

Unpacking the
Concept of Virtuality:
The Effects of
Geographic Dispersion,
Electronic Dependence,
Dynamic Structure, and
National Diversity
on Team Innovation

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To understand why the virtual design strategies that organizations create to foster innovation may in fact hinder it, we unpack four characteristics often associated with the term “virtuality” (geographic dispersion, electronic dependence, structural dynamism, and national diversity) and argue that each hinders innovation through unique mechanisms, many of which can be overcome by creating a psychologically safe communication climate. We first tested the plausibility of our arguments using in-depth qualitative analysis of interviews with 177 members of 14 teams in a variety of industries. A second study constituted a more formal test of hypotheses using survey data collected from 266 members of 56 aerospace design teams. Results show that the four characteristics are not highly intercorrelated, that they have independent and differential effects on innovation, and that a psychologically safe communication climate helps mitigate the challenges they pose. We discuss the implications of these findings for theory and research. ●

Virtual teams, variously defined as geographically dispersed, electronically dependent, dynamic, or comprising diverse members working remotely (Gibson and Cohen, 2003; Griffith, Sawyer, and Neale, 2003; Martins, Gilson, and Maynard, 2004; Kirkman and Mathieu, 2005), are growing in number and importance. A recent study by the Gartner Group indicates that more than 60 percent of professional employees work in teams characterized by virtuality (Kanawattanachai and Yoo, 2002). Such teams potentially make it easier to acquire and apply knowledge to critical tasks in global firms (e.g., Madhavan and Grover, 1998; Sole and Edmondson, 2002). For example, geographic dispersion and electronic dependence can provide access to relevant expertise even when it is scattered around the globe (Kirkman et al., 2002) and better understanding of global clients, operations, and suppliers (Boutellier et al., 1998; Gluesing and Gibson, 2004). A dynamic structure and diverse participants can enable creative and flexible responses to challenging development needs through access to diverse expertise and perspectives on an as-needed basis (Brown and Eisenhardt, 1995; Sole and Edmondson, 2002). Such capabilities are central to innovation, the collective process of making sense of new and diverse information and incorporating this knowledge into new methodologies, products, and services (Nohria and Berkley, 1994; Nonaka and Takeuchi, 1995; Dougherty, 2001).

Innovation has become a critical means of competitive advantage for firms in a variety of industries because it allows organizations to diversify, adapt, and even reinvent themselves to match evolving market and technical conditions (Schoonhoven, Eisenhardt, and Lyman, 1990). This has been demonstrated in single industry studies, including technology (Vessey, 1991; Eisenhardt and Tabrizi, 1995; Galunic and Eisenhardt, 2001), pharmaceuticals (Zellmer-Bruhn and Gibson, 2006), and automotive settings (Clark and Fujimoto, 1991; Obstfeld, 2005), as well as in multi-industry studies, which often control for industry effects, such as agriculture, aerospace, retail, professional services, medical products, chemicals, telecommunications, and consumer electronics (Imai, Nonaka, and Takeuchi, 1985; Hargadon and Sutton,

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1997; Gatignon et al., 2002). Innovation is especially critical in subunits charged with new product development, design, or research, but it is important even in those whose mandate is implementation (Brown and Eisenhardt, 1995). For example, Zellmer-Bruhn and Gibson (2006) documented how workers on a pharmaceutical manufacturing assembly line were rewarded for more efficient and effective work and had more satisfying internal team processes when they developed new mechanisms for coordinating their work across stages of assembly, an essential form of innovation.

Teams—a set of interdependent parties, small in number, who recognize themselves as a team and have some degree of shared accountability (Cohen and Bailey, 1997)—are increasingly recognized as a key mechanism for innovation in complex firms, as they are pivotal in creating and acquiring knowledge (Edmondson, 2002; Gibson and Vermeulen, 2003). Edmondson (2002) argued that innovation inherently occurs at the team level because it requires learning behavior, or transmission of knowledge bounded by tasks and opportunities that takes place through conversations among a limited number of interdependent people. These interactions are necessary because they enable individuals to combine different insights and institutionalize knowledge beyond that held by a single member (Nonaka and Takeuchi, 1995). Similarly, empirical research by Tagger (2002) suggested that team-level innovation processes are needed to bring individual creativity into use. Without favorable group interactions, individuals' insights and efforts may be carried out in vain, with no organizational benefits accrued.

Given the fundamental nature of innovation and the potential for teams to contribute to it, organizations increasingly implement them for that purpose, using designs that include some combination of geographic dispersion, electronic dependence, dynamic structure, or national diversity. Yet, to date the literature on such "virtual" teams has primarily documented the challenges involved, all of which have implications for the success of innovations (Cramton, 2001; Kirkman et al., 2002, 2004; Sole and Edmondson, 2002). For example, geographically separated team members lack "mutual knowledge" of each other's situations, increasing coordination problems in acquiring knowledge and resources (Cramton, 2001). Electronic dependence creates logistical and technological constraints that limit informal spontaneous interaction, hindering knowledge interpretation (DeSanctis and Monge, 1999). In structurally dynamic teams, full disclosure is often hampered by inexperience with the other party and lack of a shared history (Gibson and Cohen, 2003). When collaborators represent different national backgrounds, each of which has its own set of values, orientations, and priorities, this can detract from effective internal communication (Watson, Kumar, and Michaelson, 1993). Accessing, combining, and applying knowledge relevant for innovation may be inherently problematic in teams characterized by these features. As a result, team members often struggle to understand each other and must resolve misinterpretations before they can truly innovate (Dougherty, 1992; Carlile, 2004). Just bringing people with the required knowledge and skills together virtu-

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ally provides no guarantee that they will be able to work effectively and innovate across contexts.

Part of the problem in identifying the organizational performance implications of this relatively new form of teaming is that the term “virtual” has been applied imprecisely in the literature to represent very different types of teams: teams that are geographically dispersed (consisting of members spread across more than one location), mediated by technology (communicating using electronic tools such as e-mail or instant messaging), structurally dynamic (in which change occurs frequently among members, their roles, and relationships to each other), or nationally diverse (consisting of members with more than one national background). Early research on virtual work defined it as “work carried out in a location remote from the central offices or production facilities, where the worker has no personal contact with coworkers but is able to communicate with them electronically” (Cascio, 2000: 85), while virtual teams were initially defined as groups of geographically distributed coworkers that are assembled using a combination of telecommunications and information technologies to accomplish a variety of critical tasks (Townsend, DeMarie, and Hendrickson, 1998). Definitions of this type assumed that teams can be viewed as either completely virtual or face to face, leading researchers to treat virtual teams as a single “ideal” type (Bell and Kozlowski, 2002: 16). A common research design in the early experimental research was comparing manipulations of pure face-to-face versus pure computer-mediated interactions (e.g., Kiesler, Siegel, and McGuire, 1984; Spears and Lea, 1992; Straus and McGrath, 1994; Walther, 1995; Huang et al., 2003).

Recently, scholars have shifted away from this dichotomy to focus on the extent of virtualness, recognizing that most teams can be described on a continuum of virtuality. There is conceptual agreement that virtuality is multidimensional (Cohen and Gibson, 2003; Griffith, Sawyer, and Neale, 2003; Martins, Gilson, and Maynard, 2004; Kirkman and Mathieu, 2005), but the number and complexity of the dimensions varies from one conceptual framework to another. Cohen and Gibson (2003) included two dimensions, electronic dependence and geographic dispersion. Griffith, Sawyer, and Neale (2003) developed three—level of technology support, percent of time apart on task, and degree of physical distance—as did Kirkman and Mathieu (2005): the extent to which team members use virtual tools, the amount of informational value provided by such tools, and the synchronicity of team members’ interaction. Martins, Gilson, and Maynard (2004) developed four dimensions: geographical dispersion, use of computer-mediated communication, temporality, and diversity.

Further, previous research has tended to lump together various features of “virtuality,” without examining the possible independent, differential, perhaps even unintended effects of each characteristic. A Web of Science search of articles published since 2000 in the organizations, communication, psychology, international management, and information systems journals indicates that the majority of studies have included at least three dimensions as defining characteristics of virtuality. Of the 143 articles published between 2000 and 2006

that contained variations of the search terms virtual, distributed, or dispersed in a work setting, 80 included at least three dimensions. For example, Nemiro (2002) defined virtual teams as geographically dispersed, relying heavily on information technology to accomplish work, with fluid membership. Majchrzak et al. (2000) defined virtual teams as those that are geographically distributed and reliant on technology, with a more malleable structure than traditional teams. Pauleen and Yoong (2001) defined virtual work as work performed across time and distance, using information and communication technology, by members from different countries, cultures, and functions. Baba et al. (2004) defined virtual teams as culturally diverse, involving two or more nations, physical and temporal distance, interdependence, and reliance on technology. Shin (2004) suggested that virtuality is the degree to which a group has temporal, cultural, spatial, and organizational dispersion and communicates through electronic means. Chudoba et al. (2005) wrote that virtuality depends on discontinuities in geography, time zone, organization, national culture, work practices, and technology. Paul et al. (2005) argued that virtual teams are those that cut across national, functional, and organizational boundaries and are connected by telecommunications and information technology. Finally, Harvey, Novicevic, and Garrison (2005) defined virtual teams as geographically and organizationally dispersed, with members who work in different time zones, in different nations around the world, with membership that is often temporary and structure that is transitory, and who communicate primarily via technology.

Summarizing across this growing literature, the most common characteristics investigated are geographic dispersion and electronic dependence. The Web of Science search uncovered 138 articles that included geographic dispersion, 122 that included electronic dependence, 82 that included national diversity, and 23 that included a component representing fluid structure or membership. It is often assumed that teams that are more geographically distributed are also more electronically dependent, and thus more "virtual" (e.g., Baba et al., 2004; Kirkman et al., 2004; Majchrzak et al., 2004; Martins, Gilson, and Maynard, 2004; Ocker, 2005). Although electronic dependence sometimes coincides with geographic dispersion, it doesn't always. Teams whose members are located in the same office may use e-mail to avoid the trip up to another floor. Such teams are electronically dependent but not geographically dispersed. Their reliance on computer-mediated communication likely reduces informal exchanges and social cues, yet they share the same geographic context and hence will be unlikely to experience the challenges associated with linking numerous external networks.

The next most common defining characteristic is having members from multiple countries, assuming that if a team is "virtual," it is nationally diverse (e.g., Maznevski and Chudoba, 2000; Baba et al., 2004; Chudoba et al., 2005; Paul et al., 2005; Janssens and Brett, 2006). In fact, many are of a single nationality and are less likely to experience the cultural differences in communication preferences that often cause inter-

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nal process challenges. Finally, many of the published studies also define virtual teams as structurally dynamic, assuming that if a team is “virtual,” it has fluid membership (e.g., Majchrzak et al., 2000; Chudoba et al., 2005; Harvey, Novicevic, and Garrison, 2005; Shin, 2005). Yet teams that are geographically dispersed or electronically dependent are not always dynamic—they are sometimes stable across several years and hence do not experience the difficulties associated with changing membership.

What is clear from our review is that we won't understand the problems virtual designs create for innovation without examining individual elements of virtuality. To begin this task, we conceptualize virtuality here as a multifaceted higher-order construct comprising four independent defining characteristics identified in previous literature: geographic dispersion, electronic dependence, dynamic structural arrangements, and national diversity. Although they each contribute to the virtuality of the team, they are likely to have unique effects and should be considered independently.

Further, to understand how the problems associated with the elements of virtuality might be mitigated, we examine the climate for communication, because communication is so critical to virtual work, drawing on Edmondson's (1999, 2003) concept of team psychological safety. A psychologically safe communication climate, defined as an atmosphere within a team characterized by open, supportive communication, speaking up, and risk taking (Gibb, 1961; Baer and Frese, 2003; Edmondson, 1999, 2003) may help turn geographic dispersion, electronic dependence, dynamic structure, and national diversity from liabilities into assets and promote innovation. We test these ideas in two studies, the first exploring the general plausibility of our arguments using qualitative analysis of interviews in complex teams representing a variety of industries and crossing many geographic contexts; the second constituting a formal test of our hypotheses using survey data from a larger sample of aerospace teams formed at the same point in time, allowing us to control for industry, organization, team and task type, and team longevity.

