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Leveraging Social Networks and Team Configuration to Enhance Knowledge Access in Distributed Teams

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ABSTRACT

Increasingly organizations are utilizing geographically distributed teams to accomplish their goals. To a great extent this new way of working has been made possible by electronic communication technology. Yet even while managers are leveraging electronic communication technology to gain access to new knowledge and to enable new team configurations, they are concerned about the knowledge acquisition of distributed team members who interact primarily via electronic communication. The objective of this study is to deepen our understanding of the relationship of electronic communication technology use and team configuration with knowledge access in distributed teams. We do so by examining the communication networks of individuals in distributed teams, and the relationship of team configuration on those networks. We extend prior work on social networks and propose that individuals in distributed teams have two distinct communication networks that influence knowledge access: face-to-face and electronic networks. We find that these two networks differentially influence an individual's level of knowledge access from team members. In addition, we find that the relationship of each of these networks with knowledge access level is influenced by how the team is physically configured and the size of the team. These findings suggest that achieving higher knowledge access levels in distributed teams is more complex than just increasing electronic and face-to-face communication. Rather it involves understanding how communication patterns, communication mode and team configuration interact to influence the level of knowledge access for each individual in the team.

INTRODUCTION

Increasingly organizations are utilizing geographically distributed teams to accomplish their goals (Griffith, Sawyer & Neale, 2003). To a great extent this new way of working has been made possible by electronic communication technology. Electronic communication technology provides the ability for workers to span geographical, temporal and social boundaries (Sproull & Kiesler, 1991) and workers often use electronic communication to access each other's knowledge (Majchrzak, Malhotra, & John, 2005). Communication technology also provides options for managers as to how they physically configure their teams (Majchrzak, Malhotra, Stamps & Lipnack, 2004). For generations team members were wholly collocated with each other (Hinds & Kiesler, 2002). Now many workers are physically collocated with only a portion of their team (Polzer, Crisp, Jarvenpaa, & Kim, 2004). In addition, team size can vary widely, no longer constrained by the physical space limitations often experienced by wholly collocated teams (Cohen & Bailey, 1997).

Even while employees and managers are leveraging electronic communication technology to gain access to other's knowledge and to enable new team configurations, they are concerned about how technology use may alter team members' interactions and knowledge access. Social interaction has long been recognized as an important vehicle for knowledge acquisition for individuals in organizations (Borgatti & Cross, 2003). In distributed teams electronic communication technology use has been found to be associated with increased conflict and misunderstandings (Hinds & Mortensen, 2005). Use of communication technology has also been related to higher levels of effort, message feedback lags and decreased social information exchange that can lead to reduced levels of mutual knowledge among team members (Cramton, 2001). However other studies have found that over time interactions enacted through electronic communication technology can be just a strong relationally as face-to-face interactions (Chidambaram, 1996; Walther, 1995) and even more task-oriented than face-to-face interactions (Burgoon, Bonito, Ramirez, Dunbar, Kam & Fischer, 2002). These latter findings suggests that outcomes for individuals, such as their level of knowledge access, can be just as positive in distributed teams as in wholly collocated teams. However neither research nor theory currently explains why some individuals in a distributed team successfully acquire the knowledge they need from team members, while other individuals in the same team feel that their knowledge access is lacking. Do face-to-face and electronic interactions differentially influence an individual's level of knowledge access in distributed teams? In what ways does a team's configuration interact with an individual's networks to affect knowledge access level?

The objective of this study is to deepen our understanding of the relationship of electronic communication technology use and team configuration with knowledge access in distributed teams. We extend prior work on social networks and propose that individuals in distributed teams have two distinct communication networks that influence knowledge access: face-to-face and electronic networks. We find that these two networks differentially influence an individual's level of knowledge access from team members. In addition, we find that the relationship of each of these networks with knowledge access level is influenced by how the team is physically configured and the size of the team.

We begin our discussion by looking at how prior research has addressed social networks, communication mode and team configurations. Hypotheses are provided in the next section. We then review the research methodology and results, and conclude with a discussion of the findings and implications for practitioners.

THEORETICAL BACKGROUND

Knowledge Access and Communication Networks

Much of what we know is learned through interacting and communicating with other people (Brown & Duguid, 1991). While knowledge is transferred through direct interaction, it is also shared indirectly through third parties, such as other team members (Hollingshead & Brandon, 2003). Thus interpersonal communication networks are often a key factor in determining the level of knowledge access for individuals in teams (Monge & Contractor, 2003). The structure of an individual's interpersonal networks not only affects the channels through which information flows (Coleman, 1988); it also influences the ease of knowledge transfer (Reagans & McEvily, 2003). Three network characteristics have frequently been associated with knowledge-related outcomes: *centrality, cohesion* and *diversity.*

An individual's level of *centrality* in a network of interactions is the extent to which she is linked to others in a group (Ahuja, Galletta, & Carley, 2003). Cross and Cummings (2004) found that centrality was associated with higher performance and suggested that this was due in part to greater access to relevant knowledge. Centrality in a network has also been associated with an individual's knowledge contribution in networks of practice (Wasko & Faraj, 2005) as well as access to information resources in communication networks (Brass, 1984; Ibarra & Andrews, 1993). An individual's level of *cohesion* is a measure of the extent to which an individual is connected to team members through both direct and indirect communication (Burt, 1992). High levels of cohesion are associated with the benefits of information exchange (Coleman, 1988) as well as ease of knowledge transfer (Reagans & McEvily, 2003). Finally, an individual's level of *diversity* is the degree to which her communication network is heterogeneous on some dimension (Papa & Papa, 1992). In their study on the ease of the knowledge transfer, Reagans and McEvily (2003) found that knowledge transfer was facilitated when an individual's network ties spanned multiple areas of expertise. However other studies have found that when individual communicates across organizational boundaries, particularly physical boundaries, knowledge sharing is adversely affective (Cramton, 2001). Thus diversity in terms of physical locations in a communication network may be negatively associated with an individual's knowledge access level.

