How virtual are we?
Measuring Virtuality and Understanding Its Impact in a Global Organization

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Abstract

"We're becoming more virtual all the time!" is heard in many global corporations today. But basing decisions on this is elusive, as "virtuality" itself isn't measurable. Lack of definition makes it hard to assess how virtual teaming affects performance, or to design infrastructures and toolsets to support distributed work. Using the concept of discontinuities, or a decrease in expected cohesion, we propose a virtuality index to assess how "virtual" a given setting is. The virtuality index is a tool to segment aspects of virtuality and their effects on performance. Data collected at Intel Corporation reveal that virtual teaming can be measured by three overarching discontinuities: team distribution, workplace mobility, and variety of work practices. We found that being distributed in and of itself had no impact on self-assessed team performance. Work practice predictability and sociability mitigated effects of working in discontinuous environments; while variety of practices (cultural and work process diversity) and employee mobility negatively impacted performance. Implications for the design of collaborative technologies and work practices are discussed. The study also identified the prevalence of multi-teaming at Intel as an important area for future research of virtual teaming.

Keywords

Virtual teaming, virtuality, discontinuities, collaboration, distributed teams, global firm, Intel Corporation

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Introduction

Work today is increasingly "informated", turning a large proportion of corporate employees at all ranks into "knowledge workers" whose tasks are computer-mediated (Zuboff, 1984). This same trend allows work to be carried out over computer networks and reduces the need for teams to be collocated. Workers collaborate electronically with co-workers or with employees of other companies, relying on information and communication technologies (ICTs) in place of face-to-face discussions (Lipnack & Stamps, 1997; Mark, 2001). People may work with multiple teams distributed over different geographical locations. They work across major time zone differences, across internal business units, and across cultures. Some participants may never meet face-to-face, yet they form effective teams (Orlikowski, 2002). Although virtual teamwork is a current topic in the literature on global organizations, it has been problematic to define what "virtual" means across multiple institutional contexts. Information Systems (IS) researchers have defined "virtual" as: outsourcing key components of production (Kraut et al., 1999); forming ad hoc teams from diverse locations to solve problems (Jarvenpaa, Knoll, & Leidner, 1998); and working from home, satellite offices or on the road (Davenport & Pearlson, 1998). Nardi and colleagues (2002) defined virtual work as ad hoc groups of professionals who team across the Internet around a common topic. In sum, much of the literature on virtual teams focuses on distance – the challenges teams face to communicate, resolve conflicts, and maintain social interactions over time, space, or organizational units.

To compile these myriad conceptualizations of virtual work into a more unified construct, Watson-Manheim, Chudoba, and Crowston (2002) introduced the concept of discontinuities, or factors contributing to a decrease in cohesion. Examples of discontinuities include physical location, time zone difference, national culture, professional culture, and organizational affiliation. Different types of discontinuities are logically separable, but they often come in bundles (e.g., location + time zone difference + national culture). For example, working on an inter-organizational team may mean that individuals who are separated in time and/or space interact with colleagues from different professional, organizational or even national cultures (Boudreau, Loch, Robey, & Straub, 1998; Carmel, 1999).

One advantage of the concept of discontinuities is that each of the elements can be credibly measured and reported within the scope of an individual's experience, i.e., employees can reliably say whether they work with people at a physical distance, across organizations or national cultures, and how often they experience the discontinuity. The need to characterize virtuality arose in Intel Corporation's Information Technology department because the term "virtual" was used informally to describe changes in the organization in the context of plans for future enterprise collaboration tools. Virtuality seemed important, yet conceptually vague. The objective of the study was to use the concept of discontinuities to see how "virtual" Intel really was and what difference it made to employees' perceptions of their teams' performance by constructing a virtuality index to characterize the distributed work environment.

Characterizing virtuality is important for at least two reasons. First, the virtuality index structures the concept of virtual teamwork so that it encompasses prior definitions, and permits us to document and measure the conditions of virtual teamwork with more precision. Second, as a quantifiable index, it can be combined with outcome measures to assess the effects of individual features of virtuality on performance. A virtuality index can be useful in measuring rapidly moving trends, understanding the different vectors of those trends, and then responding strategically to the vectors where the index indicates potential problems. Solutions could come in many forms, including the design of collaborative application software, new network architectures, new tools for searching and sharing information, and new methods of reinforcing corporate culture in a virtual environment (Majchrzak et al. 2002; Majchrzak & Malhotra, 2003). As well, an index can simply help senior management avoid misplaced emphasis on solutions for issues that aren't problematic.

The paper continues as follows. We begin by more fully describing the motivation for the study. Next, we draw on prior research to explain the derivation of the items that comprise the virtuality index. Then we present our methods and results of our analyses. The paper concludes with a discussion of the implications of the virtuality index and how our findings are being used within Intel, along with areas for future research.

Motivation

The study arose out of a particular context within Intel's Information Technology Division. Professionals engaged in assessing the current state of collaboration tools for the enterprise felt that the proliferation of tools used throughout the company gave only the illusion of supporting remote collaboration since feedback from end-users suggested a lack of key

capabilities and integration caused extra overhead and confusion. No one tool had all the necessary features; instead, each tool was built around one key competence. It was especially noticed that users on multiple teams had to switch tools as they moved from virtual meeting to virtual meeting. At the same time, executives accurately perceived that a large investment had already been made in collaboration tools. What was the return on investment (ROI) for starting from the ground up or reworking existing capabilities into a new, integrated one? Or, why not wait for vendors to solve the problem?

Following the thinking of the phenomenologists in strategic information systems research (Ciborra & Jelassi, 1994) and organizational studies (Argyris & Schon, 1978; Schon, 1983; Weick, 2001), we believed that a collaboration strategy could emerge from a better understanding of how Intel operated in the new conditions of globalization, which had been expanding rapidly in the preceding five years. The exclamation "we're getting more virtual all the time!" called out for quantifiable observations to support that claim to the satisfaction of senior decision-makers. There had never been any metrics to assess the condition of virtuality, yet quantitative measures seemed critical to answering management's questions. No ethnographic account could convey the size of the problem.

Assuming that virtuality is part of a "formative context" (Ciborra & Jelassi, 1994; Weick 2001), what effect does articulating this context have on the insights necessary to design a tool that would impact a population of 80,000 functionally distributed worldwide employees? Many companies have manufacturing overseas, but Intel more and more has functional distribution, starting with the service organizations like IT, HR and Finance, but increasingly in product groups. For instance, many product groups have globally distributed design teams with 24x7 software engineering. Manufacturing, while concentrated in specific locations, also fosters a large amount of cross-geography communication and collaboration for maintenance of best practices and standards conformance. In brief, the study rose out of a practical aim based in the need to assess a new situation in the corporate experience, one that would likely continue to grow for some years. The study has overtones of action research in that it began in an action context, and in turn influenced the environment it came from, as senior staff, both in IT and in HR, welcomed the results.