VIRTUAL INNOVATION

The ability of teams to innovate depends on how well they generate, import, share, interpret, and apply technological and market knowledge, particularly of local markets, economies, and customers. That knowledge is a combination of information, experience, context, interpretation, and reflection (Davenport, De Long, and Beers, 1998). It must be openly shared across contexts through relationships and networks, and there must be confidence in the value of that knowledge for achieving the objectives of the collaboration (Kanter, 1988). Once these requirements have been met, innovation involves dissemination and application of the knowledge, including combining and integrating it to develop novel insights, solutions, processes, or products (Obstfeld, 2005). In a comprehensive review, Brown and Eisenhardt (1995) chronicled several decades of innovation research published in major journals, focusing on normative work in which projects were the unit of analysis, many of which involved

teams developing new products or processes. They synthesized the research into a model of factors affecting innovation success that integrates common findings. Their theoretical framework is useful in understanding how the elements most commonly included in conceptualizations of virtuality each hinder the development of unique success factors for innovation.

Geographic dispersion. Rather than being an “on-off” switch (i.e., a team is distributed or not), geographic dispersion is a continuum (Cohen and Gibson, 2003; Griffith, Sawyer, and Neale, 2003). A team that spans multiple continents is more dispersed than one whose participants are located in the same city. A high level of geographic dispersion complicates and hinders three important innovation success factors related to knowledge and resource acquisition included in Brown and Eisenhardt’s (1995) framework: external communication with different contexts, support from those outside the project in the form of resources, and the speed/productivity of the innovation process.

First, as Brown and Eisenhardt (1995) documented, a stream of research in the innovation literature has focused on the benefits of flows of information into teams (e.g., Allen, 1971, 1977; Katz and Tushman, 1981). These studies highlight the importance of external communication outside the team for innovation success. Projects are more innovative when information is brought into the collaboration, translated, and dispersed to fellow team members. Second, support and resources predict innovation success. Teams whose members lobby for such support, buffer the team from outside pressures, engage in impression management, and coordinate the use of external information for technical or design issues are more innovative (Ancona and Caldwell, 1990, 1992b). The Stanford Innovation Project asked senior executives in the electronics industry to compare pairs of product successes (defined as profit contributors) and product failures in their firms. Products that had top management support in the form of resources and expressed commitment were more likely to be successful (Maidique and Zirger, 1984, 1985; Zirger and Maidique, 1990). Finally, several studies have focused on the importance of speed in innovation, including lead time and productivity (Eisenhardt and Tabrizi, 1995). For example, Iansiti (1993, 1995) deductively examined all major products developed by the 12 chief competitors in Europe, Japan, and the U.S. in the computer industry and found that lead time and productivity were indicative of product integrity and the performance of new product development teams.

When team members are highly dispersed across different geographic locations, this hinders external communication, support, and speed of innovation. In geographically dispersed teams, members are embedded in different external contexts and thus have less shared contextual knowledge, with far greater understanding of their own (geographical) context than others’ context in the team (Gluesing et al., 2003). Participants in a site usually take for granted common knowledge and therefore often cannot readily describe that knowledge nor articulate its relevance to colleagues from other

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locations (Rennecker, 2001). Sole and Edmondson (2002) called this "situated knowledge" and found evidence from qualitative analysis of seven dispersed project development teams that the majority of conceptual misunderstandings resulted from lack of awareness of or failure to appropriate such knowledge. In contrast, co-location facilitates interaction and experience and generates greater understanding of local context and other hard-to-communicate aspects of work that help facilitate information exchange for innovation (Tyre and Von Hippel, 1997; Carson et al., 2003).

Geographic dispersion also affects innovation by increasing the coordination requirements for acquiring resources, making the process less efficient and hindering productivity. Garnering resources is far more challenging when there are numerous, diverse, and remote "environments" from which they are gathered, adding complexity that must be managed (Kirkman et al., 2002). In highly geographically dispersed teams, it is more difficult to coordinate resources, given that there are shorter windows of time for synchronous meetings, and many meetings take place at other than standard hours. Certain team members with access to resources or top management support may even be inadvertently left out of decision processes because they are not physically present (Cramton, 2001). Decreased proximity may also result in less attention and effort by dispersed coworkers and more free riding (Kiesler and Cummings, 2002). A certain amount of focused, devoted attention, and mental energy is needed to pursue innovation, and context-specific circumstances that distract from this may not leave one with enough time devoted to the team (Csikszentmihalyi, 1996). In contrast, co-location affords greater efficiency in garnering knowledge and resources, as well as top management support from a single context (Carson et al., 2003). Thus, due to reduced contextual knowledge and coordination costs when collaborators are geographically dispersed across multiple locations, innovation will be more difficult to establish:

Hypothesis 1 (H1): Geographic dispersion is negatively related to team innovation.

Electronic dependence. Some teams depend heavily on computer-mediated communication to stay in touch and get their work done. Again, electronic dependence is a continuum and is a question of the relative extent of computer-mediated versus face-to-face communication (Cohen and Gibson, 2003; Griffith, Sawyer, and Neale, 2003). A team that operates entirely through e-mail, text exchanges, and teleconferences, never meeting face to face, is more electronically dependent than a team whose participants meet monthly face to face. Two predictors of successful innovation Brown and Eisenhardt (1995) documented, subtle control and improvisation, are limited when electronic dependence is high. Across industries, researchers have observed that exercising subtle control, such that resulting products or process improvements fit with overall corporate competitive strategy, is critical (Imai, Nonaka, and Takeuchi, 1985; Clark and Fujimoto, 1991). At the same time, Eisenhardt and Tabrizi (1995) showed that innovation teams that engage in more experimental or improvisational processes, through frequent itera-

tions, more testing of ideas, and creative problem solving, develop more successful innovations.

Reliance on computer-mediated communication reduces opportunities for monitoring that enable subtle control and makes it more difficult to interpret knowledge during the improvisation process. Directly observing participants is often impossible (Carson et al., 2003), there is less informal feedback in computer-mediated communication (Hollingshead, 1996a, 1996b), and managers prefer to give feedback face to face rather than electronically (Kirkman et al., 2002, 2006), so there is often less knowledge of results, making corrective behavior more difficult. Electronic groups have also been found to have more difficulty interpreting feedback in discussions (DeSanctis and Monge, 1999). Computer-mediated communication reduces nonverbal cues about interpersonal affections such as tone, warmth, and attentiveness, which contribute to message clarity and communication richness, and collaborators who use computer-mediated communication often use more direct styles of communication with fewer social cues than those in face-to-face conditions (Tidwell and Walther, 2002). Communicators use physical and linguistic "co-presence" to make inferences about one another's knowledge. Difficulty in interpreting knowledge reduces experimentation (Hollingshead, 1998). Hence, by reducing understanding of a message, electronic dependence may have an impact on improvisation processes during innovation. As a result we propose:

Hypothesis 2 (H2): Electronic dependence is negatively related to team innovation.

Dynamic structural arrangements. Work teams in organizations today are often structurally dynamic in that change occurs frequently among participants, their roles, and their relationships to each other (Brown and Eisenhardt, 1995). Many firms partner with each other through informal, temporary, relatively unstructured arrangements, such as outsourcing or consortia, or using slightly more formal but dynamic partnerships such as licensing, networks, or project-limited structural arrangements, especially on knowledge-intensive tasks (Carson et al., 2003). Structural dynamism negatively affects a third set of factors related to innovation that Brown and Eisenhardt (1995) documented, pertaining to political processes, team member tenure, and planning. First, several researchers have noted the importance of managing the political process in innovation (Allen, 1971, 1977; Katz and Tushman, 1981; Katz and Allen, 1985). When key members of a project team act as politicians to manage the power dynamics both inside and outside the team, innovation is enhanced. Second, innovation research has established that teams with a short history together tend to lack effective patterns of information sharing and working together (Katz, 1982), limiting the amount and variety of information that can be communicated across team members. Third, extensive research has shown that planning and coordinating phases of development are critical to innovation. Examining product successes and failures in terms of profitability, sales, and market share in hundreds of industrial and manufacturing firms, Cooper and colleagues (Cooper, 1979; Cooper and

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Kleinschmidt, 1987) found that the internal organization of the innovation effort was crucial for success. Other studies (Hise et al., 1990; Zirger and Maidique, 1990; Dwyer and Mellor, 1991) have also found smooth execution of all phases of development by well-coordinated subgroups to be critical for innovation.

A highly dynamic team structure hinders the development of these success factors because it increases uncertainty and perceived risk, which complicates political processes. Turnover makes it nearly impossible to develop strong relationships and preserve organizational memory, and it makes it more difficult to plan and structure the flow of development. Dynamically structured collaborations typically include some degree of uncertainty (Chiles and McMackin, 1996), and so a complete contract specifying all relevant contingencies is impossible to write or enforce legally. Thus it is inevitable that the parties need to review, renegotiate, or reinterpret their initial agreements (Das and Teng, 1998), increasing the need to manage political processes but also making it more difficult to do so. Uncertainty often spills over into attributions and interpretations about the motives of the parties involved, resulting in hesitancy to share information in the innovation process (Dougherty, 1992, 2001). This exacerbates perceptions of risk, decreasing openness to new and innovative ideas that may come from interaction with other sites (Sole and Edmondson, 2002). Often, concerns about confidentiality and proprietary knowledge prevent members from sharing knowledge across sites, hindering the team's creative process and ability to innovate. A dynamic structure also reduces the strength of social ties among members of the team. The strength of a tie (or social relationship) is a function of the amount of interaction, emotional intensity, and reciprocity between any two individuals (Granovetter, 1973). Although it has been argued that weak ties potentially lead to greater creativity (Granovetter, 1982) because new participants bring fresh knowledge into the team, individuals often feel more comfortable sharing information that requires risk and candor across stronger ties (Perry-Smith and Shalley, 2003), such as those that have been built up over time in teams with a consistent membership. Further, it is more difficult to implement knowledge when the structure is dynamic (Burt, 2004; Granovetter, 2005). Obstfeld (2005) referred to this distinction as the idea problem versus the action problem and provided empirical evidence that the action problem may often overwhelm whatever information advantage certain structural arrangements such as networks of loosely connected actors may have. Given that innovation encompasses generating knowledge as well as making sense of it and incorporating that knowledge into new methodologies, products, and services (Nonaka and Takeuchi, 1995), the overall effect of a dynamic structure on innovation is likely to be negative. Without a shared history, the planning of development phases is hampered. When members lack knowledge of what each can contribute, it is more difficult to assign responsibilities and coordinate, especially around novel ideas (Obstfeld, 2005). Based on this argumentation, we propose:

Hypothesis 3 (H3): Dynamic structural arrangements are negatively related to team innovation.

National diversity. A final feature often assumed to coincide with virtuality is national diversity (e.g., Tan, Watson, and Wei, 1995; Jarvenpaa and Leidner, 1999; Maznevski and Chudoba, 2000). Cultures, broadly defined as characteristic ways of thinking, feeling, and behaving shared among members of an identifiable group (Earley and Gibson, 2002), exist at many different levels beyond national cultures, including organizational (e.g., General Electric's culture as compared with Johnson and Johnson's culture) and functional cultures (e.g., engineering as compared with human resources culture). But nationality is a superordinate determinant of identity that is engrained from birth and is likely to be more salient than a particular organizational or functional culture (Hofstede, 1991; Earley and Mosakowski, 2000). Being a salient source of identity, national diversity hinders a final set of innovation success factors Brown and Eisenhardt (1995) discussed that pertain to internal communication, conflict resolution, and the development of a shared vision. In the innovation literature, Ancona and Caldwell (1992a) found that teams with more thorough internal communication (e.g., they defined goals better, developed workable plans and prioritized work) had superior innovation performance. Similarly, research examining new product development efforts in over 20 firms (Dougherty, 1990, 1992; Dougherty and Corse, 1995) has shown that when diverse members of project teams combined their perspectives in a highly iterative way to improve integrated information flow, they were more innovative. Members often had distinct "thought worlds"—they understood different aspects of product development in different ways—which led to varying interpretations of the same information, but strong internal communication bridged these differences. Relatedly, in a series of studies, Clark and his colleagues (Clark, Chew, and Fujimoto, 1987; Clark and Fujimoto, 1991) found that developing a shared, overall vision contributed to innovation. Finally, Hayes, Wheelwright, and Clark (1988) described how bringing conflicts to the surface early in the development process was an important factor in successful innovation. By resolving conflicts through mutual accommodation, a clear project vision was established early on.