Distributed Teams and Networks

While each individual constructs a communication network, interactions between individuals in a team are constrained and facilitated by the physical team configuration as well as the types of communication modes available (Haythornthwaite & Wellman, 1998). Physical team configuration and available communication modes are particularly relevant to the communication networks of individuals of distributed teams.

Distributed teams comprise members with different levels of physical dispersion (Griffith & Neale, 2001). Teams may be physically organized in many different ways. The majority of the team may be collocated with each other, with only one or two remote team members. Larger subgroups can also compose teams, with each subgroup in a different physical location. Team members may find themselves working apart in the same building, across the street from each other, or across the world. Additionally, as the global economy expands and projects become more complex, team members may find that they are working in larger teams. Two recent studies found that team size has increased 50% over the last 20 years in the areas of scientific research and software development (Adams & Black, 2004; Putnam, 2005).

Due to physical dispersion members of distributed teams often experience of mix of communication modes (Rice & Gattiker, 2001). When an individual is not colocated with other team members there is less face-to-face communication (Kraut, Fussell, Brennan, & Siegel, 2002). Distributed team members often rely heavily on electronic communication for interaction and the exchange of knowledge (Griffith et al., 2003). Even when face-to-face interaction is facilitated by collocation with *some* team members, colocated individuals may choose to use electronic communication, in order to be inclusive of *all* team members.

In these ways the physical configuration of distributed teams and the communication modes available influence individual communication networks and the level of knowledge access of individuals. In the next section we will integrate prior research on communication modes, social networks, and team configurations and hypothesize as to their combined effect on an individual's level of knowledge access.

HYPOTHESES

Communication Mode and Knowledge Access

The information and knowledge benefits from interactions occur in three forms: access, timing and referrals (Burt, 1992). The transfer of knowledge is often limited by lack of access to others holding the knowledge (Griffith et al., 2003). Both access to others and the timeliness of that access is influenced by physical proximity and technology use (Cross, Parker, Prusak, & Borgatti, 2001). Thus face-to-face and electronic interactions differ in the access, timing and referral benefits they provide and the knowledge available through those networks.

Face-to-face interactions that occur when individuals are collocated facilitate knowing 'who knows what' and provide referrals in terms of 'who knows who knows what' (Monge & Contractor, 2003). Physical proximity also increases the opportunities for spontaneous, informal face-to-face communication (Kraut et al., 2002), which can improve the timing of knowledge access... Face-to-face interaction also engenders social bonding (Nardi & Whittaker, 2002), which can ease knowledge transfer (Reagans & McEvily, 2003) and is also expected to increase knowledge referrals (Coleman, 1988).

Electronic communication technology also influences the access, timing and referral benefits of interactions. Communication technology is frequently used to span physical and temporal access gaps that may otherwise restrict knowledge access (Griffith et al., 2003). By facilitating the crossing of boundaries, electronic communication expands the range and diversity of individuals' networks and increases overall communication (Monge & Eisenberg, 1990), which can increase knowledge access as well as referrals. Use of electronic communication has also been associated with increased knowledge seeking (Cummings & Ghosh 2005). Finally, electronic communication enables asynchronous information exchange (Ramirez, Walther, Burgoon and Sunnafrank, 2002), which can improve the timeliness of knowledge access for individuals who are not physically collocated.

As the mode of an interaction influences access, timing and referral information benefits, we submit that is beneficial to conceptualize an individual as having two distinct communication networks: a face-to-face and an electronic communication network. In addition we posit that these two networks have differential influences on an individual's level of knowledge access. In the next section we look at prior research that has examined the effect of networks on knowledge access, as well as the differences between face-to-face and electronic networks.

Knowledge Access in Face-to-Face and Electronic Networks

Decades of social network research provide ample evidence as to the influence of network structure on a variety of outcomes, including knowledge-related outcomes (for reviews see

(Borgatti & Foster, 2003; Brass, 2004). The network paradigm has been used to investigate communities of practice (Brown & Duguid,. 1991), transactive memory (Hollingshead & Brandon, 2003) as well as information-seeking to create new knowledge (Borgatti & Cross, 2003). Few network researchers however have explored the possibility that the multiple communication modes used by team members may constitute separate network structures that work together but separately to affect knowledge-related outcomes.

Early network research in teams was mute on the point of communication mode, formulating network structure on the basis of an individual's general contact with others (Brass, 1985; Friedkin, 1993; Rice & Aydin, 1991). As the use of electronic communication technology grew, so did the evidence that communication mode influenced the quality, quantity and structure of interactions (Hinds & Kiesler 2002). Researchers began looking specifically at electronic network structures, often focusing on email or virtual communities (Ahuja et al., 2003; Wellman, Salaff, Dimitrova, Garton, Gulia, & Haythornthwaite, 1996). Other studies continued to aggregate any kind of communication between individuals into a single network, choosing instead to differentiate networks on content such as work or friendship (Klein, Lim, Saltz, & Mayer, 2004; Van den Bulte & Moenaert, 1998) or specific types of exchange such as information-seeking or knowledge-seeking (Cross & Sproull, 2004; Cummings & Ghosh, 2005).

