Knowledge-Based and Contextual Factors Associated with R&D Teams' Improvisation Capability

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ABSTRACT

We examine three knowledge-based processes and interactions underlying an effective improvisation capability in research and development (R&D) teams: A team's ability to create a shared understanding of new knowledge, a team's experience working together, and a team's ability to gather external knowledge. Using a sample of 100 R&D teams developing computer technology innovations, we also examine the moderating role of "minimal structures" (goal clarity combined with autonomy) as a contextual factor supporting effective improvisation. Our results detected different ways in which the processes and interactions involved in an improvisation capability interacted with the context. We find support for the positive relationship between shared understanding of new knowledge and improvisation capability and find that this relationship is strengthened by minimal structures. Team's experience working together was not associated with improvisation capability, but when minimal structures are present, more experience working together is positively related to improvisation. Finally, a team's external knowledge gathering ability is positively associated with improvisation, but, surprisingly, when minimal structures are present, this positive effect is reduced. We conclude with implications for improvisation theory and for the practice of R&D teams.

Keywords: Improvisation, R&D teams, dynamic capabilities, minimal structures

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Improvisation has been defined as "the deliberate and substantive fusion of the design and execution of a novel production" (Miner, Bassoff & Moorman, 2001: 314) and "the merger of composition and execution, real-time action undertaken by teams, units, or entire firms" (Kyriakopoulos, 2011: 1053). An improvisation capability can help high-performing R&D teams, tasked with the pursuit of new knowledge and the application of that knowledge to exploit new opportunities for the commercial advantage of a business, become more innovative, and decrease cycle time (Brown & Eisenhardt, 1997; Moorman & Miner, 1998a).

The primary function of R&D teams is to recombine existing knowledge in novel ways to generate new, more advanced knowledge or innovations (Paruchuri & Eisenman, 2012). With few exceptions, the R&D literature has not been explicit about the role of improvisation in the creation of an invention that obtains a patent, but has increasingly raised the need to combine planning with more flexible and adaptable approaches to R&D. Cunha and Gomes (2003), one of the exceptions, describe five product innovation models: sequential, compression, flexible, integrative, and improvisational, ranging from more planned to more emergent approaches. While sequential, step-by-step models of innovation are still pervasive (Kamoche & Cunha, 2001), more emergent models portray innovation teams facing tasks characterized by considerable uncertainty and complexity and having no ready-made scripts to follow when completing their tasks (Bresman, 2010; Janz, Colquitt & Noe, 1997).

Studying improvisation in R&D is important because more emergent and improvisational approaches add flexibility and creativity to R&D (Cunha & Gomes, 2003; Niosi, 1999), an area where a traditional approach to planning and controlling projects may curtail creativity and increase the odds of failing (Dvir & Lechler, 2004). Unfortunately, only a few deductive quantitative studies today shed light on how to foster effective improvisation (e.g., Eisenhardt & Tabrizi, 1995; Moorman & Miner, 1998a; Vera & Crossan, 2005). Consistent with the larger movement in management theory to decompose higher-level phenomena into its lower-level components (Felin, Foss, Heimeriks & Madsen, 2012), the purpose of this paper is to examine knowledge-based and contextual factors associated with R&D teams' improvisation capability.

This study contributes to our knowledge in several ways. First, we contribute to the R&D area by stressing the role of improvisation in successful R&D teams, a context in which it has not been studied in the past and where emergent models of innovation more realistically capture their work (Kamoche & Cunha, 2001). Furthermore, not only is improvisation important for R&D, but studying improvisation in R&D contributes to our understanding of improvisation. Kamoche, Cunha, and Cunha (2003) compared the unique lessons about improvisation from four different contexts: jazz, Indian music, music therapy, and role theory. Similarly, studying improvisation in R&D refines our knowledge of improvisation, including its domains and boundary conditions, because R&D offers new contextual issues. In contrast to most art troupes, R&D teams are non-egalitarian: some members make intellectual contributions to be included in the patent, others do not. Also, knowledge about what other R&D teams are doing in a fast-changing technological context, and legal issues determining patent infringements, scope, and authorship credit, create the context for improvisation in R&D, which differs from those studied in the past.

Our second contribution to theory is to propose a capability view of improvisation in R&D. We build on Winter's (2003) view of a capability as a high-level routine, where routines are behaviors that are learned, highly patterned, repetitious or quasi-repetitious, and founded in part in tacit knowledge. This is consistent with Miner et al.'s (2001) observations of firms that appear to have learned meta-routines facilitating fruitful improvisation. They stated that “the distinct competencies in improvisation did not appear to reside in specific individuals; rather, they flowed from broader organizational routines, cultures, and collective capabilities” (Miner et al., 2001: 327). We position improvisation as a multi-purpose capability (Helfat & Winter, 2011), that is, a capability with both operational and dynamic purposes. Furthermore, improvisation can also be a second-order capability because it is a learning process that furthers the creation and development of capabilities (Eisenhardt & Martin, 2000; Zahra, Sapienza & Davidsson, 2006).

Third, while past research has generally examined knowledge resources (e.g., organizational memory, expertise, and real-time information) associated with improvisation (e.g., Brown & Eisenhardt, 1998; Moorman & Miner, 1998a, 1998b; Vera & Crossan, 2005), our focus is on knowledge-based processes and interactions among R&D team members, and the context in which R&D team members work. Specifically, we examine three key processes and interactions in R&D teams: the team’s ability to create a shared understanding of new knowledge, its experience working together, and its ability to gather external knowledge. Then, we discuss how “minimal structures,” which provide the R&D team with autonomy combined with goal clarity, change the effects of these processes. Our factors associated with R&D improvisation capability capture two tensions frequently discussed in improvisation (Weick, 1998): first, the tension between the old and the new, that is, experience (shared understanding and experience working together) and creativity (external knowledge gathering); and second, the tension between freedom (autonomy) and control (goal clarity). Identifying knowledge-based processes and interactions, and structures as factors associated with an improvisation capability in R&D has implications for the growing debate on micro-foundations of capabilities, where micro-foundations are “the distinct skills, processes, procedures, organizational structures, decision rules, and disciplines" (Teece, 2007: 1319) that undergird a capability. In this sense, our findings offer a snapshot in time of the factors underlying the capacity of an R&D team to improvise.

Fourth, we offer two important contributions to empirical research on improvisation. This study responds to the call for more large-scale quantitative research by using a sample of 100 R&D teams in the computer technology field and by using an uncommon empirical method--connecting objective patent data with surveys of the inventors--to test our hypotheses. Also, we offer one of the first empirical tests of the concept of "minimal structures" (Kamoche & Cunha, 2001) --providing some boundaries to guide actions while leaving latitude for real-time adjustment in response to actual events. This area is capturing growing attention, but is still emergent in the field. Finally, our findings have important implications for R&D managers' understanding of what it actually takes to promote their teams' improvisation capability.

THEORY

Improvisation Capability

Improvisation has been discussed in a wide range of contexts over the past 20 years, from fire disasters (Weick, 1993) and emergency response (Bechky & Okhuysen, 2011) to restructuring (Bergh & Lim, 2008) and technology-based change (Orlikowski, 2000). Increasingly, improvisation is being described as a capability. However, although 'capability' is a term used extensively in the literature, its meaning still differs among authors (Barreto, 2010). Helfat, Finkelstein, Mitchell, Peteraf, Singh, Teece, and Winter (2007), engaging in integrative work, propose that having a specific capability implies that the organization (or its parts) has the capacity to perform a particular activity in a reliable and at least minimally satisfactory manner.

We define improvisation capability as the team's capacity to act spontaneously in trying to respond to problems or opportunities in a novel way. Being a capacity, improvisation is intended and has a purpose (Helfat et al., 2007). This view is consistent with the perspective of improvisation as the "the deliberate and substantive fusion of the design and execution of a novel production" (Miner et al., 2001: 314) and as "the conception of action as it unfolds" (Cunha, Cunha & Kamoche, 1999: 302). The inclusion of spontaneity in the definition captures the extemporaneous aspect of improvisation--one central facet of definitions of improvisation (e.g., Hatch, 1998; Vera & Crossan, 2005; Weick, 1993). Nevertheless, a capacity to improvise goes beyond ad hoc activity that does not reflect practiced or patterned behavior (Helfat & Winter, 2011). In fact, Winter (2003) explicitly distinguished improvisation--a capability--from ad-hoc problem solving, arguing that ad-hoc problem solving is neither routine nor highly patterned, while improvisation depends on a "foundation of patterned and practiced performance, a fund of micro-patterns that are recombined and sequenced in creative ways" (2003: 993).

For an R&D team to have the repeated and reliable capacity to improvise means that it has developed some routines facilitating fruitful improvisation. In the context of information technology (IT), for example, Pavlou and El Sawy (2010) observe that IT teams realize that they must often be spontaneous and act quickly in urgent situations, and try to become skilled at improvising through repeated improvisation. The routines and preparation for improvisation are not specific to each unique situation, but involve learning how to improvise in any unexpected, novel, and unique situation that is likely to emerge (Pavlou & El Sawy, 2010).