Characterizing Virtual Work Environments

As distributed work arrangements became increasingly common in the 1990's, the question emerged as to how distributed work, or virtual teaming, differs from collocated work. Debates among academics and practitioners frequently resulted in a "draw" (Virtual Teams,

2000), with reasoned arguments on both sides of the issue. For example, some advocated work could only be considered virtual when all interactions were mediated by distance, with no work completed in face-to-face (FTF) mode. More recently, researchers suggest virtual teaming can be described along a continuum with variations in the extent of FTF work (Griffith et al, 2003).

ICTs are commonly recognized as enablers of virtuality. People in distributed organizations rely upon them in lieu of face-to-face interaction. They have become deeply integrated into work processes as work became more informated (Zuboff, 1984) and by that same means, less materially bound and less collocated. ICTs help overcome barriers to collaboration and enhance flexibility required to meet the rigors presented by rapidly changing work environments (Boudreau et al., 1998). As well, they address the common condition of organizations of all sizes, that their scope of business is not necessarily local. Even the tiniest businesses now rely on distant markets for marketing, sales and communications.

However, even as ICT enables people to span boundaries of time, space, organization, and so forth, its use presents new challenges. In lifting some barriers to collaboration, the technology simultaneously exposes a presumed structure that no longer applies but lingers as a model in the minds of planners and vendors (Hammer & Champy, 1993), and opens the possibility of less cohesion in the work environment. As Scott and Timmerman (1999) note, "… the very technologies that provide … [workers] with the freedom and flexibility they desire, also allow them to be further removed from key aspects of the organization" (p. 241). Watson-Manheim et al. (2002) refer to these barriers as discontinuities – *factors contributing to a lack of cohesion between workers in a collective situation*, such as geographic separation, cultural differences or organizational membership. They suggest that *discontinuities* present in virtual work can be a good way to understand virtual environments because they draw attention to underlying process issues and potential problems created by hidden boundaries. In addition, discontinuities suggest paying attention to *continuities* as their logical antithesis, thus, facilitating an examination of the dynamics of virtuality (Watson-Manheim, Chudoba & Crowston, 2004).

Drawing from the literature on virtuality, we identified six discontinuities – geography, temporal, cultural, work practices, organization, and technology – that captured distinctive aspects of the virtual teaming environment. We now explain the posited discontinuities and the items crafted to capture each discontinuity in the virtuality index. As we will describe later, an item will be evaluated based on how frequently an Intel employee experiences the specific aspect of discontinuity.

Geography

Work that occurs between people in different geographic locations forms the nexus of all conceptualizations of virtual teaming. This capability was first recognized with the advent of telecommuting in the 1970's. The term 'telecommuting' was introduced by Jack Niles (1975) to describe the situation where an employee is able to work at home by substituting telecommunications for transportation to the office. Increased integration of ICT into firm activities and processes and consequent flexibility in the location of work led to heightened interest in new organizational structures, and the introduction of the term "virtual corporation" in the 1990's (Davidow & Malone 1992). The prevalence of geographic discontinuities in 21st century work environments is brought about by the desire to bring together the most qualified people, regardless of their home location (Carmel, 1999). While geographic discontinuity is easy to detect, a precise characterization of its effects is more challenging (Griffith et al., 2003; O'Leary & Cummings, AOM). It is not clear, for example, to what extent it matters where distributed work is conducted (e.g., home, office, airport). Working across distance, in some cases, has had negative effects on communication (Olson & Olson, 2000), including misattribution (Cramton, 2001) and conflict escalation (Armstrong & Cole, 2002), suggesting the importance of assessing geographic discontinuity. This leads to the following four items to evaluate geographic discontinuity:

- Work at home during normal business days.
- Work while traveling, for example, at airports or hotels.
- Collaborate with people in different sites or geographies.
- Collaborate with people you have never met face-to-face.

Temporal

Temporal discontinuities refer to collaboration across time zones (Armstrong & Cole, 2002; Espinosa et al., 2003; Orlikowski, 2002). Duarte & Snyder (1999) suggest that teams face more complexity when members cross multiple time zones, in large part because of increased difficulties in scheduling and coordinating work activities (Espinosa & Carmel, 2003). In their longitudinal case study of three global virtual teams, Maznevski and Chudoba (2000) illustrated the importance of establishing a predictable rhythm of communication exchanges, which becomes increasingly challenging when team membership encompasses different time zones (see also Kanawattanachai &Yoo, 2002; Yoo & Alavi, 2004). Compounding the problems of working across multiple time zones is the fact that team members may have different perceptions of time such as *clock time* – e.g., time is portioned into hours and minutes or *event time* – e.g.,

time is bounded only by the agreements among participants as to what constitutes the beginning and end of a relevant activity (Saunders et al., 2004). The following two items were created to assess temporal discontinuity:

- Work extended days in order to communicate with remote team members.
- Collaborate with people in different time zones.

Cultural

Virtual teaming environments are more likely to include members who represent different cultures than teams with collocated members (Duarte and Snyder, 1999). Culture is a set of values shared by a group of people, frequently used to distinguish one group from another. Cultural values serve as a filter for one's perception of the surrounding environment, guiding behavior such as decision-making (Adler, 1997) and social interaction (Early, 1993; Zander, 1997). Language, one cultural characteristic, may be especially relevant in virtual teaming environments since most communication is mediated through ICT. Cross-cultural discontinuities frequently interact with other discontinuities, such as geography and time. For example, differences in perceptions of time have been observed across national boundaries (Hofstede, 1991), longitudes (i.e., Eastern vs. Western), and even latitudes (i.e., Southern vs. Northern cultures) (Vatsyayan, 1981). We assessed cultural discontinuity with the following two items:

- Collaborate with people who speak different native languages or dialects than your own.
- Collaborate with people from different cultural backgrounds.

Work Practices

A fourth source of discontinuity is work practices. When people are brought together on a team, it is not unusual to have different perspectives about how work should be done. Developing common work practices may be even more complicated to the extent that work groups have members who transition on and off the team (Duarte and Snyder, 1999). In addition, the propensity for miscommunication (Cramton, 2001) and conflict (Mannix et al., 2002) in distributed work environments suggests that identifying and resolving these differences can be problematic. In a case study of virtual workgroups in a software engineering company, Armstrong and Cole (2002) noted the problem of coalescing around a common set of work practices:

> [What] seemed to matter most to work groups entailed accurate understandings of how to work together. It was easy to assume that distant members understood each other's expectations and meant the same thing with words such as *project review*, *phase*

> *completion*, and *test procedure*. Experience usually called such assumptions into question (p. 174).

