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RESEARCH ESSAY

THE SPATIAL, TEMPORAL, AND CONFIGURATIONAL CHARACTERISTICS OF GEOGRAPHIC DISPERSION IN TEAMS[1]

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Abstract

As organizations operate across greater distances, scholars are increasingly interested in the work of geographically dispersed teams and the technologies that they use to communicate and coordinate their work. However, research has generally not specified the dimensions (spatial, temporal, or configurational) and degrees of team dispersion, nor has it articulated the theoretical connections between those dimensions and important team outcomes. This research essay expands upon previous field and lab studies of dispersed teamwork by presenting a new conceptualization of dispersion as a continuous, multidimensional construct, in which each dimension is theoretically linked with different outcomes. We illustrate this new conceptualization with a series of examples from real dispersed teams and present implications for research regarding technology use.

Keywords: Geographically dispersed teams, virtual teams, dispersion, distance, configuration, technology use

Introduction

As globalization pushes organizations to operate across greater distances, scholars and practitioners alike are increasingly interested in virtual or geographically dispersed teams[2] (DeSanctis and Poole 1997; Hinds and Kiesler 2002; Majchrzak et al. 2000; Malhotra et al. 2001; Piccoli and Ives 2003). Scholars are rapidly refining and extending earlier research by identifying important dispersion-related modera-

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[2]For our purposes, geographically dispersed teams are defined by the criteria of traditional work teams— boundedness, stability of membership, commonality and interdependence of task, and authority to manage their own internal processes (Piccoli and Ives 2003)—as well as the fact that geographic distances separate at least some members, leading them to use information technologies to communicate (Cummings 2004).

tors such as communication (e.g., Hinds and Mortensen 2005). Nonetheless, the defining construct for such teams (i.e., geographic dispersion) remains loosely specified and casually used. *Virtual* continues to refer to many different things (Schultze and Orlikowski 2001), including teams or organizations that are temporary or that cross one or more boundaries (Espinosa et al. 2003). *Geographically dispersed teams* are usually treated as an undifferentiated category, including everything from laboratory groups separated by temporary partitions to a team spread around the globe (Maznevski and Chudoba 2000).

Thus, this research essay builds on fundamental research regarding geographic dispersion and proposes that there are three critical dimensions of geographic dispersion in teams: (1) spatial, (2) temporal, and (3) configurational. We elaborate on these dimensions below, but in brief they capture (1) the average spatial distance among team members; (2) the extent to which team members have overlapping work hours; and (3) the number of sites at which members are located, their isolation from other members, and the balance between subgroups of members across sites.

It is important to underscore that these dimensions represent *objective, structural* aspects of geographic dispersion, as distinct from subjective dispersion and cultural, linguistic, national, and other forms of demographic diversity (Williams and O'Reilly 1998). Demographic differences among team members (also known as *social distance*) are often correlates of geographic dispersion (Hertel et al. 2005; Kirkman and Mathieu 2005; Martins et al. 2004), but we believe that a robust model of *geographic* dispersion will allow scholars to disentangle effects that can be attributed primarily to geographic distance from effects that stem primarily from social distance. We also believe that technology has greater potential to affect the outcomes of geographic dispersion than it does to mitigate the negative effects of social distance and, thus, focus this essay on geographic rather than other types of dispersion.

We further propose that the nature, operationalization, and potential effects of the *dimensions* differ in ways that are theoretically important for the study of dispersed teams and the technologies to support them. All three dimensions—spatial, temporal, and configurational—are present to varying degrees in much of the virtual teams literature, but their properties and effects are generally considered together, without differentiation. However, as we will describe in greater detail later, each dimension has its primary effects on different sets of outcomes. First, spatial distance has its strongest effects on spontaneous face-to-face communication. Second, temporal distance has its greatest influence on real-time problem solving. Third, the number of sites represented on a team most directly affects the team's coordination. Fourth, isolation in a team most strongly impacts awareness of fellow team members. Finally, the imbalance between subgroups most significantly affects conflict and majority influence.

Within any one dimension, expected effects will also vary depending on the *degrees* of dispersion. For example, the probability of spontaneous face-to-face communication drops rapidly as the degree of spatial dispersion increases (Allen 1977; Van den Bulte and Moenaert 1998) beyond hallways and floors in a building. Similarly, the potential for real-time problem solving decreases as the degree of temporal dispersion increases.

Given that current and potential technology to support dispersed teamwork focuses on different practices, processes, and outcomes (Olson et al. 2000), we propose that the use and effectiveness of such technology will vary depending on the salient dimensions and degrees of dispersion in any given team or sample of teams. For example, in teams where spatial dispersion is high but temporal dispersion is low (i.e., teams in which members' work hours are mostly overlapping), always-on video "media spaces" (e.g., those described in Bly et al. 1993) are likely to be more effective. In teams where spatial dispersion is similarly high, but temporal dispersion is also high (i.e., teams spanning many time zones), such media spaces and other video communication tools are unlikely to be effective.

We believe our proposed model will enhance scholars' ability to study geographically dispersed teams by (1) encouraging new theorizing about the causes, effects, mechanisms, mediators, and moderators of dispersion (as well as the potential interaction effects among its dimensions); (2) providing a framework or typology that can be used *ex ante* as part of new theorizing and research designs, as well as *post hoc* for meta-analyses, syntheses, or re-interpretations of previous research; (3) separating the geographic dimensions of dispersion from their frequently correlated (and potentially confounding) demographic dimensions.

In the following section, we present a selective review of research on dispersed teams, with an emphasis on previous conceptualizations and measurement of dispersion. Then, we discuss the theoretical and measurement implications of a multidimensional approach to dispersion. We conclude by discussing future directions for research on dispersion and technology use in teams.

Previous Conceptualizations of Geographic Dispersion

Distance and proximity between people have been topics of research for decades (Kiesler and Cummings 2002). This long line of studies began mostly in nonwork (i.e., social, residential, and educational) settings. The studies dealt primarily with how small distances and physical barriers between people negatively affected their interactions and friendships (Festinger et al. 1950). These and subsequent studies demonstrated a positive association between physical proximity, interpersonal liking, and communication frequency.

While the early proximity research showed quite clearly that distance matters, it did so in mostly experimental, dyadic, laboratory, and nonwork contexts. Furthermore, it did so with distances measured mostly in feet or meters, not miles or kilometers (hence the description of these studies as *proximity* rather than *distance* research). Then, in the 1970s, researchers began to demonstrate the importance of distance in work settings and to extend (slightly) the distances in question. For example, Allen (1977) showed that (1) the frequency of work-related technical communication between pairs of coworkers drops rapidly as distance between those coworkers increases; and (2) the communication frequency reaches an asymptote as the distance nears 30 meters.

To better understand the more recent ways in which scholars have defined and operationalized distance in a team context, we analyzed the empirical studies found in three reviews of the literature on virtual teams (Hertel et al. 2005; Martins et al. 2004; Powell et al. 2004). These reviews were written by authors based in the United States and Europe, and appeared in journals devoted to human resources, general management, and information systems. All three reviews identified relevant work using database searches and published bibliographies. Hertel et al. (2005) focused on quantitative field studies, but included experimental computer-mediated communications research and case studies as well. Martins et al. (2004) included 93 empirical articles, of which 66 were lab-based and 27 studied naturally occurring work teams. Powell et al. (2004) included 43 papers in their analysis. Collectively, these three reviews included more than 150 distinct empirical studies, of which 44 were field-based.

After reviewing these 150 studies for their characterization and measurement of dispersion, we found that the overwhelming majority have focused on the spatial dimension of geographic dispersion (e.g., Chidambaram and Jones 1993; Cramton 2001; Huang et al. 2003; Jarvenpaa and Leidner 1999; Maznevski and Chudoba 2000). Some experimental studies simulated spatial dispersion by locating subjects in different rooms on the same campus or forcing them to communicate electronically regardless of where they were located. Other experimental studies used teams of students drawn from multiple (usually internationally dispersed) universities, but the teams generally included the same number of students from each institution, so there was no variation in configuration and little variation in spatial or temporal dispersion for most studies.

As Table 1 shows, 23 empirical studies mentioned or implied multiple dimensions or varying degrees of dispersion, but did not characterize those dimensions explicitly or measure variations in them. For example, a few articles mentioned the challenges of temporal dispersion (e.g., Kirkman et al. 2004) and pointed to more practitioner-oriented articles regarding those challenges, but did not actually incorporate variation in temporal dispersion into their research. Similarly, Ahuja et al. (2003) mentioned the significance of clusters and related configurational dynamics, but did not actually study them.