The capabilities literature has proposed a hierarchy in an effort to bring structure to the concept of capabilities. This categorization distinguishes among operational (ordinary, zero-order, or substantive), dynamic (first-order), and learning (second-order) capabilities (e.g., Collis, 1994; Helfat & Winter, 2011; Winter, 2003; Zahra, Sapienza & Davidsson, 2006; Zollo & Winter, 2002). Winter (2003) uses a mathematical metaphor of derivatives to characterize the hierarchy: (a) zero-order operational capabilities represent how a company earns a living now; (b) dynamic capabilities are "first derivative" of operational capabilities, i.e. their change; and (c) second-order capabilities are "second derivative" of operational capabilities and the "first derivative" of dynamic capabilities, i.e. their change. Operational capabilities enable a firm to perform an activity on an on-going basis using more or less the same techniques of the same scale to support existing products and services for the same customer population (Helfat & Winter, 2011). Dynamic capabilities enable a firm to change how it presently makes its living, including altering operational capabilities, the resource base of the firm, or features of the external environment (Helfat & Winter, 2011; Winter, 2003). Similarly, Zahra et al. (2006) state that the ability to solve a problem is a substantive capability, while the ability to change the way the firm solves its problems is a dynamic capability. Learning capabilities are the ultimate second-order capabilities (Collis, 1994; Winter, 2003). Deliberate investments in organizational learning, including experience accumulation, and knowledge articulation and codification, enable the creation and modification of dynamic capabilities (Zollo & Winter, 2002).

Helfat and Winter (2011) explicitly acknowledge the difficulty in drawing a line between dynamic and operational capabilities, due in part to the existence of dual purpose capabilities -- that is, they can be used for both operational and dynamic purposes. Improvisation is a dual-purpose capability. At an operational level, R&D teams encountering unexpected problems or opportunities, for example, when obtaining unexpected test results, can improvise a solution to “fight a fire” without altering their current R&D processes, or product and market focus. In this scenario, an improvisational capability contributes to the operational functioning of the team. Improvisational solutions may have a real-time short-term impact (Miner et al., 2001), but do not permanently change the status quo of how the team operates. At a dynamic level, R&D teams can radically change the way they work by improvising new processes or methods, or by coming up with new markets or products in response, for example, to the need to react to a competitor's action, or to a sudden discovery of a patent similar to the one being created. In this scenario, improvisation changes how things are done and, when retained by the team, they can become a permanent part of the team's artifacts, processes, or knowledge (Miner et al., 2001).

Finally, improvisation can be positioned as a second-order capability because it is a learning mechanism behind the creation and evolution of other operational and dynamic capabilities, making it a multi-purpose capability. In high-velocity environments, dynamic capabilities evolve through experiential activities such as improvisation, prototyping, real-time information, and experimentation (Eisenhardt & Martin, 2000). In addition, in entrepreneurship, Zahra et al. (2006) propose that young firms, lacking routines, develop their dynamic capabilities by relying on improvisation and learning-by-doing. Following Collis (1994), to the extent that a learning mechanism, such as improvisation, is itself systematic and patterned, it can be regarded as a "second-order" dynamic capability. Figure 1 summarizes the characteristics of an improvisation capability. Our study focuses on the operational and dynamic purposes of R&D teams' improvisation capability, and the knowledge-based and contextual factors associated with it.

Insert Figure 1 about here

Hypotheses

Prior work has sought to identify conditions associated with effective improvisation. For example, Brown and Eisenhardt (1998) concluded that effective improvisation was characterized by an adaptive culture, semi-structures, and real-time communication. Moorman and Miner

(1998b) tested perceived environmental turbulence, real-time information flows, and organizational memory as moderators of improvisation effectiveness in new product development (NPD). Vera and Crossan (2005) found that expertise, teamwork quality, experimental culture, and real-time information and communication contributed to the positive link between improvisation and innovation. Recently, Kyriakopoulos (2011) studied how market information and organizational memory moderate the relationship between improvisation and cost efficiency and market performance of new products.

The primary focus of prior research has been on identifying knowledge resources that contribute to effective improvising, building on the perspective that improvisation involves the real-time recombination of knowledge available to the team (Cunha et al., 1999; Vera & Crossan, 2005; Weick, 1998). When looking at context, the primary interest has been on team or organizational culture and structure (e.g., Brown & Eisenhardt, 1998; Kamoche & Cunha, 2001). Regarding processes, although Vera and Crossan (2005) tested the moderating effects of teamwork quality on improvisation effectiveness, they recognized that 'teamwork' was a rich construct that needed to be disaggregated in future research. Work in the intersection of knowledge assets and processes in improvisation include studies looking at the development of a collective mind, and behavioral integration in teams (Weick, 1993).

In Figure 2, we depart from the emphasis on knowledge resources by shifting attention to the interactions and processes among R&D team members. Three of the factors associated with R&D improvisation capability correspond to what Felin et al. (2012) call the "processes and interactions" type of micro-foundations: the team's ability to create a shared understanding of new knowledge, its experience working together, and its ability to gather external knowledge. Our last factor--minimal structures--is a structural micro-foundation (Felin et al., 2012).

Levinthal and Rerup (2006) argue that improvisation takes at least two things: experience and creativity. The ability to create a shared understanding and experience working together contribute to the improvisation capability through experience, while the ability to gather external knowledge is a source of variation and contributes to the improvisation capability through creativity. By looking not only at main effects, but also at interactions, we offer a more ample picture of how the impact of the processes and interactions on improvisation capability are affected by “minimal structures” providing the R&D team with a mix of freedom and control.

Insert Figure 2 about here

In identifying knowledge-based factors associated with an improvisation capability in teams, the R&D context places specific demands. First, when looking at shared mental models and the demands for collective action, R&D activities are unique in that they involve inherently ambiguous and complex tasks, so that working in groups lets R&D members draw upon their knowledge base and gain from many viewpoints. Our focus on the R&D team’s capability to build a shared understanding of *new* knowledge comes from (1) changes in technology, processes, desired outcomes, and the continuous feedback in R&D projects that require team members to constantly communicate and adjust their mental models with new information (Mathieu, Heffner, Goodwin, Salas & Cannon-Bowers, 2000), (2) the strong relationship between absorptive capacity and R&D (Cohen & Levinthal, 1990), and (3) the importance of non-redundant knowledge stocks to creativity and innovation.

We also look at the amount and quality of experience team members have working together, which can help to accelerate a team’s learning curve in a context of change. Shared understanding and experience working together underlie a team's capability to act collectively, and are acutely critical concerning product complexity, uncertainty, and fast-paced environments (Kirsch, 1996). Weick (1993) was one of the first to note how interaction patterns that stabilize meaning by creating shared interpretive schemes are central for improvising, and Vera and Crossan (2005) discussed the role of shared mental models and shared understanding as part of teamwork quality when improvising. A distinction in R&D that informs our knowledge of improvisation in general is that R&D improvisation requires collective action in non-egalitarian teams, in which members' intellectual contributions are different and laws determine patent authorship credit. Kamoche et al. (2003) suggested that improvisation was unlikely to occur where there is a power disparity as this could lead to role imposition. In contrast, we argue that, even within non-egalitarian R&D teams, the capability to improvise exists in teams whose members are able to develop shared understanding and have experience working together.

The third process associated with an improvisation capability in R&D concerns the ability to gather external knowledge. R&D teams are unique in that they operate in situations in which "changes in demand, competition, and technology are … rapid and discontinuous" (Eisenhardt, 1989: 544), so that even experienced teams need extensive external knowledge to complete their tasks (Bresman, 2010). Boundary-spanning activities and gatekeepers who stay in contact with colleagues and remain informed of current scientific developments enhance R&D project performance. Moreover, R&D teams' knowledge about existing and developing patents is key for legal issues of patent infringement and scope, and is critical when improvising. Thus, the team's ability to reach out to external sources--an ability that is learned, patterned, and used repetitively--enhances its capacity to improvise.

Considering the role of context, R&D projects distinctively embody a tension between discretion and formality). In this regard, we are particularly intrigued with the concept of minimal structures, which combines “loose” elements of freedom with “tight” elements of control (Kamoche & Cunha, 2001), and highlights what some researchers (e.g., Moorman & Miner, 1998a; Weick, 1998) called the tradeoffs or tensions of improvisation (Crossan, Cunha, Vera & Cunha, 2005). We translate the concept of minimal structures to the practice of R&D teams as the combination of a “loose” environment of team task autonomy with the constraints of clearly defined team project goals. Next, each factor is discussed in detail.

Shared understanding of new knowledge and improvisation capability. The capacity to improvise requires knowledge to be collectively recombined, re-created, and reconstituted in real time (Vera & Crossan, 2005; Weick, 1998). Yet if the group is to take real-time coordinated action, effective improvisation requires that these differences be accommodated within “common or overlapping cognitive representations of task requirements, procedures, and role responsibilities” (Cannon-Bowers, Salas & Converse, 1993: 222). This shared understanding, or schema agreement, is rooted in repeated practice and experience accumulation--learning mechanisms behind the development of dynamic capabilities (Eisenhardt & Martin, 2000; Zollo & Winter, 2002). It emerges and evolves through interaction, similar life experiences, high team experience, frequent, informal communication, social integration, cross-training, debriefing, and planning, and is also related to team size and team member recruitment (Cannon-Bowers et al., 1993). Moreover, the creation of shared understandings is part of the integration process that allows individuals to make sense of their interpretations with other team members. Shared understanding is developed through knowledge articulation, dialogue, and collective discussions, and it is required for coherence, mutual adjustment and negotiated action in a team to take place (Zollo & Winter, 2002). This view is consistent with Weick’s (1993) proposal that intersubjectivity in a team emerges from the interchange and synthesis of meanings among two or more communicating selves, and that during the interaction a joint subjectivity develops, which supports improvisation and resilience.

