution directions for each person, with only minor input from the other members in the form of clarification. Any changes to the current plan require a full stop for the FAB to reconsider the new information and then he generates an entirely new plan which he then relays in lieu of their current actions. Fortunately, the FAB mostly provided adequate direction to the team that their reliance on him did not hamper the outcomes of their solution; however, they did run over the time limit to complete their objectives perhaps because of this inefficient problem-solving style.

In general, the Team B interactions tend to be focused on implementation, with the FAB clearly directing what he wants done and the team implementing with minor clarifications. Although their communications tend to flow down from the FAB, he does make an effort as they finish each segment to at least verbally confirm what has been constructed and how it changes the layout so the team will be updated as they move into the next set of obstacles. In contrast to other teams, Team B tends to attempt long, comprehensive plans that are constructed to deal with many of the obstacles encountered at once. The FAB tends to take in all the information, spend time interpreting it without additional discussion, formulate a plan, and then relay execution steps. When something changes or does not work exactly as planned, there is no mechanism for updating on the fly, but rather they either keep moving forward with the plan if possible or stopping and recreating something entirely new.

The second team that uses this approach, Team F, also centralizes their planning, idea generating, and execution plan through their FAB; however, Team F initially attempts a more decentralized approach inviting input from many team members but falling into a centralized approach following difficulties in finding a feasible solution. After this initial setback, the team struggles to stay ahead of the changing situations as they explore further, building a plan as they go rather than creating a long term strategy that then gets modified as the situation changes. In general, the team relies heavily on the FAB, even though others can be heard having side conversations with new ideas and plans that are never brought to the group as a whole; instead, there is often dead silence while the team waits for the FAB to provide the plan for implementation and execution. Notably, this team has difficulty adjusting when new information is found - the FAB is constantly asking for updates on what materials they have and reminders of what has been built - and then stop to discretely integrate that into new steps. After a first plan that the FAB announces as having multiple parts, the team never returns to comprehensive generation; instead they tend to solve issues one step at a time. In contrast to the large segment approach of Team B, Team F tends to make many incremental updates. Further, the team has difficulty recovering from their initial plan trying to implement plans that are not reflective of the actual situation. The team often tries to apply template or prior knowledge of how they might solve the problem without taking into account the specific updates to the situation. For example, at one point they spend time looking for timbers to build rather than think how they can solve the problem with the resources at hand.

The execution is very tentative as well with the team just doing exactly what is relayed by the FAB then stopping and waiting for any update. The team lacks clear direction – although they attempt to generate group consensus on ideas or probe their ranks for knowledgeable experts - leading them to default to the FAB because he was the most willing to dictate direction, even if they try to find additional avenues. For example, the team does try to solicit a number of ideas halfway through the first phase because they realize they lacked information. They discuss the goals or priorities moving forward with a new plan, but end up following the FAB's request for more exploration because they are unable to find a better solution and they lack directive experience, except for the FAB.

In the end, they solve the problem completely differently from the other teams, and the competition organizers. Team F continues to explore rather than break down their problem-solving into phases, rescuing the live miners in opposite order because they clear the obstacles at the end, rather than as they encounter them. This actually has ramifications on their final evaluation because they miss dealing with an explosive mixture and lose points for endangering the team and miners.

Subgroup approach. The second approach utilized by Team A, Team C, and Team E was to rely on the guidance of different subgroups, formed depending on the nature of the task, to allow the team members to contribute their skills while simultaneously allowing them to organize their efforts to maximize planning and execution efficiency. The best executors of this approach, Team A, seamlessly integrates these actions through continuous updating. The other teams, in contrast, apply this type of parallel and continuous interaction scheme, but lack the fully streamlined processes and alternate more centralized direction in between cycles of parallel processing.

Team A represented the smoothest use of this type of strategy. The approach is made possible because they have two semi-autonomous divisions in the team: the FAB who leads development of forward looking plans to clear the mine of obstacles (primarily through ventilation) and the captain who leads implementations and executions of these plans on the field without weighing in too much. The ability for them to work in parallel so seamlessly rests on the co-captain who serves as a conduit of information between the groups, as well as a contributor to the generation and evaluation of ideas from both parties. The co-captain keeps both groups apprised of not only the task-relevant information, but also the current progress of the execution and anticipated challenges that the forward looking FAB should consider.

Both subgroups are consistently looking ahead, voicing any predictions about how new and current information may change. The team is very in sync in using this process; each member understands where they fit and from which group leader (captain or FAB) they should take directions. Most importantly, though, the team is very vocal about sharing any new information and verifying it among multiple members to make sure they do not miscommunicate or use any bad assumptions in their plans. With this anticipating and updating strategy, Team A is proficient at working ahead in the problem – having a plan for the next few steps while the captain leads the current build plan – but never gets too far ahead and locked into a path when the situation does change.

Team A is able to be efficient because they let people work in parallel but ensure that the ideas make sense before they do anything that would affect the solution. When they encounter difficult decision points, they take the time to talk through all their concerns and options and decide what order to deal with them strategically. After, the implementers finish with the execution, and the other members trust that they are precise in their actions. The team is continuously attuned to the situation and updating their baseline plan as they need to adjust. Because of this they are very effective at quickly reevaluating, reusing their prior plans as much as possible and changing incrementally while they are working, but they also create a new baseline plan overall when the situation changes entirely. For example, they reach the obstacle during the first phase when they cannot proceed with their execution and the FAB and co-captain debate how they should resolve it. They recognize this is a change point and the rest of the team weighs in on the merits of the different ideas they have including whether they have the resources to execute either idea. Ultimately, in less than four minutes, they are able to explicitly update their understanding of what went wrong and why, present three ideas of how they should recover, debate the outcomes of each path, and then integrate the decision as much as possible into the existing plan.

Team C also uses this type of multi-stream, parallel execution strategy; however, this team tended to come together more formally to generate multiple ideas for each problem, select the best one as directed by either the captain or FAB, and then break apart to start implementation once they have agreed upon a direction. Like Team A, Team C tended to split their focus on the forward looking ventilation concerns by the FAB and the eventual exploration and build plans by the captain; the implementation stream would execute while the others in the background continually update the plan given new changes in the situation. The captain led the field members to carry out the builds and gather additional information, while the FAB and co-captain would continuously track their updates and confer about the next step of the plan. However, more than Team A, this team uses big brainstorms with the entire group. During these group brainstorms, the captain is very vocal about encouraging everyone with ideas or concerns to participate – even pulling side conversations into the focus and letting the team know if they do not share these ideas they cannot be evaluated or used.

One notable thing about Team C is their awareness of the process throughout their exercise; they spend time explicitly communicating how they are going to interact and proceed, as well as on what actually needs to be done. For example, they start their exploration by standardizing their terminology and their systems of checks for sharing and verifying information from the field. Overall, Team C uses the divided strategy to move their execution forward, without disrupting the planning ahead and then tend to regroup for major changes in ideas.

Team E ended up using a more hybrid approach; although this mix seemed to be driven by execution failures rather than a targeted effort to mix a centralized and decentralized approach. They frequently tried to have multiple members weigh in on a given problem, trying to alternate between relevant people. However, their process was not as streamlined as the parallel groups used by Team A or as efficient as Team C in bringing the groups together, decisively formulating and conceptualizing a path, and then breaking apart to implement and update. As a result, their problem-solving typically ends up being incremental, which leads them to stop any efficient implementation streams. Because of this they end up defaulting to centralized idea generation and implementation, and as they get further into the exercise, they rely more heavily on only the captain and map person to generate ideas and then implement them; though less evaluation or input is communicated from other people on the team. This allows them to at least produce a reasonable outcome, albeit outside of the time limits.

However, during these phases when Team E tries to use a split approach, the team attempts to find the correct person to drive the solution as they move through the different problems. For example, at one point they reach a point in phase two when they are unclear on how to handle a complex multi-stage ventilation and build. Team E spend a large amount of time bouncing suggestions between the captain, map person, and FAB on how to proceed, but without a clear direction about their primary goal or objective. It is clear that the captain and FAB both have relevant expertise and experience to provide ideas, but they never cohesively arrive at a baseline plan with common goals. Instead, they simply acknowledge they need to move forward and then begin chipping away at the overall problem with small steps that they can agree on. As they start to implement parts of the plan, they continually have people in the background having side conversations about what they are actually doing and what that means for their overall solution.

Finally, Team D appeared to attempt a more decentralized or participative approach, inviting many members to weigh in as they explore and plan. The team does this rather unsuccessfully, though. As a result, they ended up relying heavily on only the FAB because he possessed the most experience and was vocal about taking control when the team got off track. Even this, however, is marked with confusion as the FAB lacks authority to direct the team to complete his plans, the captain tries to interject and evaluate without clear understanding of the objectives, and the team ends up having multiple disputes about what they are and should be doing, which impairs productive resolution to the arising problems. This type of confusion is repeated throughout their exercise. Despite finding an adequate solution to meet the field objectives, the team does make critical mistakes because of misinformation and confusion. They resolve this tension by having one of their team leaders, either the captain or FAB, step in and decide their path.

In general, Team D tried to regroup to explore a wide variety of perspectives when they encountered new issues; however, they lacked the process clarity and experience to drive this approach. As a result, they tended to devolve into confused cross-talk and arguments, until either the captain or FAB decreed the direction to move forward. This limited their ability to capitalize on these different ideas and considerations because in the end they simply adhered to one plan.

Any value potentially generated by these group discussions is lost because of their disorganized attention and integration.

Team characteristics enabling approaches

As expected, the layout and recognition of the team's expertise influenced both the approach the teams used to solve the problem, as well as their success in completing the problem. However, it was not simply that the top performing teams had uniform characteristics; rather, the top teams modified their behaviors to best use their strengths or mitigate their weaknesses. In fact, recognition of the experts was a major factor in whether a team could successfully execute their approach. If a team recognized who the experts were, they could approach the problem to best use their knowledge layout. In that way, the overlap and similarity of expertise mattered, but only to the extent that it matched with what the team was trying to do. For example, the high performing teams were all moderate to high in expertise similarity – meaning they tended to overlap in their skills. However, they varied in recognition, with Team A having high expertise recognition, Team C having a moderate grasp of where expertise was located within the team, and Team B having low recognition. As such, Team A and Team C used a subgroup approach because they were able to efficiently divide resources between those who had the relevant expertise. Team A's high recognition enabled them to seamlessly divide and execute, while Team C's moderate recognition did manifest in their more frequent necessity to regroup and verify before continuing. In contrast, Team B defaulted to relying on their FAB to drive the generation and implementation of the solution. Their FAB was highly skilled, in general, and despite having a weak concept of how expertise was dispersed amongst the team, the team used a centralized approach because they were confident in the FAB's ability.

Further, having recognition developed by familiarity was more important than simply architecting teams to have the proper coverage and giving them routines to complete their work. Both Team A and Team C were high in expertise similarity, and this similarity resulted from prolonged exposure and working together consistently for years. Teams A and C showed that building schemas and routines through prolonged exposure and practice were likely better predictors of success.

In contrast, the low performing teams had weaker recognition of their expertise, with Team E having moderate recognition and Team D and Team F having low expertise recognition. Without a clear understanding of the knowledge layout, these teams could not efficiently divide the work using the productive subgroup approach. Even those teams that recognized this and instituted a more centralized approach tended to have more discussion and confusion in relying on the central team member. This lack of recognition was particularly harmful to Team D; their lack of recognition manifested in the team having multiple debates about solutions with no system for making decisions based on relevant knowledge. Further, their team actually was very different in skills – being low in expertise similarity – but because they did not realize this dispersion, the group solicited ideas from everyone and spent time weighing erroneous plans.

Finally, in the model, influence facilitates the ability of the teams to put their expertise into a productive problem-solving approach. Teams who had a clear agreement prior to the competition of who had the most influence were more likely to align their approach consistent with those leaders. For example, Team A clearly identified their captain and FAB as the highest influencers of their solutions and rated themselves prior to the competition as very good at coordinating their different expertise into a cohesive solution. Alternately, those teams that misjudged their initial influencers tended to falter. For instance, Team F's assessment of team leaders prior to the competition varied widely from those members that actually had the most part in driving the solution. The discrepancy in this influence judgment resulted in discord among the members during the competition; they struggled with deciding what to do and in accepting that the correct actions were being used.

Behaviors supportive of theoretical model

In pursuit of more insight into the nuances of model, these teams also highlight how the high-level behaviors manifested during the competition and impacted the performance: indicative of how the improvisational behaviors correlated with success. In looking closer at what drove the success, I find that it was not necessarily the approach they used, but rather how these approaches allowed them to do a few key actions that separated out the high and low performers. In some cases, teams used these actions to get back on track when they were having issues, but both the high and low performers attempted them to varying success. These actions related to productive problem-solving, regardless of what approach the team used overall. The most important behaviors in response categorized with the identification and experimentation behaviors derived theoretically. As previously noted, identification and experimentation behaviors differ most substantially from traditional learning behaviors and allow the team to adapt to the constraints in these situations. This more detailed view of how the behaviors were used in this context provide a roadmap in moving forward from this preliminary general, aggregated examination.