Only five studies actually measured *degrees* of dispersion in any way. Cummings (2004), Finholt and Sproull (1990), and Trevino et al. (2000) used Likert scales measuring whether survey respondents' colleagues were on the same floor, in the same building, in the same city, etc., and Rice and Aydin (1991) used grid units separating employees' work stations on a floor plan to differentiate degrees of dispersion *within one building*. McDonough et al. (2001) tried to account for degrees of dispersion with their three categories of teams (i.e., colocated, virtual, and global), although their categories mixed teams that were dispersed across different floors of the same building with teams dispersed across different countries. Of the studies, only Rice and Aydin actually measured any aspect of configuration.

Thus, the majority of empirical research on geographically dispersed teams has defined dispersion loosely and usually in spatial terms. Even when the spatial dimension of dispersion has been defined explicitly, it has rarely been measured. As noted by Hinds and Bailey (2003, p. 629), "Our models are incomplete in a number of respects … [including that they do] not consider a measure of geographic distribution." Most research on virtual teams has viewed them as a dichotomous alternative to colocated teams (e.g., Warkentin et al. 1997), overlooking variations in the dimensions and degrees of dispersion. There are a few noteworthy studies that have described more than one dimension of dispersion (Bell and Kozlowski 2002; Fiol and O'Connor 2005; Griffith et al. 2003; Hertel et al. 2005; Kirkman et al. 2004; Milliken and Martins 1996; Saunders et al. 2004; Zigurs 2003), but they remain exceptions, with most studies still focused on the

Table 1. Empirical Studies Addressing Multiple Dimensions and/or Varying Degrees of Geographic Dispersion in Teams

Studies	Conception of Dimensions of Dispersion	Measurement of Degrees of Dispersion
Ahuja and Carley 1999; Ahuja et al. 2003; Bélanger et al. 2001; Carlson and Zmud 1999; Cramton 2001; Eveland and Bickson 1988; Fulk 1993; Gefen and Straub 1997; Hinds and Kiesler 1999; Kayworth and Leidner 2000, 2001-02; Kirkman et al. 2004; Lurey and Raisinghani 2001; Majchrzak et al. 2000; Malhotra et al. 2001; Maznevski and Chudoba 2000; Montoya-Weiss et al. 2000; Orlikowski and Yates 1994; Robey et al. 2000; Sproull and Kiesler 1986; Suchan and Hayzak 2001; Webster 1998; Zack 1993	Multiple dimensions implicitly present in descriptions of the teams, but not explicitly addressed or systematically characterized	Did not measure varying degrees of dispersion
Rice and Aydin 1991	Explicitly considered spatial and configurational dispersion	Measured clusters of and grid distances between employees' work stations on a floor plan
Cummings 2004; Finholt and Sproull 1990; Trevino et al. 2000	Considered only spatial dispersion	Measured degrees of spatial dispersion using Likert scales
McDonough et al. 2001	Considered only spatial dispersion	Used overlapping categories to characterize spatial dispersion

extremes of full colocation versus full dispersion. As McGrath and Hollingshead (1994, p. 79) wrote, "Research to date has certainly not covered, systematically, the range of possible combinations of time and space dispersion," and as Sessa et al. (1999, p. 8) noted, "research looks only at the ends of the continuum, [but naturally occurring work] teams are rarely completely colocated or completely dispersed."

More recently, others have come to similar conclusions about the literature's generally dichotomous and unidimensional approach to dispersion (Ahuja et al. 2003; Bell and Kozlowski 2002; Griffith et al. 2003). As Hinds and Mortensen (2005, p. 304) note, "little work has yet examined different dimensions of distributed work and how these dimensions shape team dynamics." Given Allen's findings about how quickly communication drops off as distance increases to 30 meters, using a simple dichotomous measure of virtual versus co-located might seem sufficient. However, doing so implicitly defines dispersion in purely spatial terms, despite evidence that temporal dispersion (Saunders et al. 2004) and configuration (Cramton and Hinds 2005; Polzer et al. 2006) have distinct effects too. It also assumes that findings based on communication in dyads prior to the advent of e-mail, instant messaging, and on-demand conference calling hold at the team level in a more current technology context.

A Multidimensional Conception of Geographic Dispersion

Previous studies' unidimensional operationalization of distance and dichotomous comparisons of colocated and dispersed teams have limited the field's focus and the advancement of research regarding dispersion, dispersed teamwork, and teams' use of collaborative technologies. The reconceptualization and measures which we present in this research essay offer new ways of thinking about and measuring dispersion. They shift the discussion beyond basic spatial distances by enabling and encouraging a multidimensional understanding of geographic dispersion which combines space, time, and configuration. We believe that accounting for multiple dimensions of dispersion in teams will improve scholars' ability to understand teams and technology use within them.

Many models focus on one outcome or dependent variable and present a series of factors that are theoretically associated with that outcome (e.g., Compeau et al. 1999; McKnight et al. 1998). In contrast, our model shows how the different dimensions of one construct (i.e., dispersion) are theoretically linked to different outcomes and technological implications. We do not explore all possible dimension–outcome links. Rather, we

Table 2. Key Outcomes and Theoretical Mechanisms Distinctly Associated with Each Dimension of Dispersion

Characteristic	Description	Example Outcome	Example Mechanism
Spatial	Geographic distance among team members	Reduced spontaneous **communication** (Burke et al. 1999; Dennis et al. 1988; Saunders et al. 2004)	Decreasing the likelihood of face-to-face interaction
Temporal	Time difference among team members	Reduced real-time **problem solving** (Grinter et al. 1999; Herbsleb et al. 2000; Malone and Crowston 1994)	Decreasing the likelihood of synchronous interaction
Site (Configurational)	Locations where team members work	Increased **coordination complexity** (Sarbaugh-Thompson and Feldman 1998; Yoo and Alavi 2001; Zigurs et al. 1988)	Increasing the number of dependencies which must be managed
Isolation (Configurational)	Locations where team members work alone	Decreased **awareness** (Amstrong and Cole 2002; Dennis 1996; Tan et al. 1998)	Increasing the remoteness of isolated team members
Imbalance (Configurational)	Locations with uneven distribution of team members	Increased **intragroup conflict** (Allmendinger and Hackman 1995; Kabanoff 1991; Mannix 1993)	Increasing majority influence and the potential for negative subgroup dynamics

present one example for each dimension, choosing example outcomes that are considered especially important by scholars of teams and technology (e.g., communication, coordination, conflict). Through these examples and the theoretical mechanisms linking them to each dimension of dispersion (Table 2), we argue that the different outcomes cannot be predicted effectively with a generic conceptualization of teams as virtual or not, or even as more or less virtual. For example, there is no theoretical basis to link coordination challenges with "virtuality." However, there is a solid theoretical basis to link coordination challenges with the number of sites represented on a team—one aspect of our configurational dimension of dispersion.

Spatial dispersion is most closely related to reductions in spontaneous communications because it decreases the likelihood of face-to-face interaction (Allen 1977; Kraut et al. 1990; Te'eni 2001). Temporal dispersion, which becomes relevant at distances larger than those triggering reductions in spontaneous communication, decreases the potential for synchronous interaction and, thus, reduces real-time problem solving (Burke et al. 1999; Dennis et al. 1988). In addition, the extent to which a team has members working in isolation from each other is related to decreased members' awareness in a way different than any of the other characteristics. The extent to which a team is imbalanced across sites is related to increased potential for majority influence and conflict in a way that is different from any of the other characteristics.

Thus, the core of our argument is that different processes, emergent states, and other team outcomes are differentially related to the dimensions of dispersion. As noted above, the outcomes that we describe are intended to be illustrative not exhaustive. They are clearly of interest to geographically dispersed teams' researchers (Powell et al. 2004), but we expect that further research will illustrate how other outcomes are linked to particular dimensions of dispersion in theoretically distinct ways.

The outcomes in Table 2 are generally negative, but there are clearly positive outcomes that stem more from one dimension than the others. For example, access to a wider variety of nonredundant information is likely to result more from multiple sites than any of the other dimensions; performance-reducing interruptions are most likely to be inhibited by high degrees of temporal dispersion. Working from this more positive perspective, scholars could use our multidimensional model to extend the provocative but largely unexplored arguments about the unique affordances and advantages that accrue to dispersed teams (Hollan and Stornetta 1992).