Multiple mental models co-exist among team members, related to technology and equipment, job and task, team interaction, and the team itself (Mathieu et al., 2000). Improvisation is often used to deal with temporal gaps, or unexpected opportunities or problems (Miner et al., 2001). A team's collective representation of a situation needs to adapt in the moment, which highlights the dynamic nature of shared understanding. We focus on shared understanding of new technical knowledge. R&D teams, constantly learning about new procedures and technologies with feedback from internal and external environments, must keep mental models "in sync" (Mathieu et al., 2000) so that the understanding of complex tasks continues to evolve as the R&D project advances (Janz et al., 1997). The ability of team members with differentiated roles to create shared understanding of new technical opportunities or problems is a vital element of the team's capability to improvise effectively because it enables team members to adapt to and anticipate other members' information needs (Cannon-Bowers et al., 1993; Vera & Crossan, 2005).

Shared understanding has been shown to have potential drawbacks including failure to produce the most creative outcomes, tunnel vision, groupthink, and reluctance to accept new members (e.g., Amabile, 1998). We believe that these cautionary notes about shared understanding leading to rigidity are more applicable in crises (e.g., 9/11 or Apollo XIII), where team members might choose to stick to an established mental model. We see a smaller role for these drawbacks in R&D, where speed-to-market pressures can be quite strong, and fast-cycle industries--such as computer technology--are aware of the need to dynamically update team mental models in the pursuit of innovation. Hence, *Hypothesis 1: An R&D team's ability to create shared understanding of new knowledge is positively related to its improvisation capability.*

Experience working together and improvisation capability. Experience working together has been described as "the cumulative production history of pairs of individuals" (Reagans, Argote & Brooks, 2005: 869) and is a key characteristic of team composition (Taylor & Greve, 2006). Experience working together involves repeated practice and experience accumulation--learning mechanisms behind the development of dynamic capabilities (Eisenhardt & Martin, 2000; Zollo & Winter, 2002). In the case of improvisation, Powers (1981: 289) proposed that "the human propensity to improvise increases with familiarity and the amount of time spent interacting." This experience teaches team members how to cooperate and what each team member knows, producing more efficient division of labor, and greater trust and willingness to share knowledge and coordinate specialized roles (Reagans et al., 2005). Also, teams with experience working together develop relationship-specific heuristics that enhance the interactions among members performing distinct roles (Reagans et al., 2005). For example, Kanki and Foushee (1989) found that a flight crew's experience flying together reduced cabin errors; this was explained by their ability to trust and communicate with each other better than crews that had rarely flown as a team. The more experience R&D members accumulate working together on various projects and the more confident they are coordinating with each other and building on each other's expertise, the more able they will be to get out of their comfort zone and collaborate spontaneously in real time (Dyer, 1984).

Several studies have shown a positive impact of team member familiarity or prior experience on the emergence of transactive memory, especially on member awareness of expertise location (e.g., Akgün, Byrne, Lynn & Keskin, 2007). Transactive memory is derived from a history of collaboration, builds cumulatively (Lewis, Lange & Gillis, 2005), and has been proposed as a micro-foundation of dynamic capabilities (Argote & Ren, 2012). Transactive memory is a mechanism through which group experience improves group performance because group members learn who is good at what and how to coordinate their expertise (Ren & Argote, 2011). Understanding who has what knowledge enhances improvisation because it leads to a lower need for planning, greater cooperation, fewer misunderstandings, and lower confusion. This cooperation is rooted in team members' awareness of each other's strengths so that they can allocate the right roles and responsibilities according to expertise (Hollenbeck, Ilgen, Lepine, Jason & Hedlund, 1998). In fact, Ren, Carley, and Argote (2006) found that when the goal is response time, transactive memory is particularly beneficial to groups in a highly dynamic task environment or a highly volatile knowledge environment, both characteristics of R&D.

The benefits of experience working together and team longevity are well documented, but authors have also identified potential drawbacks, such as convergent thinking (Goncalo, 2004) or isolation from key information sources (Katz, 1982). Also, a team's experience working together is not always positive. Nevertheless, even teams with negative experiences working together develop transactive memory about who does or does not know something, which is useful for future interactions. Indeed, Klimoski and Mohammed (1994) argued that early team successes or failures clarify how people think about issues and, thus, can accelerate the development of team mental models. This supports Eisenhardt and Martin's (2000) assertion that mistakes and negative experiences also play an important role in the evolution of dynamic capabilities. As a result of both positive and negative experiences in working together, the memory about team members' knowledge will support the team's capacity to improvise. Hence,

Hypothesis 2: An R&D team's experience working together is positively related to its *improvisation capability.*

External knowledge gathering and improvisation capability. In the tension between the old and the new that is intrinsic to improvisation (Crossan et al., 2005; Weick, 1998), the ability to create a shared understanding and experience working together are sources of experience (the old), while the ability to gather external knowledge is a source of creativity (the new). The importance of gathering external knowledge for improvisation is consistent with research on R&D innovation, where the concept of absorptive capacity (ACAP) (Cohen & Levinthal, 1990) captures the ability to recognize the value of new external information, assimilate it, and apply it to commercial ends. External knowledge is required for R&D teams to develop a broader knowledge base and to keep abreast of cutting-edge technologies. Also, R&D teams need to decide which projects to pursue and to determine whether their invention has been patented or if it is “non-obvious.” The ability to gather external knowledge can prevent R&D teams from wasting time and resources pursuing projects with no chance of obtaining a patent.

In creative processes like improvisation, an ability to gather external knowledge is a source of variation, and helps to address some of the drawbacks mentioned above in association with shared understanding and experience working together. Knowledge from external sources can challenge the team’s internal paradigms, ignite the creativity spark that teams with homogenous mental models might lack (Amabile, 1998), and broaden and deepen the pool of resources upon which an R&D team can improvise. When external knowledge is brought in, it injects new ideas that can enrich the team’s ability to reconfigure past experiences working together in new ways. External information brings novel factors to the team (Bresman, 2010; Kyriakopoulos, 2011; Moorman & Miner, 1998b) and triggers opportunities for teams to apply and adapt their who-knows-what maps and how-to-work-together routines. When exposed to new knowledge, teams can identify current gaps in their knowledge and potential opportunities to recombine internal and external knowledge for effective improvisation.

Although the benefits of external knowledge are well recognized, scholars, particularly in the area of ACAP, have also argued that too much external knowledge can create overload and halt progress towards a solution, and that the ability to gather external knowledge does not imply an ability to assimilate, transfer, and use this knowledge in the team (Nemanich, Keller, Vera & Chin, 2010). We believe that these concerns are reduced in the case of improvisation. In fact, Bergh and Lim (2008) position ACAP and improvisation as opposite perspectives, with learning being cumulative in the case of ACAP and more short-term, real-time, and localized in the case of improvisation. A key premise of ACAP is that "the organization needs prior related knowledge to assimilate and use new knowledge" (Cohen & Levinthal, 1990: 129); thus, ACAP requires that external knowledge is not only gathered, but also assimilated, captured, and accumulated. In contrast, improvisation makes do with whatever resources are at hand--in the moment--, that is, creative recombinations of external and internal knowledge are tightly linked to the specific local issue and time (Miner et al., 2001). The ability to gather external knowledge is a source of creativity in the improvisational process, even if that external knowledge is only recombined in the moment and not accumulated for later use. Hence,

Hypothesis 3: An R&D team's external knowledge gathering ability is positively related to its improvisation capability.

The contingent role of minimal structures. In improvisation a little structure goes a long way, explaining why jazz musicians rely on templates, communicative codes, and a few specific rules such as who plays first and who follows whom, to provide an overarching framework of communication within which they can be both creative and consistent (Hatch, 1998). In firms, this combination of freedom and control has been variously called minimal structures (Kamoche & Cunha, 2001), simple rules (Davis, Eisenhardt & Bingham, 2009), and semi-structures (Brown & Eisenhardt, 1997). Minimal structures, as described by Kamoche and Cunha (2001: 758), are macro routines and high-level parameters, but can also be implemented at more of a micro level:

> Although we see the minimal structures in terms of basic prerequisites and guidelines upon which larger consequences can be anticipated, managers may well interpret it in terms of the levels of control they wish to maintain over the innovation process, how much autonomy to allow the design team, and at what stages they might allow individual members to take the lead in the development process.

In the context of R&D teams, we focus on a specific aspect of minimal structures and conceptualize minimal structures as the combination of a team's autonomy (freedom) with the team's goal clarity (control). Bailyn (1985) differentiated strategic autonomy (the freedom to set one's own problems) from operational autonomy (the discretion to decide how to pursue an established goal) and argued that R&D scientists, particularly early in their career, thrive when they are told *what* is needed (low strategic autonomy) and are given discretion about the means to solve the problem (high operational autonomy). In our conceptualization, the team's goal clarity is associated with low strategic autonomy and provides the R&D team with priorities, objectives, and guidance within which to try new things (Janz et al., 1997), while the team's autonomy refers to operational autonomy and enables an R&D team to experiment without needing to always seek management approval (Sundstrom, De Meuse & Futrell, 1990).

We argue that minimal structures, by themselves, do not necessarily promote improvisation capability, but that they will create conditions favoring the positive link between our three knowledge-based processes and interactions and improvisation capability.