While the approaches above have been informative, there is more to be learned about communication structures and knowledge access in distributed teams. Conceptualizing face-to-face and electronic communication as separate structures allows us to examine how an individual's placement in a communication structure and their associated access to knowledge, may vary by communication mode. It allows us to analyze how face-to-face and electronic communication work separately but simultaneously to affect knowledge access levels. In addition, framing an individual's communication as having two modal structures facilitates analysis of interactions. It allows us to better understand how contextual factors such as team size and physical proximity with team members may interact with communication-specific structural features to influence knowledge access by individuals.

Two sets of authors have considered the separate structures of face-to-face and electronic communication. In her study of four, 4-person groups in a distance learning class, Haythornthwaite (2001) found that network density (the number of people contacted and frequency of contact) varied between face-to-face and electronic networks. Unfortunately, face-to-face communication was not used extensively in the groups and no further comparison was made of face-to-face and electronic networks. In a field study of two newspaper editorial teams, Zack and McKenney (1995) compared the face-to-face and electronic mail structures of editorial subgroups of managers, reporting editors, copy desk slots and news desk editors. They found that the face-to-face communication patterns between subgroups closely resembled the electronic mail patterns. The sample sizes of each editorial team was small (15 and 14 members) and the managers rarely used electronic mail. In addition the study analyzed communication at the subgroup rather than the individual level of analysis, the latter of which is of interest here.

We build on the work above and consider the relationship of these two networks with an individual's level of knowledge access. The majority of the research on communication modes supports a differential effect of face-to-face and electronic interactions on outcomes (Galegher, Kraut, & Egido, 1990; Hinds & Kiesler, 2002). Therefore we posit:

> ***The Network Mode Hypothesis (H1)****: Face-to-face and electronic communication networks will differentially influence an individual's level of knowledge access from team members in a distributed team.*

Networks and Team Configuration

In prior research two factors related to team configuration have been found to influence an individual's network structure. The *physical proximity* of communication partners has been cited as influencing the creation of networks, the characteristics of network structures, and the outcomes of those structures (Brass, 2004; Monge & Contractor, 2003). *Team size* has also frequently been associated with network structure characteristics and related outcomes (Brass, 2004; Burt, 1992). We expect that these factors will interact with an individual's communication networks to influence knowledge access levels as well.

Physical Proximity and Knowledge Access. We discussed earlier how physical proximity can directly influence collocated, face-to-face interaction and most research suggests a positive relationship between physical proximity and knowledge access. Authors have generally attributed this relationship to the spontaneous, informal communication that often occurs between collocated team members, as well as the benefits of a shared context when team members are collocated (Cramton, 2001; Kraut et al., 2002; Sole & Edmondson, 2002). More recent research however has begun to recognize that spontaneous, informal communication in distributed teams is no longer solely dependent on collocation and that even physically separate team members can experience a shared context (Hinds & Mortensen, 2005). Since physically separate team members can only interact through electronic communication, this research suggests that *both* face-to-face and electronic communication can convey aspects of spontaneous, informal communication and shared context that are associated with higher levels of knowledge access. In addition, research has found that physical proximity interacts differently with face-to-face and electronic communication to affect social judgments between partners as well as task performance (Burgoon et al., 2002). We build upon these prior works and posit:

The Physical Proximity Hypothesis (H2): *Physical proximity with team members will moderate the relationship between an individual's network structure and an individual's level of knowledge access from team members.*

Team Size and Knowledge Access. Working together in a team provides the opportunity for individuals to learn precisely how the knowledge of colleagues can be helpful (Cross & Baird, 2000). As team size grows individuals are likely to have more opportunities to add contacts to their networks (Hoegl, Parboteeah, & Munson, 2003) and therefore knowledge access levels would likely increase. However two recent studies of distributed teams suggest a negative effect of team size on knowledge-related outcomes. Team size has been found to be negatively associated with the number of ideas contributed by an individual in decision-making teams (Chidambaram & Tung, 2005). Knowledge seeking by team members has also been found to decrease as team size increases (Cummings & Ghosh, 2005), suggesting that it is more difficult to seek (and perhaps access) knowledge in larger teams. However a study of 145 software development teams found no significant effect of team size on the ability of individuals to add contacts to their knowledge networks (Hoegl et al., 2003). The mixed findings from decades of research on the relationship between team size and performance-related outcomes suggest that the effect of team size is influenced by multiple factors in an organizational setting (Cohen & Bailey, 1997). We suggest that communication networks are one such factor. We posit:

The Team Size Hypothesis (H3)*: Team size will moderate the relationship between an individual's network structures and an individual's level of knowledge access from team members in a distributed team.*

METHODS

Data Collection

Survey data in this study were collected from 254 individuals in 18 distributed teams in 9 organizations. Fieldwork for this research began with semi-structured interviews of managers and members of distributed teams, in order to become familiar with issues and factors surrounding individual knowledge access in the teams. From these interviews a team member questionnaire was developed. All questions were based on previously published work. The questionnaire consisted of three parts: a sociometric question regarding communication patterns, Likert-style questions on knowledge access, and open-ended questions regarding demographic characteristics. A pilot test was conducted to refine the questionnaire and the administration process. Participation was solicited from managers and members of *on-going* distributed teams; team members had a history of working together and anticipated continuing to work together. In the sample the average individual tenure with a team was 27 months. Prior to administering the questionnaire, each manager provided the names of team members, which were used to customize the sociometric portion of the questionnaire. Questionnaires were administered either in-person via paper or pencil or by electronic e-mail form. The e-mail forms were mailed directly back to the researchers. The overall response rate for the survey was 84%, while the response rate for teams included in the study was 93%. Network analysis requires a high response rate (Wasserman & Faust, 1994) and therefore 5 teams with less than an 80% participation rate were excluded from further analysis. Table 1 provides a summary of team and organizational characteristics.