Differences in ICT such as their structural features and spirit may encourage different social interactions (DeSanctis & Monge, 1999), suggesting further complications in work practices. For example, Orlikowski (2002) describes technical discontinuities (she calls them boundaries) that she found in global software development teams in one company, such as software running on different computer platforms accommodating multiple standards. This meant that employees had to overcome differences in ICT in order to collaborate. This leads to three items to assess discontinuities in work practices:

- Work on projects that have changing team members.
- Work with teams that have different ways to track their work.
- Work with people that use different collaboration technologies and tools.

Organization

Organizational discontinuity can be intra- or inter-organization. Intra-organizational discontinuity refers to the presence of different functional and business concerns, or local versus global interests (Orlikowski, 2002) among members of a team. Representatives from multiple functional areas may bring conflicting priorities to at team or disagree about the importance of various issues (Duarte & Snyder, 1999). Espinosa and his colleagues (2003) note that intra-organizational discontinuity (they label them functional boundaries) may interact with other discontinuities such as geography, making it challenging to tease out the relationships.

In addition, numerous researchers suggest that the virtual teaming environment is more complex when team members come from more than one organization (Armstrong & Cole, 2002; Duarte & Snyder, 1999; Espinosa et al., 2003). Inter-organizational discontinuity may be problematic when individuals cooperate to achieve a common goal while retaining their membership in different organizations because of differing loyalties and competing demands (Townsend, DeMarie, & Hendrickson, 1998). At the same time, inter-organizational work teams may be required for organizations to achieve their strategic objectives and meet the needs of various stakeholders (Maznevski & Chudoba, 2000). Three items assessed organizational discontinuities:

- Collaborate with people from different Intel business groups.
- Work at different Intel sites.
- Have professional interactions with people outside Intel.

Technology

Virtual teaming environments would not be possible without ICT, and so technology is one of the keys to understanding how they function. Differences in access to ICT across members of a distributed team have also been demonstrated to affect interactions (Duarte and Snyder, 1999; Maznevski and Chudoba, 2000), with lack of access making it difficult for some team members to contribute to team efforts. Since e-mail and telephone use are endemic across all categories of Intel employees, items to evaluate technology discontinuity focused on ICTs that were less widely diffused within the company:

- Work with people via Internet-based conferencing applications.
- Participate in real-time online discussions, such as chat or instant messaging.
- Meet with people via video-conferencing tools.
- Work with mobile devices.

In summary, we began with the premise that different discontinuities or aspects of virtual teaming will have distinct impacts on the performance of non-collocated teams. We propose six discontinuities – geography, temporal, cultural, work practices, organization, and technology – that are likely to be central to characterizing and understanding the dynamics of virtual teaming environments. Isolating these differences is important as a first step for those who must devise appropriate remediation strategies and collaboration technology platforms to enhance performance.

Method

Setting

Intel Corporation is a global manufacturer of semiconductor chips, servers and other high tech products, with 80,000 employees worldwide. There are five major U.S. sites distributed throughout the Western United States, each with multiple campuses and each campus having a complex of four or more buildings. Non U.S. sites encompass manufacturing, and more and more frequently, software development. These sites span the globe from Russia to Israel to Ireland, Shanghai, Manila, India and Malaysia, with sales offices in far more countries. The major international sites mirror the size of the U.S. sites with their large campuses of multiple buildings. Architecture and floor layouts including cubicle space are standard from building to building. As tacit acknowledgement of mobility in the corporation, the buildings internally have the same navigation mechanisms, so that Intel employees can find their way around Intel buildings anywhere in the world.

The motivations for being distributed include those common to similar high-tech companies: strong presence in local markets for brand recognition and for market intelligence; economic advantages for manufacturing, both in real estate and labor pools; and the growing pool of software engineering talent all over the globe. Beyond having multiple locations, the organization is functionally distributed, so that groups of coworkers are spread across the globe. Remote reporting relationships are growing, especially in the service areas of Finance, IT and HR where about 25% of employees work in locations different from their managers, compared with a 13% overall remote reporting rate for the company. In many jobs within the U.S., Intel does not require employees to relocate, reducing moving costs and dislocation stress on the employee's family, and increasing job mobility and flexibility by not attaching major life decisions to a career decision. Increasingly, people work some part of the week at home, and so it is extremely common for work meetings to occur over the telephone.

Procedure

We conducted a web-based survey of Intel workers, in a stratified random sample of 2100 employees drawn from Intel's employee database, representing all job types and ranks proportional to the actual population: 700 from each of the Americas, Greater Asia (GAR), and Greater Europe (GER) regions. The questionnaire was posted to the Web and personalized invitation e-mails were sent to each respondent, reaching 2050 valid email accounts, with reminders following one week later. 1269 employees submitted responses, for an overall response rate of 62%. Respondents reflected the initial stratification in terms of region and Intel job categories except that manufacturing factory floor work was under-represented (37% population, 21% sample) and management over-represented (<1% population, 3 % sample). Distribution of the responses to the demographic variables is presented in Table 1. As can be seen in Table 1, teamwork is prevalent at Intel. Most people (61%) concurrently work with 3-10 different teams, which suggests multi-teaming is an important facet of the organizational environment. A large majority of respondents (82%) reported that they worked in teams of 2-10 people.

Measurement

Virtuality

We used eighteen questions to assess the six discontinuities we identified (see Appendix A). Respondents replied on a six-point scale to show how often they experienced the aspect of discontinuity, such as working with people from different business groups, time zones or cultural backgrounds; using different media and technologies; working at different sites; and working

with people outside Intel. The six-point frequency scale had options of "daily," "weekly," "monthly," "quarterly," "yearly," and "never."

Correlation and principal component factor analyses with Varimax rotation resulted in an index with 12 items that has three components with eigenvalues greater than 1.0, as indicated in Table 2. The inter-item correlations range from .17-.77, with an average of .35. The inter-item correlations are presented in Appendix B. The following overarching discontinuities, or dimensions of virtuality, resulted from this analysis.

Team distribution: the degree to which people work on teams that have people distributed over different geographies and time zones, relying upon Intel's basic collaboration technologies. The four items for this dimension have a reliability of $\alpha = .85$.

Workplace mobility: the degree to which employees work in environments other than regular offices, including different Intel sites, home, travel routes, and places outside Intel. The five items measuring this dimension have a reliability of $\alpha = .70$.

Variety of practices: the degree to which employees experience cultural and work process diversity on their teams. The three items have a reliability of $\alpha = .73$.

The questions comprising each of the three overarching discontinuities and the percentage of respondents who experienced each aspect of virtuality are shown in Figures 1, 2, and 3.

Four items were removed from the original 18-item index due to redundancy as indicated by high correlations ($\alpha > .85$), or weak or ambiguous association with the three dimensions of virtuality. In addition, two items, which loaded on a fourth factor, were removed because of their low reliability ($\alpha = .42$). The items were about people's use of new media, such as instant messaging and video conferencing tools, which registered very low frequencies of use.