In addition to being distinctly associated with different outcomes of interest, dispersion along each dimension tends to be driven by different factors. For example, spatial dispersion can stem from a desire to decrease the costs to the organization of office real estate and to decrease the cost to employees (in time and stress) of commuting. In contrast, temporal dispersion is generally the result of adopting "follow the sun" approaches to work and needing to provide customer service on a global basis (i.e., to customers in different time zones and on different schedules). Alternative team configurations can be driven by many things, but, for example, the presence of isolated members often results from the need to tap specialized expertise. In addition, imbalance often results from headquarters with satellite offices, research and development facilities, and plants, or from the merger of different sized firms.

The growing corpus of case studies and descriptive accounts of dispersed teamwork (e.g., Cramton 2001; Majchrzak et al. 2000; Maznevski and Chudoba 2000) point to multiple dimensions of dispersion. Consider Majchrzak et al.'s (2000, p. 574) description of the team in their case study:

> Two members were located in different ends of the same building, three other members were each one mile away in different buildings; one member of a second organization was located 100 miles away; and two members of the third organization were located 1,000 miles away in different buildings. [Team] members limited their travel since they were involved with many different teams within their company. As a result, all members were together only once—at the end—although there were three other formal meetings held in which some members attended.

In addition to the basic spatial distance between members, the description mentions configuration and shifts between dispersed and face-to-face work over time. Importantly, it also notes (at least in general terms) that some members are within the same building, yet relatively far apart. Although the quoted description of dispersion from Majchrzak et al. is more detailed than most other studies of dispersed teams, it would be difficult to use such a narrative for studies with larger samples of teams. For studying samples of any size, we conceptualize geographic dispersion as having three key dimensions: spatial, temporal, and configurational.

Conceptually and methodologically, there are many ways to model and measure dispersion. We base our model and measures for geographic dispersion in teams on the existing literature on teams and technology (including the case studies noted above). That literature provides insight about critical team processes and the mechanisms behind them (e.g., Marks et al. 2001; Powell et al. 2004). It also provides insight into teams' use of technology across space (Kraut et al. 1990), time (Espinosa et al. 2003), and configuration (on imbalance and subgroups, see Cramton 2001; on sites, see Grinter et al. 1999; on isolation, see Kurland and Cooper 2002). Although rarely specified as such, the important dimensions of dispersion in teams and the associated outcomes also emerge from this literature.

Spatial Dimension

The spatial dimension is the most commonly used of the three dimensions, and is measured in feet and miles (or meters and kilometers). It is similar to the measure used by Allen, but we apply it at the team (not dyadic) level, where teams members are often 10 to 100 times farther apart than they were in Allen's study. Members of such teams have to contemplate all-day or overnight travel to see colleagues in person, not just a walk down the hall or up the stairs. Large spatial distances are traversed directly with transportation technologies (e.g., boat, railroad, or airplane) or indirectly with communication technologies (e.g., semaphore, telegraph, telephone, radio, e-mail, or Internet). Small distances have typically been traversed by foot (e.g., walking down the hall), but technologies like e-mail, chat, and instant messaging are now being used even by coworkers who are quite close to one another (Mortensen and Hinds 2001). Regardless of the units of measurement, geographically dispersed teamwork (by definition) requires that at least two members be separated by spatial distance. By defining geographically dispersed teams in this way, we allow for a continuum of dispersion from teams with one remote member to teams with no colocated members.

Temporal Dimension

Temporal dispersion captures the extent to which team members' normal work hours overlap. For teams that are widely dispersed in an east-to-west direction, members may share few work hours and have to extend their days considerably to communicate synchronously. Alternatively, teams dispersed primarily north to south can have similar degrees of spatial dispersion but much less temporal dispersion, which permits synchronous communications. Temporal dispersion amplifies spatial separations, makes synchronous interaction less common and more difficult, and generally exacerbates the challenges of coordination. For some teams dispersed across time zones, the only alternative to working asynchronously is to extend the workday or travel for face-to-face meetings.

Time zones serve as fairly stable, internationally comparable descriptors of temporal dispersion. For example, "global" teams are often highly temporally and spatially dispersed, spanning many time zones. They fall in Quadrant B in Figure 1.

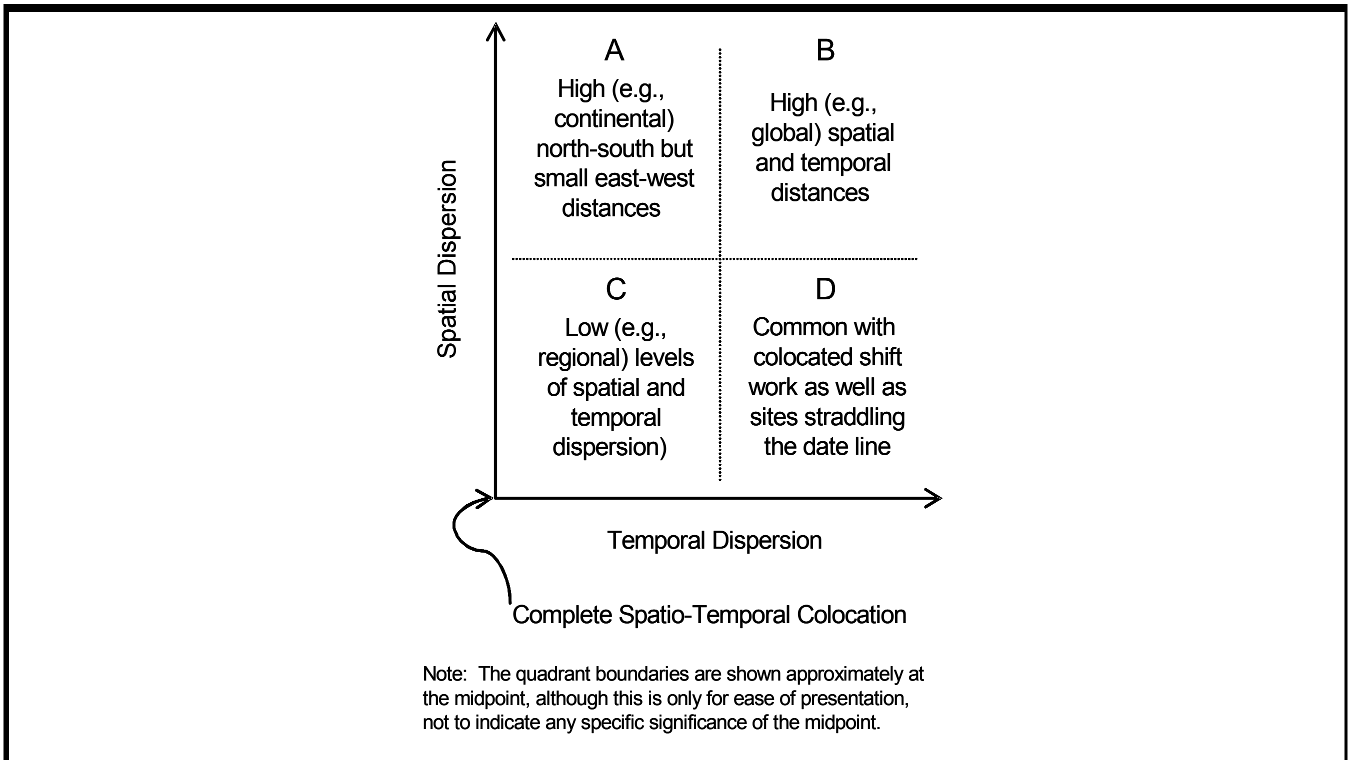

Figure 1. Combinations of Spatial and Temporal Dispersion in Teams

Teams can also be highly spatially dispersed without being highly temporally dispersed (Quadrant A). For instance, team members dispersed north to south may be separated by many miles, but still be in the same time zone. Teams split between North and South America, or between Europe and Africa are examples of high spatial and low temporal dispersion. Alternatively, dispersion can be primarily local, spanning relatively small temporal and spatial distances (Quadrant C). Large temporal distance and small spatial dispersion (Quadrant D) is possible when people work in the same location, but on different shifts. The less their shifts overlap, the more temporally dispersed they are, despite their lack of spatial dispersion. Although rare, a team closely straddling the International Date Line could also have large temporal and small spatial dispersion (Quadrant D).

Configurational Dimension

As critical as they are to understanding geographically dispersed work, the spatial and temporal dimensions alone are insufficient measures of team dispersion. The configuration of team members is also critical. As we define it, team configuration is the arrangement of members across sites independent of the spatial and temporal distances among them. A site is the building, office campus, or city where one or more team members are located. For example, an eight-member dispersed team could have as many as 21 different configurations (Figure 2). Conceptually, such configurations have no necessary relationship to the spatial and temporal dispersion among team members.