Identification behaviors: Creating shared understanding. The first key action that helped teams be more effective during the field exercise was to have a clear process to create a shared understanding of the situation, resources, and how to update that information as it changed. This tactic reinforces and deepens the use of identification behaviors in the improvisation framework:

behaviors that encompass conversations and actions that allow the team to assess the situation, modify or refine their existing understanding of the environment, and build consensus about the state of the team's resources or position. The value of creating this shared understanding was evident throughout the problem-solving; it reduced disruptive conflict that hindered idea generation, as well as the likelihood that these solutions would be based on inaccurate information, which created rework or catastrophic failure.

When the teams were not on the same page, they spent more time arguing about what needs to be done. In addition, keeping all members up to date on the situation and their available resources enhanced the team's ability to plan and evaluate, particularly on the fly. When teams consistently had up-to-date information, they could formulate ideas immediately without additional gathering. For instance, the necessity of sharing understanding was evident when Team D (27:55) reached an impasse in the first phase and the team attempts to generate ideas for how to resolve. Eventually, the captain halts the proceedings, telling the FAB "…we're all confused here. You need to repeat what you said so we can all get on the same page." Through this clarification, they realize each is operating with a different understanding of how many building materials they have, which would directly impact their plans – and the others ability to evaluate it. By communicating the accurate resource plan and situation, the team is able to quickly agree on one path forward.

Productive instances of this action included all team members, even if they were not actively engaged in the plan. The teams that had the most success consistently used this process throughout the competition, making sure that every team member was on the same page as they moved forward. This proved valuable, not just for the members actively engaged in planning, generating ideas, or executing the solution. Team C was particularly adept at this tactic and it proved beneficial during an initial water encounter in the first phase of their solution. They began to implement a ventilation plan (36:20) that was primarily driven by the captain and FAB but are stopped prior to executing by their gas person who raises an issue with the location of some wires. This saves the team from overlooking a detail that was not involved in the plan but could have been detrimental to their outcome.

Having a consistent process for providing these updates was also key. The teams that did these actions the best were those that made sure the information was both raised and integrated systematically. As expected, teams used multiple ways to accomplish the creation of shared understanding: either through clear dictation from the relevant leader or through system of repetition and confirmation. Team E primarily relied on announcements from the co-captain; these announcements were mostly informational or transactional (e.g. confirming where on the field everyone was located or what they were doing). Team C also had centralized direction, with the captain frequently announcing their situation and intentions; however, he took it further by asking for explicit acknowledgement and confirmation before continuing. Team A, on the other hand, was very vocal among all members about sharing any new information. They had a process of repetition where the information would be announced, repeated by the co-captain who liaised the information, and then confirmed by the issuer to ensure accurate communication and correct assumptions. The high performing teams tended to have an upfront discussion, or predetermined plan, about the way they were going to attack the problem. These upfront agreements helped to streamline communication and institutionalize the procedure as a routine part of the changing process.

Identification behaviors: Explicit agreement on process, goals, and priorities. The explicit agreement of goals and priorities was just as critical because these changed throughout the problem. High performing teams used this explicit agreement to effectively manage changes in the situation – particularly extreme deviations from prior trajectories – as well as resolve any disagreements when teams were in conflict about the task or process. In addition, explicit acknowledgement or setting of goals and priorities was frequently used as an anchor for conceptualizing their plans and ideas moving forward. When goals and priorities were detailed, it served to create boundaries for the team members' following discussions so that the ideas were not as scattered or unrelated. In that way, the teams were generally able to focus their following discussions more specifically, and to understand which tasks and ideas should be dealt with first. To achieve this, typically, one or a few members would step in to identify the tasks that were directly necessary to accomplish or identify the order in which the tasks should be accomplished. Particularly successful leaders also provided some rationale for these assignments, which helped strengthen the benefits of creating a shared understanding.

For instance, Team A (51:40) is halted when trying to find a way that they can ventilate a barricade with what materials they have or have encountered for use. The captain starts to generate ideas, but the FAB stops him to lay out their objectives: "We're going to have to ventilate [another portion] first…we have to send only irrespirable over the battery….get some more timbers." The captain then limits his idea generation to plans that helps achieve these goals. It also allows the other members to get involved, because although they do not have expertise in the ventilation, they are able to contribute ideas about retrieving the necessary materials.

Alternately, when goals are not clearly explained, it leads to disruptive actions, confusion, and often rework. For example, Team D during the third phase was having difficulty implementing a final execution because the members were each doing different, disconnected and potentially interfering actions. At this point (1:19:12), the captain yells, "Holy shit.

Everybody get over here and get together! Steve, what *is it* you want us to build." In sorting out his frustration, the team realizes they are trying to implement different builds because the members do not have a clear understanding of the purpose of their actions. In order to resolve this, the FAB has to provide discrete instructions to move forward, still without explicating the overarching goal.

Experimentation behaviors: Modifying plans without disruption. High performing teams had a process for acknowledging and integrating new information to modify the next steps without disrupting the current execution actions, as long as the current plan was still generally productive. This means, not that the teams would continue on an unproductive path, but rather, they were able to effectively anticipate how changes to the situation – either through their actions or from uncovering new information – would affect their underlying solution and try to resolve it as seamlessly as possible. In this way, the team would be able to efficiently build their solution, while avoiding rework or disaster from faulty solutions. This behavior was exemplified by the planning members (i.e. co-captain and FAB) in Team A's approach. Similarly, anticipation was key for Team C's success. They also keep a base plan to work towards, but their FAB is continuously updating information in the background pointing out shifts on the map. One concrete outcome of these updating is their handling of materials. Unlike some teams, Team C consistently plotted where they might need building materials or where they anticipated finding some, and they were spared from retracing their progress to pick up or recoup them (17:00-19:30).

When the changes were relatively minor, the teams could continue with the general direction of their plans, making adjustments on the fly, which allowed them to keep moving forward in the solution even when they did not have the full picture. The effectiveness of an on the fly approach was facilitated by the ability of the team to anticipate and predict upcoming goals and issues. The success corresponded with the ability of the team in setting goals, explicitly acknowledging them, and then anticipating how those goals would change. These actions helped reduce the likelihood that the teams would generate ideas and execution plans too far ahead without having adequate information to justify those decisions.

This stands in contrast to the modification processes used where the team has to reevaluate their approach after every move or where the team tries to impose their plan regardless of the changing situation. For instance, Team E during the second phase realizes that their initial plan is not going to work (51:00) because they did not consider certain areas of the field, but these changes do not alter their overall strategy for how to meet the objectives. In response, they incrementally adjust the plan, stopping after each step, rather than having a parallel updating process. These gaps highlight an inefficiency in this process, as they spend time updating their solution, realize they could at least start implementing with the existing information, and then stop again to work in small batches.

Continuous modification also guards against the pitfalls that occur when modification is done in large batch processing, such as the tendency of Team B. For example, in the third phase the team has completed all possible exploration and cannot gather any more information (1:07:20). At this point, the FAB indicates that he “might have something but it’s at least a three-parter” signaling the complexity. The FAB provides this multistage idea, which the team begins to implement. However, because they create these complex, dependent actions, they end up doing a lot more tear down and rebuilding than other teams who adjust as they go along. These efforts require them to expend time retracing their path and energy managing the coordination of the moving parts that other teams were able to do in line. Team B continually tries to make the big picture solution work by adding on additional patches, rather than adjusting slightly to make the trajectory viable and efficient.

Experimentation behaviors: Strategic regrouping. Finally, the teams that were most effective in finding a solution during this competition were capable of distinguishing when they should drastically alter their plans, regroup by instigating a full team examination of the situation, goals, and then moving forward with whatever approach the team was using. The highest performing teams were able to determine the appropriate time to regroup based on their underlying approach to solving the problem; there were not necessarily set optimal points at which to do this. For example, Team A which relied heavily on a continuous dual stream of planning and execution used these discrete regroups primarily after the first and second phase of the solution; these points were clear that they needed to drastically update or create a new baseline plan to meet the next set of objectives. During the phases, they were more likely to defer to the planning team of the FAB and co-captain when adjustments needed to be made (bringing in the others when they needed additional validation).

In contrast, Team C used regroups as soon as they identified the potential for a new solution trajectory. They much more frequently stopped and brainstormed updates to the plan, even if it was simply to validate the captain’s proposed plan on the map with the whole team. Their regroups tended to be more discrete and inclusive than Team A, who tended to prefer updating on the fly. The most valuable strategic regroups reconfirmed the understanding of the situation, provided an outlet for explicit acknowledgement of goals and priorities, and afforded an organized way for the team members to bring information and ideas to light. In doing so, the team set the boundaries of the discussion and helped to limit unproductive distractions.

Despite recognizing the benefit of regrouping, the low performing teams tended to misfire in these discussions which either harmed their solution or added no value while taking up time. For instance, Team D frequently used group huddles when they were uncertain about what to do. However, their grouping was often unproductive; they did not use them to achieve a specific purpose, often leading to confusion about what ideas were useful with all members talking over each other because there is no clear indication to whom they should defer. In one case (36:15), the FAB, being the most experienced, ended up getting angry and cutting off continued discussion, "Let's stop and see what we got! Let's settle down a minute. Y'all *listen to me* when I'm talking!" After which, all discussion stopped and the team never attempted to continue the exploration of their ideas deferring to the FAB without any evaluation; this idea coming out of this regrouping eventually had to be redone to continue the solution.

The value of these regroupings were undermined, in addition, if they simply rely on one person. When done well, regroups reduced the chance that the team would rely solely on one perspective to generate a solution without explicit confirmation. For example, the captain on Team E called the group together to discuss an idea (41:00), but cuts off questions beyond confirmation that they are listening. Ten minutes later, the team is still laboring with the same issue and they end up discarding their whole plan. The time and effort utilized for this brainstorming were wasted.

Finally, teams that did this strategically were able to mitigate splintered conversation or plans. Often, low performing teams endured side discussions or questioning of the direction of the team. Regrouping allowed everyone to voice their perspectives, raise questions to reduce confusions, and improve understanding and buy-in to aid in coordination. For instance, Team C who effectively used a captain-facilitated process to encourage input at strategic junctures, frequently and explicitly encouraged its members to bring ideas and concerns to the forefront. In fact, the captain highlights (26:40) in one circumstance where they spent unnecessary, additional time generating a solution after the FAB states he thought of that, but "talked [himself] out of it." The captain points out that next time he should voice his opinion to expedite brainstorming and implementation. In future brainstorming sessions, more members are vocal in providing ideas.

Summary comments on qualitative examination

This closer look into the actions of six teams solving the same problem indeed provides a more nuanced view of the complex interactions. The underlying relationships between the team and their improvisation process may be dependent not just on their initial preparation and structure but by more complex cycles of improvising than is reflected. The key actions tend to align with the categories derived from the learning cycle – creating shared understanding (identification), explicit agreement on process, goals, and priorities (identification), modifying plans without disruption (experimentation). Despite this alignment, the way in which the teams actually performed the behaviors in solving the problem provides confirmation that the underlying improvisation process is more complex and nuanced than may be represented simply by considering the higher-level categories in aggregate. When teams perform those actions more effectively they are indeed better performers. This is in line with the quantitative findings; higher quality improvisational behaviors was predictive of better performance. However, the choice of approach is not sufficient to predict performance fully. Instead, these behaviors should be used in support of routines that maximize the expertise and influence structures of the specific team.

This finding then has ramifications on how teams should prepare for these unexpected, time-pressured events. By looking at the way that teams use these behaviors together in conjunction with changes in the situation, it may be that to prepare actually requires additional alignment between their structure and their nuanced approach. In fact, this qualitative examination supports the notion that team structures may indeed impact how the teams carry out these improvisation behaviors: the makeup of the team did correspond with the different approaches to solving the field exercise. Teams with a clear division of their experience and expertise were able to use their recognition strategically; the teams that aligned their approach with these characteristics were able to perform the best. Teams that had only a few experts or were unable to accurately identify who those experts were tended to rely on a centralized approach. Recognition of both expertise and influence also provided a clear predictor for whether the teams would be able to coordinate this knowledge effectively and productively in finding a solution.

Therefore, this provides guidelines for moving forward in considering how teams should use the structure to prepare for effective improvisation. The structure may not just drive the behaviors, but rather should lead researchers to consider how teams vary in both the approach and the rhythm of these behaviors during the process. In order to adequately describe how teams should prepare, their structure should be customized to consider how the characteristics give rise to different approaches. Success is determined by the extent to which the team is able to use their characteristics to enact these behaviors within their chosen approach. These observations can be taken in conjunction with the quantitative study to indicate that there is value in enumerating the different approaches used beyond the high-level improvisational behaviors to truly understand how expertise and influence impacts improvisation.

Theoretical Implications

This granular process view and competition setup allows this study to make multiple contributions to the extant organizational literatures. Despite the frequent, casual references to improvising across settings, the lack of precision in the development of the process has limited how the topic can be applied or examined. By situating improvisation in the broader knowledge creation literature through delineation of behavioral activities devised from both improvisation and learning process research, this study unites multiple tangential concepts to provide a more complete and robust picture of the phenomena. This framework can be used to examine improvisation as a process by delineating the specific behaviors and actions necessary to respond, rather than the predominant examination of improvisation as a generalized skill for teams and organizations (e.g. Vera & Crossan, 2005; Miner & Moorman, 1998b).