Establishing effective internal communication and a shared vision for innovation is challenging when team members represent different nations, because national diversity creates different expectations for communication practices (Gibson and Vermeulen, 2003) and reduces identification with the team as a whole (Fiol, 1991; Hambrick et al., 1998; Gibbs, 2002). Thus, although collaborations that consist of members from different nations may have access to more information (Watson, Kumar, and Michaelson, 1993) as a result of different worldviews (Choi, Nisbett, and Norenzayan, 1999), they have been found to be fraught with difficulties that can hinder innovation through misunderstanding, stereotyping, and the inability to reach agreement, make decisions, and take action (Adler, 1997).

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Many different orientations that vary across nations have been linked to team communication (see Earley and Gibson, 2002, for a review), and nationally diverse teams often have trouble communicating due to different expectations about the communication process. By way of example, some national cultures are “high context” and others are “low context,” referring to the importance of nonverbal, contextual cues in communicating or interpreting messages (Hall and Hall, 1987; Gordon, 1991). Members of high-context cultures tend to avoid negative or confrontational responses in communicating with members of their own work group in order to save face and preserve a sense of harmony in the group (Adler, Brahm, and Graham, 1992). Members of low-context cultures use explicit language to convey exactly what is meant in a much more direct manner, even if the message is negative or confrontational. Beyond high- or low-context differences, other pertinent differences may include individualism-collectivism, uncertainty avoidance, power distance, or time orientation (Gibson and Zellmer-Bruhn, 2001; Earley and Gibson, 2002). During multicultural collaboration, differences across these dimensions are likely to cause communication breakdowns (Kirkman and Shapiro, 1997; Gibson and Zellmer-Bruhn, 2001), making it difficult to aggregate and process information, particularly for knowledge that is uncodified (Nonaka and Takeuchi, 1995).

In addition, high national diversity and members' identification with their nationality are likely to lead to social categorization, a process in which individuals from different groups (e.g., nations) make “in-group/out-group” distinctions purely on the basis of nationality, particularly when they have inadequate information about others involved (Whitener et al., 1998). These distinctions can result in stereotyping, distrust, and suspicion of out-group members (Brewer, 1981), reducing team identification and integration as well as the team's ability to leverage information (Adler, 1997; Hambrick et al., 1998). Although they examined collocated teams, Gibson and Vermeulen (2003) found a strong negative relationship in a variety of team types between the team's demographic heterogeneity (including nationality) and team learning behaviors, a set of actions that teams are likely to engage in during innovation. In particular, developing a shared vision is precarious in nationally diverse teams because of strong identification with subgroups (Fiol, 1991; Mathieu et al., 2000), which may hamper innovation. As a result, we propose:

Hypothesis 4 (H4): National diversity is negatively related to team innovation.

Mitigating Effects of a Psychologically Safe Communication Climate

For teams characterized by a high degree of geographic dispersion, electronic dependence, dynamic structures, or national diversity, a psychologically safe communication climate may act as a moderating variable that helps overcome the negative effects of these features of virtuality to increase innovation. The general concept of communication climate is grounded in the organizational communication literature (Gibb, 1961; Bastien, McPhee, and Bolton, 1995) and refers

to the environment in which communication occurs, including communicative phenomena such as management's receptivity to employees and the accuracy of information (Dillard, Wigand, and Boster, 1986). Although it overlaps with the notion of organizational climate, communication climate has been established as a separate dimension (Welsch and LaVan, 1981) and has been distinguished from other types of organizational climate, such as motivational climate or achievement climate (Poole, 1985). Further, communication climate has been shown to differ across teams or subunits within organizations (Falcione, Sussman, and Herden, 1987: 205), with a "group communication climate" defined as "those molar factors . . . which affect the message sending and receiving process of members within a given organizational group." A supportive group communication climate has been shown to predict satisfaction and commitment (Guzley, 1992) and includes variables such as participation in decision making and communication openness (Trombetta and Rogers, 1988).

We focus on a specific type of group communication climate, a psychologically safe communication climate characterized by support, openness, trust, mutual respect, and risk taking. A psychologically safe communication climate facilitates innovation because it involves speaking up, raising differences for discussion, engaging in spontaneous and informal communication, providing unsolicited information, and bridging differences by suspending judgment, remaining open to other ideas and perspectives, and engaging in active listening. Psychologically safe communication climate draws on the construct of team psychological safety, defined as a shared belief that a team is safe for interpersonal risk taking (Edmondson, 1999). Most of the research on psychological safety represents it as a cognitive phenomenon comprising an aggregated set of individual perceptions (Edmondson, 1999; Edmondson, Bohmer, and Pisano, 2001), while our concept of a psychologically safe communication climate focuses more specifically on communication behavior and team members' interactions, as constituted by messages and message-related events. Yet more recent research has acknowledged the importance of communication in creating psychological safety (Detert, 2003; Lee et al., 2004), and Edmondson (2003: 1447) indicated that "speaking up" is a behavioral manifestation of the psychological safety belief. Further, although a psychologically safe communication climate involves trust, the two are not synonymous. Trust is an assumption that the actions of others will be beneficial to one's interests and a resulting willingness to be vulnerable to such actions (Robinson, 1996). This assumption is likely in place when a psychologically safe communication climate exists, but a psychologically safe communication climate involves a broader set of communication-related behavior. Finally, although a psychologically safe communication climate may help strengthen social ties among team members that are weakened through the effects of virtuality, it is not synonymous with cohesiveness, which can produce effects opposite to psychological safety, such as groupthink and decreased risk taking (Edmondson, 1999).

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Psychological safety has been found to play a critical role in fostering team learning and innovation. Analyzing 51 work teams in a manufacturing company, Edmondson (1999) found that psychological safety helped teams learn more effectively by mitigating the interpersonal risks involved and encouraging members to admit mistakes, question current practices, ask for help, and solicit feedback. More recently, Edmondson and colleagues (Edmondson, Bohmer, and Pisano, 2001; Edmondson, 2003) drew on interviews with members of 16 cardiac surgery teams to illustrate the processes through which psychological safety leads to team learning and innovation: minimizing functional and status differences promotes speaking up across such boundaries, and designing preparatory practice sessions and early trials helps encourage new behaviors in technology implementation. Other empirical studies have found that innovation was inhibited by the lack of psychological safety in dyadic teams, as fear of failure resulted in less experimentation (Lee et al., 2004), and that psychological safety moderates the relationship between process innovation and firm performance (Baer and Frese, 2003).

A psychologically safe communication climate likely helps overcome the challenges posed by elements of virtuality for a number of reasons. First, the establishment of a psychologically safe communication climate can help overcome the barriers to innovation associated with geographic dispersion (Donnellon, 1996). Only if partners are able to share information across contexts despite their contextual differences will they be able to garner the resources and support they need to innovate. A psychologically safe communication climate can help in ironing out the potential kinks in daily operations across geographic locales and make for a satisfactory working relationship, increasing the likelihood that team members will efficiently accumulate the necessary external links to acquire knowledge and resources. In support of this, Sole and Edmondson's (2002) analysis revealed that a team's situated knowledge was more likely to be shared and appropriated across locations when members were familiar with ongoing practices in the multiple sites across which the team was dispersed, and this was more likely when there was open information exchange, such as that found in a psychologically safe communication climate.

Second, a psychologically safe communication climate helps to increase informal communication and giving and receiving feedback to overcome problems of subtle control, low message clarity, and knowledge interpretation that result from reduced face-to-face interaction (Short, Williams, and Christie, 1976) and lack of social cues (Sproull and Kiesler, 1986) during electronic communication. Empirical evidence points to the need for social and personal communication (in addition to the exchange of business or technical information) in electronically dependent teams and its role in balancing control with learning and experimentation (Knoll and Jarvenpaa, 1998; Gibson and Birkinshaw, 2004). A psychologically safe communication climate encourages frequent, spontaneous, informal, and direct communication in quick conversations or short e-mails (Monge, Cozzens, and Contractor, 1992). This type of communication has been found to be criti-

cal to the work of teams with innovative projects because it creates the opportunities to evaluate knowledge and ideas necessary for improvisation (Miner, Bassoff, and Moorman, 2001; Edmondson, 2003).

Third, a psychologically safe communication climate has been identified as particularly important in structurally dynamic collaborations because it helps create trust (Jarvenpaa and Leidner, 1999; Gibson and Cohen, 2003) and reduce perceptions of risk (Handy, 1995; Dutton, 1999). When a psychologically safe communication climate exists, collaborators are more likely to provide unsolicited information to other members as a way of showing both goodwill and intimacy, strengthening relationships in the team and creating incentives for building a shared history, which contributes to work flow (Das and Teng, 1998; Zaheer, McEvily, and Perrone, 1998). As the reciprocal process engenders credibility, a sustained information flow can overcome the uncertainty and weakened relationships caused by dynamic structural arrangements (Knoll and Jarvenpaa, 1998).

Finally, a psychologically safe communication climate may also help to bridge national differences and reduce in-group/out-group bias (Gudykunst, 1991; Maznevski, 1994). Larkey (1996) argued that the social categorization process that occurs in diverse teams often results in "divergence," defined as adherence to culturally based communication patterns, in contrast to convergence, defined as adjustment of one's communication style to match one's partner. Convergence is more common when there is a psychologically safe communication climate, and it helps to counterbalance in-group/out-group dynamics (Larkey, 1996), which can facilitate innovation. Open and accommodating communication is an important antecedent of shared cognition (Gibson, 2001); in its absence, teams' mental models have been found to diverge over time (Levesque, Wilson, and Wholey, 2001). Team members who communicate more supportively with one another are more likely to develop a common frame of reference and shared mental model (Klimoski and Mohammed, 1994). Further, the innovation process requires that the parties involved suspend judgment, remain open to others' ideas and perspectives, and put forth the effort required to integrate new knowledge with existing knowledge to produce the innovation. When this occurs, exposure to new processes of working or a new approach to a problem may propel one to pursue previously unexplored directions or to integrate new ideas, leading to novel and innovative solutions (Okhuysen and Eisenhardt, 2002; Perry-Smith and Shalley, 2003). In support of this, Gibson and Vermeulen (2003) found that the differences associated with national demographic heterogeneity in teams could be bridged if mild subgroups formed and created a psychologically safe environment. Through information exchange, members identified and developed more commonalities, reducing in-group/out-group barriers and increasing information processing capacity (Gibson and Vermeulen, 2003). Based on these observations, we propose:

Hypothesis 5 (H5): A psychologically safe communication climate reduces the negative effects of (a) geographic disper-

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sion, (b) electronic dependence, (c) dynamic structure, and (d) national diversity on team innovation.

Table 1 summarizes the elements of virtuality, the innovation success factors they each negatively affect, the mechanisms by which the effect occurs, and the potential moderating effect of a psychologically safe communication climate.

Table 1

Summary of Effects of Elements of Virtuality on Innovation

Element of virtuality	Innovation success factor (Brown and Eisenhardt, 1995) affected by element	Specific effects on innovation	Mitigating effects of psychologically safe communication climate
Geographic dispersion	External communication with contexts members are embedded in Support (garnering and provision of resources) Speed/productivity	Reduces contextual knowledge of other sites. Increases coordination complexity in acquiring knowledge and resources.	Increases exchange of contextual knowledge, which aids in efficiently garnering resources. Increases willingness to contribute and extend effort on productive learning.
Electronic dependence	Control Improvisation/experimental tactics	Reduces opportunities for monitoring. Reduces message clarity and communication richness.	Increases informal communication and giving and seeking feedback. Helps develop social cues necessary for improvisation.
Dynamic structure	Power/political processes Tenure Planning/overlapping of development phases	Increases uncertainty about motives requiring political risk management. Difficult to preserve organizational memory due to turnover. More difficult to develop flow and development phases.	Strengthens relationships by increasing trust and reducing perceptions of risk. Creates incentive for building shared history, which contributes to workflow.
National diversity	Internal communication Vision	Creates different communication preferences. Reduces identification with team as a whole (more difficult to create shared vision).	Bridges in-groups/out-groups to resolve conflicts. Increases information processing capacity by aiding in integration while allowing for cultural differences to co-exist.