First, minimal structures create a favorable context for shared understanding to promote improvisation capability by ensuring that team members are on the same page and their actions are aligned towards a common goal when they engage in autonomous creative action Sundstrom et al., 1990). In contexts with high autonomy and low goal clarity, team's collective efforts towards developing a shared understanding of new knowledge could lead to chaotic action. Likewise, in contexts with high goal clarity and low autonomy, collective efforts towards creating a shared understanding of new knowledge could lead to paralysis. High levels of autonomy and goal clarity provide R&D teams with "permission" (freedom) and "guidance" (control) so that their ability to create shared understanding of new technical knowledge facilitates their improvisation. Supporting this argument, in a sample of 27 information systems teams from 13 companies, Janz et al. (1997) found that goal clarity interacted with information-sharing behaviors and team innovativeness to enhance team performance. Similarly, research in the computer industry linked the combination of clear priorities with extensive real-time communication and successful NPD, and described this context as one favoring improvisation (Brown & Eisenhardt, 1997). Hence,

Hypothesis 4: Minimal structures positively moderate the relationship between an R&D team's ability to create shared understanding of new knowledge and its improvisation capability, such that the relationship is stronger when minimal structures are greater.

Second, minimal structures strengthen the relationship between R&D teams' experience working together and improvisation capability by empowering teams to decide how to proceed with their work, while keeping them focused on the common goal. As mentioned above, one of the mechanism through which experience working together enhances an improvisation capability is transactive memory. In contexts with high autonomy and low goal clarity, a team's efforts to assign responsibilities and roles according to each member's knowledge could lead to chaotic action. Likewise, in contexts with high goal clarity and low autonomy, these collective attempts at role assignment and division of responsibilities may end in paralysis. The combination of high autonomy and goal clarity guides teams in the assignment of the right responsibilities and roles to the most knowledgeable person and gives members the freedom to leave their comfort zone and formal job descriptions so that R&D teams' experience working together facilitates the capability to improvise.

The autonomy afforded by minimal structures supports experienced R&D teams' improvisation because members feel free to capitalize on each other's broad set of competences and go past formal responsibilities and narrow job descriptions. At the same time, clear goals avoid fragmentation of efforts. Experience working together coupled with minimal structures allows individuals to risk the comfort of their formal job roles and management level, and lets them coordinate in real time in novel ways. Hence,

Hypothesis 5: Minimal structures positively moderate the relationship between an R&D team's experience working together and its improvisation capability, such that the relationship is stronger when minimal structures are greater.

Third, minimal structures strengthen the relationship between R&D teams' ability to gather external knowledge and improvisation capability by providing autonomy combined with guidelines, priorities, and legal boundaries to the collection of external knowledge. External knowledge gathering is closely associated with the first dimension of absorptive capacity, evaluation, where individuals have the ability to scan the environment for new technological developments originating outside the firm and can accurately assess the most valuable external knowledge to target for assimilation (Nemanich et al., 2010). An external knowledge sourcing strategy includes decisions about multiple aspects, such as: depth and breadth of knowledge sourcing; local or distant knowledge sourcing; knowledge sourcing methods such as access to informal networks, R&D collaboration, licensing, and technology acquisition; sources of external knowledge such as universities, supplier-buyer partnerships, outsourcing agreements, and joint research projects; and characteristics of sources such as relational and geographical proximity (Katila & Ahuja, 2002; Rosenkopf & Nerkar, 2001).

In contexts with high autonomy and low goal clarity, R&D teams' efforts towards external knowledge gathering could result in redundant action and misuse of resources. In contrast, in contexts with high goal clarity and low autonomy, external knowledge gathering efforts could lead to narrow-minded perspectives and a dearth of creativity. High levels of autonomy and goal clarity channel external knowledge gathering so that it enriches the improvisation capability. Minimal structures create agreement about the goals, legal boundaries, and priorities associated with the different knowledge sourcing dimensions, so that, within these guidelines, R&D teams have unfettered scope for creativity and autonomy in gathering external knowledge. Thus,

Hypothesis 6: Minimal structures positively moderate the relationship between an R&D team's ability to gather external knowledge and its improvisation capability, such that the relationship is stronger when minimal structures are greater.

METHODS

To test our theory, we combined archival data on innovation and R&D team characteristics with survey data on team capabilities and context. We chose teams who developed computer technology innovations because of the critical role of capabilities for succeeding in rapidly evolving fields and research has demonstrated the relevance of improvisation capability specifically to computer innovations (Brown & Eisenhardt, 1997). In order to select specific innovations for analysis we reviewed the United States Patent and Trademark Office (USPTO)'s patent classification guide to identify all patent classes that included computers or data processing in their title. After eliminating classes dedicated to minor specific fields (i.e. data processing for vehicle navigation), we selected the four most commonly used patent classes in this field: 345 (computer graphics processing), 365 (static information storage or retrieval), 707 (data processing), and 709 (electrical computers and digital processing systems), which contained a total of 10,232 patents from the latest year.

Recent innovations with patents granted in the previous calendar year were selected to enable respondents to accurately remember their development. We randomly selected 2000 patents from this set that met the following criteria: a minimum of two inventors composing the team, an identifiable mailing address, and a unique lead inventor. We used the USPTO data within each individual patent to assess the team's experience working together and the control variables. We then mailed an invitation to participate in an internet survey to the lead inventor (specified on the patent) of the R&D team that developed each of these innovations. We received 151 responses, but missing data reduced the sample to 100 teams with complete responses. Our final sample of 100 teams included teams from 53 companies and 2 universities across a range of computer-related industries. The inventions patented by the teams included methods and systems of accomplishing various hardware and software related issues. We used this survey data to assess the team's improvisation capability, shared understanding capability, external knowledge gathering capability, and minimal structures.

The co-inventors on the patent were used as a proxy for the R&D team (Banerjee & Campbell, 2009). The presence of multiple inventors in a patent has been described as a clear indicator of deliberate collaboration (Ma & Lee, 2008). Although this proxy is well supported in the literature, we conducted detailed follow-up interviews with seven respondents to verify its validity. The interviewees reinforced the assumption that legal requirements drove them to ensure that everyone who made intellectual contributions to the innovation and only those people were listed on the patent as the inventors. They indicated that the work done by those named on the patent was largely collaborative, with only a small percentage of work done independently (e.g., the origination of the idea was frequently mentioned as the aspect of the work done independently), suggesting that they were indeed teams, rather than collections of individuals. They also agreed that situations requiring improvisation were common for R&D teams.

We used lead inventors as key referents. Although research that collects data on member perceptions of team *climate* often employs multiple respondents per team, we were collecting data on team *capabilities*. Key informants are appropriate in our context since they are preferred over multiple informants when the selected person is uniquely qualified to respond to the issues in question (Dyer & Hatch, 2006).

Measures

Table 1 reports the scale items. Archival measures were determined using the USPTO database. Survey measures—with the exception of the improvisation capability measure, built on existing scales—were newly developed and derived through a multi-step process. First, we carefully defined each construct, and then drafted initial scale items based on a review of the literature. Next, we put this list of items through several iterations to verify face validity, adherence to the construct definition, and full capture of the construct. As part of this process, the items were refined separately by two of the authors, and then reviewed by a third researcher with expertise in scale development. Differences of interpretation were resolved. Finally, we refined the measures through a pilot test performed with a sample of graduate students, using a seven-point Likert scale from strongly disagree (1) to strongly agree (7).

Insert Table 1 about here

We used three items to capture the dependent variable, *improvisation capability* in R&D teams (alpha = 0.83). We built our measure on the existing measures of improvisation created by Moorman and Miner (1998a) and Vera and Crossan (2005). As suggested by the examples from our interviews, R&D teams used the improvisation capability for both operational and dynamic purposes. Hence, our items capture improvisation being used to respond to unexpected problems or opportunities, but are not explicit to the degree to which improvisational actions contributed to the operational functioning of the team or changed the team's operational routines.

We measured *shared understanding of new knowledge ability* with three survey items (alpha = 0.93), reported in Table 1. *Experience working together* was the natural logarithm of the number of previous patents that the team had developed jointly. *External knowledge gathering ability* was measured with the two survey items reported in Table 1 (alpha = 0.93).

To our knowledge, no scale for minimal structures is available in the literature. In their case-based research, Brown and Eisenhardt (1997) collected qualitative data on minimal structures focusing on the presence of extensive communication, clear responsibilities, clear priorities, and formal cross-project meetings. Relatedly, Davis, Eisenhardt, and Bingham (2009) operationalized the concept of structure as simple rules, as part of a simulation-based study. We assessed *minimal structures* as the product of two measures that capture both the freedom and control aspects of the construct. This follows the method used, for example, by Mom, Van den Bosch, and Volberda (2009) when measuring ambidexterity--a construct that also incorporates two necessary aspects (the need to simultaneously explore and exploit). Those scoring high on the construct score high on both dimensions, while scoring low on either dimension substantially reduces the overall score. Thus, in our case, those scoring high on minimal structures show high levels of both freedom and control, which corresponds to the scenario of “freedom within boundaries” or “constrained freedom.”

An important consideration in operationalizing minimal structures is the fact that freedom and control could be conceptualized as opposite ends of a continuum if one assumes that the two constructs are strongly inversely correlated--as control goes up, freedom goes down, and vice-versa. In such a case a curvilinear specification would best capture the nature of the relationship of minimal structures and the dependent variable, where the optimal level occurs at the inflection point of the inverted-U relationship. However, as in the case of ambidexterity (where exploration and exploitation are orthogonal constructs), we measure control and freedom on two separate aspects of the working environment so that greater scores on each reflect greater levels of the two necessary aspects needed for minimal structures. We assessed the freedom aspect with the R&D team’s level of task *autonomy* in developing its innovation and the control aspect as the *goal clarity* of priorities and objectives. In contrast to “freedom” and “control,” “autonomy” and “goal clarity” are not inversely correlated. Having high goal clarity about priorities and objectives does not imply having low autonomy in making operational decisions about the innovation. Similarly, having low goal clarity about priorities and objectives does not imply having high operational autonomy in making decisions about the innovation. In our operationalization of minimal structures, having high autonomy and high goal clarity result in the highest level of minimal structures; since both aspects are needed to achieve “freedom within boundaries”, we use the product of the two factors.