In contrast to most conceptions of distance, configuration has to do with the location of team members, *not* the average distance among them. For example, the configurational dimension recognizes that an eight-site team with one member at each site could have the same average distance among members as one of the two-site teams, yet the pattern or arrangement of members across sites would be far from the same. Some of the 21 potential configurations shown in Figure 2 include multiple sites without any isolation (e.g., 4-2-2 and 3-3-2). Others include relatively high levels of isolation with a concentrated core of members and the other members located at peripheral or satellite sites (e.g., 5-1-1-1 and 4-1-1-1-1). A third category includes highly balanced configurations (e.g., 4-4 and 2-2-2-2).

Number of Sites	Configurations
2	7-1, 6-2, 5-3, 4-4
3	6-1-1, 6-2-1, 6-3-1, 6-2-2, 3-3-2
4	5-1-1-1, 4-2-1-1, 3-3-11, 3-2-2-1, 2-2-2-2
5	4-1-1-1-1, 3-2-1-1-1, 2-2-2-1-1
6	3-1-1-1-1-1, 2-2-1-1-1-1
7	2-1-1-1-1-1
8	1-1-1-1-1-1-1-1

For example, a 4-4 configuration represents a two-site team with four members at each site. A 3-3-2 configuration represents a three-site team with three members at one site, three at another site, and two at the third site.

Figure 2. The 21 Possible Configurations for an Eight-Member Dispersed Team

While very few researchers studying geographically dispersed teams have investigated configuration, several speak to its importance. For example, Baba et al. (2004) studied a team with 20 members dispersed across 7 sites. The large number of sites created coordination complexity across sites for the team. Grinter et al. (1999) also address configuration when they discuss the location of isolated experts (pp. 313-314). Their isolation decreases other team members' awareness of their activities. Armstrong and Cole (2002) discuss the implications of imbalance between large and small sites and the intragroup conflicts that it caused. From such studies and anecdotal accounts of geographically dispersed teams, configuration emerges as an important enabling and constraining condition for various group processes and outcomes. From this research, the three key aspects of configuration are (1) the number of sites represented on a team, (2) the isolation of individual members, and (3) the imbalance between geographically defined subgroups.

Measuring Geographic Dispersion

Without a better approach for measuring geographic dispersion in teams, information systems and teams research will be limited to broad and potentially spurious or conflicting generalizations about such teams and their use of technology. Thus, we developed several new measures to characterize the multidimensional nature of dispersion in teams. The measures can all be derived from a single data point for each team member (i.e., his or her geographic location), which is commonly available in organizations' human resources or other employee databases. Based on this location, spatial and temporal distances between members and teams' configurations can all easily be computed.[3] Using objective, structural measures of dispersion drawn from organizational information systems provides several empirical advantages. First, it eliminates a reliance on self-reported estimates of distance, which are notoriously inaccurate (Harrison-Hill 2001). Second, it reduces the burden on respondents and common-method/ common-source problems by relying on organizational information systems instead of self-reports. Third, it provides standard measures, which researchers could use to compare their findings across studies and conduct *post hoc* analyses of data sets in which dispersion was not originally conceptualized in multidimensional terms, but for which information on team members' location is available.

We illustrate each measure with figures and examples from five real teams for which we have case study data. The examples that we use are not intended as a vehicle to comment on or simulate the performance or success of these teams; rather we use them to convey the meaning behind the measures. The teams are from one global communications firm and include teams focused on instructor development, customer support, system documentation, product distribution, and communication protocols. Table 3 provides the formulae for each measure, which we then describe in the sections that

[3]A variety of free programs generate the time zones and coordinates (latitude and longitude) for world cities and/or postal codes. The distance between any two sites can be calculated easily using a spreadsheet and the formula Great Circle distance between any two sites = RadiusEarth * ACOS(COS(RADIANS(90-Lat1)) * COS(RADIANS(90-Lat2)) + SIN(RADIANS(90-Lat1)) * SIN(RADIANS(90-Lat2)) * COS(RADIANS(Long1 * Long2)), where RadiusEarth equals 3,963 miles or 6,377 kilometers, and Lat1, Long1, Lat2, and Long2 refer to the decimal coordinates of the two sites.

Table 3. Formulae for Calculating Dispersion Indices

Index	Formula
Spatial Distance	$$\frac{\sum_{i-j}^{k}(Miles_{i-j} * n_i * n_j)}{(N^2 - N)/2}$$ where $Miles_{i-j}$ is the miles between sites i and j, k = the total number of sites represented in the team, n_i = the number of team members in the i^{th} site, n_j = the number of team members in the j^{th} site, and N = total number of team members across all sites
Time Zone	$$\frac{\sum_{i-j}^{k}(TimeZones_{i-j} * n_i * n_j)}{(N^2 - N)/2}$$ where $TimeZones_{i-j}$ are the number of time zones between sites i and j, k = the total number of sites represented in the team, n_i = the number of team members in the i^{th} site, n_j = the number of team members in the j^{th} site, and N = total number of team members across all sites
Site	k = Total number of sites (e.g., buildings) represented in the team
Isolation	Percent of team members with no other team members at their site
Imbalance	Standard Deviation (n_i, n_j, … n_k)/N, where k = the total number of sites represented in the team, n_i = the number of team members in the i^{th} site, n_j = the number of team members in the j^{th} site, and N = total number of team members across all sites

follow. In addition, a series of five figures presents pairs of these teams side-by-side to demonstrate the distinct aspects of dispersion that each measure captures. In each figure, the pair of teams are quite similar in regard to one aspect of dispersion, but distinctly different in regard to another. These figures and sample teams help illustrate how a unidimensional understanding of dispersion fails to capture important differences in real geographically dispersed teams.

While a single measure of dispersion would be analytically convenient, no single "index" is likely to capture team dispersion adequately. In this sense, geographic dispersion in teams is a multidimensional profile construct (Law et al. 1998), which exists at the same level as its dimensions, but whose component dimensions cannot be mathematically combined. Rather than advocating any one or two of the measures, we encourage researchers to choose carefully and explain their choices based on the constructs and processes under study. For example, if a data set includes teams that are all dispersed between the same two sites, neither the spatial nor temporal measures would be necessary, but the configurational imbalance and isolation indices might capture important variation.

Spatial Distance Index

Research on virtual teams has always included some conception of spatial distance (Bell and Kozlowski 2002), even if it generally hasn't been measured. To capture spatial dispersion, we developed a *spatial distance index* (SDI) which uses the geodesic or "crow flies" distances between sites, weighted by the number of members at the sites, based on a matrix of all possible, nonredundant, member-to-member connections (see formula in Table 3). For example, the instructor development team had six members dispersed across five sites in cities in Illinois, Florida, China, Brazil, and the United Kingdom. The mileages separating the sites are shown in Table 4.

With the number of members per site $n_{IL} = 2$, $n_{FL} = 1$, $n_{CH} = 1$, $n_{BR} = 1$, and $n_{UK} = 1$, the SDI for this team would be calculated as follows:

SDI = [(1183*2*1) + (6562*2*1) + (5241*2*1) + (3935*2*1) + (7739*1*1) + (4099*1*1) + (4376*1*1) + (10920*1*1) + (5101*1*1) + (5483*1*1)]/[(6^2-6)/2] = 71,925/15 = 4,795

Table 4. Mileages Separating Sites in the Instructor Development Team

	Illinois	Florida	China	Brazil
Illinois (IL)				
Florida (FL)	1,183			
China (CH)	6,562	7,739		
Brazil (BR)	5,241	4,099	10,920	
United Kingdom (UK)	3,935	4,376	5,101	5,843

Note that redundant connections are *not* included in the calculation. For example, the miles between Illinois and Florida are in the first term, but not again as the miles between Florida and Illinois. However, connections between members located at the same site *are* included in the denominator term, which captures the unique number of member pairs on the team.

The higher the SDI, the more spatially dispersed the team. For example, the instructor development team was dispersed across sites in four countries (Brazil, China, the United States, and the United Kingdom) and had an SDI of 4,795 (see Figure 3).

In contrast, the customer support team was the same size, but was split between only Israel and Illinois, giving it a smaller SDI of 2,048.[4] The SDIs for these teams and the other sample teams are shown for comparative purposes in Table 5.