STUDY 1

Methods

Overview. Study 1 consisted of an exploratory interview-based analysis of the plausibility of our arguments that geographic dispersion, electronic dependence, dynamic structure, and national diversity negatively influence innovation and that a psychologically safe communication climate helps to mitigate these effects. It was designed in accordance with recommendations by qualitative researchers (Glaser and Strauss, 1967; McCracken, 1988; Strauss and Corbin, 1990; Wolfe, Gephart, and Johnson, 1993) and recent research on related topics (e.g., Gibson and Zellmer-Bruhn, 2001; Mohrman, Gibson, and Mohrman, 2001). Specifically, we (1) verified the existence of the elements in our model, (2) elaborated on and defined them in terms of measurable variables,

(3) examined interrelationships among the variables proposed, and (4) verified the relationships in context. To provide a deeper understanding, each author independently conducted a more holistic content analysis of the interview transcripts, studying illustrative team interactions in the context of the full interviews to corroborate and generate richer insights.

Sample and contexts. The analysis includes a total of 177 interviews across 14 teams. Within these teams, 7 industries, 18 nations, 32 cities, 16 organizations, 45 organizational subunits, and 11 different functional areas were represented. Thirty percent of the sample was women. Team size ranged from 4 to 23 members, and we were able to interview 83–100 percent of each team, with a mean of 92 percent of each team represented in the sample. Team longevity varied from two years to indefinite, and we followed each team for six months to two years. Teams varied in the extent of their geographic dispersion, electronic dependence, structural dynamism, and national diversity. Table 2 provides descriptions of the teams.

Procedure. Interviews were one to two hours in duration and were conducted on site, including multiple sites for each team. All were tape recorded, and about 50 percent were videotaped, except when we were denied permission. Interview questions were broad and pertained to the structure of the team, members' roles, the nature of work, communication processes, the technology used, interpersonal relationships and processes, team characteristics, and team experiences. The Appendix provides a summary of the interview protocol. We also collected archival data, including background information about the teams, organizational charts, e-mail or other electronic transcripts, evaluations of the team, project plans, and written mission statements. We transcribed all the interviews and entered them into a content analysis text database. This text database consisted of over 1,000 pages, including 399,474 words, with an average of 2,257 words per interview. We used the Atlas.ti software program for content analysis, which allowed us to use flexible non-hierarchical qualitative coding as well as to create frequency distributions and take inventories of specific words or categories in a text.

Measures. For *geographic dispersion*, following team heterogeneity research (Bantel and Jackson, 1989; Bunderson and Sutcliffe, 2002), we used Blau's (1977) formula to calculate a measure of categorical dispersion across locations in each team. This measure takes into consideration both the number of locations and the number of individuals in the team residing in each location. The minimum value for this variable was 0, indicating that all members had the same location, and the maximum value was .85, indicating extreme geographic dispersion (e.g., 4 locations represented by approximately 2–3 members in each location), with a mean of .42 and a standard deviation of .35. To measure *electronic dependence*, we employed two independent raters external to the teams to rate each team. Raters were Ph.D.-level assistants in organizational behavior, experienced at coding and knowledgeable about the general domain. We measured electronic

Table 2

Characteristics of Teams in Study 1

Team	No. of members	No. of inter-viewed	Industries	Nations	No. of firms	No. of locations	No. of sub-units	Functions	Team tasks	Team longevity	Virtuality
1. Competency Center Team	20	18	Professional services	US, Netherlands, Australia, Sweden, Argentina	1	11	1	Professional services	Management consulting	Indefinite	
2. Community Team	17	15	Automotive	US, Germany, Brazil	2	10	8	Engineering, marketing, IT, professional services	Leadership development and education	Indefinite	
3. Function Team	16	15	Automotive	US, Germany	2	3	1	Management, accounting	Develop internal procurement methods	Indefinite	
4. Design Team	11	11	Retail/design	US	1	4	4	Marketing, research, academic	Identify future product needs	2 yrs.	
5. Frame Team	23	20	Aerospace	US, UK, Netherlands, Ireland	4	4	12	Engineering, IT	Design/build jet fighters	10–15 yrs.	
6. Pilot Team	21	20	Aerospace	US, UK, Spain, Mexico, Netherlands, India, Greece	4	4	5	Engineering, IT, management	Design/build jet fighters	2 yrs.	
7. Europe Connect	9	8	Information technology (IT)	Germany, Netherlands, India, Austria, Finland	6	4	6	Engineering, IT, academic, professional services, management	Develop technology design concepts for children	2 yrs.	
8. Tool Team	16	14	Agricultural & machine tools	US	1	1	4	Engineering, sales, marketing, management	Product line focus	Indefinite	
9. South Market Team	10	9	Travel	US, Mexico	1	3	5	Operations, IT, management, accounting	Technical service provider	3 yrs.	
10. North Market Team	12	10	Travel	US, Mexico	1	2	5	Operations, IT, finance, management, accounting	Technical service provider	3 yrs.	
11. Machine Team	13	12	Agricultural & machine tools	US	1	1	6	Engineering, operations, marketing, management	Product line focus	Indefinite	
12. Platform Team	17	16	Agricultural & machine tools	Canada, France, Italy	1	1	6	Engineering, sales, IT, marketing, management, finance, accounting	Cross-product responsibility	Indefinite	
13. European BU Team	5	5	Agricultural & machine tools	Ireland	1	1	2	Sales, management	Area-based product management	Indefinite	
14. Canadian BU Team	4	4	Agricultural & machine tools	France	1	1	2	Operations, sales	Area-based product management	Indefinite	

dependence at the team level based on work by De Jonge et al. (1999) and Karasek and Theorell (1990), who argued that as reflections of the objective work environment, team-level measures of job characteristics are less prone to bias than individual-level self-reports. The two raters coded the teams using a 3-point Likert scale based on overall subtext analysis of the team's interview transcripts, as well as records of e-mail traffic, with "1" representing a low level of electronic dependence, "2" representing a moderate level, and "3" representing a high level. These categories were inductively derived based on overall subtext analysis and comparisons across teams. A subset of teams clearly used electronic communication much more than all other teams; we considered these highly dependent. Likewise, a subset clearly used electronic communication much less than all other teams; we considered these low on electronic dependence. All other teams were considered moderate. We computed an interrater reliability of .87 (Cohen's kappa) across the two raters, and because it showed adequate internal consistency, we averaged the two ratings to arrive at one score for each team. A quote from a member of Design Team at Office Systems reflects low electronic dependence: "We often meet face to face . . . there is a common visual. Work is supported visually. Everyone is looking at it. We devote more time to it. There is more of a sharing of information." A quote from a member of Function Team at Auto Unification Company demonstrates high electronic dependence:

E-mail—I respond to probably 30–50 per day and receive 100 per day. That has been an incredible benefit to us. I can't imagine doing the job that I have now before having it. Two and a half years ago, it would have been a manual fax, or hard copy mail, and there would have been a 3 to 5 or 10 day delay, with all the issues of proofing and typing. You have responses within hours in some cases. You can collect and complete an initiative.

To measure the *dynamism of structural arrangements*, we asked the same two independent raters to rate each team, instructing them to examine archival data about each team, including organizational charts, team membership lists, intranet sites, and historical documents to determine the degree to which the members and structure had changed during the life of the team. Raters used a 3-point scale, with "1" representing a structure that had not changed, "2" representing a moderately dynamic structure, and "3" representing a highly dynamic structure. Again, categories were inductively derived based on overall subtext analysis and comparisons across teams. We computed an interrater reliability of .82 (Cohen's kappa) across the two raters, which showed adequate internal consistency, so we averaged the two ratings to arrive at one score for each team. As an example, the Community Team, charged with knowledge management at Auto Unification Company, was highly dynamic, with numerous instances of temporary outsourcing and subcontracting and a constant flux in members, roles, and their relationships to one another. In contrast, Frame Team in the aerospace industry had no changes in membership or structure during its history.

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To measure *national diversity*, following team heterogeneity research (Bantel and Jackson, 1989; Bunderson and Sutcliffe, 2002), we used Blau's (1977) formula to calculate a measure of categorical dispersion across nationalities in each team. The minimum value for this variable was 0, indicating that all members had the same nationality, and the maximum value was .78, indicating extreme national diversity (e.g., 7 nationalities represented on the team with approximately 2–5 members in each nationality), with a mean of .30 and a standard deviation of .26. Nationality is not a reflection of where individuals were physically located but, rather, their national background, as indicated when asked about their nationality. In addition, nationality is not confounded with company (members often represented different firms but had the same nationality and vice versa).

We used a different approach to measure *psychologically safe communication climate* and *innovation*. Because these variables are more complex and not easy to characterize without intimate knowledge from the participants' perspectives, we captured evidence of these variables by examining each individual team member's experience as relayed in the interviews. The first step was to identify interview excerpts that contained this evidence. Following previous research (e.g., Kabanoff, Waldersee, and Cohen, 1995; Gibson and Zellmer-Bruhn, 2001), we compiled a list of key words pertaining to each variable based on a comprehensive review of survey instruments used to measure these variables, research articles, and a snowball synonym using dictionaries and thesauruses. For example, psychologically safe communication climate was captured by terms such as "empathy," "openness," and "understanding"; innovation was captured by terms such as "novelty," "improvement," and "unprecedented" (the full set of terms is available from the authors). We then instructed our content analysis program (Atlas.ti) to search for any word in a category for each variable and generate output files for each variable containing excerpts that included any word in the category list for that variable. Unitization was at the sentence level. During a process of "in-context verification," excerpts in the subtext databases were then reviewed by two independent raters (with similar qualifications as those mentioned earlier) and coded as either (1) reflecting the variable or (0) not reflecting the variable. An interrater reliability coefficient (Cohen's kappa) of .75 was computed for psychologically safe communication climate and .79 for innovation by comparing the codes of the independent raters. Discrepancies between codes were discussed and reconciled, eliminating any excerpt that was not coded as adequately reflecting each variable, to arrive at a final set of excerpts demonstrating evidence of each variable. For example, psychologically safe communication climate was evidenced by excerpts such as "We're really good at asking questions, helping people make incremental improvements in their understanding" (Office Systems, Design Team), and "People seem to feel comfortable discussing their problems and issues" (Auto Unification, Community Team). Innovation was evidenced in excerpts such as "We are strong on innovative ideas, and fairly flexible" (Machines Inc., Machine Team), and "We also felt that it was important

that we churn out new stuff all the time. This is a world where ideas are changing rapidly, and we are looking to building and churning out new things" (Professional Service, Competency Center Team). We then computed a frequency count for each interviewee for each variable of the number of times he or she used a word representing the variable to express evidence of that variable in his or her team. To control for differences in the length of interviews and capture the emphasis on a variable relative to an interview's length, we weighted the number of occurrences by the total number of words in an interview transcript.

Both a psychologically safe communication climate and innovation are team-level concepts, but we used individual interviews to derive measures of those characteristics. In the parlance of multilevel theory (Klein and Koslowski, 2000: 41), we considered these characteristics "shared unit-level constructs" and gathered data from individuals to assess team-level characteristics that we presumed to be shared within a team and capable of differentiating across teams. Conceptually, this makes sense, given that individual team members are most familiar with the extent to which the team exhibits these attributes. Yet it is critical with such aggregated variables that we statistically demonstrate within-unit agreement and between-unit differences (Klein and Koslowski, 2000). To do so, we computed intraclass correlation coefficients using one-way analysis of variance on the individual-level data with team as the independent variable and the scores on psychologically safe communication climate and innovation as the dependent variables. Others have suggested that an indication of convergence within teams is an ICC(1) value in the .05 to .20 range with a corresponding ANOVA F-statistic that is statistically significant (Kenny and LaVoie, 1985; Bliese, 2000). For psychologically safe communication climate, $ICC(1) = .23$, $F = 5.11$, $p < .01$. For innovation, $ICC(1) = .20$, $F = 4.57$, $p < .001$. Finally, r_{wg} was used to assess internal agreement within a team for each variable, ranging from 0 (no agreement) to 1 (complete agreement) (James, Demaree, and Wolf, 1993). Glick (1985) suggested a cut-off criterion of .60. The mean r_{wg} values were .80 for psychologically safe communication climate and .78 for innovation, indicating adequate internal agreement. Given these results, we aggregated this individual-level data to the team level by taking the mean across individuals in a team for each variable.