By identifying relevant components of the different knowledge creation constructs, and merging their findings, I advance knowledge in the separate fields of research, as well. Recent reviews in the improvisation literatures call for more nuanced and dynamic understanding – and empirical tests – of how the concept unfolds and antecedents to the process (e.g. Leone-Ludovica, 2010). Further, prior empirical work has been retrospective, looking at the general abilities of the teams based on how they feel about their abilities after they improvise (e.g. Moorman & Miner, 1998b; Vera & Crossan, 2005). However, this may obscure systematic appraisal of what teams are doing during an unexpected event. By actually looking at situations where improvisation is necessary, this study distinguishes between potentially confounding effects of the decision to improvise and the team's general ability to improvise. By comparing teams that are solving the same problem, this study provides more definitive conclusions about the previously equivocal direct relationship between improvisation and performance.

Similarly, recent reviews in learning have identified the need for greater identification of the constraints in specific contexts in order to advance team learning research (e.g. Edmondson et al., 2007). Further, recent learning reviews (e.g. Sanner & Bunderson, 2015; Cronin &

Bendersky, 2012; Cronin et al., 2011) emphasize that context matters and can account for a significant amount of variance in the effects of antecedents on different types of learning. Environments where improvisation is frequently needed are becoming more prevalent, and therefore, there is increased importance in having insight into how teams can manage successfully in them (Hackman & Katz, 2010; Ilgen et al., 2005). Without consideration of the environment in which effects are taking place, prior research produces an incomplete picture of how these factors impact learning and performance.

This study expands what is known about how team structure, particularly specialized forms of expertise, hierarchical patterns, and roles impact the ways teams undertake novel production, particularly in unplanned, time-constrained events. Most notably, this work provides a meaningful extension of the rotational leadership literature and the importance of dynamic influence structures in teams. This study expands on the role of expertise overlap and recognition to a new context outside of existing studies in the laboratory, furthering the use of dynamic influence patterns as a way to promote innovation (Aime et al., 2014). Rotational leadership had the biggest effect in driving a team's ability to improvise, having both a main effect on improvisation and moderating the two-way interaction of expertise similarity in observer-rated behavior and the three-way interaction of expertise recognition and expertise similarity in self-reported behavior. Coordination plays a large role in both improvisational examinations and in the crisis management literature (e.g. Rico et al., 2008; Vashdi et al., 2013; Bigley & Roberts, 2001), and so perhaps unsurprisingly the mechanism that provides a template for productive interaction and enactment of resources is extremely valuable in these unexpected and uncertain situations.

As predicted, teams benefit from the dynamic influence allocation that a rotational leadership scheme provides. This finding provides evidence for the need for a dynamic understanding of emergent, adaptive coordination in teams engaged in knowledge work, rather than a static leadership structure (Okhuysen & Bechky, 2009). This lends support to the fact that there is value beyond simply allowing all team members to have a say in the solution; the performance is enhanced by the dual informational and coordination benefits of changing to relevant experts.

This study extends knowledge on the applicability and importance of rotational leadership in crisis situations: giving a more realistic view of how influence changes in situations where timing and coordination must be managed explicitly. This dynamic conceptualization shows one avenue through which teams can manage the necessity for novelty and efficiency using real-world, established teams. This field study, conducted with teams that are persistent, long-standing and with an organizational context in which to base their determinations of expertise and influence, extends prior laboratory based research to consider how these structures in context affect team functioning in a specific situation beyond traditional, static models of leadership.

Practical Implications

The clearest managerial implication of my dissertation is that teams can benefit from enacting certain behaviors during crisis situations in order to improve the likelihood that they will produce an effective response. A common refrain when discussing improvisation across contexts is that merely improvising does not guarantee success in responding to unexpected challenges (e.g Vera & Crossan, 2005; Moorman & Miner, 1998; Fisher & Amabile, 2009). However, this work shows that focusing on productive improvisational behaviors can improve the chances that a solution will be useful. This provides a framework for teams for the behaviors they should use when improvising in order to affect success.

Moreover, this provides a roadmap for how crisis teams should integrate interaction schemes that enhance their knowledge layout in their preparation. As suggested in prior studies, teams use cross-training and specialization frequently to ensure that their team has the proper knowledge to deal with unknown problems in these situations (e.g. Bechky & Okhuysen, 2011; Majchrzak, Jarvenpaa, & Hollingshead, 2007; Wilson, Burke, Priest, & Salas, 2005). However, this research suggests that it is equally important to consider how they will use that knowledge during responses through leadership and interactions. Teams should consider how their knowledge is situated and adjust their interaction schemes to best enhance the quality and efficiency of their actions during improvisation. For example, teams that rely on subgroups should work to enhance their rotational leadership capabilities, developing expectations that situationally-relevant experts will take the lead and then preparing interaction patterns to facilitate those transitions. However, teams who have high redundancies in expertise benefit less, suggesting these teams may not benefit from changing influence and may be able to just as effectively solve the problem by developing on consistent leadership. Overall, teams should expand their training beyond simply building knowledge to strategically developing this stock and using it productively in real-time.

Concluding Comments

Improvisation is a vital part of organizational life, particularly those in which teams must respond in crisis situations. When improvisation is done well, teams can be more successful in effectively managing the situation, but prior to this study there was limited examination of precisely what it means to improvise well or poorly. However, in this study I have moved the literature forward in identifying the critical actions of improvisation by which teams are able to respond to an event by identifying, reflecting on knowledge and frames held within the team, and strategically experimenting to generate, evaluate, and implement responses in a short timeframe. Further, I combine knowledge from a number of improvisation, learning, and crisis management examinations to identify antecedents that would allow teams to best prepare these spontaneous and improvised actions when the opportunity arises.

Despite, the non-significance of some components of the hypothesized model, the data contributes to multiple literatures including work in improvisation, learning, and team structure. This provides avenues for future research that underscores the relationship between expertise and coordination, particularly in unpacking the role of rotational leadership as a structuring pattern for effective improvisation and applying this framework outside of crisis management. This study is only the beginning in understanding the real-time dynamics of improvisation. Although I consider how dynamic leadership schemes set up productive team behaviors for improvisation, there is room to expound on how the changes in decision-making and the content and alignment during the process impacts both team outcomes and their preparation for future events. Future research should look more closely at other aspects than just the underlying behaviors of the improvisation process during the event to continue to understand the process.

In addition, more research would help to understand whether these relationships are pertinent to any improvising team or only those that face high pressure, dangerous situations such as those faced by critical action teams. Other types of action teams that must similarly create novel outcomes in material convergence with the planning, such as performing teams, may place different importance on the necessity to coordinate. The relationship between improvisational behaviors and performance should extend to teams that are improvising in any situation, from crisis scenarios to those that are using it as a planned entry into a process (e.g. "concepting" sessions in advertising); all forms of improvisation are united by the need to balance novelty and efficiency.

Finally, although this model was designed to extend to any improvising team, the optimal use of the improvisational behaviors, and therefore the configuration of the structure necessary to provoke those behaviors may vary depending on the specific situation, even if the overall quality of these activities drives success in all contexts. For example, Crossan and colleagues (2005) categorize improvisation by the extent that teams must manage outcome uncertainty and time pressure. In those situations where time pressure is low, teams may need to place more emphasis on generating creative solutions during improvisation, rather than responding to the immediacy of the problem, which may change how teams need to develop and use their resources. Future work should test whether there are differences in the pattern of behaviors between different scenarios and should validate that the same team structural components of expertise similarity, recognition, and dynamic influence interact in the same way for successful improvisation.