At very low degrees of spatial dispersion (e.g., less than 30 meters), the SDI captures the potential for teams to engage in spontaneous communication and is grounded in the long line of propinquity theory and research (Allen 1977; Homans 1951; Newcomb 1961). As the SDI increases beyond levels that allow for spontaneous face-to-face interactions within one's own building (if not on one's own hallway or floor), its relevance relates more to the financial, logistical, and other costs of planned face-to-face meetings. The SDI captures the effects of both mechanisms and, thus, would allow scholars to assess the functional form of the relationship between spatial distance and communication. It would also allow researchers who have explicitly measured distance to assess the potentially moderating effects of communication technology use.

[4]Note that we label U.S. sites by state and other sites by their country name to preserve the anonymity of the company from which we draw our examples. Although using city names for all sites would provide more consistent labeling, it would compromise that anonymity.

Since the costs of planned face-to-face meetings are closely linked to travel time, and travel times vary depending on the travel infrastructure available to each team member, one might consider replacing the miles variable in the SDI with a travel time variable. However, spatial distance is highly correlated with travel time. For example, for the world's 100 largest cities, the correlation between the spatial distances and travel times between them is 0.861 ($p < .01$). In addition, the calculation of travel times is a burdensome and inexact process, which depends heavily on programs like Expedia.com, which cannot process more than one calculation at a time. In contrast, spatial distance between any two locations can be calculated simply, formulaically, and with a high degree of precision. Given this high correlation and the challenges of obtaining travel time data, we recommend miles (or kilometers) as the basis for the SDI.

Time Zone Index

The challenges of working across time zones are well known (Saunders et al. 2004), and because time zones are based on east-west spatial distance, they are linked to spatial distance. However, there is an important difference between teams that are dispersed in an east-west direction and those that are dispersed in a north-south direction. For example, the SDI would describe a team with sites in the eastern United States and Brazil as having almost the same level of dispersion as one split between the same U.S. site and one in the United Kingdom—because the distance in miles among the three sites is similar. However, the eastern United States and Brazil are in the same time zone, facilitating synchronous communication within normal business hours for both sites. The eastern United States and the United Kingdom are five time zones apart and have far less flexibility for synchronous conversations.

Our *time zone index* (TZI) captures this distinction by gauging how many work hours team members have during which they

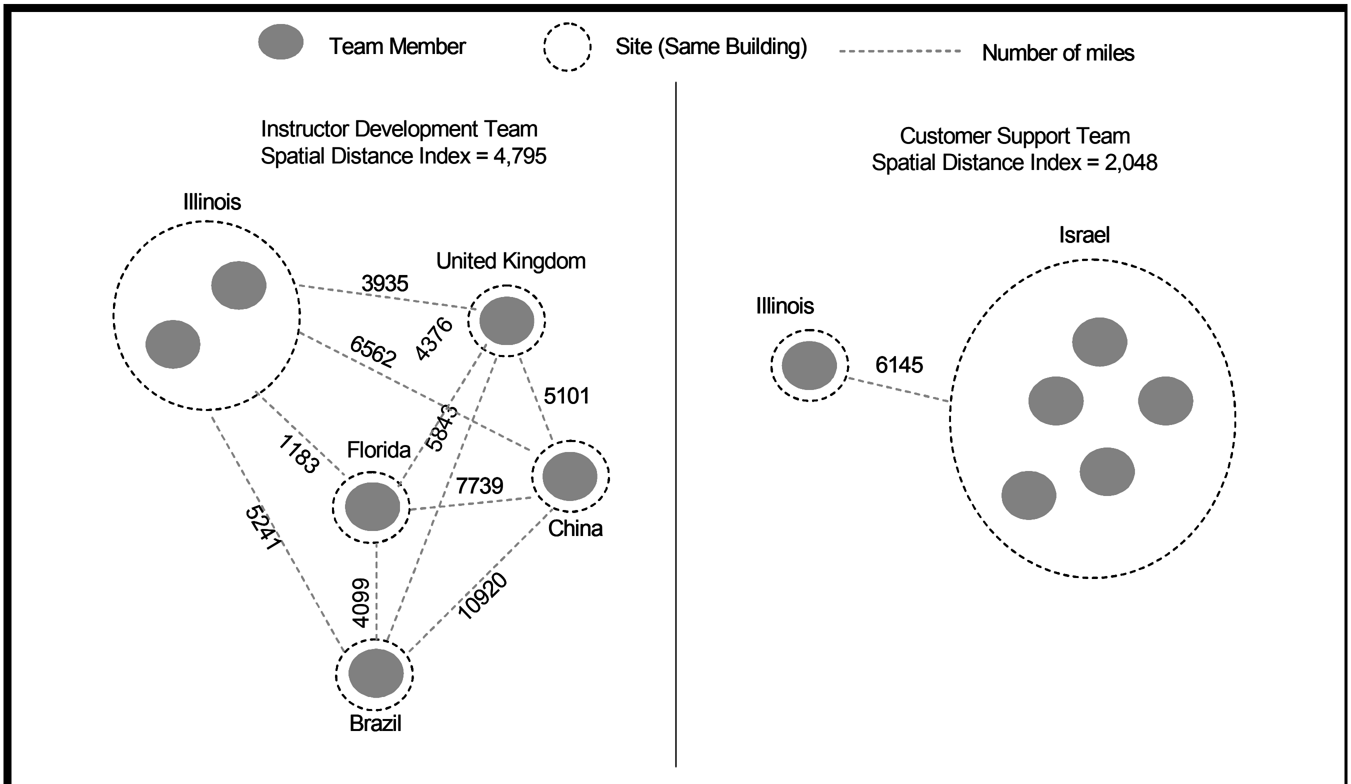

Figure 3. Comparison of Two Teams with Different Values on the Spatial Distance Index

Table 5. Summary of Dispersion Indices by Team

Team	Countries or States	Spatial Distance	Time Zone	Site	Isolation	Imbalance
System documentation	IL, FL, CA, MD, WA, CO	1,280	1.38	8	.70	0.07
Customer support	IL and Israel	2,048	2.67	2	.17	0.47
Instructor development	Brazil, China, United Kingdom, United States	4,795	6.07	5	.67	0.07
Product distribution	Japan and Malaysia	1,755	0.53	4	.10	0.17
Communication protocols	Scotland, Russia, Germany, and Israel	1,374	1.38	4	.00	0.06

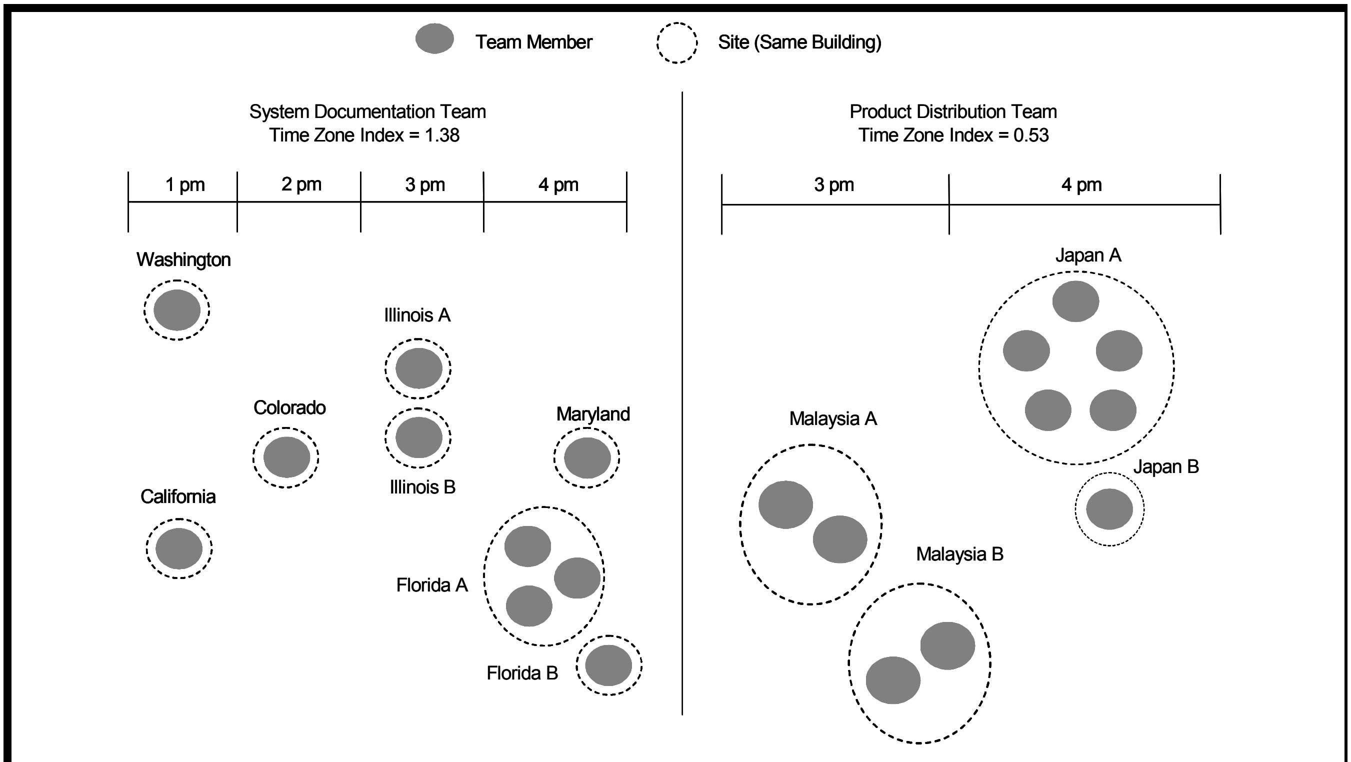

Figure 4. Comparison of Two Teams with Different Values on the Time Zone Index

could communicate synchronously. Calculation of the time zone index parallels that of the SDI, building on a matrix of all possible member-to-member connections. With the TZI, however, the matrix is populated by the number of time zones between members (see formula in Table 3).