The factor analysis results in Table 2 suggest solid albeit not perfect convergent and discriminant validity, which means the items measuring one particular dimension of virtuality are strongly associated with it, and not other dimensions (Chin et al., 1997). Convergent validity is demonstrated by an item's high loadings on its own dimension, which are all close to .60 or higher. The items' low loadings with the other two dimensions (<.38) suggest the items are distinguishably associated with only one dimension of virtuality. The validity of the scales is reinforced by the high reliability measures.

<u>Team Performance</u>

In order to demonstrate the value of the 12-item virtuality index, we used it to examine the perceived effects of virtuality on team performance. Measuring performance or productivity across an 80,000-employee enterprise doing very different tasks at all levels of the organization is challenging. One metric that all Intel employees understand is the set of Intel espoused (and widely *enacted* per Argyris & Schon, 1978) values. Other researchers have also evaluated performance in terms of organizational values (Cummings, 1981; Kuo, 2004), which can include assessments of team work outcomes, including work quality and adherence to schedule (Aladwani, 2002; Henderson & Lee, 1992).

Intel values date to the beginning of the company and have changed very little over time. These values of customer orientation, discipline, great place to work, quality, risk taking, and results orientation provide a common metric of performance across the organization. Employee annual and interim reviews include indicators of which three values employees feel they have excelled in, with 360-degree input from peers assessing an employee's performance to values. When we discuss "performance" in the paper, it is a rollup of scoring on items that capture these six values.

Ten questions about interpersonal relationships, communications, team member commitment and participation, and outcomes assessed team performance, as reflected by Intel values (see Appendix C). Respondents used a seven-point scale (never to very frequently) to register their experience of team performance. Responses to questions about negative situations were reversed for analysis so that for all the questions, the higher the rating, the better the performance. The overall performance score from averaging the 10 questions has a reliability of α=.81.

Other Factors that Impact Team Performance

The three dimensions of virtuality are based on discontinuities that may disrupt established communication activities and flows of information. Other factors are known to influence communication patterns or team work, and should serve as control variables in the relationship between virtuality and performance. We identified three factors likely to be especially important to those engaged in virtual teaming, based on prior internal research at Intel – social interactivity, knowledge networking, and work predictability.

Social interaction in virtual teams has been widely studied and is regarded as a key element that differentiates the operation of virtual work teams from collocated counterparts. Purely social or non task-specific interaction between members is an important aspect of work

that is embedded in work-related talk as well (Wynn, 1979). Authority, power, and role definitions, as well as interpersonal attraction and compatibility are constructed through social interactions between group members (Hirokawa & Johnston, 1989). Social interactions enable the development of common grounds for communication (Krauss & Fussell 1990; Weedman, 1991), which increases communication effectiveness and enhances the ability of individuals to work together. As well, through over-layered social ties, team members establish trust that carries over into feelings of safety in sharing ideas about the work process (Katzenbach & Smith, 1994).

We used four questions to assess how often people socialized for work and non- work purposes with team members, as well as with Intel employees not on their teams, along with the adequacy of team interaction frequency. Frequencies were measured with a six-point scale, from "never," (1) to "daily" (6). Adequacy was measured on a seven-point scale, from "too little" to "too much," with a middle point of "about right." The seven-point scale was folded at the middle point to create an adequacy scale of 1 to 4, with "too little" or "too much" being 1 and "about right" being 4. In other words, one is the least adequate level, with social interaction being either too much or too little, while 4 is most adequate.

Knowledge networking: ICTs enable employees to interact more spontaneously and more broadly with people who are not direct coworkers, facilitating *knowledge* networking over broader spaces. There is significant evidence that work is accomplished through relationships and informal political systems (Sachs, 1995; Watts, 2003) and that networks amplify information "productivity" (Bulkley & van Alstyne, n.d.). Tacit knowledge of skills and procedures is embedded in social practices and the work environment itself, thus engendering overall effective work practices. The notion of "community of practice" has been historically based on tacit knowledge embedded in a shared physical space and common history (e.g.; Suchman, 1987; Wenger, 1998; Wynn, 1979; Wynn, 1990). Collocation tended to limit the physical range of tacit knowledge sharing, while increasing the depth and degree of commonality. ICT enables interactions among workers who are not physically collocated thereby broadening their access to relevant knowledge (Cummings, 2004; Kraut & Streeter, 1995). However, in conditions of virtual teaming, the depth of practice sharing can suffer from the thinness of the shared environment.

We measured the extent that employees interact with people outside their teams for knowledge and resource sharing purposes with three questions. Respondents used a six-point scale to indicate frequency of sharing knowledge or resources with people outside their teams,

getting help from people outside their teams, and participating in discussions via email lists, with 1 being "never" and 6 being "daily." We averaged the three questions to form a scale that has a reliability of $\alpha = .73$.

Work predictability: Task characteristics like *predictability* affect communication patterns. Jobs characterized by predictable tasks have known procedures and methods of performance. Performance generally involves gathering information in response to clearly defined questions, e.g., report preparation. Jobs with low task predictability do not have such clearly defined procedures (Perrow, 1967); much of the information needed to answer questions and perform the work is determined in the course of work, e.g., research, strategic planning, emergencies. Less predictable jobs require more intensive and explicit communication with co-workers than do predictable jobs (Kraut 1987, Van de Ven, Delbecq, & Koenig, 1976). Coworkers may emergently construct procedures for such tasks. Finally, research shows that remote tasks may benefit from increased predictability in the case of teleworkers (Fritz, Narasimhan, & Rhee, 1998). However, when remote teamwork becomes the norm, people must also handle open-ended tasks in the virtual setting, posing new problems.

One question asked how much people relied on established procedures and processes in their work, or how predictable their work was. This question was adapted from Van de Ven, Delbecq, & Koenig (1976). The options on a five-point predictability scale were coded 1 to 5, with 1 being "rarely" and 5 being "largely."

Results

We used a three-step hierarchical regression analysis to understand the impact of virtuality on team performance in the context of a number of other variables that are widely believed to impact team performance. Three groups of variables were entered in the regression model as the independent variables: a) demographic variables; b) variables of team participation, social interaction, work predictability, and knowledge networking, which are related to the nature of their work; and c) the three dimensions of virtuality from the factor analyses. For the demographic variables, two dichotomous variables were created for region: the Greater Asia Region (GAR) and Greater Europe Region (GER). Americas was the omitted category. We created four dichotomous variables for different job roles in Intel, including administrative, manager, manufacturing technician, hardware and software engineer, with other individual contributor (Sales and Marketing, HR, Finance, Legal, IT and other support roles) being the omitted category.