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FIGURES

Figure 1 – Model including hypothesized relationships

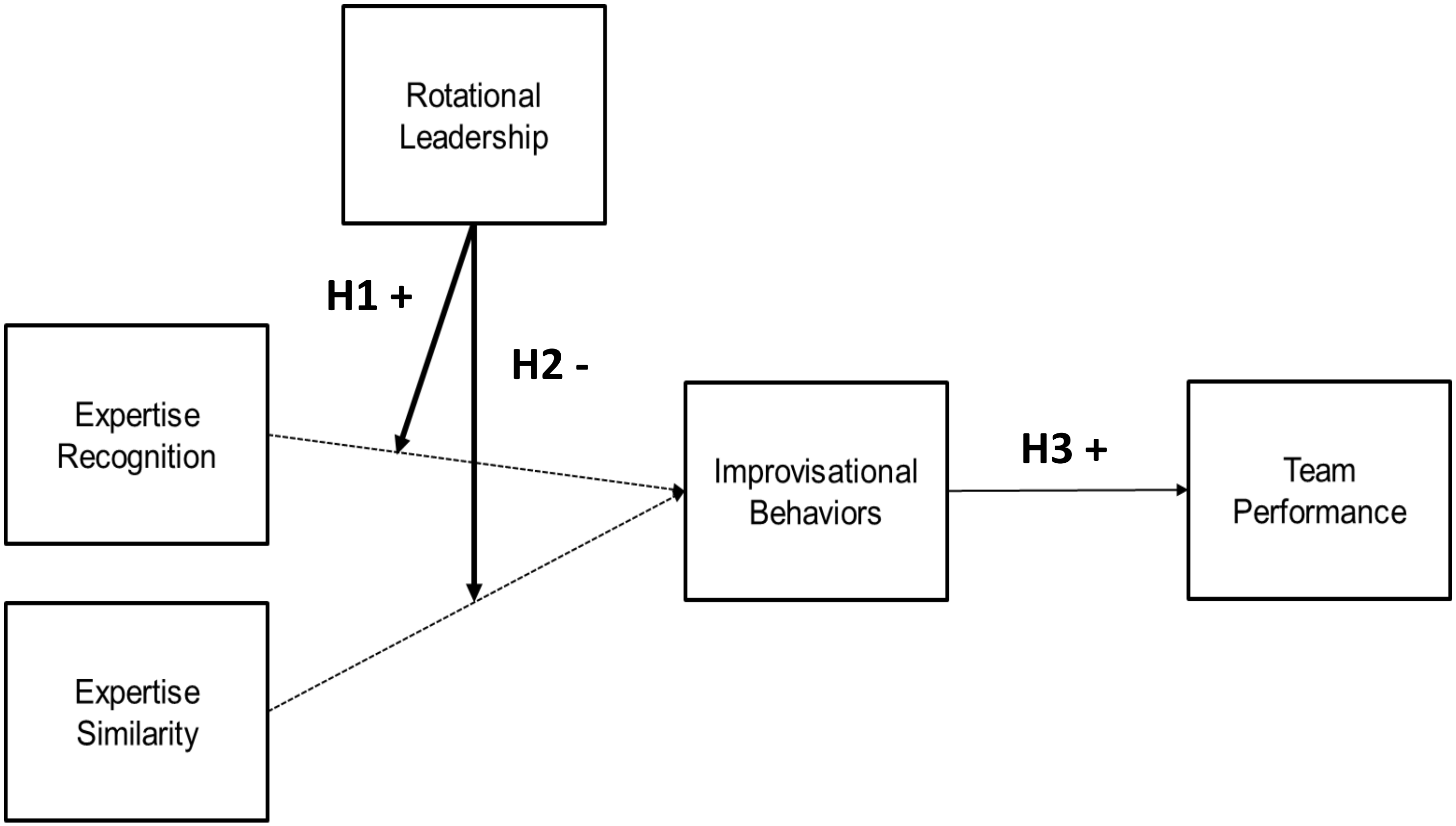


Figure 2 – Proposed relationship for hypothesis 2

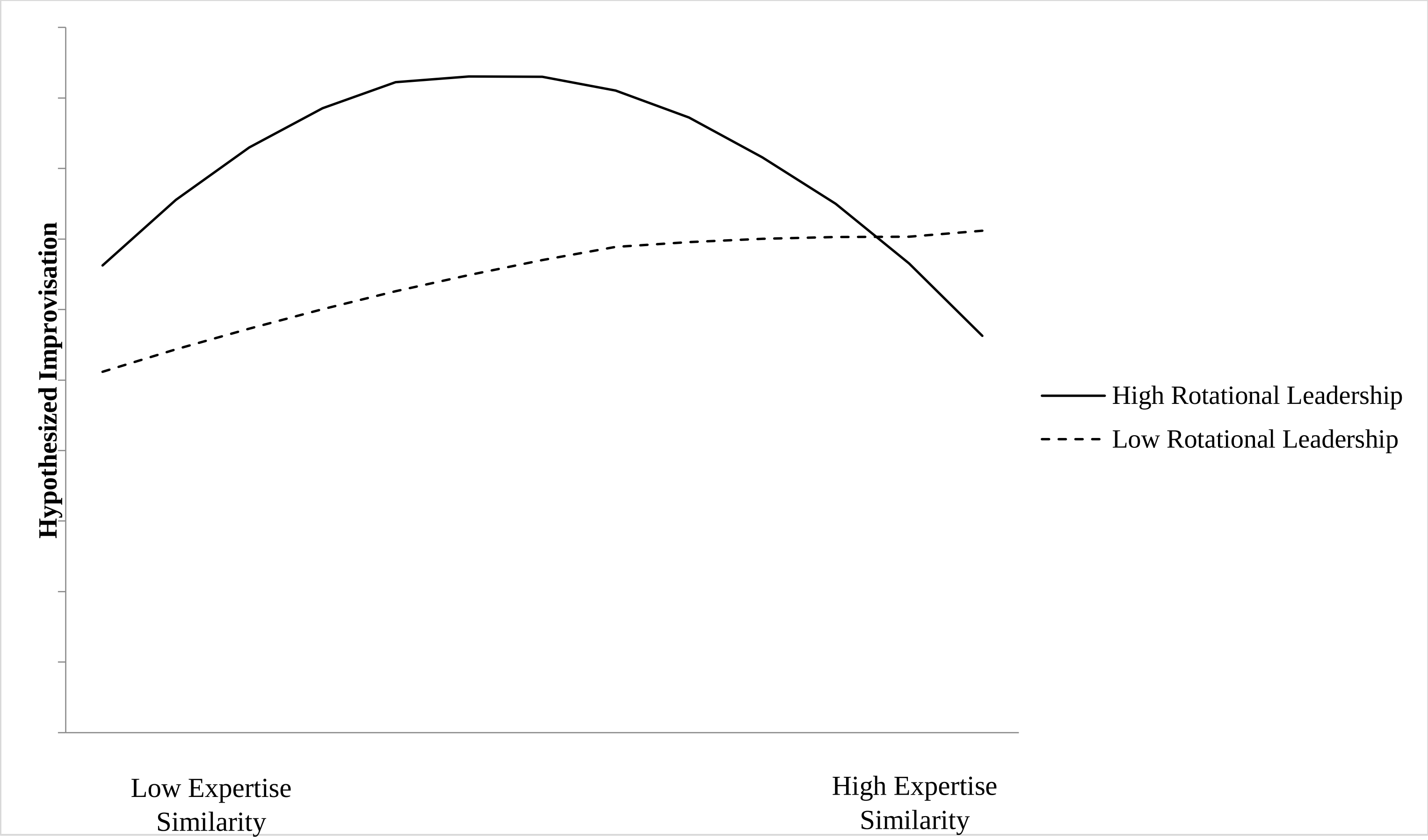


Figure 3 – Relationship between improvisation and team performance grouped by competition

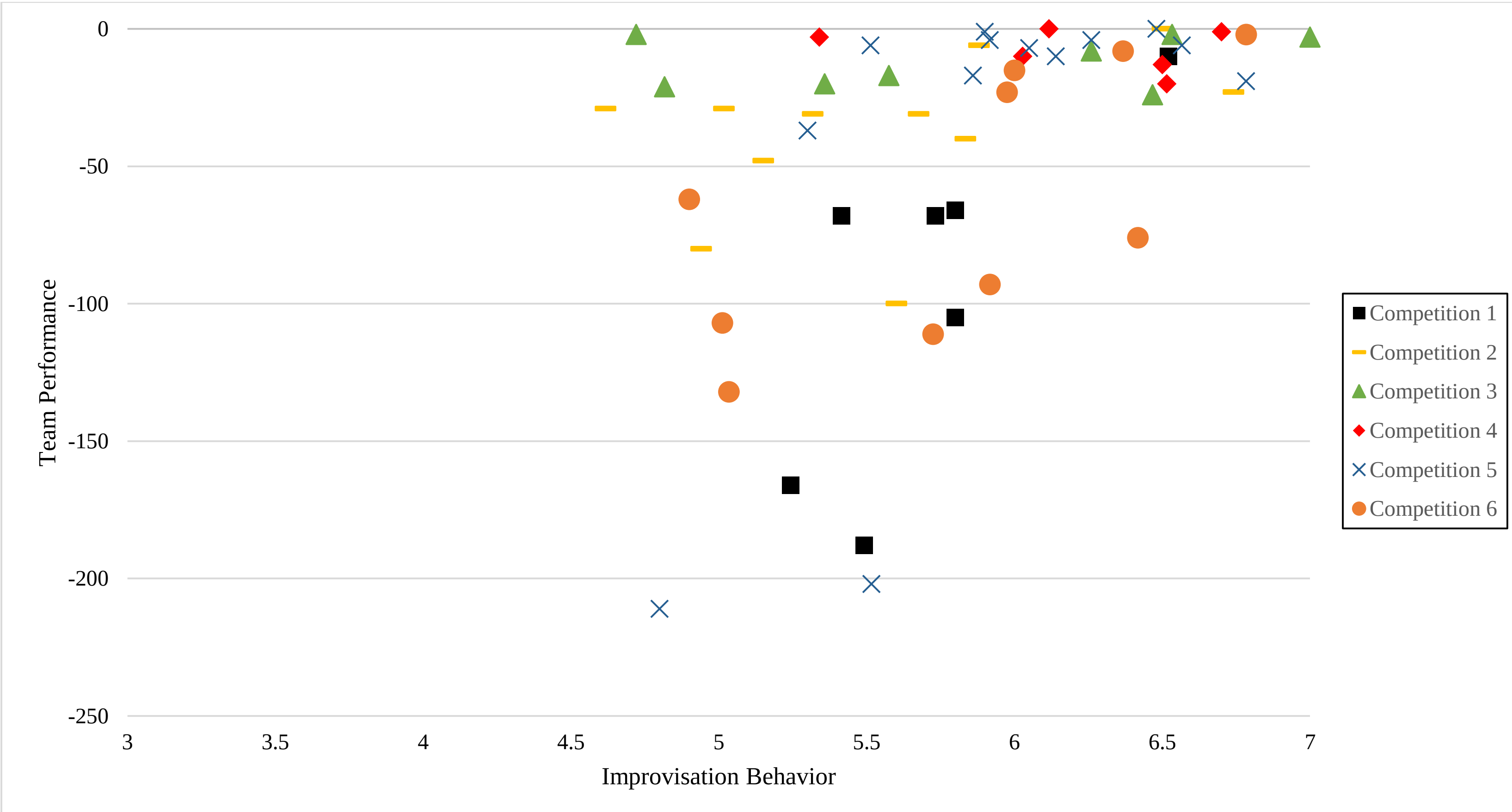


Figure 4 – Relationship between improvisation and performance grouped by average team mine rescue experience

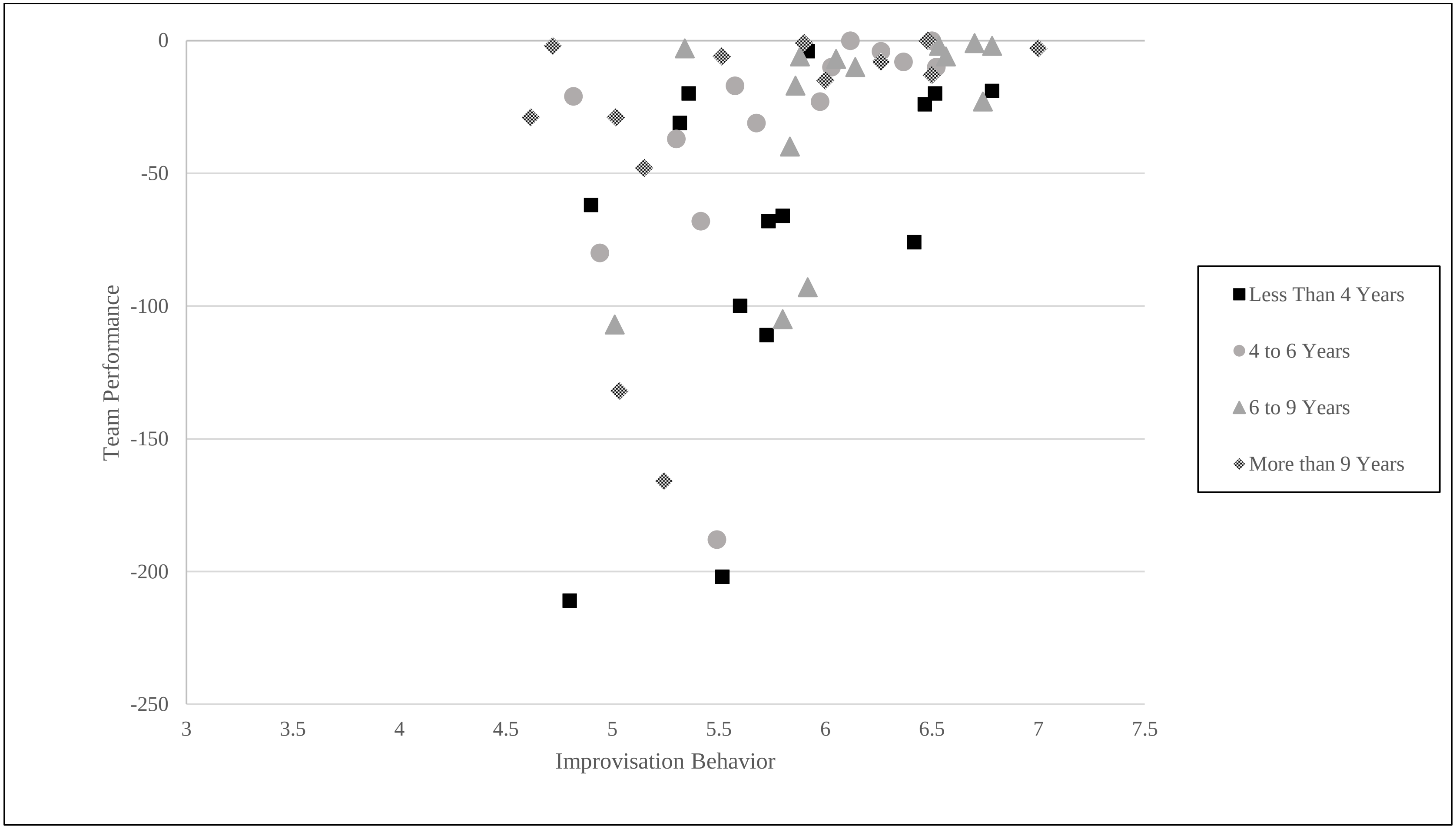


Figure 5 – Interaction plot for hypothesis 3 for observer-rated improvisation

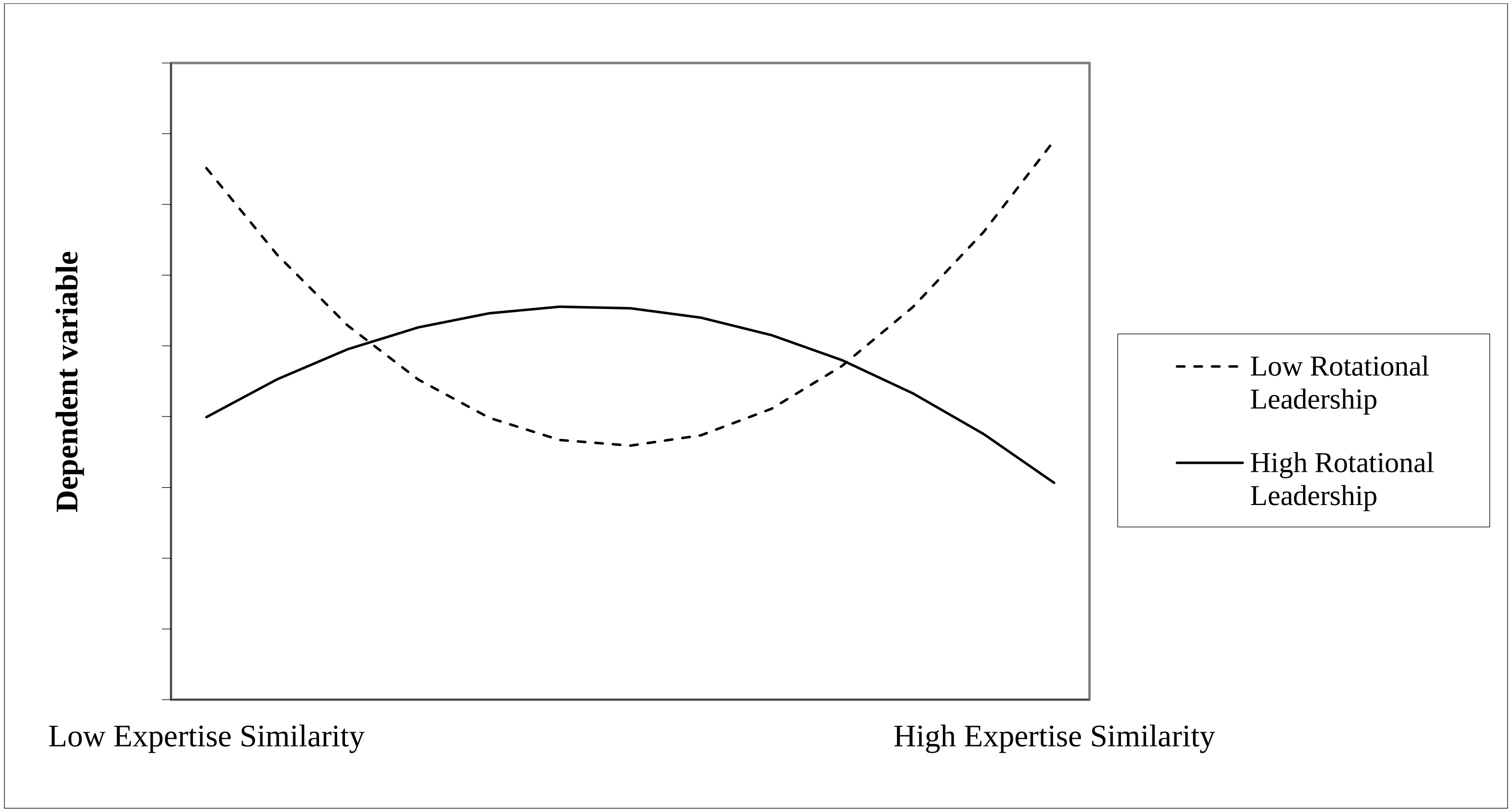


Figure 6 – Interaction between rotational leadership and subgroup formation on observer-rated improvisation