Measures

Knowledge Access Level. The dependent variable of knowledge access level was developed in several steps. During preliminary interviews, team members and managers were asked about access to other's knowledge and how working in a distributed team may influence that access. Next prior literature was searched to find pre-existing questions that best corresponded to the comments expressed in these interviews. In the questionnaire ***Knowledge Access Level*** was measured through three Likert-style questions that were based on Faraj and Sproull (2000). These questions were further refined based on feedback from pilot participants and are listed in Table 2. Upon completion of the final data collection a factor analysis showed that the three questions loaded together with a Cronbach-alpha of .77. An inspection of the graph of the variable showed that is was slightly skewed, and therefore a Box-Cox transformation was performed in order to meet normality assumptions.

Network Measures. In the sociometric portion of the questionnaire individuals were asked to indicate the team members with whom they exchanged workflow inputs and outputs, and how often (Brass, 1984). Communication frequency options ranged from '0' – Don't contact for workflow, to '5' – Contact every day for workflow. Data on both the frequency of face-to-face (F-to-F) and electronic communication with each team member was collected. Two sociomatrices were constructed for each team, one face-to-face and one electronic. For each individual in each sociomatrix three network characteristics were calculated: *centrality, cohesion,* and *diversity.*

An individual's level of centrality in the face-to-face and electronic networks was calculated using Freeman's degree centrality (Freeman, 1979) as calculated by UCINET 6 software (Borgatti, Everett, & Freeman, 2002):

$$Z_i = \sum_j z_{ji}$$

where z_{ji} is the frequency of contact from j to i. Two variables were calculated for each individual: ***F-to-F centrality*** and ***Electronic centrality*****.**

The level of cohesion for each individual in each network was operationalized as the constraint on his network ties (Burt, 1992; Reagans & McEvily, 2003). As calculated by UCINET 6, the level of constraint on individual i due to her interaction with j is calculated as (Burt, 1992):

$$Z_i = \sum_j [\ (p_{ij} + \sum_q p_{iq} p_{qj})^2\ ] \quad q \neq i, j$$

Where p_{qj} and p_{ij} are the proportional frequency of q's and i's contact with j. This constraint is summed across all j's to construct a measure of total constraint on an individual. Two variables were calculated for each individual: ***F-to-F cohesion*** and ***Electronic cohesion***.

An individual's level of ***diversity*** is the degree to which her communication network is heterogeneous on some dimension (Papa & Papa, 1992). We calculated an individual's network diversity across physical boundaries as (Burt, 1983; Reagans & McEvily, 2003):

$$Z_i = 1 - \sum_{k=1}^{m} p_k p_{ik}^2$$

Where p_k is the strength of connections in physical location k and p_{ik} is the strength of the connection between person i and others in physical location k; m is the total number of physical locations within each team. The strength of connections within physical location k is calculated as:

$$p_k = \sum_{j=1}^{n_k} z_{ij} / \sum_{q=1}^{s_k} z_{iq}$$

Where n_k is the number of team members in physical location k, and z_{ij} is the frequency of contact from a team member in area k to a team member in the same physical location; s_k is the total number of contacts cited by team members in area k and z_{iq} is the frequency of contact from an team member in physical area k to any team member. The strength of the connection between person i and others in physical location k (p_{ik}) is calculated as:

$$p_{ik} = \sum_{j=1}^{g_k} z_{ij} / \sum_{q=1}^{g} z_{iq}$$

Where g_k is the number of team members in physical location k and g is the total number of team members; z_{iq} is the frequency of the contact from person i to contact q and z_{ij} is the frequency of contact from person i to contact j. Two variables were calculated for each individual: ***F-to-F diversity*** and ***Electronic diversity***.

Physical Proximity. Following work by Olson and Olson (2000) physical proximity of an individual to team members was operationalized as the number of team members physically located in the same building. The building location was obtained from the team member questionnaire and verified through interviews with key informants. The total number of collocated team members for each individual was calculated as the ***# People Collocated***.

Team Size. ***Team size*** was calculated as the total number of team members in each sociomatrix .

Control Variables. Prior research suggests that task variety and interdependence can influence the structure of an individual's networks (Cross, Rice, & Parker, 2001). To control for differences in task across teams, we asked each manager to answer four Likert-style questions concerning the team's ***task complexity***. Task complexity for a team was calculated as the average of task interdependence and task variety, and was measured on a scale from 1 (low) to 7 (high). In addition, information on each team member's gender, education, age group, rank, number of hours worked, team tenure, job title tenure, and organizational tenure was collected.

None of these factors were statistically significant in any of the models and were subsequently dropped from further model analysis.

Analysis

Table 3 shows descriptive statistics and correlations. A few of the correlations between the independent variables are high, but generally within the accepted limit for inclusion in regression models (Nunnally, 1978). We ran an ordinary least squares regression model with the independent variables and knowledge access level as the dependent variable, in order to check the variance inflation factor (VIF). The VIF was less than 4.0 for all variables and within acceptable levels (Neter, Kutner, Nachtsheim & Wasserman, 1996). Finally, in our interviews and fieldwork respondents indicated that they could easily differentiate between the frequency of their face-to-face and electronic interactions with another, and they considered those two types of contacts as distinct. Therefore we progressed to the next step of analysis, which was multilevel modeling.