Table 3 presents results of the regression analysis. In Step 1, different regions have different observations of team performance. GAR and GER employees have a higher assessment of team performance than employees from the Americas. The difference between GER and Americas becomes insignificant in Step 3, after controlling for the dimensions of virtuality variables. Hardware and software engineers experience better team performance than other job roles. In Step 2, people whose work is more predictable observe better team performance (β = .12, p <.001). Social interaction affects team performance; people who interact even with non-team members feel good about their team's performance (β = .16, p <.001), as do those who have adequate interaction with their team members (β = .08, p <.05). Per Step 3, variety of practices (β = -.14, p <.001) negatively impacts performance, while team distribution across distance has no significant relationship with perceptions of team performance. Workplace mobility has a negative impact, but it is not significant at the .05 level (β = -.07, p <.10). Among all the variables examined, variety of practices has the largest effect as indicated by its regression coefficient.

The regression models suggest that the dimensions of virtuality within the Intel environment have significant implications for people's observations of team performance. An examination of collinearity statistics suggests that all the variables have sufficient tolerance to sustain the regression models. Team distribution, workplace mobility and variety of practices have collinearity tolerances of .52, .67, and .69 respectively, suggesting they can be discriminated from other variables about team work and collaboration, including the number of teams people are on, the typical size of teams, predictability of work, social interaction and knowledge networking activities. This further validates the discriminant validity of the three dimensions of virtuality.

In an effort to determine the index's external validity, we randomly split the sample into halves – one half of the sample was used to repeat the exploratory factor analysis discussed previously; the other half was used to repeat the regression analysis. The factor analysis result and reliability measures are presented in Appendix D and are generally consistent with those obtained with the entire sample. The other half of the sample was used to conduct the 3-step hierarchical regression analysis. The relationships between the virtuality variables and team performance are confirmatory with those identified with the whole sample. This substantiates the external validity of the virtuality index and its concepts of team distribution, workplace mobility and variety of practices, as well as the scales measuring the concepts.

The variables in this study were measured at one single point of time with a common method, thus the internal validity of this study may face the threat of common method variance, which may bias results by inflating the observed relationships (Bagozzi, Yi, & Philips, 1991). To check for common method variance, we entered all the items used to measure virtuality and all the items for team performance into a single factor analysis. Principal component factor analysis with Varimax rotation identified five factors, with the items for virtuality loading on three of them, and the items for team performance distinctively loading on the other two factors. None of the factors accounts for a substantial amount of the variance, with the largest percentage of variance equal to 25%. The result rules out the threat of common method variance.

We may still face a response bias even though we had a high response rate. Response bias was assessed using the Armstrong and Overton (1977) procedure. We divided the sample into two subgroups: one for responses submitted before the reminder emails (n = 734), and the other for those submitted after (n = 535). One-way ANOVA was used to assess whether there were any significant differences between the two groups regarding the demographic variables and responses to the virtuality and team performance questions. We found no difference regarding demographic variables, including gender, region, job role, and length of working experience at Intel, and their perception of team performance. However, there were significant differences related to the virtuality variables. Those people who responded without the reminder experienced greater team distribution ($F(1, 1266)=21.89$, $p < .001$), workplace mobility ($F(1, 1264) = 5.77$, $p < .05$), and variety of practices ($F(1, 1257)=19.10$, $p < .001$). A reasonable explanation is that people are naturally more interested in responding to a survey that is relevant to their work situations. Nevertheless, we did not identify any significant differences in demographic variables or team performance, and so we concluded that response bias was not a factor contributing to the relationships we observed.

Discussion

We have described a study conducted at Intel Corporation to develop a measure of virtuality, which has been conceptualized as discontinuities of geography, time, culture, work practices, organization, and technology. The contribution of this study is twofold. First, we developed an index measuring how much virtuality Intel employees experience. We identified three dimensions of virtuality – team distribution, workplace mobility, and variety of practices – that are overarching discontinuities with important implications for our understanding about how virtual collaboration and remote work impact team performance. Statistical analyses suggest good validity and reliability of the index. Second, we identified significant relationships between virtuality and team performance that provide insights for the design of ICT tools that can reinforce the effectiveness of those engaged in virtual teaming.

As an outcome of the study we found ourselves able to provide initial answers to the questions "how virtual is Intel?" and "what difference does it make?" In answering the first question, it is interesting that variety of work practices is an important component of virtuality along with more commonly known features of virtual teaming like geography. We measured variety of practices by asking how much employees collaborated with people who track their work in different ways, use different ICT tools, or experience process changes due to changes in team membership. Whereas in past years people worked primarily within the context of informal local networks that provided a common corporate culture, locality is less important than it once was in conveying common practices. The implications of practice-related discontinuities suggest an avenue for future research because of its focus on the *process* of working virtually. Practice consistency can compensate for other discontinuities and provide a basis for common expectations. With inconsistent practices, there are no boundary spanning tools with which to resolve either uncertainties or ambiguities (Carlile, 2002). This reinforces the role that employee education modules, performance reviews and the like play in creating consistent work practices. Intel offers trainings on working in a multicultural environment, constructive confrontation and effective meetings as ways to provide a common corporate culture for these encounters. A strong corporate vocabulary for routine situations is an important success factor (Gabarro, 1990), but our findings should not be interpreted as a call to excessive standardization that could hinder creativity, innovation, and responsiveness, all necessary to maintain competitiveness in today's work environment.

The third component of the virtuality index, workplace mobility, is also interesting. Workplace mobility describes how much employees move around from home, to different

offices, and travel locations. This raises the possibility that today, many employees face challenges commonly associated with sales and marketing people who work from their briefcases or laptops on the road (Madden, 1995). Supporting these mobile workers is a key priority for IT organizations now and in the future. Collaboration tools need to provide a form of continuity that parallels that of workers who stay at one desktop (home or office).

Using the virtuality index to address our second question and assess impacts of virtual teaming on performance, we found that distance itself is not a factor that impairs any aspects of virtual collaboration. The concept of team distribution measures the extent that people work in teams distributed across different time zones, different nations, and the extent people rely on Internet-based conferencing tools instead of face-to-face meetings for communications. Our data suggest no relationship between team distribution and performance, including mutual trust among team members, effectiveness of communications and coordination, commitment and contributions of individual members, and quality and punctuality of team products.

This contradicts the conclusions of many studies that characterize distance itself as a significant hurdle to effective team communication, coordination and productivity. For example, drawing on lab work and field observation of remote teams in different companies around the world, Olson and Olson (2000) stated that "differences in local physical context, time zones, culture and language all persist despite the use of distance technologies …" (p. 141) and "collaborative work at a distance will be difficult to do for long time…" (p. 173). Olson et al. (2002) documented the effectiveness of dramatically collocated teams, and reiterated that "even with the best of tools, there are some major complications to work at distance," which "arise from the fact that the more remote the partner, the more likely cultural boundaries will be crossed, with all its concomitant effects on trust, common ground, and different local contexts." (p. 131). Similarly, virtual team members in The Boeing Company encountered many challenges including difficulty in maintaining participation, developing a group culture, and integrating remote teams in the primary work sphere (Mark, 2001).