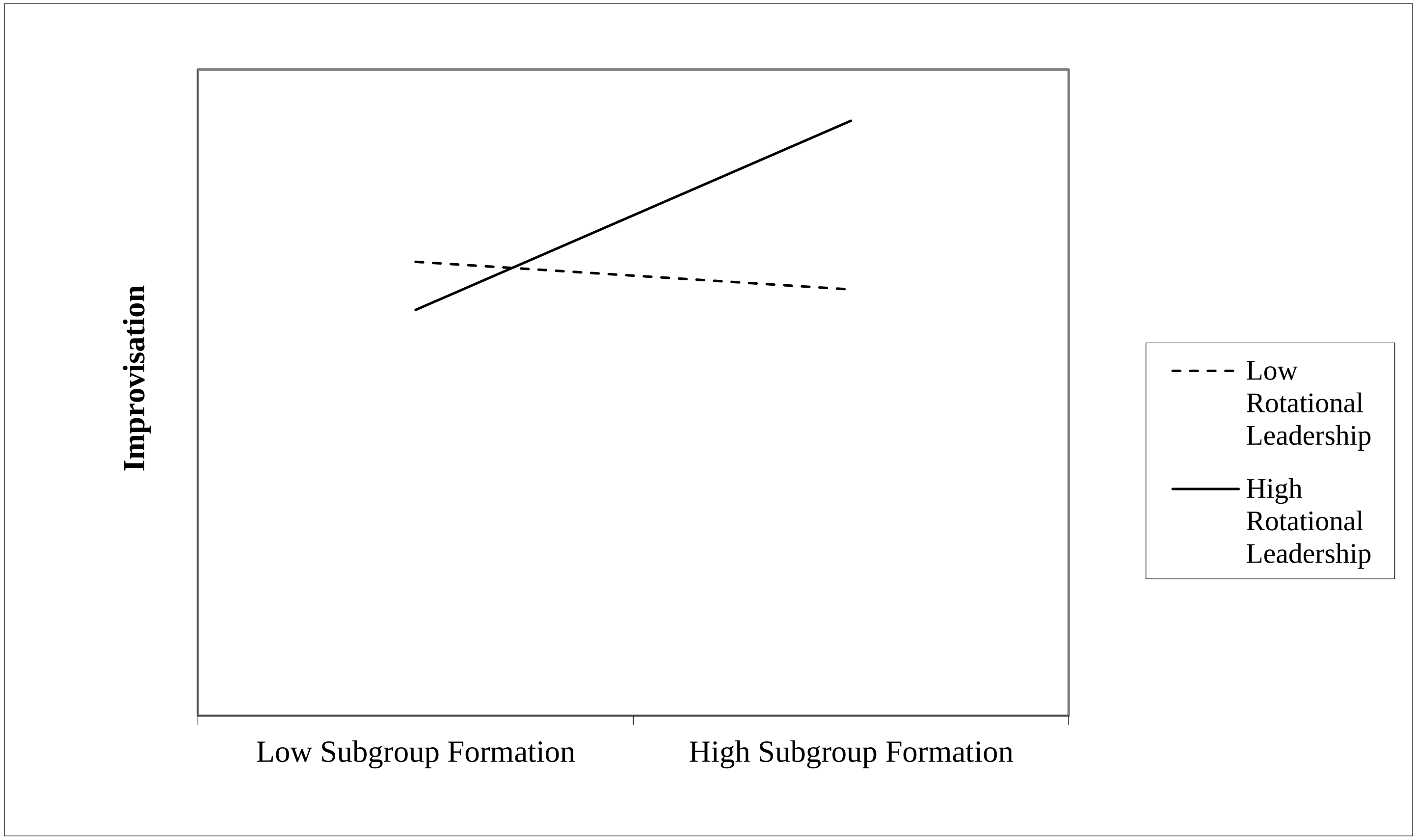


Figure 7 – Three-way interaction effects with high expertise recognition for the self-reported improvisational behavior

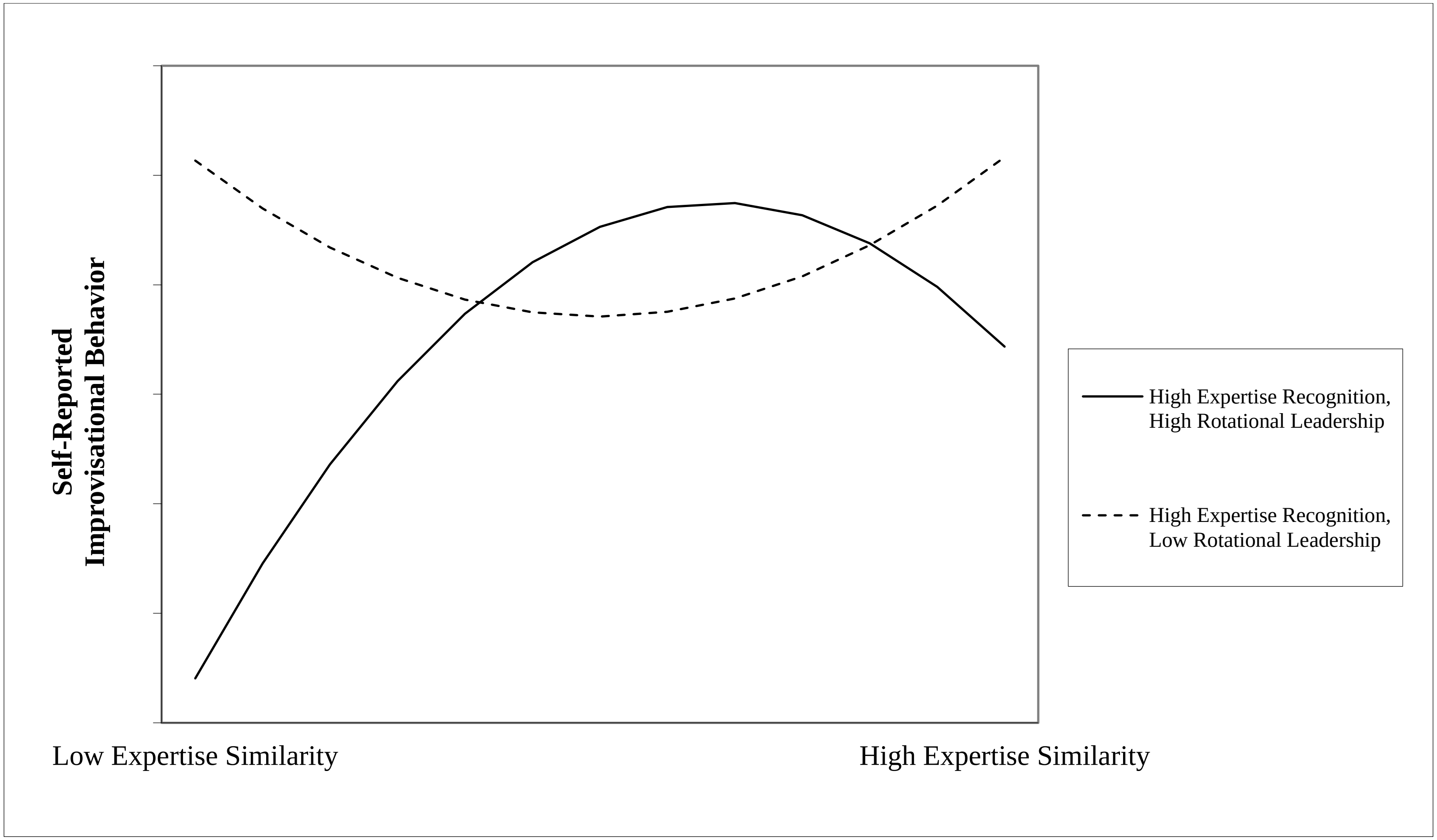
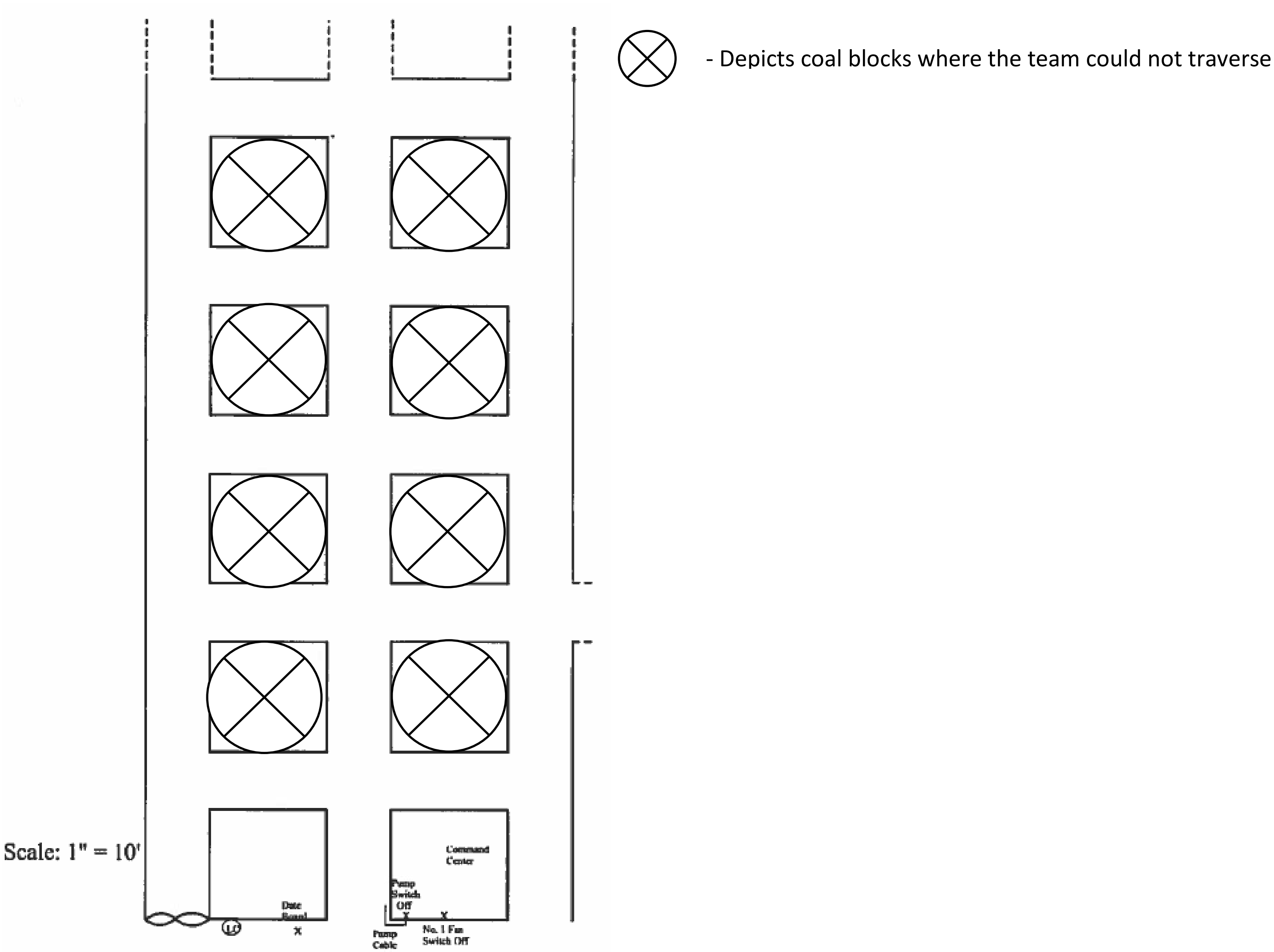


Figure 8 – Map of field layout during competition



TABLES

Table 1 – Team learning behaviors relevant to improvisation and definitions as derived by Savelsbergh et al (2009)

Category	Behavioral Concept	Definition
Identification	Updating of situation	Mutual conversational actions of team members refining or modifying the understanding of the situation in some way.
Reflection	Exploring different perspectives	Conversational actions of team members to explore, share knowledge, opinions and different perspectives
	Co-construction of meaning	Mutual conversational actions of team members by refining, building on, or modifying the original offered meaning in some way to come to new meanings in the collaborative work that were not previously available to the team
	Reflection on processes and outcomes	Collectively discuss the team goals, assumptions, working methods and strategies, checking whether the team is doing the right things and doing things right Collectively look back or ahead on experiences and actions (e.g., by feedback or communicated errors) to evaluate and learn from them
Experimentation	Generating new ideas	Discussing or sharing ideas to move the team forward in the problem
	Evaluating prior to implementation	Discussing and analyzing potential outcomes collectively to assess the idea viability
	Implementation	Actions of the team member that are intended to solve a problem or put an idea into execution