Construct validity analysis. We conducted several tests of convergent validity for our core concepts. To test that our objective measure of geographic dispersion involving locations corresponded to subjective perceptions of geographic dispersion, we constructed a perceptual measure based on word counts in the interviews as described above and then aggregated these to the team level. In our process of in-context verification, in which excerpts in the subtext databases were reviewed by two independent raters and coded as either reflecting or not reflecting the variable, interrater reliability was adequate (Cohen's kappa = .70). Aggregation indices were adequate [$ICC(1) = .11$; mean $r_{wg} = .87$], and this subjective measure was significantly correlated with our objective measure ($r = .59$, $p < .001$). We also constructed a

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perceptual measure of electronic dependence based on word counts in the interviews, which captured each time a respondent mentioned being reliant on electronic means of communication, aggregated to the team level. This variable also showed adequate interrater reliability (Cohen's kappa = .85), and aggregation indices [ICC(1) = .19; mean r_{wg} = .77] and was significantly correlated ($r = .57, p < .001$) with our objective measure of electronic dependence.

Results

We first assessed direct relationships between the features often associated with virtuality and innovation. We used non-parametric statistics, specifically Spearman's Rho, which is an inferential test designed for small samples of ordinal or interval measures that are potentially not normally distributed (Saslow, 1982; Mohrman, Gibson, and Mohrman, 2001). The interrelationships among the variables are presented in table 3. As argued, the four team characteristics demonstrated varying degrees of association with each other, rather than consistent positive interrelationships. National diversity was closely associated with electronic dependence ($\rho = .65, p < .01$) as well as with geographic dispersion ($\rho = .71, p < .01$), but geographic dispersion was not significantly related to electronic dependence. Likewise, dynamic structural arrangements were not significantly associated with any of the other characteristics, although previous research has typically assumed that these features coincide.

Next, we examined relationships between each element and innovation. The relationship between geographic dispersion and innovation was negative and statistically significant ($\rho = -.55, p < .05$), suggesting the plausibility of H1. The qualitative analysis supported that being distributed across multiple locations was often detrimental to innovation, as it impeded sharing information and made it difficult to coordinate interaction. For example, Platform Team in the agricultural product development business had a core team that was co-located, but many of its extended team members worked remotely. In addition, the managers of most of the team members were not on site but were based in different functional and engineering discipline groups. Almost all decisions were referred for approval through a complex maze of "hierarchical superiors" who were distant physically and were not themselves aligned. As a result, members of this team felt they were held hostage to slow processes of approval and micro-management, which hindered the spontaneous innovation

Table 3

Correlation Matrix, Study 1 (N = 14 teams)

Variable	Mean	S.D.	1	2	3	4	5
1. Geographic dispersion	1.58	1.88					
2. Electronic dependence	2.43	.65	.44				
3. Dynamic structure	2.43	.76	.10	.17			
4. National diversity	.30	.26	.71**	.65**	-.38		
5. Psychologically safe communication climate	2.58	1.11	-.21	-.39	.30	-.60*	
6. Innovation	3.08	.94	-.55*	-.54*	.01	-.66**	.58*

* $p < .05$; ** $p < .01$.

process. Requests for support to Europe from North America, for example, were often seen as disappearing into a "black hole," unless there was a relationship with people at the other end. People often did not know where to go for information, and the interface points were not clearly specified. The challenges of geographical dispersion for innovation are also illustrated through the following quote from a member of the Competency Center Team in a professional service firm:

I'm typically in a location where it's very difficult to get to me, so I don't participate to the extent that I desire to and probably the rest of the people who are working on it desire that I do. So I sort of "fall into the cracks." Any interaction with the team, I need to make some extraordinary effort to do that, and the team is under no obligation to make any extraordinary efforts to accommodate me, so they don't.

The relationship between electronic dependence and innovation was negative and statistically significant ($\rho = -.54, p < .05$), suggesting the plausibility of H2. Our qualitative interview analysis corroborated this, providing numerous examples that electronic communication hindered message clarity and the motivation for improvisation. Many informants indicated that the creative synergy needed for innovation was much more easily established face to face. The difficulty in sparking a creative exchange of ideas over computer-mediated communication, rather than face to face, is illustrated in the following quote from a member of Professional Service's Competency Center Team:

It is really tough working on knowledge creation over the phone and via e-mail. A good example is this project. It is conceptual. We know there is something there, but trying to kick-start a conversation on that is really tough. The way I have done it is that Jack and I have been in the same office with a white board, to at least kick-start it. When you are introducing concepts, that is really hard to do over the phone. How do you motivate people when they aren't in the same room? I think it is so valuable to be there in person.

There was no statistical evidence for the plausibility of the negative relationship between dynamic structure and innovation proposed in H3, although we did find evidence for a lack of relationship building due to member turnover and tensions and conflicts due to changes in reporting structures. For example, turnover was very high among purchasing representatives in Machines Inc.'s Platform Team, and members reported that these representatives left just as they were starting to understand the complex trade-offs involved in living in a world of global purchasing and trying to meet the needs of the development platform. Members who were transferred to other teams were also perceived as not sufficiently dedicated to the team's efforts, and their experience was often called into question. Several teams had a large number of new hires, but training and mentoring for them were limited, which created tension between the experienced and new members. As a result, innovation was inhibited.

Finally, suggesting the plausibility of H4 on the effect of national diversity on innovation, the relationship between

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these variables was negative and statistically significant ($\rho = -.66, p < .01$). Corroborating this, many informants discussed how national differences in norms, expectations, and behavior hindered innovation. These differences included different definitions of concepts such as teamwork, as well as different values placed on work and hierarchy. Norms around knowledge sharing were culturally conditioned, as were communication styles, resulting in in-group/out-group dynamics that reduced information flow. Such differences are evident in the following quote:

The major issue is probably cultural. In America, knowledge sharing is a lot more promoted. People are very open about sharing knowledge and work in these open cubicles. . . . I'm from Europe, which is a little more competitive in terms of what you know. You feel like if you tell people what you know, then you are at a disadvantage. People are then a little bit more reluctant to share knowledge. They also think that if you share a lot of knowledge, then maybe your job can be taken by somebody else. (Auto Unification, Community Team)

We explored the plausibility of the idea that a psychologically safe communication climate moderates the negative relationship between the elements of virtuality and innovation, using subgroup comparisons, the technique most appropriate for an exploratory, qualitative analysis (Roberts, 1997; Fielding and Lee, 1998), given that Study 1 was designed to explore the plausibility of our arguments rather than to be a definitive test of the relationships (Study 2 presents results of moderated regression analysis as a more formal test of hypotheses 5a–5d). First, we broke the sample into the most psychologically safe versus non-psychologically safe communication climates using a median split on the psychologically safe communication climate scores. We then compared excerpts that discussed the relationship between characteristics of virtuality and innovation in teams with high vs. low psychologically safe communication climates. Table 4 provides examples of these excerpts.

The strongest evidence for a moderating effect occurred for the relationships between national diversity and innovation and geographic dispersion and innovation. For teams without a psychologically safe communication climate, national diversity was perceived as very detrimental, and innovation was dramatically low when diversity was high. For teams with a psychologically safe communication climate, national diversity was not nearly so much of a challenge and in some teams was reported to be an asset. In terms of geographic dispersion, in teams without a psychologically safe communication climate, geographic dispersion was perceived as a barrier to overcome in order to achieve innovation, while in teams with a psychologically safe communication climate, geographic dispersion was seen as either “just a given” or a “plus.” Less clear support was obtained for a moderating effect of a psychologically safe communication climate on the relationship between electronic dependence and innovation. For teams with a psychologically safe communication climate, electronic dependence was less of an issue in pursuing innovation. In contrast, for teams without a psychologically safe communication climate, innovation was higher when teams

Table 4

Examples of Interview Evidence for Effects of Psychologically Safe Communication Climate on Innovation, Study 1

	Relationship between geographic dispersion and innovation	Relationship between electronic dependence and innovation	Relationship between dynamic structure and innovation	Relationship between national diversity and innovation
Teams with highly psychologically safe communication climates	<p>"The fact that they are virtual, spread out, has introduced points of view that we wouldn't have gotten if they weren't virtual. . . . If we made everyone move to the same place to do the work, that would alter their point of view and wouldn't be a very effective solution for this kind of work." (Office Systems, Design Team)</p>	<p>"It is important to get to know each other also personally. If you are able to get on a personal basis during electronic meetings, process improvements can be realized very fast. This makes all the further telephoning and videoconferencing very simple." (Auto Unification, Function Team)</p>	<p>"I feel that we may sometimes over-team. We do things by committee that aren't necessary. This can stifle individual innovation. It can get frustrating. With ever changing roles, we tend to have some overlap between jobs that leads to blurring of boundaries. This can create frustrations that we are doing other jobs than our own." (Machines Inc., Tool Team)</p>	<p>"It has got to be that you are bringing in different points of views, different practices, and as a result of that cooperation, you come up with an improved product." (Aerospace, Pilot Team)</p> <p>"I never felt that the cultural differences were a real problem. In most every case, those differences are known by the partners and accepted by the partners. Those things don't make any problems, they can be an advantage for bringing up new ideas." (Auto Unification, Function Team)</p>
Teams with non-psychologically safe communication climates	<p>"The biggest problem is that 90% of the decisions are made in the bathroom or near the coffee pot. They had to get the people that they needed to bring information into the meetings and discuss it there. If 2 out of 3 people are in Fort Worth and one of them is in the UK and not there, then that person is out of the loop. Early on it was a very significant problem." (Aerospace, Frame Team)</p> <p>"Everything about the product was changing very rapidly. We couldn't communicate all those changes to different parts of the world." (Aerospace, Frame Team)</p> <p>"The geography is going to prevent our team and theirs from ever becoming a cohesive unit. Everything is geared toward the field. Our job function is never incorporated into it. For example, we rolled out a new tool, and nothing has been communicated out to the field. We've received a lot of brick walls." (Travel Service, South Market Team)</p>	<p>"There is never that connection with the other team members. When the CSRs [customer service representatives] were here, they could visualize the processes and systems that the CSRs use. Not having this has created some challenges for us." (Travel Service, South Market Team)</p> <p>"I am completely locked into e-mail. But I don't think it replaces the human contact side of the phone. It coordinates things, but big things are never sorted out on e-mail." (Aerospace, Frame Team)</p>	<p>"If the group keeps changing, if you don't have any communication in between meetings, it's very normal that at the beginning of each meeting you have to update the people that are new or are not there anymore what the meeting is all about. This wastes time." (Auto Unification, Community Team)</p>	<p>"Yes, there was discussion. But most of the time they were not discussions in which new ideas would come up. It's really two sides and it stays like that." (Europe Connect)</p> <p>"I realized that in the discussions about motivation of people, how to get people to share their knowledge, I had the feeling that it is totally natural for [Americans] to share their knowledge. For Germans I realized that it is not natural." (Auto Unification, Community Team)</p>

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relied less on electronic means of communication. Finally, most teams reported a slight decline in innovation when their structure was dynamic. Taken as a whole, these contrasts provide preliminary support for the plausibility of the moderating effect of a psychologically safe communication climate, although this effect is not uniformly strong across characteristics.

Study 1 thus indicated that the negative direct effects of geographic dispersion (H1), electronic dependence (H2), and national diversity (H4) on innovation were readily apparent in the contextual analysis of the interviews, while the effect of dynamic structure (H3) on innovation was equivocal. Findings also provide preliminary support for the argument that a psychologically safe communication climate mitigates the negative effects of geographic dispersion (H5a) and national diversity (H5d) on innovation, with less clear support for the other proposed moderating relationships. Further, as we anticipated, the elements of virtuality were not all highly correlated. This indicates that a team can be characterized as "high" on one element, while being "low" on another. Perhaps most importantly, geographic dispersion was not significantly related to electronic dependence, as conventional wisdom has often assumed. This coincides with our assumption that although electronic dependence sometimes goes hand in hand with geographic dispersion, this is not always the case. We observed this in the automotive industry Community Team and in the professional services Competency Center Team. Although members were spread across the globe, they found it more efficient to meet face-to-face once a month rather than use electronic communication and in fact rarely communicated using e-mail or other electronic tools between meetings. Such teams are geographically dispersed but not electronically dependent. These findings provide preliminary support for the idea that the elements of virtuality are independent and that the absence of one element does not negate the effect of the other elements (e.g., having a "0" value on electronic dependence does not mean that a team should no longer be considered virtual). Extrapolating from this evidence suggests that it is inappropriate to combine the elements of virtuality in a multiplicative way (i.e., geographic dispersion \times electronic dependence \times dynamic structure \times national diversity), as has been suggested in some of the conceptual literature (see Cohen and Gibson, 2003).