There are at least two possible explanations for the contradictory finding about the impact of distance from this study. One is that the difficulties of remote work detailed in previous studies can be offset by the benefits of the team distribution, thus overall, distance itself does not impact team performance. Another explanation is that employees at Intel have adapted to remote work environments by developing continuities such as sensitivity to cultural and organizational differences caused by distance, and strategies to embrace these differences.

In addition, we found that variety of practices has significant negative implications for team performance, and with a marginal significance, workplace mobility was also found to be detrimental to the effectiveness of teamwork. The negative impact from variety of practices and mobility can be potentially remedied by management policies that support mobility technologies and consistent usage of tools within the organization, and an establishment of repeatable processes through more diligent information and document sharing within teams so that personnel changes will not interrupt the continuity of team work processes. At the very least, the overhead of shifting documents from one team document repository to another, maintaining the versions, and rolling up three to five team milestones into a single individual timeline would be reduced if these conditions were better understood in tool design.

IT teams at Intel are tackling these issues and have applied for intellectual property on some innovations. Our findings support a collaboration model developed by the Virtual Collaboration Research Team. A patent has been submitted based on this model, which differs radically from any existing collaboration software because of the interlocking or cascading network of teams. An architecture that supports every person with one view into all of their work is an important aspect of providing appropriate continuity to overcome any negative repercussions from excessive practice variety and a mobile workforce (Pickering & Wynn, 2004). In addition, IT teams are working with major vendors to influence standard tools with these needs.

Future Research

The virtuality index provides an opportunity to benchmark Intel's condition of virtuality against other companies with only one major adaptation – appropriate metrics to assess performance that is congruent with another company's values. We suggest that such a dependent variable may need to be organization-specific. This also helps to strike a balance between the idea of a virtuality index as generalizable index and one that paints a portrait of a particular company. Using the same template, other portraits can be taken and compared, while still using performance indicators understood by different employee populations.

In addition to the virtuality index, our study reveals the prevalence of multi-teaming at this global corporation. We know of no prior data on this phenomenon. Over 60 percent of the employees responding to the questionnaire reported being on three or more teams concurrently, while 28 percent are on five or more teams. Multi-teaming may not be a new condition, but it is so little discussed in the literature that we expect it is a recent trend. It could be indicative of organizations' emphases on flatter organizations, downsizing, and teamwork. Or it could be a

characteristic of a particular management practice, such as matrixed reporting. Not only do people participate in more teams, but predictably, they are also in more meetings, so they transit rapidly from one team environment to another with less time between interaction incidents. Additional research is needed to determine whether multi-teaming is an additional discontinuity or an elemental characteristic of team participation, and the ramifications of this for performance in virtual teaming environments. A factor not explored in this research, but that we expect to be highly correlated to multi-teaming, is multi-tasking. Descriptively speaking, most Intel employees at the middle ranks are familiar with the practice of carrying laptops even to face-to-face meetings, and handling e-mail emergencies for other non-present activities while meeting face-to-face with a group.

Conclusions

We have described a study of employees at Intel Corporation to assess virtual teaming within the organization, its impact on performance, and the resultant implications for ICT platforms to support virtual teaming environments. The virtuality index was developed in response to a need to understand the current situation of the organization and its potential need for collaboration solutions based on this situation. The construct we used derived from the concept of discontinuities, or factors contributing to a decrease in cohesion. The study suggests that virtual teaming can be characterized in terms of three overarching discontinuities – team distribution, workplace mobility, and variety of work practices.

In addition to expanding the how virtual teamwork is characterized, the virtuality index was useful tool in understanding the impacts specific features of virtual teaming on performance. Our data suggest that work predictability and social interaction with non-team members mitigate the consequences of working in discontinuous environments, while greater variety of practices (e.g., more cultural and work process diversity) and greater mobility negatively impact performance. IT departments and designers of collaboration environments can take these effects into account, while senior management can lay to rest certain myths about the effect of being distributed on organizational cohesiveness. Results of the research have been used in management presentations, strategic long range planning and product lifecycle reviews, and continue to inform a set of key research questions about the ideal collaboration environment for the circumstances, including underlying architectures, user interface issues, and the dynamics of asynchronous teaming (Pickering & Wynn, 2004).

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Figure 1 – Percentage of Respondents Who Experience Aspects of Team Distribution

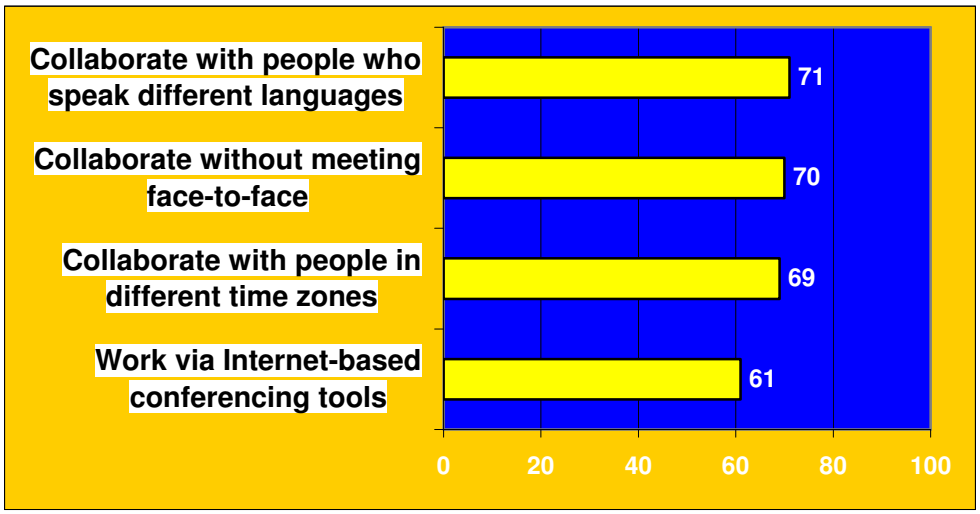

Figure 2 – Percentage of Respondents Who Experience Aspects of Workplace Mobility