Table 2 – Survey items and count indicators used for the ratings of improvisational behavior

Behavioral Category	Improvisational Quality Items (Scale of 1 to 7)	Improvisational Count Indicators
Identification	- The members of this team identified problems as a group. - The members of this team shifted focus to address new problems as they occurred. - The team discussed the impact on their tasks whenever the situation changed. - The members of this team made sure everyone had the same understanding of the situation.	- Number of times the team acknowledges or builds on information about the current situation; someone highlights changes to the situation or to each other's understanding of the situation, - Number of times the team updates each other on their resources or conditions of their position (not when mapping, but rather to ensure all have same understanding).
Reflection	- The team transferred and combined information between members. - The team used questions and discussion to understand issues. - The team made an effort to understand their teammates' information. - Team members wanted to understand the information others held and how they would apply it.	- Number of times a team member complements or build on information provided from other members; number of times the team collectively draws conclusions based on ideas discussed as a team; number of times team members elaborate on each other's information and ideas. - Number of times the team discusses their work methods, their interaction processes, or their work procedures - Number of times the team discusses their solution, the actions they have taken - Number of times team members listen to each other's ideas, number of times they question information for clarity, encourage a different perspective, gives an opinion on a problem or asks for the opinion of others

Experimentation	- The team generated a number of solutions to problems. - The team discussed potential outcomes of the solutions they generated. - The team focused on avoiding rework. - Team members offered ideas when we encountered issues. - Team members checked each other's ideas to make sure they would work. - The team worked together to evaluate potential outcomes before choosing one. - This team wanted to find the best solution possible.	- Number of times a team member shares a new idea relevant to solving problem or moving forward in process - Number of times the team tests a new method, takes action to solve a problem - Number of times the team discusses what outcome an idea may bring, predict the results of their actions, seek feedback on a potential course of action

Table 3 – Examples of observations from recordings in each behavioral category

Category	Concept and Definition	Examples
Identification	Updating of situation: mutual conversational actions of team members refining or modifying the understanding of the situation in some way.	"Did we take that line curtain? Maybe - we needed to. Yes we have it." "We don't need that extra build because it's closed off behind." "There's explosives here and a cave over there, right?"
		"We picked up a bradish cloth in front of the cave. Now we're carrying two."
		"P1: We've got a line curtain here. Should we pick it up? P2: Yes we can carry it."
Reflection	Exploring different perspectives: conversational actions of team members to explore, share knowledge, opinions and different perspectives	Repetition of a ventilation plan by multiple parties. Clarifying information about placement of explosive sources and discussing how the air flow would work.
		Where are you going to move the air from? Hey, he said we can pull it diagonal. Check with {FAB}. What does he think? "P1: Should we build with this. P2: What materials do we have? P1: There's a couple more laying around that we could build with. What do you guys think?"
	Reflection on processes: collectively discuss the team goals, assumptions, working methods and strategies, checking whether the team is doing the right things and doing things right Reflection on outcomes: collectively look back or ahead on experiences and actions (e.g., by feedback or communicated errors) to evaluate and learn from them	"Alright, talk to me, are we allowed to build here or not? We only have one build, do you think we should save it. Yes, let's wait." "We should do our app check while they figure this out." "What in the world are we doing?"

Experimentation	Generating new ideas: discussing or sharing ideas to move the team forward in the problem	"We probably should build that because there a bradish cloth sitting there. Yeah, let's not leave it sit there." "Ok so we have to go over here. Right now we have the line curtain and 3 timbers. Should we drop the timbers do you think? Yeah let's stretch it over here." "We have a vent over here. Because it's air tight we could try to move the air over here." "Ok. Move the air through here. But there's a battery scoop, nope explosive, nope explosive, exhaust. So is that unsafe on the corner considered explored? Can we take explosive over there then if we're under apparatus." "Take it down and take it with you out of airlock. We might need it. We can tear down at 80, ok tear down at 80. You said just tear it down and rebuild it. No we should tear it down and take it out with you. And then move it over. Ok got it." "We have to build here and here. Where? We don't know what's on the back side. How are we going to build that? It's not going to go through to the door, we'll have to do both on a diagonal..."
	Evaluating prior to implementation: discussing and analyzing potential outcomes collectively to assess the idea viability	"We can't build on the diagonal because it's an overcast. We need a quick advance stop." "Ok here's what we'll do. A diagonal here. Isn't there a battery scoop in there? Then move it up, across, down. Check your map to see if we're picking up anything. So we're doing..."
		"P1: Take it down and take it with you out of airlock. We might need it. P2: We can tear down at 80, ok tear down at 80. P1: You said just tear it down and rebuild it. P2: No we should tear it down and take it out with you. And then move it over. P1: Ok got it."
		"P1: Ok. Move the air through here. But there's a battery scoop, nope explosive, nope explosive, exhaust. **P2: So is that unsafe on the corner considered explored? Can we take explosive over there then if we're under apparatus**? P1: Alright go for it. I think he's got it."
	Implementation: actions of the team member that are intended to solve a problem or put an idea into execution	"Build it there. We're using that bradish cloth to build right there. [completing the build]." "Make the [vent] change, Mr. Judge." "The door to this overcast is now closed."

Table 4 – Descriptive statistics and correlations between variables

Variable	M	SD	1	2	3	4	5	6	7	8	9
1. Mine Site Team	0.69	0.46									
2. Age (Years)	37.20	4.89	0.24*								
3. Education	1.86	1.86	-0.39**	-0.16							
4. Prior Competitions	4.13	1.83	0.08	0.02	0.03						
5. Ave Mining Experience (Years)	13.93	6.15	0.17	0.74**	-0.04	0.13					
6. Ave Mine Rescue Exper (Mos)	77.82	39.47	0.29**	0.62**	0.00	-0.18	0.42**				
7. Team Familiarity (Mos)	77.37	46.21	0.31**	0.56**	-0.28**	-0.20	0.40**	0.62**			
8. Average Expertise	3.90	0.45	0.22*	0.31*	-0.33**	0.04	0.13	0.22*	0.28*		
9. Situational Experience	4.33	0.89	0.15	0.24	-0.06	0.03	0.21	0.20	0.30*	0.17	
10. Competition Difficulty	69.29	10.79	-0.03	0,03	-0.01	0.26*	0.12	-0.27*	-0.20	0.11	-0.32
11. Expertise Similarity	0.88	0.10	-0.12	0.13	-0.17	0.20	0.21*	-0.20	0.11	0.46**	0.02
12. Expertise Recognition	-0.54	0.33	-0.01	0.01	-0.06	0.01	0.07	0.03	0.02	0.21*	-0.02
13. Rotational Leadership	5.82	0.41	0.07	0.24*	-0.23*	0.03	0.13	0.05	0.17	0.40**	-0.21
14. Self- Report Improvisational Behavior	5.89	0.62	0.07	0.11	-0.24	-0.08	0.16	0.11	0.28*	0.38**	0.39**
15. Observer Rated Improvisational Behavior	4.33	0.86	0.01	-0.18	-0.02	-0.28	-0.05	-0.26	-0.02	0.10	0.42
16. Team Performance	-43.65	46.62	0.05	-0.23*	-0.01	0.04	-0.32**	0.14	-0.04	0.26*	0.07
17. Performance Time (Mins)	66.62	13.76	0.04	0.06	-0.11	-0.17	0.14	-0.03	-0.05	-0.20	0.01

$^{*}p < .05$, $^{**}p < .01$, N= 58 teams

Table 4 (cont'd)

Variable		10	11	12	13	14	15	16
1.	Mine Site Team							
2.	Age (Years)							
3.	Education							
4.	Prior Competitions							
5.	Ave Mining Experience (Years)							
6.	Ave Mine Rescue Exper (Mos)							
7.	Team Familiarity (Mos)							
8.	Average Expertise							
9.	Situational Experience							
10.	Competition Difficulty							
11.	Expertise Similarity	0.11						
12.	Expertise Recognition	-0.14	0.10					
13.	Rotational Leadership	0.10	0.33**	0.13				
14.	Self- Report Improvisational Behavior	-0.30*	0.32*	0.20	0.31*			
15.	Observer Rated Improvisational Behavior	0.16	0.15	0.09	0.04	0.50*		
16.	Team Performance	-0.34**	0.02	0.22	0.15	0.4**	0.33*	
17.	Performance Time (Mins)	0.21*	-0.15	-0.19	-0.20	-0.33*	0.11	-0.34**

Table 5 – Models for hypothesis 1 for both self-reported and observer-rated improvisational behaviors

Variable	Team Performance			
	Self-Report Improvisational Behaviors		Observer-Rated Improvisational Behaviors	
	Model 1	Model 2	Model 3	Model 4
Constant	97.76*	127.88*	168.29**	311.94**
Controls				
Competition Difficulty	-1.93**	-2.29**	-2.99**	-3.13**
Main Effects				
Improvisational Behavior		22.95**		31.16**
Log Likelihood	-475.13	-274.65	-116.40	-110.87
df	185	106	45	40
ΔLL		200.48***		5.53*

$^{+}$ $p < .10$, $^{*}p < .05$, $^{**}p < .01$, N = 63 (self-report), 31 (observer-rated)

Table 6 – Models for hypotheses 2 and 3 tests for self-reported improvisational behaviors

Variable	Self-Report Improvisational Behaviors										
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10	Model 11
Constant	7.14**	5.70**	5.82**	5.61**	5.37**	5.44**	5.36**	5.35**	5.42**	5.37**	5.39**
Controls											
Competition Difficulty	-.02	-.01	-.01+	-.01	-.01	-.01	-.01	-.01	-.01	-.01	-.01
Situational Experience		.23**	.22**	.23**	.28**	.27**	.28**	.28**	.27**	.28**	.27**
Main Effects											
Expertise Similarity			.19**	.18**	.11+	.12+	.12+	.11+	.13	.08	.12
Expertise Recognition				.08	.06	.02	.06	.05	.01	.07	.06
Rotational Leadership					.20**	.20**	.20**	.20**	.20**	.19*	.09
Expertise Similarity Squared										-.02	.01
Moderators											
Expertise Similarity * Expertise Recognition						.10			.09		.03
Expertise Similarity * Rotational Leadership							.01		.01		.18
Expertise Recognition * Rotational Leadership								-.03	-.02		-.04
Expertise Similarity Squared * Rotational Leadership											-.08
F	6.15*	6.97**	8.14**	6.52**	7.23**	6.06**	5.93**	5.95**	5.39**	5.97**	5.39**
Adj. R^2	.08	.17	.26	.26	.34	.34	.32	.32	.31	.33	.31
ΔR^2		.09**	.09**	.00	.08**	.00	-.02	-.02	-.03	.01	-.02

$^{+}p < .10$, $^{*}p < .05$, $^{**}p < .01$, N = 63 (self-report), changes in R^2 are from previous model except models 6-10 are compared to model 5

Table 7 - Models for hypotheses 2 and 3 tests for observer-rated improvisational behaviors

Variable	Observer-Rated Improvisational Behaviors										
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10	Model 11
Constant	5.15**	7.10**	7.48**	7.73**	8.27**	8.50**	9.16**	8.22**	9.12**	8.18**	8.54**
Controls											
Competition Difficulty	.01	.01	.02	.02	.02	.03	.04+	.02	.04+	.02	.03
Situational Experience		.51	.41	.42	.48	.45	.44	.47	.42	.47	.39
Main Effects											
Expertise Similarity			.43	.41	.42	.29	.29	.38	.23	.34	-.50
Expertise Recognition				.08	.04	.24	.06	.10	.08	.07	.25
Rotational Leadership					.28	.29	.93*	.27	1.10*	.23	1.22*
Expertise Similarity Squared										-.21	.45
Moderators											
Expertise Similarity * Expertise Recognition						-.39			.28		-.99
Expertise Similarity * Rotational Leadership							-1.08*		-1.39*		-.60
Expertise Recognition * Rotational Leadership								.10	.26		.19
Expertise Similarity Squared * Rotational Leadership											-1.22+
F	.61	1.91	2.04	1.58	1.55	1.38	2.74+	1.25	2.22	1.33	2.44
Adj. R^2	.01	.10	.14	.12	.13	.12	.35	.08	.35	.10	.46
ΔR^2		.09	.04	-.02	.01	-.01	.23**	-.05	.23**	-.03	.36**

$^{+}p < .10$, $^{*}p < .05$, $^{**}p < .01$, N = 31 (observer-rated), changes in R^2 are from previous model except models 6-10 are compared to model 5

Table 8 – Models for post-hoc testing for self-reported improvisational behaviors

Variable	Self-Report Improvisational Behaviors	
	Model 1	Model 2
Constant	5.35**	5.60**
Controls		
Competition Difficulty	-.01	-.01+
Situational Experience	.30**	.24**
Main Effects		
Expertise Similarity	.14	.18+
Expertise Recognition	.00	.01
Rotational Leadership	.16	.10
Expertise Similarity Squared	.05	.03
Moderators		
Expertise Similarity * Expertise Recognition	-.01	.33+
Expertise Similarity * Rotational Leadership	.14	.26*
Expertise Recognition * Rotational Leadership	.18	.31*
Expertise Similarity Squared * Rotational Leadership	.09	.05
Three-Way Interactions		
Expertise Similarity * Rotational Leadership * Expertise Recognition	-.45+	.04
Expertise Similarity Squared * Rotational Leadership * Expertise Recognition		-.85**
F	3.60**	4.61**
Adj. R^2	.33	.43
ΔR^2		.10**