Our holistic analysis also confirmed that each element adds a unique facet to the experience of working virtually, indicating in a preliminary way that the elements are non-substitutable and that having more of one element does not compensate for having less of another. Combining the elements of virtuality additively to form a single index (i.e., geographic dispersion + electronic dependence + dynamic structure + national diversity) may result in a loss of explanatory power, because the elements are differentially related to innovation. For example, an additive index fails to discriminate between a hypothetical "Team A" that scores equally on each of the four elements (e.g., 3 on geographic dispersion + 3 on electronic dependence + 3 dynamic structure + 3 national diver-

sity = 12) and "Team B" that scores differentially across elements (e.g., 0 on geographic dispersion + 2 on electronic dependence + 10 on dynamic structure + 0 on national diversity = 12). But the results of this study suggest that geographic dispersion and national diversity are negatively related to innovation, while dynamic structure is not related to innovation. Thus, Team A is more likely to experience problems in innovation because of its higher score on geographic dispersion and national diversity. This implies that a model including each element independently may have more explanatory power than one based on an additive combination. Based on these preliminary findings, in Study 2, in addition to formally testing H1–H5, we explored the idea that independent effects of geographic dispersion, electronic dependence, dynamic structure, and national diversity will explain more variance in team innovation than a multiplicative or additive combination of these elements.

STUDY 2

Methods

Overview. Study 2 was intended to complement Study 1 in three ways. First, Study 2 consisted of a larger sample at the team level (56 teams, as described below) and quantitative survey-based measures and thus enabled us to use hierarchical moderated multiple regression techniques to formally test H1–H5. Second, the teams in Study 2 were all of the same team type and function (engineering project teams), had been existence for the same period of time (one year), and were from the same firm in the aerospace industry. This design controlled for many factors that may influence innovation and enabled us to isolate characteristics of virtuality and to examine effects of the communication climate. Finally, innovation in Study 2 was rated by internal customers of the focal teams, allowing for an independent assessment of the independent and dependent variables.

Sample. The 56 engineering project teams included in the study were working on a contract to design a state-of-the-art, next-generation military aircraft. Worth over \$200 billion, this program was unique in that it represented a collaborative team effort across numerous nations and sites. The program's managers had enlisted the assistance of the researchers to measure, document, and provide feedback about process and performance of the program, with the aim of improving innovation, effectiveness, and the satisfaction of team members. Viewing this as an opportunity to refine their day-to-day interactions, team members were highly motivated to participate, as evidenced by a high response rate and informal comments received, and eager to see results, which were presented after the analyses were completed. The measures for variables in this study were included as a part of a larger research effort testing numerous theories and hypotheses. A total of 266 individuals responded to the survey, with an average team size of 4.75, ranging from 4 to 10. The average response rate within a team was 79 percent. Discussions with project participants indicated that the sample was comparable to the population in terms of gender,

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age, profession, and tenure, suggesting no evidence of non-response bias.

Procedure. An on-line survey was administered to all teams in the program and two to three internal customers of each team over a period of four weeks. Customers were selected by the program leader (who was two hierarchical levels above the teams), were internal to the program but downstream in design and production, and had ample familiarity with a given team's work. For example, a team that worked on airframe design was rated by a representative from assembly and a representative from systems integration. Teams varied in their degree of geographical dispersion, electronic dependence, structural dynamism, and national diversity, but they did not vary significantly in terms of task type. All teams rated their design tasks as non-routine (mean of 3.63 on a 5-point scale), and ANOVA confirmed there were no significant differences between teams on task routineness ($F = .90$, n.s.).

Measures. We measured *geographic dispersion* as in Study 1, using Blau's (1977) formula to calculate a measure of categorical dispersion across locations in each team. The minimum value for this variable was 0, indicating that all members had the same location, and the maximum value was .94, indicating extreme geographic dispersion (e.g., 4 locations represented on the team with approximately 1–2 members in each location), with a mean of .13 and a standard deviation of .29. *Electronic dependence* was measured by four items asking about the extent to which members relied on three forms of electronic communication (e-mail, teleconferencing, and collaborative software), as well as their overall reliance on electronic communication, using a 5-point scale (1 = not at all; 5 = to a very great extent). These four items loaded on a single factor with an eigenvalue of 2.06, accounting for 51 percent of the variance, with loadings ranging from .60 to .82. The reliability of this scale (alpha) was .72. We measured the extent to which the team had a *dynamic structure* with three items ("Members of this team change frequently"; "It is difficult to know who is on this team and who is not"; and "We lack a consistent operating structure in this team.") using a 5-point scale (1 = not at all; 5 = to a very great extent). These items loaded on a single factor with an eigenvalue of 1.81, accounting for 60 percent of the variance, with factor loadings ranging from .63 to .86. Reliability (alpha) was .70. As in Study 1, *national diversity* was measured using Blau's (1977) formula to calculate a measure of categorical dispersion across nationalities in each team. The minimum value for this variable was 0, indicating that all members had the same nationality, and the maximum value was .99, indicating extreme national diversity (e.g., 5 nationalities represented on the team with approximately 1–2 members of each nationality), with a mean of .26 and a standard deviation of .34.

Discriminant validity of virtuality elements. To verify the distinctiveness of our constructs, we established discriminant validity through confirmatory factor analysis (Venkatraman and Grant, 1986). The analysis clearly supported the four-variable structure, with separate factors for each of the elements

(chi square = 27.69, d.f. = 18, $p < .07$; GFI = .98, CFI = .97, root mean square residual = .04). We compared the four-factor model with a one-factor model which assumes that the items represent a single construct. The results showed reduced fit for the one-factor model (chi square = 32.51, d.f. = 17, $p < .01$; GFI = .75, CFI = .75; root mean square residual = .07). The four-factor model also had a significantly better fit than alternative models. These tests demonstrate that the items do not tap a single underlying construct.

As a final step, we created two additional variables to explore the idea derived from Study 1 that virtuality is best captured by considering the effects of the virtuality elements independently (geographic dispersion, electronic dependence, dynamic structure, and national diversity), rather than as an additive combination (geographic dispersion + electronic dependence + dynamic structure + national diversity), or a multiplicative combination (geographic dispersion \times electronic dependence \times dynamic structure \times national diversity), as has been traditionally assumed. The additive term was computed as the sum of the four characteristics, and the multiplicative term was computed as their product.

We measured the extent to which a *psychologically safe communication climate* existed by asking team members to indicate the extent to which their team was characterized by four items ("Members are able to say what they think"; "When there's a problem, members talk about it"; "People use words that are considerate of others' feelings"; and "Members are free to be assertive about what they think and feel.") using a 5-point scale (1 = not at all; 5 = to a very great extent). The minimum score was 3.0, the maximum score was 5.0, the mean was 4.19, and the median and mode were 4.25. Items loaded on a single factor with an eigenvalue of 2.49, accounting for 62 percent of the variance, factor loadings ranged from .70 to .87, and reliability (alpha) was .79.

Innovation was measured by a survey administered to two to three internal customers of each team, as described above. Customers were asked to respond to the following: "Compared to what is possible (100%), estimate how effective has this team been at innovation using a percentage. For example, if Team X is 80% innovative compared to what is possible, enter 80% for innovation." The minimum rating given by customers was 60 percent innovative, the maximum was 100 percent innovative, the mode was 75 percent, and the mean/median were 80 percent. Convergent validity for this measure was demonstrated by the high correlation between innovation and technical performance ($r = .53$, $p < .001$) and between innovation and overall effectiveness ($r = .42$, $p < .001$) as rated by customers. In addition, our measure for innovation was positively correlated with a 4-item measure of knowledge sharing that customers completed ("Did members of this team share knowledge with non-team members in your organization?"; "Were people outside the team able to learn from the team?"; "Do you believe the success of this team will spur others in your organization"; and "Will processes and activities developed by this team provide a

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road map for other teams in the organization?") ($r = .35, p < .01$).

Aggregation. As in Study 1, we computed intraclass correlation coefficients using one-way analysis of variance on the individual-level data with team as the independent variable and the scores on electronic dependence, dynamic structure, psychologically safe communication climate, and innovation as the dependent variables. For electronic dependence, $ICC(1) = .09, F = 1.45, p < .05$; for dynamic structure, $ICC(1) = .07, F = 1.41, p < .05$; for psychologically safe communication climate, $ICC(1) = .09, F = 1.47, p < .05$; and for innovation, $ICC(1) = .08, F = 1.41, p < .05$. Adequate internal team agreement was demonstrated for electronic dependence (mean $r_{wg} = .72$), dynamic structure (mean $r_{wg} = .82$), psychologically safe communication climate (mean $r_{wg} = .85$), and innovation (mean $r_{wg} = .72$). Given these results, as a final step, we aggregated the individual-level data to the team level by taking the mean across individuals in a team for each variable; for innovation, we took the mean across customers who rated a team.

Controls. We included four control variables: *team size*, *task interdependence*, *leadership style*, and *team training effectiveness*. These four variables have demonstrated impacts on team outcomes in prior research, may vary across teams that have different levels of the elements of virtuality, and may represent alternative explanations for the variance in innovation (e.g., Campion, Medsker, and Higgs, 1993; Brown and Eisenhardt, 1995; Earley and Gibson, 2002; Gibson and Vermeulen, 2003). Team size is the number of people on the team. Task interdependence was measured using Campion, Medsker, and Higgs' (1993) 3-item scale (e.g., "Members of this team depend on each other for completion of their work."). Leadership style was measured using three items that capture how proactive a leader is in taking initiative and action (e.g., "Our leader fails to take necessary actions to ensure team effectiveness," reverse coded). Team training effectiveness was measured using three items that assess the extent to which team members perceived their team training as effective (e.g., "The training I have received on our computer systems helps me work effectively with others in the team.").

Results

Table 5 displays the means, standard deviations, and zero-order correlations for the study variables. Corroborating the results of Study 1, the four characteristics of virtuality demonstrate varying degrees of association with each other, rather than consistent positive interrelationships. As in Study 1, the relationship between national diversity and geographic dispersion is positive and significant, while dynamic structural arrangements is not significantly related to geographic dispersion. In contrast with Study 1, the relationship between national diversity and electronic dependence is non-significant, while the relationships between geographic dispersion and electronic dependence and between dynamic structural arrangements and electronic dependence are positive and significant. The relationship between national diversity and

Table 5

Correlation Matrix, Study 2 (N = 56 teams)							
Variable	Mean	S.D.	1	2	3	4	5
1. Geographic dispersion	.13	.29					
2. Electronic dependence	4.18	.75	.28*				
3. Dynamic structure	1.19	.41	.24	.26*			
4. National diversity	.26	.34	.44***	.16	.31*		
5. Psychologically safe communication climate	4.19	.45	-.53***	-.47***	-.41**	-.32*	
6. Innovation	80.31	9.12	-.48***	-.41**	-.46***	-.49***	.61***

* $p < .05$; ** $p < .01$; *** $p < .001$.

dynamic structure is also positive and significant. As expected, each of the elements of virtuality is significantly and negatively correlated with innovation, while psychologically safe communication climate is significantly and positively related to innovation.

Hypothesis tests. We tested H1–H4, on the negative direct effects of the four elements of virtuality, by regressing innovation on the controls (team size, task interdependence, leadership, and training) and geographic dispersion, electronic dependence, dynamic structure, and national diversity. As shown in table 6, none of the controls predicted a significant portion of the variance in innovation in step 2. The relationships between geographic dispersion and innovation, between electronic dependence and innovation, between dynamic structure and innovation, and between national diversity and innovation in the regression model were consistent with the correlational results, and the overall R^2 value for the model was significant, providing support for H1–H4.