For example, the system documentation team was scattered across six states in North America and had an SDI of 1,280 and a TZI of 1.38.

In contrast, the product distribution team split between Japan and Malaysia had a larger SDI (1,755), but a smaller TZI (.53) because Japan and Malaysia are dispersed primarily north to south and, thus, are closer from a temporal standpoint.

$$TZI = [(1*2*5) + (1*2*1) + (1*2*5) + (1*2*1)]/[(10^2 - 10)/10] = 24/45 = .53$$

In addition to distinguishing between teams that are closer in miles but farther apart in terms of time zones (and, thus, overlapping work hours), the TZI also captures other differences that would be missed with a purely spatial approach to dispersion. For example, some teams' temporal dispersion includes members who act as "links" between sites. In two teams that we studied, members were dispersed Miami-London-Hong Kong and Boston-London-Tokyo. While none of the sites was "close" to each other, team members in Miami, Hong Kong, Boston, and Tokyo all described their colleagues in London as important temporal "lynch pins," who could talk briefly with their colleagues in Asia (before their offices closed and without having to extend their workdays) and then relay important news or information to colleagues in the eastern United States (with which London shared nearly half its workday). In contrast, members in Boston and Miami only rarely spoke with their Asian colleagues, and only then by dialing in for midnight team calls. Had these teams' temporal dispersion been characterized simply as high or low, they would have been considered equally temporally dispersed and the important linking dynamics would not have been captured. Again, degrees of dispersion matter as well as dimensions.

Although we propose an index based on time zones as a proxy for overlapping work hours, an index based directly on overlapping work hours would be more sensitive to cultural variation in work hours and days, team members who are at the same site but work different shifts or flexible hours, and the few countries that do not adhere to the global standard time

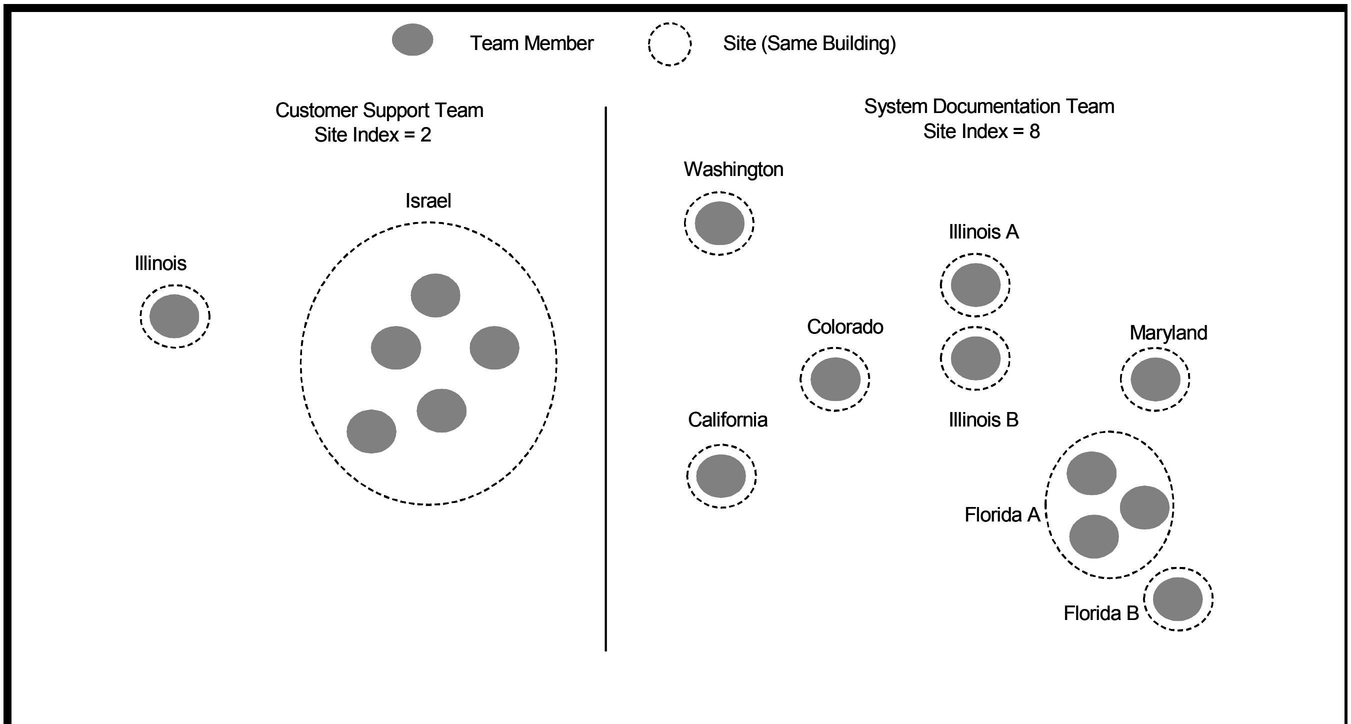

Figure 5. Comparison of Two Teams with Different Values on the Site Index

zone system. Fundamentally, the choice between an index based on overlapping time zones and overlapping work hours depends on two conditions: (1) the nature of one's sample (e.g., does it include significant variation in work hours, days, and weeks, and does it include shift workers); (2) the source of one's data (e.g., do the data include details on members' specific work days and hours—usually only available from their own self-reports—or do they include only the members' locations). The use of any measure involves tradeoffs among precision, ease of calculation, and availability of data. Because we wanted to offer measures that can all be calculated based on one objectively obtained data point available for each team member in organizational information systems, we propose a time-zone-based measure. However, replacing the time zone variable with overlapping work hours in the TZI might be warranted and possible in some situations depending on the two conditions noted above.

In summary, the temporal dimension and TZI add an important theoretical and empirical component to the traditionally spatial approach, but the SDI and TZI do not capture a third important dimension: configuration. The following three indices—site, isolation, and imbalance—address the geographic configuration of members and sites *independent of the spatial and temporal distances among them*.

Site Index

Coordination across more than one location is challenging (Grinter et al. 1999). Other things being equal, the more sites at which team members work (i.e., the *site index*), the more dispersed a team. The definition of *site* is far from clear-cut (Olson et al. 2002), with some colocated teams spread across one floor of a building, while other colocated teams are spread across a corporate campus or city. Depending on the specific context being studied, site could be operationalized at the floor, building, or city level, leaving room for site effects even at relatively close geographic proximity. In practice, the site index should be operationalized at the most meaningful level for the context in which it is studied. In our examples, the building where team members resided was the threshold for defining a site.

The system documentation team represents one extreme in terms of the site index, with eight sites (i.e., eight *buildings* across six states and seven cities in the United States; see Figure 5).