$^{+}p < .10$, $^{*}p < .05$, $^{**}p < .01$, N = 63 (self-report)

Table 9 – Summary characteristics of the teams in competition

Team	Demographics (age, education)	Industry Experience	Mine Rescue Experience
Team A	• Average age of 34.7 years old. • Average of 2.7 years of post-high school education • 3 members with post-high school education, two of whom had graduate degrees	• Average 12.5 years of industry experience • Most of members worked over 12 years, with only their captain and co-captain working in mining for only 5 years • Most of their team worked in either coal production or in health and safety	• Attended 4 competitions in 2014 • Average of 4.7 years of mine rescue experience • Team members had experience in a range of positions, with all members except the gas person having served in at least two other non-gas positions
Team B	• Average age of 33.7 years old • Average of 2.8 years of post-high school education • Youngest team on average in competition, but most highly educated with 4 members having four year degrees	• Average of 12.8 years of industry experience • Team members worked in a variety of roles at the mine, including engineering, mining production, maintenance supervision, and machinery operators	• Attended 4 competitions in 2014 • Average of 4.6 years of mine rescue experience • Team members had experience primarily in their own position and the gas position
Team C	• Average age of 39.3 years old • Average of 1.8 years of post-high school education • 3 members with either a bachelor's or associate's degree, and one completing an additional certificate program	• Average of 7.3 years of industry experience • Team members worked in variety of roles including in managerial positions supervising operations, production, and health and safety administration	• Attended 8 competitions in 2014 • Average of 3.3 years of mine rescue experience • Team members had experience primarily in their own position and the gas position
Team D	• Average age of 41.5 years old • Average of 0.7 years of post-high school education • Had two retired persons on team	• Average of 16 years of industry experience, but skewed by tenure of map person and FAB • Most were machine operators, but map person and FAB were retired	• Attended 3 competitions in 2014 • Average of 11.8 years of mine rescue experience, skewed because two members had 28 and 35 years • Team members had experience primarily in their own position and the gas position
Team E	• Average age of 40.8 years old • Average of 0.3 years of post-high school education • Only one person completed any post-high school education	• Average of 18.2 years of industry experience • Most of the team had supervisory positions, some held maintenance and operations	• Attended 4 competitions in 2014 • Average of 6.3 years of mine rescue experience • 3 members had experience in at least 3 positions
Team F	• Average age of 38.8 years old • Average of 0.7 years of post-high school education • Only one person completed any post-high school education	• Average age of 16.3 years • Most of the team members worked in mining production, operating machinery	• Attended 6 competitions in 2014 • Average of 4.6 years of mine rescue experience • Team members with experience in many positions, but many less than 1 year

Table 10 – Summary of improvisational approaches in qualitative examination

Performance	Team	Approach	Examples of Approach During Competition
High Performers	Team A	**Subgroups** • Divided most activity between planning (idea generation led by FAB) and execution (implementation led by captain) • Co-captain served as liaison between groups to keep in sync as well as contributing member to both streams • Focused efforts allowed for efficient planning and execution occurring in parallel • Co-captain facilitated on the fly updates leading to little rework or stoppage	Their handling of the second phase provides a good example of their typical process. Up until this point, the team had not had to stop to brainstorm, choosing for the FAB to problem-solve and adjust the long range plan while the captain was doing implementation. At this point, they encounter the deep water that closes off an entire segment of the mine, and both groups are not sure what their next step should be. The FAB steps in and asserts the priorities and objectives of this phase. The co-captain starts aggregating and listing options, with the captain interjecting with some things to consider for each option. The FAB then integrates all this information to generate an idea for what plan will work to best meet the objectives he stated. As the FAB relays back this integrated plan to the team, the co-captain simultaneously details how they would actually implement this. Through this dialog, Team A highlights and keeps track of dual considerations to make sure they have cleared out the water and air and to make sure they are able to implement these changes successfully. This step requires them to keep track of multiple goals including pumping water, performing multiple ventilations and fan changes, and constructing and tearing down temporary builds. The team maintains a clear process to continuously update their expectation, communicate exactly what each subgroup is doing, and creating a plan for the next step. They coordinate this process primarily by the FAB and co-captain continuously discussing their plan and updating it based on the execution input, with the co-captain then focusing on the captain to adjust and validate the implementation plan. If they need to adjust either part, they pause and come together to figure it out and justify their decision-making. Although there is clear division between these three in terms of their primary focus – FAB tracks ventilation and long term effects, captain tracks the builds and resources, co-captain validates that the plans align – through this process they are able to execute a complex, multi-stage plan with minimal regrouping.
	Team B	**Centralized** • Most direction driven by FAB with some procedural guidance from Co-Captain • FAB responsible for individual idea generation	Partway through their execution, the team reaches the issue where they realize they do not have enough information to design a plan around the first water obstacle. However, the team uses their approach to try to resolve this issue by allowing the FAB time to come up with a new, more involved solution – at one point being so silent the captain checks to make sure their equipment is functional. This time, the co-captain asks a few probing questions to validate the efficacy of the plan because they wasted time on the previous plan, and the others try to process whether they have the materials necessary to complete

		• Team involvement typically restricted to procedural checks and clarification of situation • FAB provided direct instruction even on implementation • Success driven by the expertise of the FAB	the executions laid out for them. Still, no one makes material suggestions or even tries to understand the rationale behind the maneuvers; based on communication, the co-captain implies he has a detailed understanding of the entire, multistep plan, while only the FAB has the big picture of why this plan should work.
	Team C	**Subgroups with Collective Brainstorming** • Used parallel groups for execution and continuous planning, but used demarcated collective brainstorming to set the direction before dividing • Repeated cycles of collective and decentralized approach throughout • Captain directed the approach, encouraging participation from all members and communicating procedure	Their approach is very clear when they arrive at the water obstacle in the first phase that created problems. This team ends up solving the problem differently than most of the teams by doing a preliminary build before continuing exploration. Because they trust their synchronicity of understanding, the captain leads the gas person and medic in doing builds to block off the water and gas at the intersection without direction; then they make sure to update the co-captain and FAB on their actions so they can discuss a modified plan for what they need to do next. However, once they have reached this point, they feel the situation has changed so drastically that it changes the trajectory they are on. In this instance, and in general when this happens, the team stops, huddles together to look at the map, and brainstorms to create a new, detailed baseline plan. Because it is not immediately clear what the goal of the next phase should be, they do a session of iterative idea generation to find a number of potential solutions. During this brainstorm, they have two streams of inquiry that they decide: the captain leading a discussion about exploration and building requirements in the next phase and the FAB and co-captain discussing how the completed build and the anticipated builds from the captain would lead to a new overall plan. They are very cognizant of the process by which any plans will have to be implemented, and the way they would divide to execute those is explicitly discussed.
Low Performers	Team D	**Decentralized but Lacking Control** • Multiple members would weigh in during exploration and planning • Confusion in driver frequently led to the FAB as most experienced stepping in to direct plan • Even during FAB direction, plans are questioned with no authority structure to control,	In the first phase, there is tacit agreement to let the FAB drive a solution, but following exploration there are questions raised between the members about whether the FAB understands both the situation and positioning fully. Despite acknowledging the confusion among members, they do not actually address it until the group starts to splinter into two separate discussions and plans about how to solve the problem. The FAB continues to move forward in communicating a plan, but the team is clearly frustrated in understanding the rationale and how to implement it and actually begin arguing about what to do. The FAB at this point gets angry that others are talking over his attempt to direct a plan and insists they listen and use his idea. This outburst quells the confusion and cross-talk momentarily, but their final implementation of the first ventilation is dotted with side conversations trying to sort out the plan that the FAB lays out, even while they are executing.

		focus efforts, and communicate	This is similar to how Team D handled the same mounting confusion in the third phase, although the direction comes from the captain instead of the FAB because of the different focus of questions. Although the team was in agreement on a high-level plan, the field members were confused about how to actually implement the ideas and start to air their frustrations about being asked to perform without a clear understanding of where they are going and why. This time, the captain tries to facilitate an implementation plan but people start talking over each other with ideas and clarification questions. The captain then becomes frustrated and raises his voice both about the feasibility of the plan and their ability to implement it efficiently. This leads to a closed discussion with only the captain and FAB where they do idea generation and execution planning between themselves before directing the others without input.
	Team E	**Alternating Control and Centralized Contingency** • Initial attempts to have multiple members weigh in and then follow relevant plan • Failures in decisiveness, feasibility and efficiency result in incremental changes • Captain and map person centralized to drive plan following failure, generating ideas separately from the group and then strongly directing their implementation • FAB provides only support evaluation and confirmation	This mixed approach is shown in how Team E handled two issues during the second phase of the exercise. For example, in the first part of the problem, the FAB is preoccupied with recording the next phase of exploration on his map. While this is happening, the captain and the map person have a side conversation tracing out on the map potential ideas for ventilation. The rest of the team gathers and watches the captain and map person consider the options, but provide no further commentary on their agreement. The captain figures out a plan that he is comfortable with, and tells the FAB to check prior to implementation. Although the FAB tentatively validates, the captain leads the field in executing while discussions continue between the FAB and co-captain on its long range viability. In contrast, their second ventilation in this phase effectively divides the responsibilities more clearly. Because they are extending work from the first part of the plan, the captain leads an execution implementation, building and tearing down in support of the next phase. In the background, the FAB is aware that they need to run through some additional checks and when the building team pauses, they have a plan for the next step ready based on the changes that were made. However, Team E is not able to generate and implement as seamlessly as Team A does in this approach. The additions that the FAB plots out tend to be incremental, leading to a number of start and stops, rather than a continuously updated plan. Some of the time, the team acknowledges they need to keep moving forward so they perform any execution that they can see next, rather than to stop and contextualize the entire problem before making a plan. As a result, they end up having periods of full stops when the captain then intervenes, creates a plan with the map person on his own as he did previously, and then relays it to the FAB for evaluation while they begin implementing it. Their process is characterized by the attempts to use a multi-group approach, but ending with a more centralized actual execution. The other members only seem to interject if they immediately recognize an incorrect assumption about something

			concrete like the placement of a relevant object; although the plan is widely broadcast, there is little explicit input or evaluation beyond that.
	Team F	**Tentatively Centralized** • Planning, idea generation, and execution steps driven by FAB • Initially attempt to involve more team members but struggle with solution so default to only considering FAB solutions • Other members hold sideline conversations rather than contribute • Despite reliance on one member for ideas, lack clear direction	When they arrive at the common water obstacle issue, they attempt to figure out how to get materials to make a preplanned approach work, rather than adjust their plan based on the resources they actually have available. They discuss some possible steps, but never resolve what objectives take priority considering water pumping, ventilation, and rescuing the miner prematurely. In the absence of consensus, they decide at this point to just default to more exploration because the FAB suggest it and they follow him as the most experienced. During this time there is some sideline conversation between other members that never gets relayed or integrated into the team process as a whole. Since no one is clearly the expert, they continue to defer to the FAB who keeps providing tentative directions. The execution is similarly tentative with the team doing exactly what the FAB tells them to do, but then stopping and waiting for their next instruction. Even the FAB (their de facto leader) is uncertain and keeps asking about the field with no mutual understanding of the situation or their actions.