We used hierarchical linear modeling (HLM) to test our hypotheses. HLM has frequently been used for analyzing network data (Cross & Cummings, 2004; Klein et al., 2004) as well as cross-level relationships (Hoegl et al., 2003; Seibert, Silver & Randolph, 2004) when the primary level of analysis (the individual) is nested within a higher level (teams). Multilevel models in HLM allow for partitioning of the variance between the group and individual levels, and the models have increased power and unbiased estimates compared to single level models used with the same data (Raudenbush & Bryk, 2002).

The first step in the analysis was to determine if there was sufficient between-team variance to justify further multilevel modeling. Luke (2004) suggests using the intraclass correlation coefficient (ICC) to measure the proportion of variance that exists between groups, on which a chi-squared test can be performed to determine if the variance is significantly different from zero. We ran a null model with knowledge access as the dependent variable and no predictors. The ICC was 22.7%, with the chi-squared test indicating that the between group variance was significantly different from zero (p-value < .001). We then fit three additional models as shown in Table 4, starting with the individual level variables (Model 1) and their interactions (Model 2), and then adding in interactions with group level variables (Model 3), as suggested by Raudenbush and Bryk (2002).

Multilevel modeling separates group and individual level effects and therefore the assessment of model fit differs somewhat from that used with OLS regression. Multilevel models calculate a separate R^2 for each level. Model fit is assessed through the change in residual variance at each level and change in deviance (-2 log likelihood). The former is termed the pseudo-R^2 and is interpreted in a similar manner as the traditional R^2 statistic. Each individual and group level pseudo-R^2 is computed and interpreted here following work by Snijders and Bosker (1994).

RESULTS

The results of the analysis are shown in Table 4. The fit of the three models is good and statistically significant as compared to the null model, as assessed by the change in the deviance statistic (row 26). The R^2 increases with each model, with model 3 explaining 20% of the variance at the individual level and 45% of the variance at the group level (rows 23 and 24).

Hypothesis 1, the network mode hypothesis, posited a differential effect of face-to-face and electronic networks. This hypothesis is partially supported. In model 1, face-to-face centrality has a positive relationship with knowledge access level (row 2, b=0.14, p<0.01) and electronic centrality is not significant (row 3, b=0.01, p>0.05). All other network variable effects are non-significant in model 1 (rows 4 through 7). In models 2 and 3, as we control for interaction effects, further differences emerge between the effects of face-to-face and electronic networks on knowledge access levels.

Hypothesis 2, the physical proximity hypothesis, posited that physical proximity with team members would moderate the relationship between network structure and knowledge access level. This hypothesis is partially supported in Model 2, row 12 (b=-3.27, p<0.05). To better understand this relationship we divided the data into two groups based on the mean value (nine) of the variable '*# of people collocated*', and graphed the bivariate relationships, which are shown in Figure 1. When individuals are collocated with fewer than nine team members, electronic cohesion is positively associated with knowledge access levels. When the number of collocated team members is nine or more, electronic cohesion is negatively associated with knowledge access level.

Support for Hypothesis 2 is also found in row 13 of Model 2 (b=-1.11, p<0.05). In Figure 2 we see that there is negligible association between face-to-face diversity and knowledge access level when an individual is collocated with fewer than nine team members. However with nine or more collocated team members, there is a negative relationship between face-to-face diversity and an individual's knowledge access level.

Hypothesis 3, the team size hypothesis, posited that team size would moderate the relationship between network structure and knowledge access level. This hypothesis is partially supported in Model 3. Team size interacts with face-to-face centrality (row 17, b=.03, p<0.05) and face-to-face cohesion (row 19, b=1.86, p<.05) to influence knowledge access level. To further examine these relationships the data was divided into the 25th, 50th and 75th percentiles to represent small, medium and large team sizes. These relationships from regression Model 3 are illustrated in Figures 3a and 3b. While face-to-face centrality and cohesion have a positive association with knowledge access levels in medium and large teams, they have a negative association with knowledge access level in small teams. Results in row 22 also support Hypothesis 3, showing that the negative relationship between electronic diversity and knowledge access level is positively influenced by team size (row 22, $b=1.16$, $p<0.05$). Figure 4 shows that as team size increases, the negative effect of electronic diversity diminishes.

Comparing row 14 in Models 2 and 3, we see that after controlling for team size interactions, the interaction between electronic diversity and the number of people collocated is now significant ($b=1.05$, $p<.05$). Figure 5 illustrates the bivariate relationship, which shows that the significant negative relationship of electronic diversity with knowledge access level occurs primarily when individuals are collocated with fewer than nine team members. The relationship between electronic diversity and knowledge access level becomes positive when individuals are collocated with nine or more team members

Finally, in support of the network mode hypothesis, note that in Model 3 many of the interaction effects differ in significance and direction between modes. Most notably, the direction of the interaction of diversity with the number of people collocated differs by mode. Face-to-face diversity interacts with the number of people collocated to negatively influence knowledge access level (row 13). However electronic diversity interacts with the number of people collocated to have a positive influence on knowledge access level (row 14).

Summarizing, Hypothesis 1, the network mode hypothesis, is partially supported through both direct effects and interaction effects. Hypothesis 2, the interaction between an individual's networks and the number of people collocated with individual is partially supported. Electronic cohesion, electronic diversity and face-to-face diversity all interact with the number of people collocated to influence knowledge access level. Hypothesis 3, the interaction between an individual's networks and team size is also partially supported. Team size interacts with face-to-face centrality, face-to-face cohesion, and electronic diversity.

DISCUSSION

These findings enhance our understanding of knowledge access in distributed teams by suggesting that face-to-face and electronic networks differentially influence individual knowledge access levels. The findings also suggest that team configuration plays an important role in influencing individual knowledge access; the influence of face-to-face and electronic networks varies with team configuration. In the following sections we discuss those findings in more detail.