Site Index = 1 Building (Washington) + 1 Building (Colorado) + 1 Building (California) + 1 Building (Maryland) + 2 Buildings (Illinois) + 2 Buildings (Florida) = 8

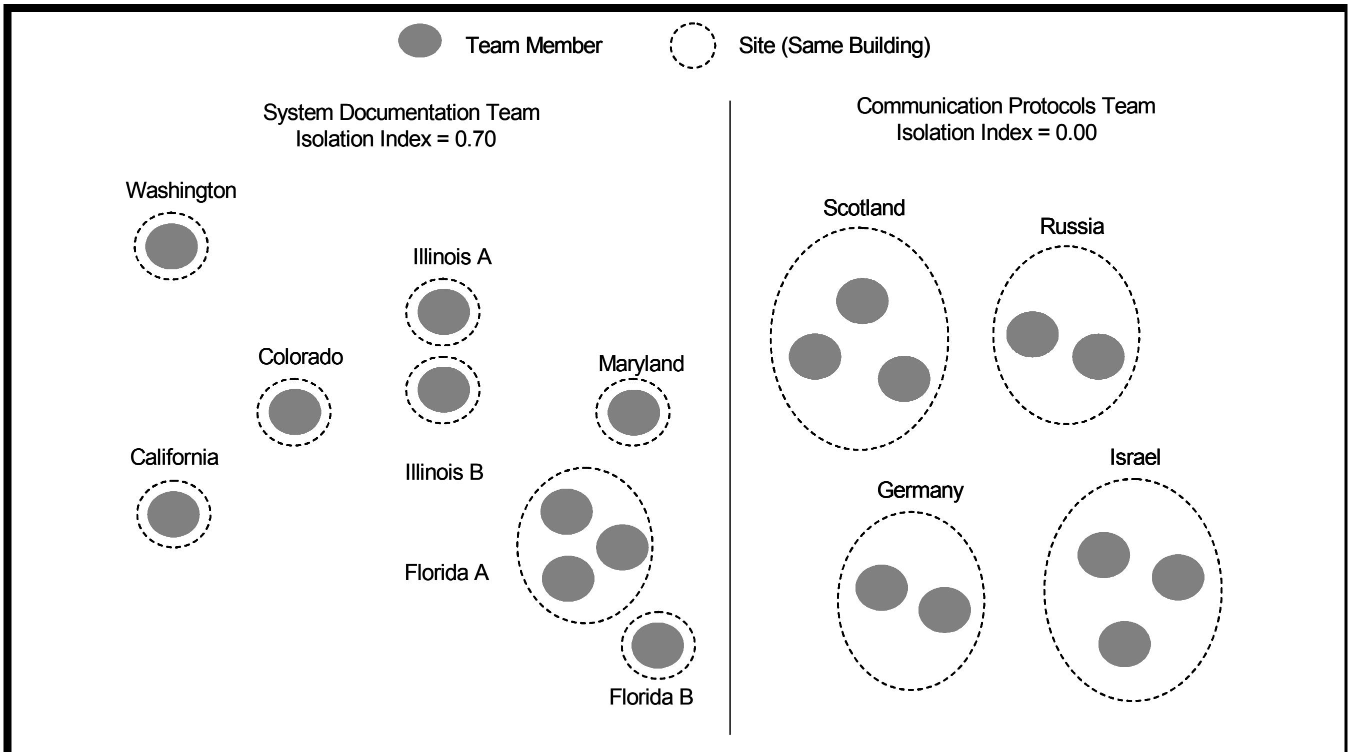

Figure 6. Comparsion of Two Teams with Different Values on the Isolation Index

At the other extreme, teams are often split between only two sites, as was the case with the customer support team, whose members were in two buildings, one in Israel and the other in Illinois. The customer support team was more dispersed than the system documentation team based on the spatial distance index (2,048 versus 1,280) and time zone index (2.67 versus 1.38), but far less dispersed from a site index standpoint (2 versus 8). These differences in degree are especially relevant for the management of dependencies and the resulting coordination complexity.

Isolation Index

Although research has identified a number of potentially problematic aspects of being isolated from one's colleagues (e.g., see the studies reviewed by Cooper and Kurland 2002, pp. 512ff), the site index does not address the *number* of team members per site. For example, previous approaches to dispersed teams would equate the dispersion of the system documentation team (distributed 3-1-1-1-1-1-1-1) with that of the communication protocols team whose 10 members were dispersed 3-3-2-2 across four sites in Scotland, Russia, Germany, and Israel. While the similar spatial distance indices and equal time zone indices would suggest similar degrees of spatial and temporal dispersion, 70 percent of the documentation team members are isolated, while none of the communication protocols team members are (see Figure 6). On this configurational basis, the dispersion patterns of these teams are actually quite different.

Isolation Index = [1 per site (Washington) + 1 per site (Colorado) + 1 per site (California) + 1 per site (Maryland) + 1 per site (Illinois A) + 1 per site (Illinois B) + 1 per site (Florida B)]/10 site = 7/10 = 0.70

Without traveling for face-to-face meetings, synchronous work within the system documentation team would require more technology-enabled interaction, while the communication protocols team could divide its work so that highly interactive work was done by colocated pairs. This suggests a second configurational measure, which we call the *isolation index* and define as the proportion of team members who are at sites with no other team members. Low values of the index indicate low levels of isolation.

The range for this index is 0 (no team members alone at their site) to 1.0 (all members alone at their sites). The more re-

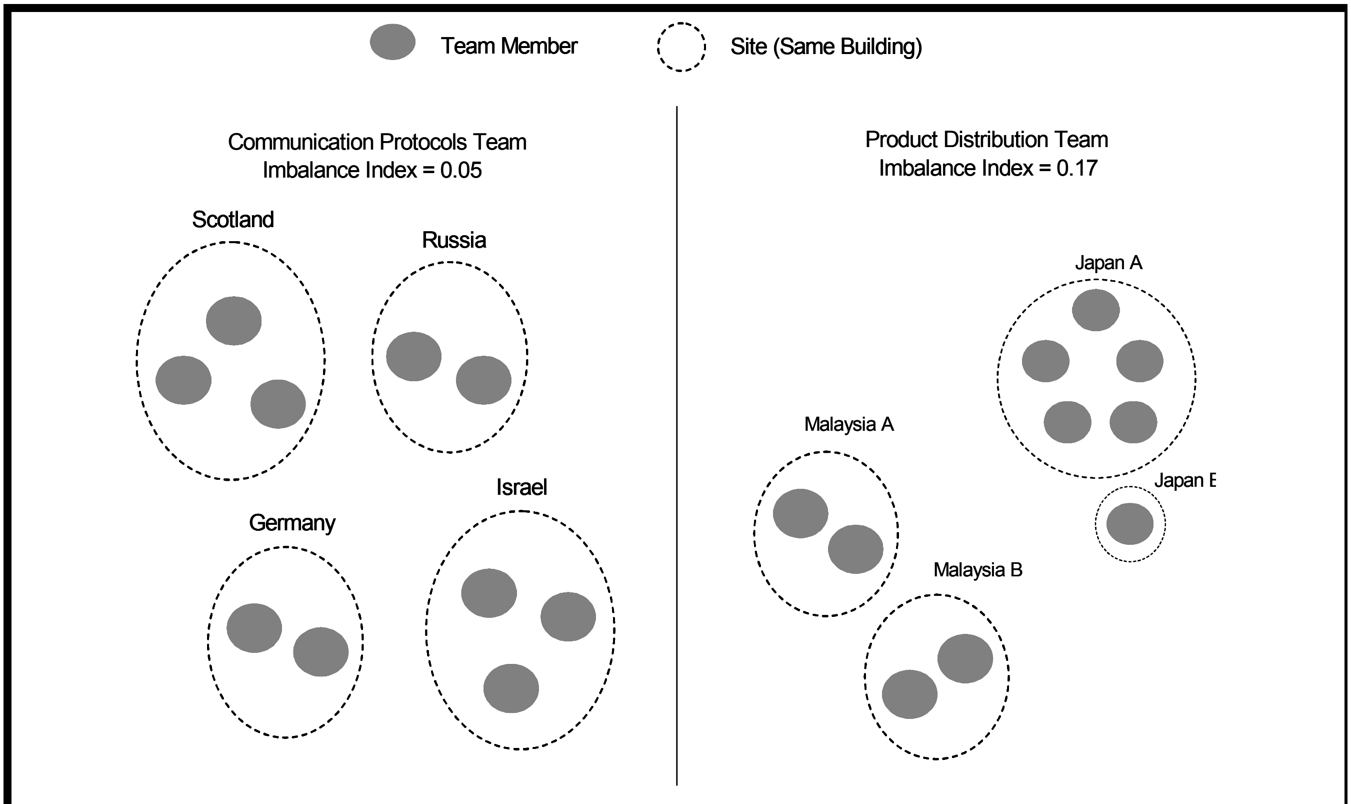

Figure 7. Comparsion of Two Teams with Different Values on the Imbalance Index

mote a member is, the less aware other members will be of his or her activities. As with the other configurational measures, the isolation index is theoretically independent from spatial and temporal dispersion (except that completely colocated teams must, by definition, have SDI, TZI, and isolation indices of zero). For example, a sample of teams could include wide variation in the SDI (because the spatial distances among members varies widely), but have constant levels of isolation across teams or varying isolation that is not at all correlated with the SDI. The correlation between SDI and TZI drops and their independent value increases as dispersion shifts from east-west to north-south.