Autonomy, the capability to act autonomously without seeking management approval, was measured with three survey items (alpha = 0.89) reported in Table 1. We assessed the control aspect by looking at whether the team's direction was constrained by defined project goals. Although many R&D projects start out with one goal and that goal can then shift, our items capture the notion of the goals being clear from the beginning of the project without limiting them to one static goal. *Goal clarity*, the extent to which the R&D team's objectives are clearly defined for the team at any point in time, was measured with three survey items (alpha = 0.88).

The construction of the minimal structures variable as the product of autonomy and goal clarity effectively makes the tests of the interaction hypotheses three-way interactions. We ran additional analyses including all main effects and two-way interactions of the three variables from this perspective (including the additional two-way interactions), and found they did not change our analysis conclusions. That is, the addition of the other two-way interactions did not change the significance levels of any of the hypothesized effects.

To develop a comprehensive set of control variables that represent potential alternative explanations for an improvisation capability in R&D teams, we used Cunha et al.'s (1999) extensive review of the improvisation literature. We included as controls the following widely accepted factors influencing improvisation: group size, skill, procedural memory and declarative memory, and sense of urgency (Cunha et al., 1999; Crossan et al., 2005; Weick, 1993).

We used the number of co-inventors on the patent as a proxy to control for *team size*. We controlled for whether the R&D teams were virtual or *collocated* with a dummy variable set to one for geographically collocated teams. We controlled for both technical skill and procedural memory with the variable *technical expertise*, which assesses experience gained from developing prior innovations in the field. Technical expertise in innovation-dependent industries has been measured in previous research by assessing the cumulative number of patents issued to individuals or firms on the basis that each patent represents success in applying knowledge in an innovative way (Song, Almeida & Wu, 2003). Patent counts are highly skewed, so we measure team technical expertise as the natural logarithm of the combined number of patents previously developed by team members (Jaffe & Trajtenberg, 2002).

We controlled for declarative memory--knowledge of facts--, which has been theorized as an antecedent to improvisation effectiveness (Cunha et al., 1999; Moorman & Miner, 1998a, 1998b; Vera & Crossan, 2005; Weick, 1998). We translated declarative memory in R&D as the team's *knowledge stocks* in their area of innovation. Patents provide documented insight into the source of relevant knowledge through citations that are audited by an independent patent examiner. Thus, we measured *knowledge stocks* as the percentage of self-citations (patents, publications, etc.) versus citations to external sources listed in the patent (Jaffe & Trajtenberg, 2002).

We controlled for the team's sense of urgency by the level of *time pressure* they perceived in developing their project. We asked, "When you began working on this project, how important were each of the following possible objectives?" Five objectives were listed, including keeping costs low and incorporating state-of-the-art technology. We measured time pressure by the importance assigned to "getting to market quickly." Finally, we included two firm dummy variables to partially control for firm effects. Although 53 different firms were represented, two firms comprised 25% of the sample. Thus, we controlled for these two firms with dummy variables, *Firm 1* and *Firm 2*. We withheld the names to protect promised confidentiality.

RESULTS

Table 2 includes descriptive and correlation data. Interaction variables were centered and hierarchical regression was used in order to reduce the effects of collinearity (Aiken & West, 1991; Hair Jr, Black, Babin, Anderson & Tatham, 2010). Although we used two separate data sources, we ran a Harman single factor test for common method variance. It showed five factors with eigenvalues greater than 1 and the largest factor explained only 25% of the variance. Since a single factor did not emerge and the primary factor did not explain a majority of the variance, there is no indication that common method variance is a significant source of bias (Podsakoff & Organ, 1986).

Insert Table 2 about here

Table 3 shows the results of the hierarchical regression models. In Model 1, which includes just control variables, only autonomy is significantly related to improvisation ($p < 0.001$). Across all models, the non-survey control variables knowledge stocks and collocated approach were significant in at least one model. In Model 2, a team's shared understanding and external knowledge gathering are positively related to improvisation capability ($p < 0.01$), providing strong support for H1 and H3. Experience working together is not significantly related to improvisation capability, which does not support H2. Model 2 explains an additional 33% of the variance in improvisation capability over the control variables.

Insert Table 3 about here

Interaction effects introduced in Models 3 to 5 are shown in Figure 3 following Aiken and West's (1991) simple slope analysis. This analysis depicts the effects of shared understanding, experience working together, and external knowledge gathering on improvisation at different levels of the moderating variable, minimal structures. The interaction of shared understanding and minimal structures is positively related to improvisation capability ($p < 0.001$) in Model 3, providing strong support for H4. Figure 3 shows no relationship between shared understanding and improvisation when minimal structures is at the mean level. Shared understanding and improvisation are positively related when minimal structures is one standard deviation above the mean, and negatively related when minimal structures is one standard deviation below the mean.

Insert Figure 3 about here

The interaction of experience working together and minimal structures is also positively related to improvisation capability ($p < 0.05$) in Model 4, providing support for H5. Figure 3 shows no relationship between experience working together and improvisation when minimal structures is at the mean level. Experience working together and improvisation are positively related when minimal structures is one standard deviation above the mean, and negatively related when minimal structures is one standard deviation below the mean.

The interaction of minimal structures and external knowledge gathering is negatively related to improvisation capability ($p < 0.05$) in Model 5, which is the opposite effect suggested by H6. Figure 3 shows a slightly positive relationship between external knowledge gathering and improvisation when external knowledge is at the mean level. However, the relationship is somewhat stronger when external knowledge is one standard deviation below the mean and somewhat weaker, but still positive, when external knowledge is one standard deviation above the mean. Thus, because the effect is in the opposite direction specified, H6 was not supported.

Model 6 is the full model with all control, independent, and interaction variables entered simultaneously. The significance of shared understanding, external knowledge gathering, and the interaction of shared understanding and minimal structures remained the same, while the other two interactions became non-significant. This provides further support for H1, H3, and H4.

DISCUSSION

Overall, our results identified different ways in which the knowledge- based factors associated with an R&D improvisation capability interact with the context. Our main findings are that: (1) R&D teams' ability to create a shared understanding of new knowledge is positively related to improvisation capability and this relationship is strengthened by minimal structures; (2) R&D teams' experience working together is, by itself, not associated with improvisation capability, but when minimal structures are present, more experience working together is positively related to improvisation; and (3) R&D teams' external knowledge gathering ability is positively associated with an improvisation capability, but, surprisingly, when minimal structures are present, this positive effect is reduced.

Our finding of a relationship between the ability of an R&D team to create a shared understanding of new knowledge and improvisation capability extends past research that has identified knowledge resources as essential to improvisation. Moorman and Miner (1998a) found that organizational memory (e.g., standard procedures, strong skills) improved the impact of improvisation on various process and product outcomes, and Vera and Crossan (2005) found an effect for the moderating role of team expertise (e.g., awareness of critical issues, knowledge in diverse fields). Creating shared understanding goes beyond having a knowledge resource, such as memory or expertise; it involves collective knowledge articulation and integration in the team. Shared understanding is closely related to Weick's (1993) discussion of improvisation, role theory, and resilience in the Mann Gulch disaster. As Weick (1993) suggested, many role systems do not change fast enough to keep up with a rapidly changing environment. Because we measure the ability to create a common understanding of *new* knowledge in contrast to *prior* knowledge, we help to provide a more dynamic view of the common representation of knowledge that supports effective improvisation. Thus, our results advance prior work by highlighting not only the need for teams to build on shared knowledge from declarative or procedural memory from the past (Moorman & Miner, 1998b), but also the importance of making sense of the new information coming in the moment in order to improvise effectively.

The lack of significance for the effect of experience working together on the capacity to improvise suggests that the drawbacks of team experience and longevity play a role bigger than we anticipated, so that, on average, the benefits and drawbacks of experience working together wash themselves out. For example, Goncalo (2004) studied convergent thinking in groups and argued that previous success often causes groups to think narrowly around strategies that have worked in the past, even when external change has rendered these strategies ineffective. Moreover, Sundstrom et al. (1990) related effectiveness to team lifespan and working time and suggested that this relationship might decline over time; while Harrison, Mohammed, McGrath, Florey, and Vanderstoep (2003) concluded that high familiarity among members might be more useful early in a team's development, rather than in the long term.

Another factor to consider in the relationship between experience working together and improvisation capability is the fact that R&D teams are potentially assembled and disassembled depending on the project, which could reduce the benefits of experience. Our assumption was that when membership in creative teams is fluid, teams are more likely to reconvene for new projects when their members are satisfied with previous collaborative efforts, so the gain in collaboration from experience would be amplified by selectivity in assembling teams that work well together (Taylor & Greve 2006). However, fluid membership in R&D teams could also have implications for goal congruence when project-based teammates have competing goals.

Studying the congruence between team members' individual goals and the team's goals, as they relate to the team's experience working together, would provide deeper understanding of the link between experience and improvisation in creative and fluid contexts, such as R&D.