Electronic Networks and Knowledge Access Levels

This study suggests that in on-going distributed teams, an individual's electronic networks play a large role in influencing knowledge access level. We found that when interactions are controlled for, electronic networks have a main effect on knowledge access level, while face-to-face networks have no significant main effect. Higher levels of knowledge access are associated with higher cohesion and lower diversity in an individual's electronic networks.

Electronic Cohesion and Team Configuration. These findings support prior research that has found that cohesion positively influences knowledge access (Reagans & McEvily, 2003). We extend that work, finding that cohesion in face-to-face and electronic networks interact differentially with team configuration variables to influence knowledge access levels. The positive association between electronic cohesion and knowledge access level is moderated by the number of people collocated with an individual. As cohesion in a network increases, so does information sharing (Coleman, 1988), so that team members with low physical proximity but highly cohesive electronic networks benefit in terms of knowledge access. However, high electronic cohesion can also interfere with effective knowledge access. We found that for individuals collocated with a relatively larger number of team members, a cohesive electronic network has a negative relationship with knowledge access. Why may this be so? An individual's social context has a strong influence on attitudes, behaviors and the knowledge that is formed (Salancik & Pfeffer, 1978). Individuals with a large number of collocated team are likely to experience a strong, locally context-specific framing of knowledge due to a sharing of physical space and reinforcement of context-specific knowledge from many collocated team members (Olson & Olson, 2000). At the same time an individual's cohesive electronic network can become a community, a social entity with its own base of knowledge and contextual-framing (Hampton & Wellman, 2001; Wellman et al., 1996). This cohesive electronic network may provide a body of knowledge that differs from the local body of knowledge. Due to this conflict, individuals with large numbers of collocated team members and highly cohesive electronic networks may have trouble reconciling differences in knowledge and may report low levels of knowledge access.

Electronic Diversity and Knowledge. We also find that electronic diversity has a negative main association with knowledge access level. This relationship is supported by prior work that has found that knowledge sharing is adversely affected when team members who are physically dispersed interact electronically (Cramton, 2001). However our finding differs somewhat from Reagans and McEvily's (2003) finding that diversity in communication networks facilitates knowledge transfer. They suggest that more diversity in communication can prepare an individual to convey and receive complex knowledge successfully across boundaries.

The contrast in findings between this study and Reagans and McEvily's study may be explained by considering the interactions with electronic diversity found in this study. Looking at Figures 4 and 5, we see that the number of collocated people and team size both have a strong positive interaction effect with electronic diversity. Based on these findings we suggest that in environments with large numbers of collocated team members, diversity in electronic networks may act as a counter force to strong, local social and contextual forces. In contrast to a cohesive electronic network, a diverse electronic network helps individuals acquire diverse knowledge and many points of view. This electronic diversity may help an individual reconcile different perspectives which can result in a higher level of knowledge access. This is in line with Reagans and McEvily's position that diversity supports knowledge access. We add the proviso that diversity is beneficial when individuals are collocated with larger numbers of team members. Similarly, in large teams, exposure to a higher number of contacts and diversity may assist in reconciling diverse perspectives, so that contextual differences are not as detrimental to knowledge access levels.

Face-to-Face Networks and Knowledge Access Levels

These findings also suggest that there are instances when face-to-face networks influence the level of knowledge access for individual's in distributed teams. While we found no main effects of face-to-face networks, being central in a face-to-face network positively influences knowledge access level when an individual is in a large team, but has a negative influence in small teams (Figure 4a). Similarly in large teams cohesion is positively associated with knowledge access level, but the association is negative in small teams (Figure 4b). This is true regardless of the number of people collocated with an individual. Why do these network variables have opposite effects in large and small teams? In a large team access to others' knowledge is more difficult than in a small team (Cummings & Ghosh 2005). In such a challenging environment being central and in a cohesive face-to-face network would facilitate access to knowledge from a wide variety of others. In contrast, in a small team it may be easier to be familiar with multiple local contexts and to be in contact with a large percentage of the team face-to-face. For individuals that have made the effort and have become central or are in a cohesive face-to-face network in a small team, it may seem that they have low knowledge access because there is little new knowledge to be gained from others.

Finally, these findings suggest that diversity in face-to-face networks decreases knowledge access level when an individual is collocated with more team members. Note however that there is no significant main effect of face-to-face diversity on knowledge access level. Also in Figure 2 we see that diversity has a significant and negative effect only with nine or more collocated team members. What is perhaps most interesting about this finding is that the opposite effect is true for electronic networks. For individuals with nine or more collocated team members, diversity in electronic networks increases knowledge access levels (Figure 5). What is different about diversity in these two networks that creates a differential influence on knowledge access levels? Prior research tells us that more cues and contextual information are communicated in face-to-face versus electronic interactions (Daft & Lengel, 1986; Kraut et al., 2002; Olson & Olson, 2000). In particular many more social cues are transmitted in face-to-face communication (Nardi & Whittaker, 2002). Thus diverse face-to-face networks are likely to transmit more cues and information about potentially conflicting social and physical contexts, which would make it more difficult to reconcile diverse knowledge. This in turn would decrease knowledge access levels for individuals with diverse face-to-face networks. In contrast, the reduced cues associated with electronic interaction can facilitate knowledge exchange by diminishing potentially confusing information (Monge & Eisenberg, 1990), thereby leading to increased knowledge access levels for individuals with diverse electronic networks.