Appendix A – Complete scales and items included in the surveys

Survey	Construct	Items	Citation
Initial	Demographics	• What is your age? • How many years of post-high school education did you complete? (0= high school degree; 1-10 = number of college years completed)? • What best describes your team: mine-site/corporate-sponsored, composite/contract, MSHA/state-sponsored, other	
Initial	Experience (General Expertise)	• How many years have you worked in the mining industry? • What is your current job at the mining site? • How many years/months have you worked on a mine rescue team? As a team member? As a trainer? • What is your current position on the mine rescue team: team captain, gas person, map person, medic, co-captain, FAB/Briefing Officer? • How long have you held the following positions on the team: team captain, gas person, map person, medic, co-captain, FAB/Briefing Officer? Consider both your current position and previous teams. • How many competitions did you participate in 2014?	Gardner (2012) Gardner, Gino, & Staats (2012)
Initial	Expertise (Task/Domain-Specific Expertise)	• How would you rate your [captain, co-captain, map person, gas person, briefing officer, medic] expertise in the following areas (on a scale of no experience to highly experienced): o Ventilation, Gas detection, Roof support, Combustible materials, Electrical, Water hazards, Fire protection and suppression (fire brigade), Maps, First aid and medical assistance, Communication, Explosives and blasting, Hoisting and ropes, Emergency evacuation procedures, Shaft exploration procedures, Shaft sealing and surface structures, Mine recovery	Austin (2003) Gardner et al (2012) Van der Vegt & Bunderson (2005) Skills taken from Mine Rescue Safety Training Manual and MSHA 30 CFR Part 49
Initial	Dyadic Deference/Influence/	• This person influences [on the way I work, over me] • (1 to 5 never to always)	Bunderson et al (2015) Bunderson (2003)
Initial	Familiarity	• How long have you known [team captain, gas person, map person, medic, co-captain, FAB/Briefing Officer]? • How long have you worked on a mine rescue team with [team captain, gas person, map person, medic, co-captain, FAB/Briefing Officer]?	Reagans, Argote, & Brooks (2005) Huckman, Staats, & Upton (2009)
Initial	Formal leadership behaviors (directive/participative)	My team captain: • Gives others responsibilities. • Asks for advice when making decisions. • Uses advice and suggestions when making decisions. • Controls much of the activity. • Encourages team to come up with solutions. • Stays out of the way when members work on problems. • Encourages team to figure out the causes and solutions to problems.	DeRue (2011) Pearce & Sims (2004)

		• Gives me instructions on how to carry out tasks.	
Initial	Team member flexibility	• Most members of my team know each other's jobs • It is easy for the members of my team to fill in for one another • My team is very flexible in terms of changes in membership	Campion et al (1993)
Initial	Rotational Leadership	• Our team allows members to alternate who provides input on the problem solution. • Our team allows members who have the most relevant expertise to influence the solution. • Our team changes who has influence on the solution and activities depending on the needs of the situation. • We allow different members to take the lead when they have the most relevant insights and experiences. • Our team identifies who has relevant expertise when a situation changes.	Eisenhardt & Davis (2011)
Initial	Deference to Expertise	• Team members here are comfortable asking others with more experience for help. • Important decisions on this team are made by those with the most experience. • When someone cannot solve a problem, they seek someone with more experience to solve it.	Vogus & Sutcliffe (2007)
Initial	Team Structure	• Our individual roles are very clear and we don't stray from them. • Each team member has their particular area of specialty. • People in this team know which team members have expertise in specific areas. • There is a clear leader who directs what we do. • We follow a very structured plan. • Our team's goals and plans are clearly communicated.	Boumgarden & Bunderson (2010)
Initial	Team Trust	• I am able to count on my team members for help if I have difficulties with my job. • I am confident that my team members will take my interests into account when making work-related decisions. • I am confident that that my team members will keep me informed about issues that concern my work. • I can rely on my team members to keep their word. • I trust my team members.	DeJong & Elfring (2010)
Initial	Psychological Safety	• Members of this team are able to bring up problems and issues. • It is safe to try new things on this team. • If you make a mistake on this team, it is often held against you. • It is difficult to ask other members of this team for help.	Edmondson (1999)

		• No one on this team would deliberately act in a way that undermines my efforts. • Working with members of this team, my unique skills and talents are valued and utilized.	
Initial	Team Identification	• I feel emotionally attached to the team • I feel a strong sense of belonging to the team • I feel as if the team's problems are my own	Allen & Meyer (1990) Van Der Vegt & Bunderson (2005)
Initial	Expertise Coordination (bringing to bear dimension)	• Team members know who on the team has specialized skills and knowledge that is relevant to their work • People in our team share their special knowledge and expertise with one another • There is virtually no exchange of information, knowledge, or sharing of skills among members (R) • If someone in our team has some special knowledge about how to perform the team task, he or she is not likely to tell the other member about it (R) • More knowledgeable team members freely provide other members with hard-to-find knowledge or specialized skills	Faraj & Sproull (2000)
Initial	Conflict	• How much relationship tension is there in your team? • How often do people get angry while working in your team? • How much emotional conflict is there in your team? • How much conflict of ideas is there in your team? • How frequently do you have disagreements within your team about the task of the project you are working on? • How often do people in your team have conflicting opinions about the project you are working on? • How often are there disagreements about who should do what in your work group? • How much conflict is there in your group about task responsibilities? • How often do you disagree about resource allocation in your work group?	Jehn & Mannix (2001)
Final	Information Elaboration [Information is shared] [Information is processed] [Information is integrated in group]	• We considered new information provided by each team member. • As a team, we generated ideas and solutions that were much better than those we could develop as individuals. • We considered all perspectives in order to generate the best solutions. • We helped each other complete the problem by openly sharing knowledge. • • **Information is shared (information sharing)**	Kearney et al (2009) Bunderson & Sutcliffe (2002) Sung & Choi (2013)

		○ To what extent is information used to make key decisions shared freely among members of the team? ○ To what extent did team members work hard to keep one another up to date on their activities? ○ To what extent were team members kept “in the loop” about key issues affecting the unit? • **Information is processed** • **Information is integrated (knowledge utilization)** ○ Team members’ knowledge and skills were effectively used in solving problems we encountered. ○ The different knowledge and skills of our team members helped us obtain the best outcome ○ Team members’ knowledge and skills were fully used in our activities.	
Final	Improvisational Learning Behaviors [Identification, Reflection, Experimentation]	• **Identification** ○ The members of this team identified problems as a group. ○ The members of this team shifted focus to address new problems as they occurred. ○ The team discussed the impact on their tasks whenever the situation changed. • • **Reflection** ○ The members of this team made sure everyone had the same understanding of the situation. ○ The team transferred and combined information between members. ○ The team used questions and discussion to understand issues. • • **Experimentation** ○ The team generated a number of solutions to problems. ○ The team discussed potential outcomes of the solutions they generated. ○ The team focused on avoiding rework. ○ Team members offered ideas when we encountered issues. ○ Team members checked each other’s ideas to make sure they would work. ○ The team worked together to evaluate potential outcomes before choosing one.	Savelsbergh et al (2009) Edmondson (2003)
Final	Innovation	• Our team found solutions to the problem that were very novel and original.	

		• Our final solution was unique and useful.	
Final	Perceived Effectiveness [Team performance, team satisfaction, team development] They satisfy internal and external clients, They develop capabilities to perform in the future, and The members find meaning and satisfaction within the group	• The team met its goals as quickly as possible • The team delivered a highly effective final solution • This problem helped our team develop skills for future activities. • I was satisfied working in this team • I was satisfied with the way our team worked together.	Hackman (1987; 2002)
Final	Rotational Leadership Deference to Expertise	• Our team allowed members with the most relevant skills to influence the solution. • Our team identified who has relevant expertise when a situation changes. • Our team alternated who had input on solving issues. • Our team changed who had influence on the solution and activities depending on the needs of the situation. • We allow different members to take the lead when they have the most relevant insights and experiences. • • Important decisions were made by those with the most experience. • When a team member could not solve a problem, they asked someone with more experience to solve it. • Team members were comfortable asking others with more experience for help.	Davis & Eisenhardt (2011)
Final	Situational Experience	• Members of the team had encountered similar problems before. • This situation was unlike any other we had faced before. • We had the necessary skills in our team to solve the problem. • We had the right knowledge in the team to find a solution.	
Final	Perceived Task Difficulty/Complexity	• We were able to follow a repeatable sequence of steps in solving the problem. • We were able to use established procedures and practices to solve the problem. • It was difficult to anticipate what we would need to solve the problem. • The tasks required to solve the problem were very routine.	Withey, Daft, & Cooper (1983) Bunderson et al (2015) Haerem & Rau (2007)

		• It was difficult to identify how to solve the problem. • We came up against unexpected factors in responding to the problem	
Final	Use of expertise	• How would you rate yourself and each of your team members [captain, co-captain, map person, gas person, briefing officer, medic] in terms of the amount of influence you each had over the team's final solution. In other words, how much did each team member shape, direct and contribute to the team's outcome?'	Bunderson (2003) Gardner (2012)

Final	Team Conflict Handling (Management)	• Accommodation: When my team experienced some conflict,
		    ○ I gave in to the wishes of my teammates.
		    ○ I went along with the suggestions of my teammates.
		    ○ I allowed concessions to my teammates.
		• Competition: When my team experienced some conflict,
		    ○ I used my authority to make a decision in my favor.
		    ○ I used my influence to get my ideas accepted.
		    ○ I used my expertise to make a decision in my favor.
		• Collaboration: When my team experienced some conflict,
		    ○ I collaborated with my teammates to come up with decisions acceptable to us.
		    ○ I tried to work with my team members to find solutions to a problem that satisfy our expectations.
		    ○ I exchanged accurate information with my teammates to solve a problem together.
			Montoya-Weiss, Massey, & Song (2001)

Appendix B – Additional analyses on self-report data

I also examined the data using hierarchical linear modeling (HLM) as an alternate to clustering the standard errors to account for the non-independence due to the fact that teams could participate in multiple competitions. Like the clustering of the standard errors, HLM provides an alternative way to account for the clustering of competition outcomes as a result of teams. In this appendix, I report the HLM outcomes for the self-reported improvisational behaviors, which are comparable to the self-reported results reported with clustered standard errors.

In the HLM model, the level-1 variables are those that are specific to a competition and the level-2 variables are team-level characteristics that do not differ across competitions. For example, in a model considering the main effects of expertise similarity, expertise recognition, and rotational leadership on team improvisation, the improvisational behaviors in for each team in a single competition would be a level-1 outcome, while the others would be level-2 variables because they do not vary across competitions. Below I provide a table that summarizes the self-reported improvisational data using the HLM models. These results are comparable to the results reported in Table 5. The analyses revealed that 37 percent (t00 = .53, p < .001, ICCl = .37) of the variance in improvisation resided between teams (to be explained by level-2 variables).

The model used to test Hypotheses 1 and 2:

Level-1 Model:

$$Improvisation_{ij} = \beta_{00} + \beta_{01}(Prior\ Experience) + \beta_{02}(Competition) + \beta_{03}(Average\ Expertise) + r$$

Level-2 Model:

$$\beta_{00} = \gamma_{00} + \gamma_{01}(Expertise\ Recognition) + \gamma_{02}(Expertsie\ Similarity) + \gamma_{03}(Rotational\ Leadership)$$

$$+ \gamma_{04}(Expertise\ Recognition * Rotational\ Leadership) + \gamma_{05}(Expertise\ Similarity * Rotational\ Leadership)$$

$$+ \gamma_{06}(Expertise\ Similarity)^2 + \gamma_{06}(Expertise\ Similarity^2 * Rotational\ Leadership) + u_0$$

$$\beta_{01} = \gamma_{10} + u_1$$

$$\beta_{02} = \gamma_{20} + u_2$$

$$\beta_{03} = \gamma_{30} + u_3$$

Table B.1 – HLM results for Hypotheses 1 and 2

Variable	Self-Report Improvisational Behaviors			
	Model 0	Model 1	Model 2	Model 3
Constant	3.25**	4.77**	4.75**	4.36**
Controls				
Competition 1 (2)	-.07	-.08	-.09	-.15
Competition 2 (3)	-.16	-.03	-.03	.02
Competition 3 (6)	-.18	-.06	-.07	-.05
Competition 4 (4)	.09	.33	.32	.43
Competition 5 (7)	.01	.05	.05	.05
Situational Experience	.18	.25*	.25*	.24*
Average Expertise	.46*	.01	.01	.12
Main Effects				
Expertise Similarity		.12	.11	.13
Expertise Recognition		.07	.07	.14
Rotational Leadership		.20*	.19*	.07
Expertise Similarity Squared			-.01	-.03
Moderators				
Expertise Similarity * Expertise Recognition				-.08
Expertise Similarity * Rotational Leadership				.25+
Expertise Recognition * Rotational Leadership				-.03
Expertise Similarity Squared * Rotational Leadership				.08
LL	-54.71	-55.52	-57.40	-61.92
AIC	131.42	139.05	144.79	163.84

All models were estimated with iterative maximum likelihood techniques (Friedkin, 2001) using the computing environment R and the NLME (Nonlinear and Linear Mixed Effects models) package (Pinheiro, Bates, DebRy, & Sarkar, 2016).

Table B.2 – OLS Results for Hypotheses 2 and 3 including average expertise as a control variable

Variable	Self-Reported Improvisational Behaviors										
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10	Model 11
Constant	4.56**	3.64	4.42 **	5.68**	5.00**	5.29**	5.00*	5.01**	5.27**	4.78**	4.68**
Controls											
Competition	-.02*	-.01	-.01+	-.01	-.01					-.01	-.01
Difficulty						-.01	-.01	-.01	-.01		
Situational Experience		.20*	.20*	.21*	.27**	.27**	.27**	.27**	.27**	.27**	.26**
Average Expertise	.61**	.54**	.36+	.31	.11	.04	.10	.10	.04	.17	.19
Main Effects											
Expertise Similarity			.13+	.13+	.10	.11	.11	.10	.12	.04	.08
Expertise Recognition				.05	.05	.02	.05	.04	.01	.06	.08
Rotational Leadership					.19*	.20*	.19*	.19*	.20*	.16+	.05
Expertise Similarity Squared										-.03	-.01
Moderators											
Expertise Similarity * Expertise Recognition						.09			.08		-.01
Expertise Similarity * Rotational Leadership							.01		.01		.19
Expertise Recognition * Rotational Leadership								-.02	-.01		-.04
Expertise Similarity Squared * Rotational Leadership											.08
F	8.59**	8.03**	7.03**	5.68**	5.98**	5.11**	5.04**	5.05**	3.84**	5.12**	3.21**
Adj. R^2	.18	.26	.26	.26	.32	.32	.30	.30	.29	.30	.31
ΔR^2		.08*	.00	.00	.06*	.00	-.02	-.02	-.03	-.02	.01

$^{+}p < .10$, $^{*}p < .05$, $^{**}p < .01$, N = 63 (self-reported), changes in R^2 are from previous model except models 6-10 are compared to model 5