Nevertheless, while hypothesis 2 about the main effect of experience working together was not supported, we did find a positive effect between experience working together and improvisation when minimal structures were present (hypothesis 5), suggesting that under conditions of high autonomy and clear goals, the benefits of team experience do outweigh the potential drawbacks mentioned here. The lack of support for hypothesis 2 and the support for hypothesis 5 is also consistent with the idea that experience working together may actually force team members into pre-defined roles that preclude them from participating in the group and improvising beyond their perceived expertise. In contrast, when the context emphasizes autonomy within clear goals, team members are more likely to go beyond their formal roles and build on their experience to improvise. This finding can help to refine and contextualize theories about the role of repeated practice and experience accumulation as learning mechanisms behind the evolution of dynamic capabilities (Eisenhardt & Martin, 2000; Zollo & Winter, 2002).

An insightful result of this study is that minimal structures, by themselves, are not related to an improvisation capability. Our plots show the impact of minimal structures, clarifying that this variable does have an effect; it just does not have an unconditional effect, which offers a different perspective on minimal structures than the one suggested in the past, where qualitative and theoretical work suggested a main rather than an interaction effect(e.g., Brown & Eisenhardt, 1997; Cunha et al., 1999; Kamoche & Cunha, 2001).

For both the ability to create a shared understanding of new knowledge and experience working together, when minimal structures were used in the R&D teams, high levels of these variables were positively associated with improvisation capability. These findings about the contingent role of minimal structures advance prior work relating teamwork skills to effective team improvisation. Past research was sometimes vague about what it really meant to have "teamwork quality" that enabled improvisation. For example, Vera and Crossan's (2005) teamwork construct included factors as diverse as acceptance of ideas coming from others, trust, encouragement of different points of view, being alert to opportunities presented by others, and taking the lead at different times depending on the needs of the situation. In this sense, the concept of shared understanding of new knowledge and experience working together within the boundaries of autonomy and clear goals creates a more comprehensive and detailed picture of what teamwork behind an improvisation capability looks like.

A surprising finding was the fact that minimal structures did not strengthen, but weakened the positive relationship between external knowledge gathering and improvisation capability. A potential explanation for this negative interaction effect is that "the search for new technological knowledge entails a complex mixture of strategic and opportunistic behavior, triggered by the special circumstances of innovation races" (Lane & Probert, 2007: 7). When engaged in opportunistic behavior, clear goals, priorities, and objectives might inhibit the possibilities that external knowledge opens for R&D teams' improvisation processes. In contrast, when engaged in strategic behavior, high autonomy may lead to the misuse of the resources targeted for a specific strategic intent. Thus, external sourcing of knowledge might benefit from low minimal structures in the form of low autonomy and high goal clarity, in the case of strategic action; or low minimal structures in the form of high autonomy and low goal clarity, in the case of opportunistic action. Another reason why minimal structures might weaken the link between external knowledge gathering and improvisation is that R&D members are experts in their fields

(Bailyn, 1985; Raelin, 1985) and their expert status might be enough to guide their external knowledge gathering efforts as part of their improvisation capability. This opens an appealing possibility for future research to look at boundary conditions for the role of minimal structures and the role played by the level of individual professionalism and expertise.

Finally, one of our control variables, knowledge stocks, which we operationalized as the ratio of self-citations to external citations in the patent, had a positive and significant ($p<.05$) effect on improvisation capability, in five of our six models. This self-citation ratio has been also used in the as a proxy for innovation radicalness, with higher ratios of self-citations indicating incremental innovation and lower ratios indicating radical innovation (Lanjouw & Schankerman, 2003). When this control variable is interpreted from the perspective of radical versus incremental innovation, this result suggests that incremental innovation provides a safer context for improvisation, and that R&D teams are more likely to use their improvisation capability when they come up with incremental innovations by relying more on their internal knowledge stocks, and less on external knowledge. Future research could further examine the link between incremental and radical innovation and improvisation that our control variable starts to suggest.

Limitations

This study has some limitations of which readers should be mindful. Since the sample was limited to R&D teams in computer technology, future research can assess the generalizability of our results to other R&D fields. However, the sample did include teams from 53 different organizations from industry and 2 from academia. Most of the teams worked in the computer industry, but our sample also included teams from the telecom, medical equipment, and aerospace industries. This variety provides some confidence for inference to other high-technology arenas. Yet, because our sample included numerous different firms, our dummy variables for firm effects only applied to 25% of our sample. Future studies should consider limiting the sample to only a few firms to allow for definitively controlling for firm effects.

The combination of data from inventor surveys and archival data from patents necessitated a focus on successful R&D teams. Thus, our sample might suffer from a survival bias, which could lead to range restriction, reducing our power to detect relationships, and increasing the likelihood of Type II error. Yet, we do not believe that survival bias substantially negatively affects the study of the factors promoting an effective improvisation capability due to the complexity of the improvisation-performance link, which past research has modeled through contingent factors that enhance improvisation effectiveness (e.g., Moorman & Miner, 1998a; Vera & Crossan, 2005). Furthermore, if team performance is strongly related to improvisation capability, our findings are likely to understate the actual strength of the relationships we examine. Thus, we would speculate that the relationships we discovered may be stronger in teams that were not successful, which we recommend should be investigated in future research.

Another limitation of our design is that we asked R&D scientists to reconstruct the fabric of working relationships of a past project, which might limit the accuracy of the data due to biases and selective retention. The tradeoff was that focusing on projects that had received patents allowed us to incorporate both archival and survey data in the study. We tried to reduce this time frame by only sampling projects that had received a patent within the foregoing year. Further, as with all survey research, our findings might reflect the respondent's beliefs rather than purely causal effects. We believe that this is less of a possibility in our research than in most studies. First, our data include numerous objective measures, which would not be subject to perceptual biases. Second, our analysis includes a number of interactions that, because of their complexity, are less likely to be statistically supported due to perceptual preconceptions of respondents.

The low response rate on the survey data is also a limitation. In addition to the 8% of the surveys that were returned fully or partially completed, we had a very large number of returned and undeliverable requests due to high levels of mobility in this technology field. After analysis, we estimate the actual response rate to be 14%. We did develop evidence that the response rate was large enough to yield a representative sample. We compared the respondent sample to the full sampling frame on the means of team size, invention scope (number of technological sub-classes into which the patent was classified), and invention size (number of unique claims for the innovation approved by the patent examiner), and found no significant differences (p = 0.75, 0.70, and 0.97 respectively). We also used t-tests to compare early respondents to late respondents on all the independent and dependent variables, and found no significant differences. Follow-up communication with five respondents and five non-respondents suggested that our response rate was highly satisfactory considering that this population is extremely sensitive to issues concerning patent confidentiality both for legal and competitive reasons. Respondents indicated that they trusted our promise of confidentiality enough to respond since the patent had been awarded. Non-respondents generally felt that their firms would not want them to share information on innovation development even for academic purposes. Thus, response rate would appear to be a complication directly related to the specific phenomena and context we studied. Future studies outside the context of R&D, within a technology field that is less competitive or less reliant on innovation for competitive advantage, or conducted within a single firm's R&D lab with the support of executive management, may be able to avoid this difficulty.

Further, the low response rate resulted in us having a final sample size of 100 teams. Because our full model included 17 independent variables, our lowest sample size to independent variable ratio is 5.9:1, which is below the desired level of 15 or 20 to 1, but above the general rule that it should not fall below 5:1 (Hair, et al., 2010). Thus, because we did not reach the desired level, the generalizability of the results may be reduced (Hair, et al, 2010).

Finally, there are also some limitations with our measures. Our measure of goal clarity did not differentiate whether the goals are set top-down or self-determined, and our measure of autonomy did not incorporate the level or levels of management approval needed. These aspects could affect the perception of autonomy and should be considered in future research. In addition, our measure of experience working together is based on the number of patents successfully developed by the team. This measure may not fully capture the construct because some teams without many patents may have spent a considerable amount of time working together. Future research should broaden the domain of this measure to reflect time working together.

Implications for Theory

This study offers several theoretical and empirical contributions. First, we contribute to R&D research by highlighting the role of an improvisation capability in successful R&D teams. At the same time, examining the improvisation capability in R&D, a context in which improvisation had not been studied before, calls attention to new facets of improvisation in management. Past research has suggested that improvisation could be difficult in non-egalitarian teams like the ones in our sample, but our study provides evidence that improvisation is present in R&D teams, despite the power imbalances and legal constraints.

Second, we position improvisation as a capability and open the debate about improvisation as a special type of capability with operational and dynamic purposes, and which can also be a learning mechanism for the development of other capabilities. Our measure of improvisation capability works for both operational and dynamic purposes because it focuses on the capacity of R&D teams to deal with unexpected surprises and problems in real-time. This is the essence of improvisation independent of whether the capability is being applied to unanticipated problems or opportunities in the current operational functioning of the team, or to unanticipated problems or opportunities that change how the team operates. Another differentiating factor is that, in contrast to dynamic capabilities that support specific activities of the firm, such as conducting acquisitions or new product development, improvisation is a generic capability without a functional orientation. We hope our proposal of a capability view of improvisation helps to spark more dialogue about the costs and benefits of developing this special multipurpose capability.

Third, scholars have mostly identified the contingencies related to effective improvisation, yet, we propose that a new, fruitful path is to examine the underlying routines, structures, and skills of improvisation (Teece, 2007). Although our cross-sectional design did not allow us to examine our factors associated with R&D improvisation capability as micro-foundations impacting its origin and development, our findings offer a snapshot in time of several knowledge-based and contextual factors supporting the capacity of an R&D team to improvise. Depending on the levels of autonomy and goal clarity, the ability to create a shared understanding of new knowledge, experience working together, and the ability to gather external knowledge influence an R&D team's improvisation capability. The work on minimal structures is particularly exciting and timely, given the growing interest in this and related concepts like minimal constraints, semi-structures, and simple rules. We provide one of the first empirical tests of minimal structures and provide a different picture of the relationship by finding that minimal structures are not related to improvisation directly but that, when coupled with teams' shared understanding or experience working together, they enhance teams' improvisation capability. At the same time, a provocative and unexpected finding was the negative interaction effect between external knowledge gathering and minimal structures.