Implications for Practitioners

What do these findings suggest for managers and individuals seeking to enhance knowledge access levels in distributed teams? *First,* in terms of *electronic networks*, higher cohesion is associated with higher knowledge access levels. At the same time diversity in terms of the physical location of electronic network contacts is associated with lower knowledge access levels. This suggests that individuals should seek to minimize diversity in electronic contacts across locations while building a closely-knit network of electronic contacts with whom they frequently exchange knowledge. Managers can assist individuals by minimizing the number of physical locations in teams and encouraging a culture of knowledge exchange. One exception to these findings is for individuals located with nine or more team members. In this setting, higher knowledge access levels are associated with *lower* cohesion and *higher* diversity in electronic networks. *Second,* in terms of *face-to-face networks*, team size makes a significant difference. In teams with fewer than nine members, centrality and cohesion is associated with lower knowledge access levels. In larger teams, the same face-to-face network characteristics are associated with higher knowledge access levels. *Finally,* these findings suggest that achieving higher knowledge access levels in distributed teams is more complex than just increasing electronic and face-to-face communication. Rather it involves understanding how communication patterns, communication mode and team configuration interact to influence the level of knowledge access for each individual in the team.

Limitations

This study was limited to studying knowledge access between team members, where team membership was pre-defined by the manager. A sociometric, rather than egocentric, questionnaire was used for data collection. The advantage to this approach is that it provides interaction information on all team members, but the drawing of appropriate team boundaries is critical and errors can lead to misleading results (Reagans & McEvily, 2003). In addition with this type of data collection information regarding cross-team knowledge access was not collected. Another limitation of the study was the team level sample size, which was 18 teams, providing low power to find team level effects. It is possible that other team effects, such as task complexity, could be identified if additional groups were added to the sample. In addition, characteristics specific to the teams in this sample, such as work patterns or the type of collaborative work performed, may have influenced the results. Subsequent studies are needed to validate these findings in a variety of organizational contexts.

CONCLUSION

These findings suggest that members of distributed teams today have found a way to access the knowledge they need from others even when team members are physically dispersed. As with wholly collocated teams, cohesion and diversity in communication networks are important influences on knowledge access, but in distributed teams these influences occur primarily through electronic rather than face-to-face networks. This suggests that individuals seeking to enhance knowledge access in distributed teams should pay close attention to electronic communication networks. This is not to say that face-to-face communication is not relevant, but rather that members of distributed teams should value their electronic interactions as they do their face-to-face interactions and understand how each network differentially contributes to knowledge access.

How management chooses to configure a distributed team also plays an important part in determining the level of individual knowledge access. The mix of collocated team members and team size can have a significant effect on how communication networks can be leveraged by individuals to increase knowledge access levels. Therefore management should work with individuals in distributed teams to understand how knowledge access can be enhanced in a given team setting.

Finally, this study suggests several avenues for future research. A study with a larger number and variety of teams would be an important step toward ensuring the validity and reliability of these findings in multiple organizational contexts. Further investigation is also needed as to how individuals can best achieve the various combinations of communication network patterns suggested here for enhanced knowledge access.

Table 1

Descriptive Statistics for Participating Teams and Organizations

Org #	Organization Type	Teams Based Wholly U.S. or Internationally	# of Teams	Team Sizes
1	Technology	Internationally	3	9, 6, 15
2	Technology	Internationally	4	4, 7, 20, 25
3	Technology	Wholly U.S.	1	23
4	Technology	Wholly U.S.	2	7, 11
5	Human Service	Wholly U.S.	1	23
6	Human Service	Wholly U.S.	2	15, 25
7	Human Service	Wholly U.S.	1	21
8	Pharmaceutical	Wholly U.S.	3	7, 9, 11
9	University	Wholly U.S.	1	16

Table 2

Knowledge Access Level Questions

1. My coworkers share their special knowledge and expertise with me
2. If a coworker has some special knowledge about how to perform a task he or she is not likely to tell me about it (reverse coded)
3. More knowledgeable coworkers freely provide me with hard-to-find knowledge or specialized skills

Table 3

Variable Descriptive Statistics and Correlations[a]

		Mean	s.d.	1	2	3	4	5	6	7	8	9
1	**Knowl. Access Lvl**	30.93	9.71									
2	**F-to-F Centrality**	25.08	16.14	.19								
3	**Electronic Centrality**	25.78	18.20	.12	.68							
4	**F-to-F Cohesion**	.39	.21	-.05	-.57	-.45						
5	**Electronic Cohesion**	.35	.16	-.03	-.54	-.63	.72					
6	**F-to-F Diversity**	.46	.36	-.08	.05	.07	.02	-.04				
7	**Electronic Diversity**	.58	.30	-.08	-.02	.06	.11	-.01	.68			
8	**# People Collocated**	8.94	5.68	.21	.53	.31	-.48	-.39	.17	-.04		
9	**Team Size**	17.45	6.45	.06	.43	.39	-.68	-.63	.08	.14	.31	
10	**Task Complexity**	22.94	2.51	.11	-.30	-.49	.16	.39	-.24	-.24	-.18	-.22

[a]Values greater than 0.16 are significant at the 0.01 level; Values greater than 0.13 are significant at the 0.05 level