We tested H5a–5d using moderated regression. Table 6 displays the results. In step 1, we entered the control variables. In step 2, we entered the main effects for geographic disper-

Table 6

Results of Moderated Regression Analysis, Study 2*				
Predictor variable	Step 1	Step 2	Step 3	Step 4
Team size	-.26	-.01	.01	-.03
Task interdependence	.03	-.04	-.08	-.05
Leadership	-.28*	-.07	-.03	.02
Training	-.07	-.02	-.01	.03
Geographic dispersion		-.24*	-.11	-3.73***
Electronic dependence		-.22*	-.12	-5.34***
Dynamic structure		-.24*	-.17*	-2.73**
National diversity		-.27*	-.26*	-1.89*
Psychologically safe communication climate			.34**	2.60***
Geographic dispersion × Communication climate				3.18***
Electronic dependence × Communication climate				-4.91***
Dynamic structure × Communication climate				2.29**
National diversity × Communication climate				-2.04**
ΔR^2		.31	.06	.17
ΔF		6.77***	6.12**	5.68***
$\Delta d.f.$		4,47	1,46	4,42
Total R^2	.16	.46	.53	.69
F	2.36	5.09***	5.70***	7.30***
D.f.	4,51	8,47	9,46	13,42

* $p < .05$; ** $p < .01$; *** $p < .001$.
* Reported values are standardized regression weights.

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sion, electronic dependence, dynamic structure, and national diversity. In step 3, we entered the main effect of a psychologically safe communication climate. In step 4, we entered interaction terms for each of the four virtuality variables and the communication climate. As shown in table 6, adding the interaction terms results in a significant increase in R^2 , indicating moderating effects. In support of H5a–5d, the interaction terms for all four interactions are significant. As recommended by Aiken and West (1991: 12–13), for each significant interaction term, we then plotted the relationship between the element of virtuality of interest and innovation, at values of a psychologically safe communication climate one standard deviation above the mean and one standard deviation below the mean. We examined the slopes of the two regression lines to interpret the nature of the interaction. These plots are shown in figures 1a–1d. As expected, the relationships between each element of virtuality and innovation are all less negative when a psychologically safe communication climate exists than when it does not.

We conducted a final set of analyses to test the idea derived from Study 1 that virtuality is best captured by considering

Figure 1a. Effect of communication climate on the relationship between geographic dispersion and innovation.

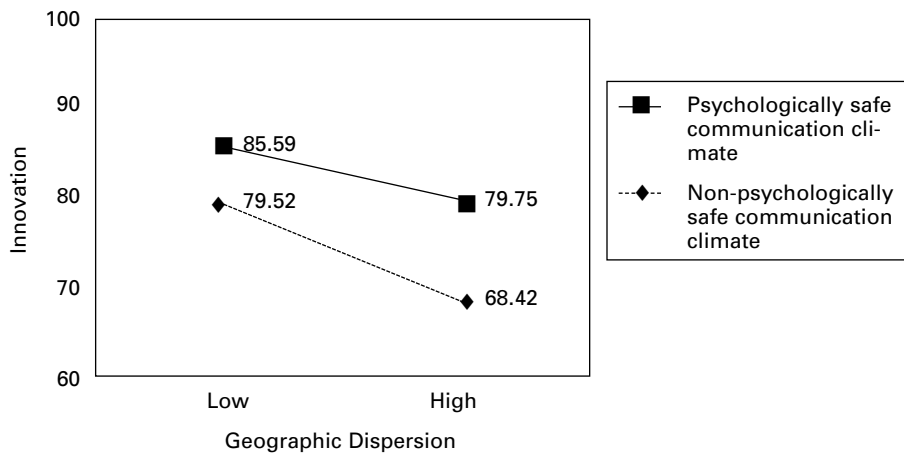


Figure 1b. Effect of communication climate on the relationship between electronic dependence and innovation.

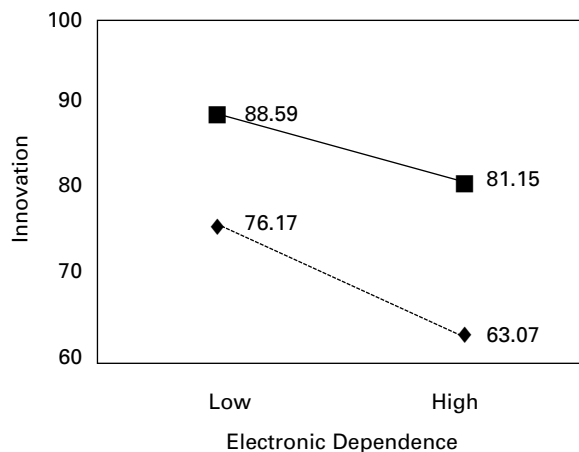


Figure 1c. Effect of communication climate on the relationship between dynamic structure and innovation.

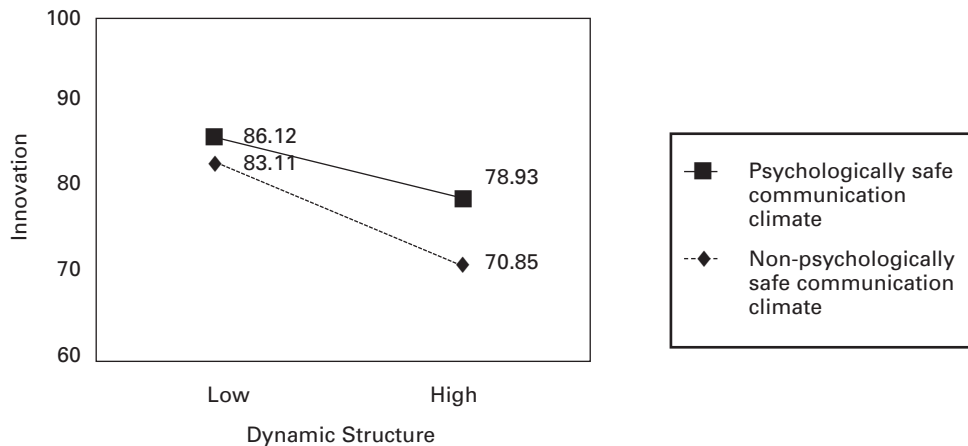
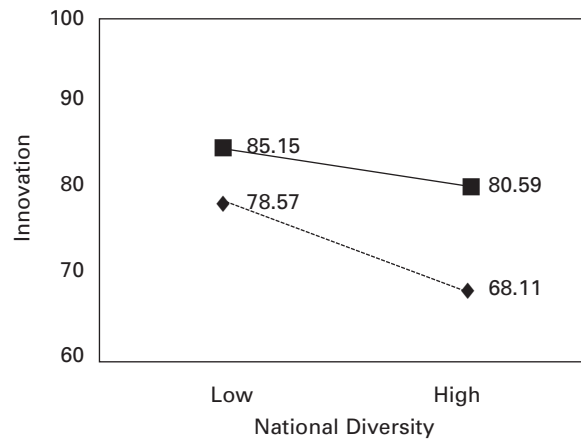


Figure 1d. Effect of communication climate on the relationship between national diversity and innovation.



the effects of the virtuality elements independently, rather than as an additive or multiplicative combination. Using the approach recommended by Cohen and Cohen (1983), we computed an F-test for the difference in total variance explained by each model. Results supported our argument. The total variance explained in model 1 ($R^2 = .46$, $F_{8,47} = 5.09$, $p < .01$), which contained separate terms for each virtuality characteristic, was significantly greater than the total variance explained in model 2 ($R^2 = .43$, $F_{5,50} = 7.65$, $p < .01$), which contained the additive term (F-test for the difference in R^2 values = 2.42, d.f. = 55, $p < .05$). The variance explained in model 1 was also significantly greater than that explained in model 3 ($R^2 = .33$, $F_{5,50} = 4.98$, $p < .01$), which contained the multiplicative term (F-test for the difference in R^2 values = 8.93, d.f. = 55, $p < .01$).

DISCUSSION

We set out to capture the concept of virtuality more precisely by unpacking the negative effects on innovation of characteristics most often conceptualized as dimensions of virtuality and showing how they can be mitigated by a psychologically

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safe communication climate. The two studies we conducted are among the first to examine comprehensively and simultaneously the features of relatively new work designs that have proliferated rapidly. In doing so, we uncovered numerous important findings that have implications for future theory and research in several areas: conceptualization and theory pertaining to virtuality, social network theory, and theories of communication climate and psychological safety.

Theoretical Implications

First, this research represents a more nuanced conceptualization of virtuality and one of the first comprehensive empirical attempts to operationalize multiple components independently. As a result, we teased apart the effects of geographic dispersion, electronic dependence, dynamic structure, and national diversity that have previously been either confounded in one variable or studied in isolation. Our measures captured these specific elements with greater precision than those in previous investigations. For example, some previous research has contrasted teams that are “virtual” with teams that are “not virtual” based on assignment to laboratory conditions or a simple count of the number of face-to-face meetings (e.g., Kirkman et al., 2004). Our results suggest that the four team characteristics often associated with virtuality are not as highly interrelated as previously assumed. For example, national diversity was not associated with electronic dependence in Study 2, contrary to research that has confounded these two distinct characteristics. Likewise, dynamic structure was not related to geographic dispersion in either study, suggesting that teams can be geographically dispersed yet still have stable membership and structure. These findings indicate the criticality of considering each team feature in its own right. Researchers who lump them together are missing important complexities in the realities of team work. Importantly, in Study 2, our attempts to operationalize the higher-order “virtual” construct by combining the four elements failed to produce a model with superior fit and predicted less variance in innovation than did a model that considered each characteristic separately. This reiterates the importance of considering the independent effects of each characteristic.

Second, our results demonstrate the possible negative, often unintended and unanticipated effects of the four team characteristics on an important outcome, innovation. This has implications for organization design theory and innovation, which are of broad importance, given that features of virtuality are becoming commonplace in modern organizations and innovation has become such a crucial source of competitive advantage for organizations. Virtual teams have been proclaimed as a promising design for integrating firms and are often established to take maximum advantage of innovation-creating capabilities (Nonaka and Takeuchi, 1995). Yet our findings suggest that these characteristics also pose challenges that can be detrimental to innovation. We contribute to the extant literature on the success factors for innovation (Brown and Eisenhardt, 1995) by extending this framework to virtual teams, finding that national diversity, geographic dispersion, and electronic dependence had negative effects

across the two studies, while dynamic structure had a negative relationship with innovation in the aerospace industry teams surveyed in Study 2. Our conceptual arguments suggest that these effects occur through unique mechanisms, which should each be considered to predict the ramifications for designing teams with a high degree of any one of these features.

These findings provide further support for network theory, which has shown that certain structural arrangements, such as those that result in contextual complexity, weak ties, and structural holes can be problematic for innovation by preventing the implementation of ideas (Burt, 2004; Obstfeld, 2005). In prior work, scholars have suggested that it is important to consider the potential benefits of teams with moderate levels of features of virtuality, such as geographic dispersion (Burke et al., 1999). This implies a possible curvilinear effect. To test this alternative relationship, we re-ran our models in Study 2, entering a squared term for geographic dispersion after the direct effects. But we found no evidence for a curvilinear relationship between geographic dispersion and innovation (i.e., the addition of the squared term did not result in a significant change in R^2 , and the coefficient for the term was not statistically significant), indicating that the relationship in our data is best described as a direct linear negative effect. Likewise, we explored the possibility that our contradictory evidence regarding dynamic structure (no relationship with innovation in Study 1; a negative relationship with innovation in Study 2) could be masking a potential curvilinear effect, such that moderate levels of structural dynamism are most beneficial. But again, we found no evidence for a curvilinear relationship: adding a squared term for dynamic structure after the direct effects did not account for significant variation in innovation in Study 2. Hence, even though some benefits may be realized in idea generation, our findings indicate that on balance, contextual complexity and weak ties created by geographic dispersion and dynamic structure may be problematic for innovation because of challenges in implementing ideas.

Finally, our findings in Study 2 revealed significant interaction effects, such that a psychologically safe communication climate reduced the negative effects of all four elements of virtuality on innovation. Although it is certainly not a panacea, a psychologically safe communication climate appears to be an important facilitator of innovation in teams by helping them overcome the challenges posed by virtuality. Our interviews revealed that the negative effects of geographic dispersion were often mitigated by a psychologically safe communication climate because it helped to raise and clarify contextual differences, helping teams coordinate and garner resources for innovation across contexts. The difficulty in sparking a creative exchange of ideas over computer-mediated communication was mitigated in some cases by a psychologically safe communication climate developed through expert use of the technology. The disadvantages of a dynamic structure for innovation, such as the lack of relationship building due to member turnover and tensions and conflicts due to different reporting structures, were lessened by a psychologically safe

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communication climate that helped overcome mistrust and turn the team's fluid membership into a source of new ideas and expertise. Finally, mitigating the negative effect of national diversity, a psychologically safe communication climate helped raise and clarify differences in national orientations and norms, resolve conflict, and foster an open environment in which team members felt comfortable to ask questions, admit to a lack of understanding, and voice opinions. This increased innovation by allowing different perspectives and viewpoints to be heard, enabling the merging of ideas and helping to establish a middle ground and bridge differences.