Finally, our study offers empirical contributions given that it is among the still rare work that presents systematic quantitative research on improvisation. Our improvisation measure can be easily adapted to contexts other than R&D and, to our knowledge, is the first attempt to measure capabilities by asking informants to assess their improvisation capability in contrast to their improvisational actions. Another difference between ours and prior measures is that our scale is not neutral about effectiveness. Future scale development efforts that focus on improvisation as a capability will help to further understand what it takes to become skillful in improvisation.

Implications for Practice

Our results have important managerial implications. Firms struggle to respond to dynamic environments, competitive moves from rivals, and changing institutional climates. Improvisation capabilities can be used to help firms create competitive advantages and innovate. R&D teams are at the heart of innovation in organizations. A better understanding of improvisation in R&D teams enables managers to better assess an innovation's potential, particularly in relation to the speed of innovation, the rate of innovation, and the reaction time to rivals' innovations.

In particular, our findings suggest that R&D managers should carefully consider group dynamics, processes, and interactions, in forming teams for projects that may benefit from improvisation. The ability to reach a shared understanding and the ability to gather external knowledge are key aspects to consider when selecting and training members of a team. In creating the context in which the R&D team will work, managers should realize that delegating authority to the team for autonomous action and providing it with clear goals for the project's outcome will enhance the benefit of the team's ability to create shared understanding and its experience working together on the team's capacity to improvise. External knowledge gathering ability will always benefit improvisation capability, but the autonomy and clear goals that enhance the relationship between shared understanding and improvisation and the relationship between experience working together and improvisation, will suppress some of the positive effects of external knowledge gathering on improvisation.

Future Research Directions

We see several natural directions for future research. First, as mentioned earlier, scholars could look at how the improvisation capability is developed. Our cross-sectional design did not allow us to capture capability origins and evolution. Longitudinal or qualitative research could validate the knowledge-based process and interactions and the context we identified as actual micro-foundations of the improvisation capability. Given prior research arguing that improvisation is a skill that can be learned (Vera & Crossan, 2005), it would be intriguing to test the development rate and the learning speed of this capability in teams. Furthermore, longitudinal work would also enable the examination of the dynamic aspects of our model. Both the knowledge-based factors and the minimal structures discussed are dynamic and can impact each other. Thus, future research can look, for example, at how a change in minimal structures may affect R&D teams' knowledge-based processes and interactions over time.

Second, improvisation has been described as a paradoxical and dialectic process with inherit tensions (Weick, 1998). Our study took a first step at operationalizing minimal structures by focusing on autonomy and goal clarity, suggesting that "freedom within boundaries" was achieved at higher levels of both. Freedom and control could also be operationalized with measures of the work environment that capture the more conventional conception of freedom and control, where the two measures are strongly negatively correlated and envisioned as endpoints of the same continuum. Such a measure would allow the identification of the optimal level of freedom versus control by identifying the inflection point in the inverted U-shaped curvilinear model. Further, our study also incorporated the tension between experience (shared understanding and experience working together) and creativity (ability to gather external knowledge). This coexistence of “old” and “new” knowledge is consistent with the phenomenon of ambidexterity, the balance between exploration and exploitation. The capability to improvise could help teams to achieve real-time ambidexterity because teams can explore and develop novel solutions to problems or opportunities by exploiting and recombining current routines. New studies could further examine the dialectical essence of the improvisation capability.

Third, the circular relationship between improvisation and learning opens rich possibilities for future research. We studied three knowledge-based processes and interactions associated with R&D improvisation capability, which are closely associated to experience accumulation and knowledge articulation—learning mechanisms behind the development of dynamic capabilities (Zollo & Winter, 2002). But, while learning mechanisms help improvisation capability to be developed, improvisation itself is a learning mechanism that helps other capabilities to be developed (Eisenhardt & Martin, 2000; Zahra et al., 2006). Future research could look go deeper into the feedback loops interconnecting learning and improvisation.

Finally, we see great potential in studying the link between improvisation and routines with a multilevel approach that decomposes capabilities and routines into lower level constructs such as individual behavior, cognition, skills, habits, and emotions. Also, future research might explore routines *as* improvisation, which builds on Feldman and Pentland’s (2003) idea of routines as alive and as never executed exactly the same way twice, so that, every time we execute a routine, we are improvising. We invite researchers to further explore the ways in which an improvisation capability can enable firms to sense threats, seize opportunities, and maintain competitiveness.

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Table 1

Survey measures

Variable
Improvisation Capability (alpha = 0.83) 1. While designing this innovation, our team was very good at dealing spontaneously with unanticipated problems. 2. While designing this innovation, our team was very capable at responding extemporaneously to unexpected opportunities. 3. While designing this innovation, our team had a strong capability to creatively improvise.
Shared Understanding of New Knowledge Ability (alpha = 0.93) 1. With respect to communicating about valuable new technical knowledge, our team was very competent at pooling it within the team. 2. With respect to communicating about valuable new technical knowledge, our team had a strong ability to develop a shared understanding of it. 3. With respect to communicating about valuable new technical knowledge, our team was skillful at combining it to create a collective understanding.
External Knowledge Gathering Ability (alpha = 0.93) 1. With respect to new technological developments originating outside your company, at least some individual team members were very capable at gathering news about them. 2. With respect to new technological developments originating outside your company, at least some individual team members were very skillful at finding out about them.
Minimal Structures Autonomy (alpha =0.89) 1. Without seeking management approval, our team could experiment freely while designing the innovation. 2. Without seeking management approval, our team could make our own decisions about the innovation design. 3. Without seeking management approval, our team could try out our ideas for the innovation design. Goal Clarity (alpha = 0.88) 1. From the beginning of this invention project, our team was very clear about its objectives. 2. From the beginning of this invention project, our team was given clear guidance on what our top priority objectives should be. 3. From the beginning of this invention project, our team had a firm understanding about the objectives we were expected to achieve.

Table 2

Descriptive statistics

Variable	Mean	SD	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1. Improvisation[a]	5.97	0.83																	
2. Team Size[b]	3.23	2.26	-0.13																
3. Collocated[b]	0.76	0.43	0.06	-0.09															
4. Technical Expertise[b]	2.60	1.23	0.12	0.08	-0.17														
5. Knowledge Stocks [b]	13.4	19.5	0.13	0.01	0.02	0.16													
6. Time Pressure[a]	5.03	1.61	0.15	0.04	0.01	0.07	-0.07												
7. Firm 1[b]	0.13	0.34	0.13	0.01	-0.06	0.12	0.14	0.09											
8. Firm 2[b]	0.12	0.33	-0.06	-0.11	0.21	-0.12	0.27	0.15	-0.14										
9. Number of Claims[b]	25.8	19.6	-0.05	0.11	-0.02	0.13	-0.12	-0.02	0.02	-0.07									
10. Goal Clarity[a]	5.14	1.57	0.28	0.04	0.22	-0.08	-0.01	0.21	0.13	0.07	-0.07								
11. Autonomy[a]	6.31	0.94	0.51	-0.40	0.05	-0.05	0.04	-0.02	0.21	-0.02	-4.E3	0.24							
12. Shard Understanding[a]	5.84	1.01	0.63	-0.16	0.06	-0.09	-0.12	0.10	0.08	-0.03	-0.08	0.40	0.36						
13. Experience[b]	0.52	0.71	0.22	-0.16	0.09	0.38	0.09	0.08	-0.01	-0.03	0.16	0.03	0.10	0.01					
14. External Knowledge [a]	5.26	1.31	0.48	0.01	-0.12	0.03	-0.15	0.24	0.03	-3.E3	-0.04	0.25	0.14	0.52	0.04				
15. Minimal Structures	32.8	11.5	0.42	-0.14	0.21	-0.08	0.01	0.15	0.20	0.05	-0.07	0.92	0.58	0.45	0.07	0.26			
16. Shared Und. X MS.	-0.53	4.89	0.60	0.01	0.21	-0.07	0.01	0.18	0.08	-0.01	4.E3	0.32	0.41	0.50	0.08	0.27	0.35		
17. Experience X MS.	-0.01	0.90	0.30	0.07	0.22	-0.02	-0.02	0.28	-0.09	0.10	0.09	0.15	0.06	0.30	0.07	0.12	0.08	0.54	
18. External K. X MS.	3.90	18.7	-0.22	0.06	-0.03	0.11	-0.04	-0.12	0.07	-0.19	0.13	-0.07	-0.09	-.02	-.10	-.20	-.06	-.38	-0.38

Notes. N = 100; [a] Survey measure; [b] Archival measure;

$p < 0.05$ when $r > |0.20|$; $p < 0.01$ when $r > |0.26|$; $p < 0.001$ when $r > 0.32$.