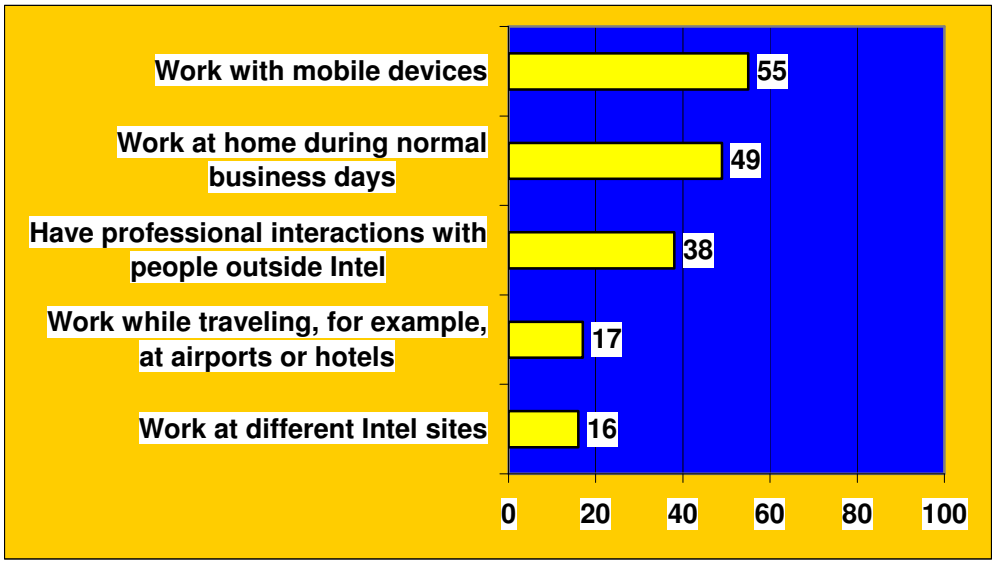

Figure 3 – Percentage of Respondents Who Experience Aspects of Variety of Practices

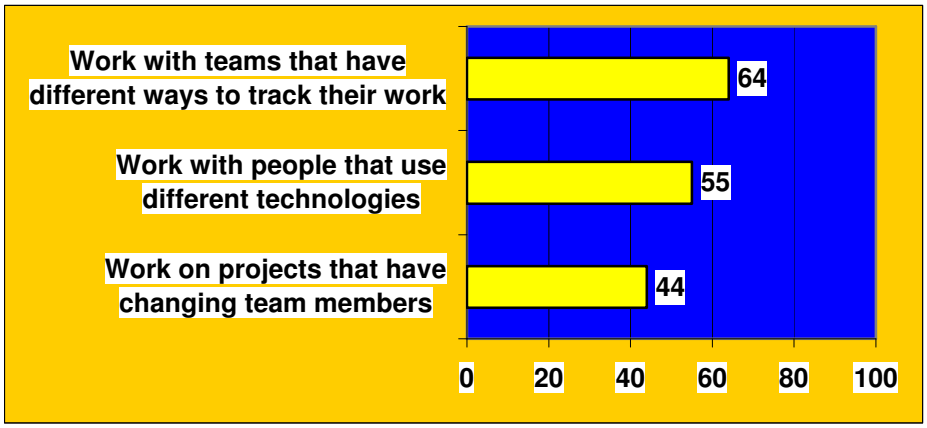

Table 1 Frequency Distributions of Demographic Variables

Variable	Frequency Distribution				
Gender	Male: 75%			Female: 25%	
Region	Americas: 34%		GAR: 36%	GER: 30%	
Job Roles	Admin.* 4%	Manager: 3%	Hardware/software Engineering: 29%	Manufacturing: 21%	Others: 42%
Number of teams	0: 3%	1-2 36%	3-4: 33%	5-6: 15%	> 6: 13%
Typical team Size	No team: 2%	2-5 people: 39%	6-10 people: 43%	11-15 people: 8%	> 15: 7%

Note. * Abbreviation for "administrative assistant."

Table 2 Factor Loadings on Dimensions of Virtuality (n=1175)

	Component		
	1	2	3
Team distribution			
Collaborate with people in different time zones.	**.827**	.237	.267
Work with people via Internet-based conferencing applications.	**.807**	.245	.131
Collaborate with people you have never met face-to-face.	**.831**	.162	.219
Collaborate with people who speak different native languages or dialects than your own.	**.604**	.116	.269
Workplace mobility			
Work at different Intel sites.	.287	**.736**	.073
Have professional interactions with people outside Intel.	.065	**.560**	.356
Work with mobile devices.	-.005	**.587**	.260
Work at home during normal business days.	.370	**.557**	-.042
Work while traveling, for example, at airports or hotels.	.267	**.807**	.125
Variety of practices			
Work on projects that have changing team members	.162	.329	**.539**
Work with teams that have different ways to track their work.	.379	.154	**.763**
Work with people that use different collaboration technologies.	.225	.082	**.824**
Eigenvalues	4.985	1.288	1.066
Cumulative variance	41.5	52.3	61.2

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

Table 3 Relationship between Virtuality and Team Performance (n = 1033)

	Step 1		Step 2		Step 3	
	b	β	b	β	b	β
(Constant)	4.416		4.268		4.492	
Year	.002	.008	.007	.031	.008	.036
Gender[a]	.041	.019	.013	.006	-.005	-.002
GAR	.255	.134***	.252	.132***	.195	.102**
GER	.185	.092**	.157	.078*	.125	.062ψ
Admin	.131	.025	.085	.016	.050	.010
Manager	-.165	-.035	-.111	-.023	-.107	-.022
Hardware/Software Engineer	.328	.164***	.233	.117**	.193	.096**
Manufacturing Technician	-.007	-.003	-.159	-.071*	-.226	-.100*
Team Size			-.034	-.042	-.031	-.037
Number of Teams			-.074	-.108**	-.055	-.080*
Work Predictability			.107	.119***	.101	.112***
Frequency of Team Social Interaction			-.010	-.017	-.008	-.013
Frequency of Non-Team Social Interaction			.043	.077*	.045	.080**
Adequacy of Team Social Interaction			.125	.153***	.113	.138***
Adequacy of Non-Team Social Interaction			-.017	-.022	-.011	-.015
Knowledge Networking			-.069	-.092***	-.018	-.025
Team Distribution					.017	.027
Workplace Mobility					-.054	-.071ψ
Variety of Practices					-.093	-.143***
R^2	.043***		.107***		.127***	

Note: [a] Male=1, female=2.
***p*<.05. ****p*<.01. *****p*<.001. ψ p<.10.

Appendix A: Complete List of Original Items Intended to Measure Virtuality

Items
Geography
1. Work at home during normal business days.
2. Work while traveling, for example, at airports or hotels.
3. Collaborate with people in different sites or geographies.
4. Collaborate with people you have never met face-to-face.
Temporal
5. Work extended days in order to communicate with remote team members.
6. Collaborate with people in different time zones.
Cultural
7. Collaborate with people who speak different native languages or dialects than your own.
8. Collaborate with people from different cultural backgrounds.
Work Practices
9. Work on projects that have changing team members.
10. Work with teams that have different ways to track their work.
11. Work with people that use different collaboration technologies and tools.
Organization
12. Collaborate with people from different Intel business groups.
13. Work at different Intel sites.
14. Have professional interactions with people outside Intel.
Technology
15. Work with people via Internet-based conferencing applications.
16. Participate in real-time online discussions, such as chat or instant messaging.
17. Meet with people via video-conferencing tools.
18. Work with mobile devices.