Imbalance Index

A growing stream of research supports the importance of configuration (e.g., Cramton 2001; Polzer et al. 2006). As authors have noted, some teams have more or less balanced membership across sites. For example, a 12-person team could be split evenly (or nearly evenly) between two sites (6-6 or 7-5), or it could be divided unevenly with nine members at one site and three at another. The even or "balanced" configurations may trigger heightened intergroup-like relations between sites (Alderfer and Smith 1982), while uneven or imbalanced configurations (e.g., 9-3) may trigger majority-minority (Nemeth 1986) or subgroup (Lau and Murnighan 1998) effects.

Members at sites with a small percentage of the team (minority sites) may also feel more "out of the loop" and face greater communication challenges. Except in cases where a minority site has only a single member, the isolation index would not capture such effects. However, a measure we call the *imbalance index*, equal to the standard deviation of members per site divided by the size of the team, does address such configurations (see Figure 7). In the product distribution team, for example, the standard deviation of 5, 1, 2, and 2 would be calculated (1.7) and then divided by the size of the team (10) to arrive at the team's imbalance index of 0.17.

Imbalance Index = Standard Deviation(5_{JapanA}, 1_{JapanB}, $2_{MalaysiaA}$, $2_{MalaysiaB}$)/(5+1+2+2) = 1.7/10 = 0.17

In contrast, the communication protocols team mentioned above has almost equal numbers of members at each of its sites (3-3-2-2) and, thus, has a very low imbalance index (0.06).

Teams with an equal number of members at all sites (e.g., 4-4-4 or 2-2-2-2-2-2) are maximally balanced and have an imbalance index of 0.0 (even if their configuration differs in other important ways). Teams with highly unequal numbers of members across sites (e.g., 9-3 or 6-1-1-1-1-1-1) have a high imbalance index. Theoretically, the index reaches an asymptote at the square root of 0.05. In practice, however, most teams (i.e., those with 25 or fewer members) would have degrees of imbalance between 0 and 0.65, with higher degrees of imbalance increasing the likelihood of intra-group conflict.

Implications for Research

We believe that the primary contributions of this research essay are twofold: (1) it provides scholars with a robust, theoretically grounded, multidimensional model of geographic dispersion, which effectively captures the critical ways in which teams' dispersion varies; and (2) it provides measures for each of those dimensions. The implications of these two contributions are that scholars can more carefully assess the independent effects of space, time, and configuration, and separate those effects from socio-demographic ones, which are often correlated with dispersion, but which exert theoretically different effects. Theory building regarding geographically dispersed teams' performance and technology use will be enhanced by scholars' more explicit specification of the relevant dimensions and degrees of dispersion.

For example, the enduring question of "How does geographic dispersion affect coordination?" can be addressed much more fruitfully if we consider dispersion as multidimensional. Coordination theory posits that coordination challenges are fundamentally about managing dependencies (Crowston 1997). Such dependencies are not likely to grow as teams become farther apart spatially, but they are likely to become much more salient as the number of sites on a team grows. Scholars have also struggled to establish a clear link between dispersion and types of communication. In this case, much of the research has not accounted for temporal dispersion. Our model provides a framework for doing so and should, thus, allow for theoretical advancement regarding communication and technology use in geographically dispersed teams by helping researchers conceptualize and measure dispersion more explicitly and constructively than has generally been the case.

It is not necessary to measure every dimension in every study, but we believe that it is important to make conscious, well-informed, theoretically guided choices about which dimensions to measure and control. For scholars studying one specific process, or studying it in a very specifically defined context (e.g., with equally sized subgroups, no isolates, or all members in the same time zone), it may be sufficient to focus on one dimension or a dichotomous conception of dispersion. For others, it may be important to explicitly control for spatial and temporal dispersion, in order to focus on the effects of configuration. Thus, the use of our proposed measures should be guided in part by the outcomes of interest in any particular study and the nature of the sample itself.

As with all new conceptualizations and measures, ours have limitations. In particular, we note three here. First, teams have long been defined partly in terms of stable boundaries and membership (Alderfer and Smith 1982). However, teams' boundaries are often (and perhaps increasingly) permeable (Ancona et al. 2002), their members often change (Arrow and McGrath 1993), and they have core and periphery members (Cummings and Cross 2003). This seems to be especially common in geographically dispersed teams. For samples of teams with rapidly changing membership, scholars would need to confirm that a team lens is appropriate and that the entities under study are not better described as coacting groups, networks, communities of practice, etc.

Second, assuming that a team lens is appropriate, measures of dispersion might need to be taken more than once if team membership changed significantly over time. At a minimum, scholars would want to measure dispersion at the same time in each team's life (e.g., at a team's launch or midpoint). They should also ground their measurement of teams' dispersion with a site-specific definition of core and periphery members.

Third, we present an objective, structural conceptualization of dispersion, but organizational, technological, and individual factors can reduce feelings or perceptions of dispersion (Wilson et al. 2005). The same objective-subjective dynamic exists in regard to time and timing (Orlikowski and Yates 2002). Future research should explore the relationship between the objective aspects of dispersion and people's perceptions thereof, with an eye toward how technology use can minimize perceived dispersion.

Implications for Technology Use

Over the last quarter century, the consequences of dispersion have been given increased attention, but the construct of dispersion itself has generally been taken for granted. This essay argues that distance and dispersion need to return to the foreground in this age where ideas about "anytime, anywhere" work and the "death of distance" (Cairncross 1997) are at odds with findings that distance (and proximity) still matter (Olson et al. 2002). Twenty five years ago, a detailed floor plan could capture the bulk of interaction among work colleagues. Today, especially in large, global organizations, that is no longer the case. A new understanding of dispersion (and accompanying measures to characterize it) has the potential to change our approach to studying information systems and teams research.

We also believe the measures reemphasize the importance of the rich context in which geographically dispersed teams work, a context that is complex, dynamic, and multifaceted. Furthermore, the measures can be as valuable for researchers doing small-sample qualitative work as they are for those doing large-sample quantitative studies. The detailed calculations may be less relevant for the former, but the concepts behind those calculations and the dimensions proposed here can be part of any rich, descriptive study of dispersed work (as they were, implicitly, in Majchrzak et al. 2000).

We believe that the conceptualization and measures presented here can enhance our understanding of technology use in dispersed teams. The reconceptualization argues that geographic dispersion is multidimensional and comes in varying degrees. For technology to support teams at different points along the three dimensions of dispersion, that technology and its use must also be conceived of in a multidimensional, multifaceted way that reflects the real range and variety of geographic dispersion in organizations today. Given that virtual teams are not a uniform category, we expect that their technology needs and use will not be uniform either.

Especially in large teams, the potential for and likelihood of salient subgroups grows. As a team's configuration becomes more complex, so do the challenges for effective team functioning and opportunities for IT to assist in that functioning. For example, technology has the potential to minimize the unhealthy effects of subgroup dynamics through features like anonymous online voting, which could reduce the dominance of larger subgroups. Other tools might also help members identify more strongly with the team as a whole.

Teams with geographic isolates could benefit from technologies that minimize those members' feelings of isolation and increase their sense of connectedness and involvement. Because isolates can play a positive role and improve overall team functioning (e.g., by serving as devil's advocates), technologies might be designed to support that positive role. As levels of isolation increase, teams need to be increasingly conscious that their choice of media does not exclude those members who are "out of sight."

In addition to these technology implications for teams that vary in their configurations, as dispersion increases beyond certain key levels, use of communication media and their component features (Griffith and Northcraft 1994) may shift because only some media enable synchronous interactions and only some provide visual cues. For example, as dispersion increases beyond the point at which team members can travel roundtrip to/from each others' sites within a work day, they will shift away from face-to-face communication to e-mail or phone.

In summary, we are not advocating a single measure of geographic dispersion, nor do we propose a grand theory of it. However, we do believe that the model captures three objective, structural aspects of dispersion (i.e., spatial distance, temporal distance, and configuration). The nature, operationalization, and effects of the *dimensions* and *degrees* of dispersion differ in ways that are theoretically important for the study of dispersed teams and the technologies to support them. Technology use and effectiveness will vary depending on the salient dimensions and degrees of dispersion in any given team or sample of teams.

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