These findings make important contributions to the research on communication climates and psychological safety. First, we extend theory on communication climates (Dillard, Wigand, and Boster, 1986; Trombetta and Rogers, 1988; Guzley, 1992) by being the first to demonstrate group-level effects on the important outcome of team innovation. Previous research has focused on effects on attitudes such as satisfaction and commitment. Second, we contribute to the theoretical refinement of psychological safety by conceptually developing the communication component of the construct and demonstrating new evidence of a direct relationship between this component and innovation, as well as moderating effects. This supports conceptualizing the construct as multidimensional and highlights important antecedents and outcomes. Further, our findings extend related prior research by testing relationships when teams varied on the four elements of virtuality and by indicating the critical role of psychologically safe communication in such settings. Importantly, it was not just the creation of trust that mitigated the effects of virtuality, as has been suggested in previous research (Jarvenpaa and Leidner, 1999). To help rule out trust as an alternative explanation, we included a nine-item measure of trust in our survey in Study 2. Replacing team scores on trust for the psychologically safe communication climate variable in our analyses produced an entirely different pattern of results. There was no significant main effect of trust on innovation, and there were no significant interaction effects between the elements of virtuality and trust. This provides evidence that it is a psychologically safe communication climate, and not trust, that is operating here to mitigate the negative effects of the elements of virtuality.

Limitations and Future Research

Our contributions must be understood alongside the limitations of our research stemming from the research design. First, although we were able to unpack certain features assumed to be associated with virtuality, there may be other factors that contribute to innovation that we did not examine that are in some ways confounded by the features we included. For example, the underlying rationale for why national diversity is a challenge in virtual teams pertains to the complex differences that arise when members represent different nations, such as different cultural values, legal and economic systems, and religions (Earley and Gibson, 2002). We did not directly measure these more specific manifestations of national diversity, so we cannot be certain which mechanisms are driving the impacts on innovation. Harrison and col-

leagues (Harrison, Price, and Bell, 1998; Harrison et al., 2002) suggested that the longer a team works together, the lower the importance of surface-level characteristics of diversity and the greater the importance of deep-level diversity, such as personality, values, and attitudes, become. The teams in Study 2 were all formed at the same time, so there was no variance in teams' longevity, and we could not test this issue directly; however, our qualitative analysis in Study 1, in which teams did vary in longevity, still showed consistent negative effects of national diversity on innovation regardless of team longevity. That said, an important next step in research on teams is to examine the variety of factors underlying national diversity to determine their effects on innovation over time. An additional step is to further examine the role of team type or work type. We addressed this concern to some extent through the design of our two studies. In Study 1, the type of team and work varied dramatically. Some of the teams were design teams charged specifically with innovation, while others were more standard work teams that executed services or other organizational processes. Yet the negative relationship between elements of virtuality and innovation was evident in all types of teams. In Study 2, we controlled for team type and work type by sampling teams that were all involved in non-routine design tasks, and we ensured this by confirming that there was no significant variance in task routineness across teams. Yet we saw different levels of the elements of virtuality and innovation across these teams. Hence, we can be fairly confident that the relationships we uncovered occur even after controlling for the type of team and work. At the same time, we acknowledge that the contexts we selected may have restricted the range and variety of responses concerning innovation and a psychologically safe communication climate. But this restriction in range means that our results are fairly conservative, and additional research in even more varied contexts should provide that much more precision.

We also recognize the limitations of capturing innovation based on a relatively simplistic measure (in Study 1, perceptions of members; in Study 2, the percentage of innovation achieved as rated by customers downstream in the process). The ideal design would include more objective measures of the incorporation of new and diverse information into new methodologies, products, and services, as well as stronger indicators of subsequent organizational performance implications. We provided evidence for the construct validity of our innovation measure in Study 2 by correlating it with overall effectiveness as rated by customers. Scholars in the innovation literature argue that although there may be some overlap in predictors of innovation and predictors of overall effectiveness, the set of success factors for each criterion is not entirely the same (e.g., Brown and Eisenhardt, 1995). But an alternative explanation for our findings is that our models would hold if we were to replace our innovation dependent variable with an overall effectiveness dependent variable. We conducted this analysis and found that this was not the case. Replacing innovation with overall effectiveness as the dependent variable in Study 2 produced a different pattern of results. There was no main effect for national diversity, electronic dependence, geographic dispersion, or a psychological-

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ly safe communication climate, and only one of the four interaction effects (dynamic structure \times psychologically safe communication climate) was significant. Although exploratory and post hoc, this analysis suggests that there is something special about the effects of the elements of virtuality and a psychologically safe communication climate on innovation that doesn't pertain to general effectiveness. We argued that this is because of the negative effects of the elements of virtuality on specific factors associated with innovation that aren't necessarily predictive of overall effectiveness in general. We encourage future research along these lines. Finally, although we did not directly examine the intentions or objectives firms had in implementing teams characterized by virtuality, this is an important avenue for future research. If increased innovation is explicitly the intended motivation, how often is this actually achieved? Longitudinal intervention studies that examine the level of innovation prior to and following the implementation of elements of virtuality would be a welcome extension of our research.

The two studies reported here have unpacked the elements of virtuality and illustrated their differential interrelationships and negative effects on innovation. Our results indicate that organizations intending to implement teams characterized by national diversity, geographical dispersion, electronic dependence, or structural dynamism for the purpose of innovation should take heed that these teams may not fulfill this promise unless effective team processes are developed. Our findings underscore the need for psychologically safe communication in teams characterized by a high level of the elements of virtuality. Such communication behaviors should lead to improvements in the innovation process, which is of primary importance in today's competitive business environment.

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APPENDIX: Summary Interview Protocol

- I. Interviewee's background
 - a. Job in company, function, profession
 - b. Have you moved across functions/disciplines in your career?
 - c. Where located
 - d. Country of birth, residence, identity
- II. Interviewee's Role on the Team
 - a. What is your role on this team?
 - b. How long have you been with this team?
 - c. How was this role determined?
 - d. Percentage of time dedicated to team?
 - e. How were you selected for the team?
 - f. Do you have any other responsibilities outside of the team? What are they?
 - g. To whom do you report? Where do you feel you owe your primary allegiance? To the team or to your function/unit? Why?
 - h. Do you belong to other teams? Are any of them virtual?
 - i. How would you prioritize your work on this team as compared to your other responsibilities?
 - j. Have you worked with anyone on this team before? In what context?
- III. Objectives
 - a. What is the mission of your team? How does it fit into the business's overall strategy?
 - b. Why is this team virtual as opposed to non-virtual?
 - c. From your perspective, what are the specific objectives of the team?
 - d. Are these objectives well understood and shared by the team members?
 - e. How were these objectives determined? By whom?
 - f. Is the team start and finish point clear? (i.e., scope and time?) What is it?
- IV. Task and Team Structure
 - a. Describe how work gets done in your team. What are the steps involved?
 - b. Do you share responsibility and accountability for outcomes (or do some persons have this responsibility and others do not)?
 - c. How much does the work or work requirements for your team change over time?
 - d. Are the boundaries between your team and other teams clear? If so, how were they developed?
 - e. Who does the team report to? Do team members share the same reporting relationships? If not, what is the impact of this?
 - f. Are certain members core to the project and others more peripheral? Please describe.
 - g. How much of the team's work gets done face to face?
- V. Information Technology and Applications
 - a. How frequently does your team use e-mail, phone calls, phone conferencing, voice mail, faxes, video conferencing, chat rooms, electronic meeting systems or bulletin boards, intranet, file sharing, workflow applications, or other technologies?

- b. Which of the technologies are most helpful in working/communicating with other members of your team? Why?
- c. Which of the technologies are least helpful in working/communicating with other members of the team? Why?
- d. Could anything be done to increase the usefulness of these technologies?
- e. Did the team receive any training to help members be able to use the available technologies? If so, how effective was it?
- f. Are these technologies used to communicate with other teams or with key stakeholders? If so, for what purposes and how effectively?

VI. Benefits and Costs of Virtuality

- a. What do you view as the benefits and costs of working across functions, sites and countries? Why?
- b. How would the team operate differently if it were less virtual?
- c. What are the measures used to evaluate team effectiveness?
- d. Compared to what is possible with a virtual team (100% is all that is possible), how effective is the team at achieving its overall mission?
- e. Would it be easier to achieve the mission if everyone was co-located? If yes, would it take more time, less time, or the same amount of time to accomplish the mission?
- f. How critical is the team's mission to the success of your business?
- g. Are team members excited about the work the team is doing? Why? Or why not?
- h. Would you want to work with the other members of your team in another project? Why? Or why not?

VII. Team Leadership and Team Processes

Given what you have said about effectiveness, which of the following do you believe impacts the team's level of effectiveness the most: leadership, goal-setting processes, coordination of work, communication, or decision-making?

Leadership

- a. Is there an officially designated leader for your team? Do other members play leadership roles?
- b. Give me an example of when leadership of the team occurred very well. Not so well?
- c. How effective is team leadership? Why do you say this?

Goal-Setting

- d. Describe how the team sets goals.
- e. Give me an example of when the goal-setting process went very well. Not so well?
- f. How effective is team goal-setting?

Coordination of Work

- g. How does the team make sure that work is coordinated?
- h. Describe a time when work was coordinated extremely well. Extremely poorly?
- i. In general, how effectively does the team coordinate its work?

Decision-Making

- j. Describe how the team makes decisions.
- k. Describe a time when you felt a key decision was made extremely well. Not so well?
- l. In general, how effectively does the team make decisions?

Communication

- m. Describe how team members communicate with each other. With key stakeholders?
- n. Give me an example of when communication was handled really well. Not so well?
- o. In general, how effectively do team members communicate with one another? With stakeholders?

Information Sharing and Conflict Resolution

- p. Do you find that you frequently use certain acronyms, expressions, or jargon in this team? Which ones?
- q. What kinds of misunderstandings arise on the team (probe for goals, work processes, use of technology, resources, performance, and

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rewards)? How often do misunderstandings occur? How are they handled?

- r. Do you encounter conflicting priorities? Explain.
- s. Where does the team get the information/knowledge it requires for its work? Are these information sources adequate for your needs?
- t. What percentage of the team's critical communications are virtual versus face to face? (Probe).

VIII. Trust

- a. How much trust is there on the team? How do you know?
- b. How much do you trust others?
- c. How much do others trust you?
- d. If there are any discrepancies, why?
- e. How much trust is there that time and money will be used in the best interest of the team? That they will be used in a fair and equitable way?
- f. Do people trust each other to contribute worthwhile ideas?
- g. Do people trust each other to do what they say they will do?
- h. How did the team develop trust among its members? What factors hinder trust?

IX. Characteristics of Members

- a. Do members have all the skills that are needed on the team? Team and interpersonal skills? Technical skills? Please describe.
- b. If the team needs skills or knowledge that reside outside the team, how is that knowledge obtained? What role do members play in obtaining it?
- c. How do differences in culture, discipline, home organization, or other differences influence the way members work together?
- d. Do problems occur because of these differences? If so, how do you resolve them?
- e. Do individuals act as "interpreters" or "translators" between different functional areas? Between different units? Between different cultures? How do they do this?
- f. Do members of the team have similar work values?

X. Performance Management and Human Resources

- a. How are the contribution and performance on the team and individual members evaluated?
- b. What kinds of behaviors and performance are rewarded?
- c. Is there a team performance reward and recognition system? If so, what is it?
- d. How aligned is the team reward and recognition system with the goals of the business?
- e. Are there any other organizational or human resource practices that we haven't discussed so far that have an impact on team effectiveness? Describe positive or negative impact.

XI. Lessons Learned

- a. What lessons has the team learned since it began operating on how to make a virtual team effective?