Appendix B: Inter-Items Correlations among the Items Measuring Virtuality

Virtuality Items	Mean	Std Deviation	1	2	3	4	5	6	7	8	9	10	11
1. Collaborate with people in different time zones.	4.112	1.871											
2. Work with people via Internet-based conferencing applications.	3.663	1.830	.692										
3. Collaborate with people you have never met face-to-face.	4.116	1.738	.766	.658									
4. Collaborate with people who speak different native languages	4.288	1.855	.511	.406	.440								
5. Work at different Intel sites.	2.099	1.289	.415	.412	.330	.249							
6. Have professional interactions with people outside Intel.	2.824	1.804	.333	.226	.301	.220	.333						
7. Work with mobile devices.	3.639	2.327	.219	.226	.194	.195	.293	.274					
8. Work at home during normal business days.	2.712	1.861	.347	.371	.327	.226	.369	.210	.253				
9. Work while traveling, for example, at airports or hotels.	2.048	1.349	.449	.391	.358	.289	.664	.437	.346	.432			
10. Work on projects that have changing team members	3.248	1.468	.326	.290	.324	.300	.285	.261	.236	.268	.351		
11. Work with teams that have different ways to track their work.	3.869	1.872	.518	.440	.459	.378	.327	.318	.254	.239	.328	.411	
12. Work with people that use different collaboration technologies.	3.470	1.882	.408	.327	.358	.286	.244	.269	.211	.186	.273	.350	.651

Appendix C: Descriptives of Items in the Team Performance Scale

Items	*N*	Mean	Std Deviation
Team projects were delayed.	1240	4.583	1.643
Quality of team deliverables was excellent.	1235	4.875	1.351
Team members did not meet their commitments.	1221	4.783	1.475
People's ideas were not effectively communicated	1230	4.449	1.475
There was not enough trust among team members.	1230	5.046	1.603
Some team members were not given enough opportunities to contribute.	1229	4.727	1.580
Work was fairly distributed across the team.	1230	4.255	1.546
Team members were unwilling to take risks.	1224	4.551	1.587
I really enjoyed working with other team members.	1235	5.229	1.411
Team did not focus on the right questions.	1231	4.816	1.479

APPENDIX D

Split Half Factor Analysis and Regression Analysis

In an effort to determine the index's external validity, we randomly split the sample into halves – one half of the sample was used to repeat the exploratory factor analysis discussed previously; the other half was used to repeat the regression analysis. The two sub-samples have very consistent distributions of gender, length of experience, region, job roles, and team participation in terms of the number of teams that respondents work with and the size of their current teams.

The factor analysis result and reliability measures shown in Table D1 are consistent with those obtained with the entire sample, except for the item "have professional interaction with people outside Intel," which became ambiguous between dimensions "workplace mobility" and "variety of practices." The item "work on projects that have changing team members" had a weaker association with "variety of practices" as compared to the whole sample factor structure. All three scales still have acceptable reliability measures, which is $\alpha = .85$ for team distribution; $\alpha = .70$ for workplace mobility; and $\alpha = .72$ for variety of practices.

The other half of the sample was used to conduct the 3-step hierarchical regression analysis. The result is presented in Table D2. The relationships between the virtuality variables and team performance are confirmatory with those identified with the whole sample. While team distribution is not associated with team performance, there is a significant negative relationship between variety of practices and team performance ($\beta = .12$, $p < .05$). Using the smaller sample, workplace mobility did not have a statistically significant impact on performance, although the coefficient is negative in both samples. One explanation is that the magnitude of the impact cannot be detected with a smaller sample size. The split half results suggest the construct structure of virtuality can be obtained with one sample of participants, and the variables can be used to understand the team performance of another sample of participants. This substantiates the external validity of the virtuality index and its concepts of team distribution, workplace mobility and variety of practices, as well as the scales measuring the concepts.

Appendix D – Table D1. Split Half Factor Analysis Results (N=595)

	Component		
	1	2	3
Team distribution			
Collaborate with people in different time zones.	**.824**	.233	.263
Work with people via Internet-based conferencing applications.	**.813**	.241	.083
Collaborate with people you have never met face-to-face.	**.842**	.154	.198
Collaborate with people who speak different native languages or dialects than your own.	**.603**	.111	.279
Workplace mobility			
Work at different Intel sites.	.240	**.772**	.104
Have professional interactions with people outside Intel.	.091	**.463**	.435
Work with mobile devices.	-.036	**.516**	.336
Work at home during normal business days.	.367	**.600**	-.023
Work while traveling, for example, at airports or hotels.	.245	**.826**	.184
Variety of practices			
Work on projects that have changing team members	.155	.332	**.483**
Work with teams that have different ways to track their work.	.358	.125	**.785**
Work with people that use different collaboration technologies.	.213	.073	**.828**
Eigenvalues	4.916	1.289	1.141
Cumulative variance	41.0	52.7	61.2
Reliability (α)	.85	.70	.72

Note. Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

Appendix D – Table D2: Split Half Hierarchical Regression Analysis (N=526)

	Step 1		Step 2		Step 3	
	b	β	b	β	b	β
(Constant)	4.364		3.632		3.896	
Year	.003	.012	.011	.049	.011	.050
Gender[a]	.033	.015	-.012	-.005	-.030	-.014
GAR	.246	.127*	.246	.127**	.191	.099*
GER	.255	.124*	.244	.119*	.196	.096*
Admin	.171	.033	.207	.040	.183	.035
Manager	-.255	-.052	-.130	-.026	-.141	-.029
Hardware/Software Engineer	.353	.174***	.264	.131**	.212	.105*
Manufacturing Technician	.084	.038	-.041	-.018	-.145	-.066
Team Size			-.065	-.080ψ	-.061	-.075ψ
Number of Teams			-.071	-.103*	-.048	-.070
Work Predictability			.173	.189***	.163	.177***
Frequency of Team Social Interaction			.018	.029	.022	.036
Frequency of Non-Team Social Interaction			.074	.133**	.073	.130*
Adequacy of Team Social Interaction			.151	.186***	.142	.175***
Adequacy of Non-Team Social Interaction			-.054	-.068	-.049	-.061
Knowledge Networking			-.021	-.028	.033	.043
Team Distribution					-.002	-.004
Workplace Mobility					-.057	-.074
Variety of Practices					-.078	-.120*
R^2	.044***		.149***		.165***	

Note: [a] Male=1, female=2.
*p<.05. ** p<.01. *** p<.001. ψ p<.10.