Table 3

Regression results for improvisation capability

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Variable	B (s.e.)	B (s.e.)	B (s.e.)	B (s.e.)	B (s.e.)	B (s.e.)
Size	0.01 (0.04)	0.03 (0.03)	0.01 (0.03)	0.02 (0.03)	0.03 (0.03)	0.01 (0.03)
Collocated	0.16 (0.18)	0.25 (0.14)	0.11 (0.13)	0.18 (0.14)	0.25† (0.13)	0.09 (0.13)
Technical Expertise	0.08 (0.06)	0.06 (0.05)	0.08 (0.05)	0.06 (0.05)	0.08 (0.05)	0.07 (0.05)
Knowledge Stocks	4.E3 (4.E3)	7.E3* (3.E3)	6.E3* (3.E3)	7.E3* (3.E3)	7.E3* (3.E3)	6.E3* (3.E3)
Time Pressure	0.07 (0.05)	0.03 (0.04)	0.01 (0.03)	0.01 (0.04)	0.03 (0.04)	0.01 (0.03)
Firm 1	-0.07 (0.05)	-0.01 (0.17)	-0.01 (0.15)	0.03 (0.17)	-0.01 (0.17)	0.01 (0.16)
Firm 2	-0.16 (0.25)	-0.11 (0.18)	-0.05 (0.17)	-0.13 (0.18)	-0.17 (0.18)	-0.07 (0.17)
Number of Claims	-3E3(4.E3)	-02E3(3.E3)	-02E3(3.E3)	-03E3(3.E3)	-01E3(3.E3)	-02E3(3.E3)
Goal Clarity	0.06 (0.05)	0.05 (0.19)	0.05 (0.19)	-0.08 (0.19)	-0.03 (0.19)	-0.35† (0.19)
Autonomy	0.44 ***(.10)	0.38* (0.15)	0.33† (0.19)	0.27† (0.16)	0.30† (0.15)	- 0.03 (0.16)
Shared Understanding		0.40*** (0.07)	0.30*** (0.07)	0.36*** (0.07)	0.43*** (0.07)	0.29*** (0.07)
Experience		0.12 (0.09)	0.09 (0.08)	0.11 (0.08)	0.09 (0.08)	0.09 (0.08)
External Knowledge		0.16** (0.05)	0.14** (0.05)	0.17*** (0.05)	0.14** (0.05)	0.15** (0.05)
Minimal Structures		-0.02 (0.03)	0.04 (0.03)	0.01 (0.03)	-0.01 (0.03)	0.05 (0.03)
Shared Und. X Min. Structures			0.07*** (0.01)			0.06*** (0.02)
Experience X Min. Structures				0.16* (0.07)		0.05 (0.07)
External Knowledge X Min. Structures					-0.01* (3.E3)	0.00 (3. E3)
R^2	0.32***	0.65***	0.72***	0.67***	0.67***	0.73***
Adjusted R^2	0.25***	0.59***	0.67***	0.61***	0.61***	0.67***
ΔR^2		0.33***	0.07***	0.02*	0.02*	0.07***

Notes. N = 100;

†*p*<.10

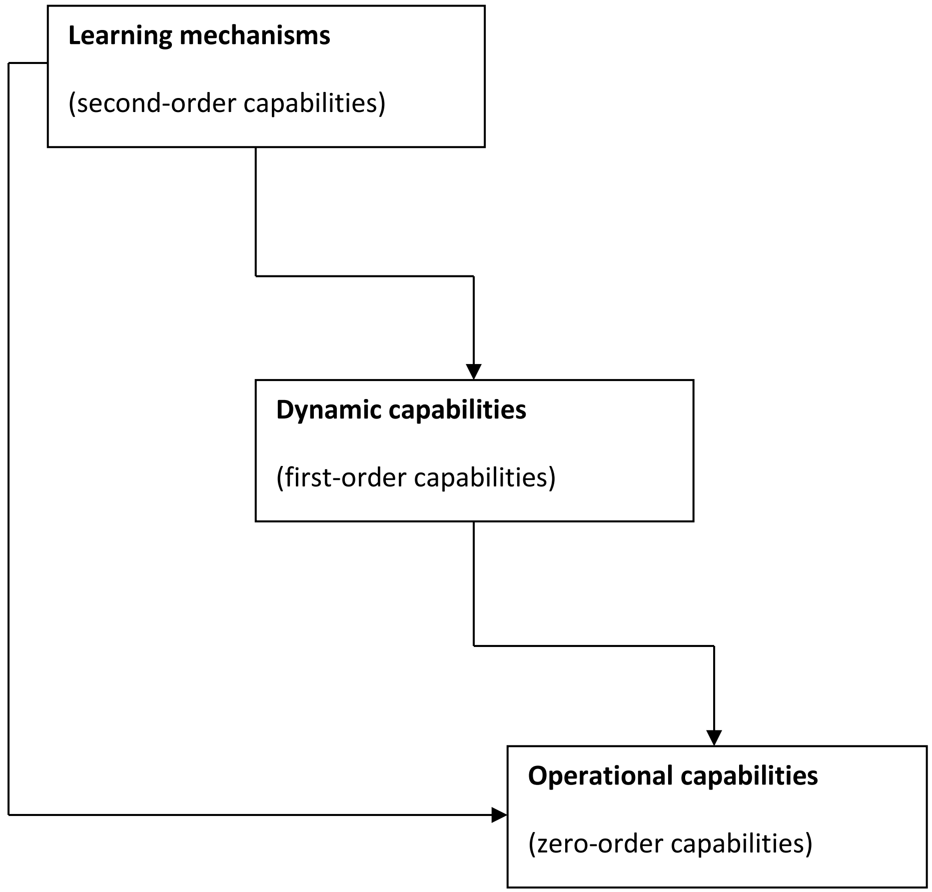
**p* < .05

** *p* < .01

*** *p* < .001.

Figure 1

Improvisation capability and Zollo & Winter's (2002) capability hierarchy



Improvisation as a learning mechanism builds on learning by doing, and can be a part of long-term trial-and-error learning. Improvisation guides the development of dynamic and operational capabilities particularly in high-velocity environments and entrepreneurial settings.

A **dynamic capability in improvisation** enables a team to alter how it "earns a living" (Winter, 2003). Improvisation is the team's capacity to act spontaneously in trying to respond to problems or opportunities in a novel way. Improvisational outcomes are retained and change the team's current processes, product, and services.

An **operational capability in improvisation** enables a team to "earn a living" (Winter, 2003). Improvisation is the team's capacity to act spontaneously in trying to respond to problems or opportunities in a novel way. Improvisational outcomes are short-term and do not permanently change the team's current processes, products, and services.

Figure 2

Conceptual model

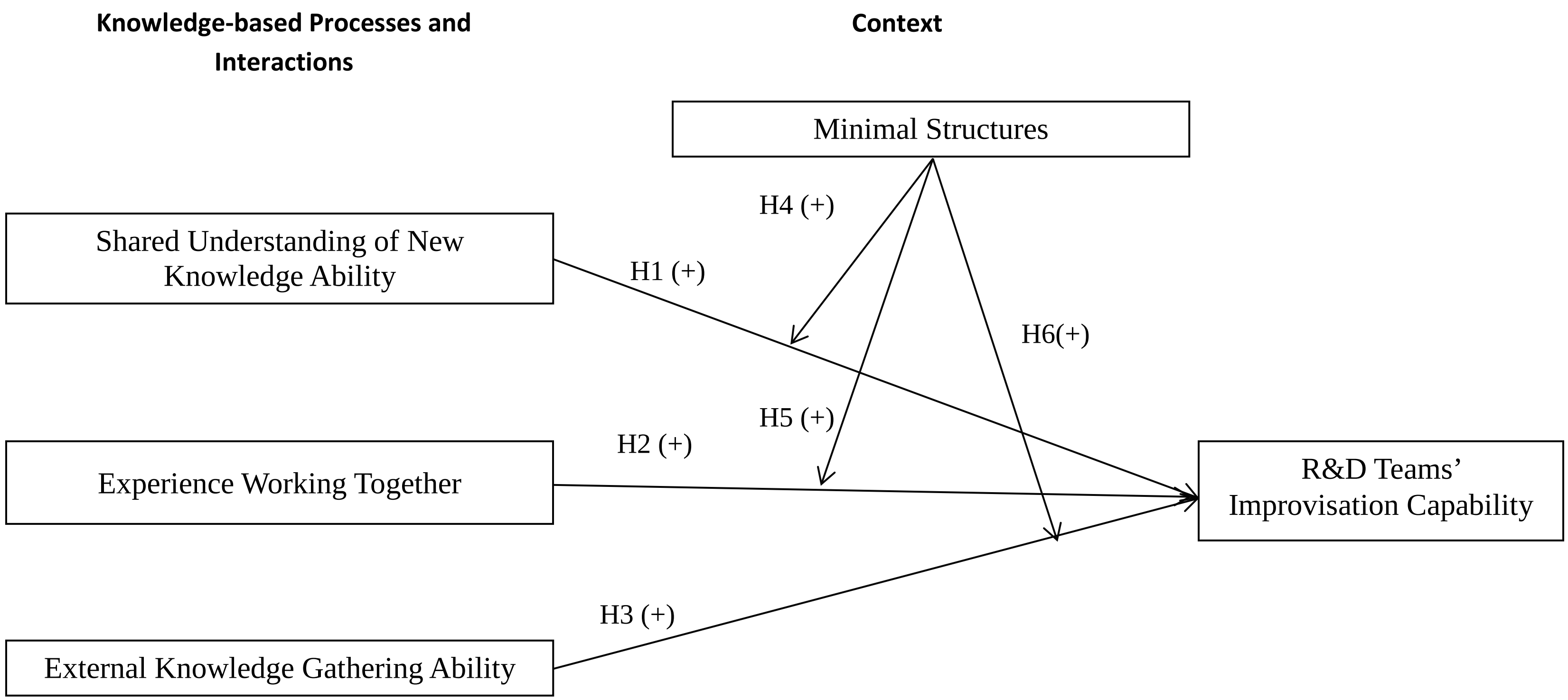


Figure 3

Interaction effects