TABLE 4 Face-to-Face and Electronic Networks and Knowledge Access Level

	Variables	Null Model	Model 1	Model 2	Model 3
	Individual Level[a]				
1	Intercept	**30.65*** (1.24)**	**30.17*** (1.38)**	**29.89*** (1.27)**	**28.94*** (1.48)**
2	F-to-F Centrality		**.14** (.05)**	.01 (.15)	.07 (.17)
3	Electronic Centrality		.01 (.06)	.10 (.12)	.26 (.16)
4	F-to-F Cohesion		6.01 (4.15)	.91 (8.57)	10.04 (10.24)
5	Electronic Cohesion		7.98 (4.86)	**23.8* (10.01)**	**33.71** (12.54)**
6	F-to-F Diversity		-2.07 (2.51)	4.25 (3.93)	7.18 (4.34)
7	Electronic Diversity		.96 (2.64)	-5.91 (4.93)	**-12.34* (5.85)**
8	# People Collocated		**.20** (.07)**	.30 (.20)	.19 (.21)
9	F-to-F Centrality * # People Collocated			.01 (.01)	-.01 (01)
10	Electronic Centrality * # People Collocated			-.01 (.01)	-.01 (.01)
11	F-to-F Cohesion * # People Collocated			1.58 (1.59)	.51 (1.69)
12	Electronic Cohesion * # People Collocated			**-3.27* (1.45)**	**-3.27* (1.43)**
13	F-to-F Diversity * # People Collocated			**-1.11* (.50)**	**-1.29** (.49)**
14	Electronic Diversity * # People Collocated			.98 (.52)	**1.05* (.52)**
	Team Level[a]				
15	Team Size		.25 (.20)	.37 (.23)	**.58* (.22)**
16	Task Complexity		.67 (.51)	.79 (.55)	.50 (.46)
	Cross-Level Interactions[a]				
17	Team Size and F-to-F Centrality				**.03* (.01)**
18	Team Size and Electronic Centrality				-.02 (.01)
19	Team Size and F-to-F Cohesion				**1.86* (.81)**
20	Team Size and Electronic Cohesion				-1.44 (1.00)
21	Team Size and F-to-F Diversity				-.07 (.40)
22	Team Size and Electronic Diversity				**1.16* (.51)**
	Fit Statistics				
23	Individual Level Pseudo-R^2		.04	.13	.20
24	Team Level Pseudo-R^2		.08	.29	.45
25	Deviance	1845.23	1825.18	1826.19	1818.16
26	Deviance Change [b]		20.05*	19.03*	27.06*

* p<0.05, **p<0.01, ***p<0.001. Standard errors in parentheses.
[a]All coefficients are unstandardized
[b] Significance statistic is based on a chi-square distribution with 13 degrees of freedom, .05 level

Figure 1
Electronic Cohesion and Knowledge Access Level by # of People Collocated

-------- Collocated with fewer than 9 team members
——— Collocated with 9 or more team members

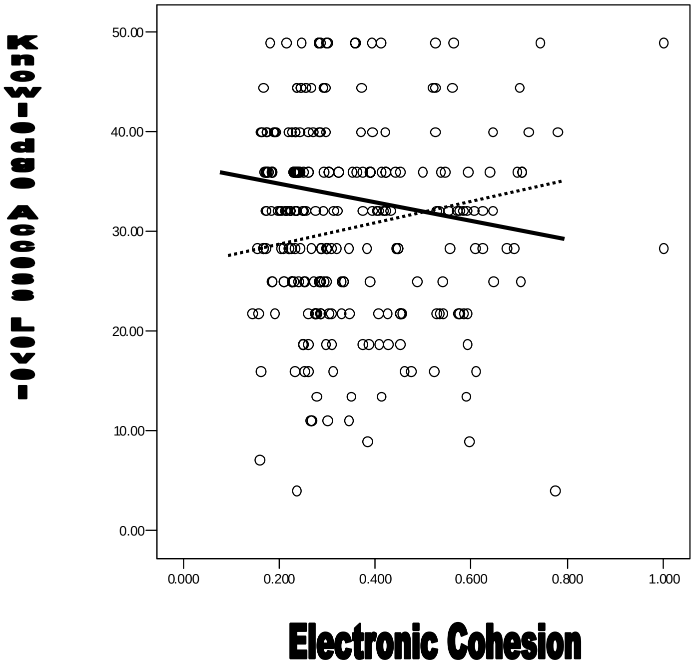


Figure 2
Face-to-Face Diversity and Knowledge Access Level by # of People Collocated

-------- Collocated with fewer than 9 team members
——— Collocated with 9 or more team members

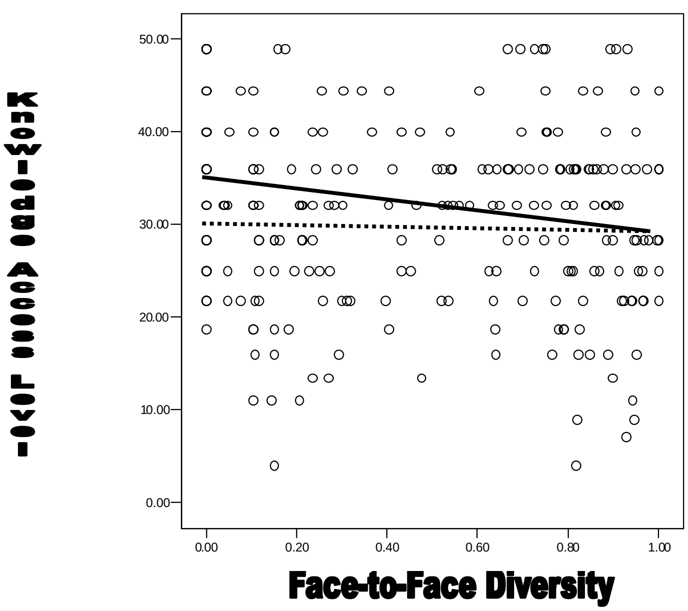


Figure 3a
Face-to-Face Centrality and Knowledge Access Level by Team Size

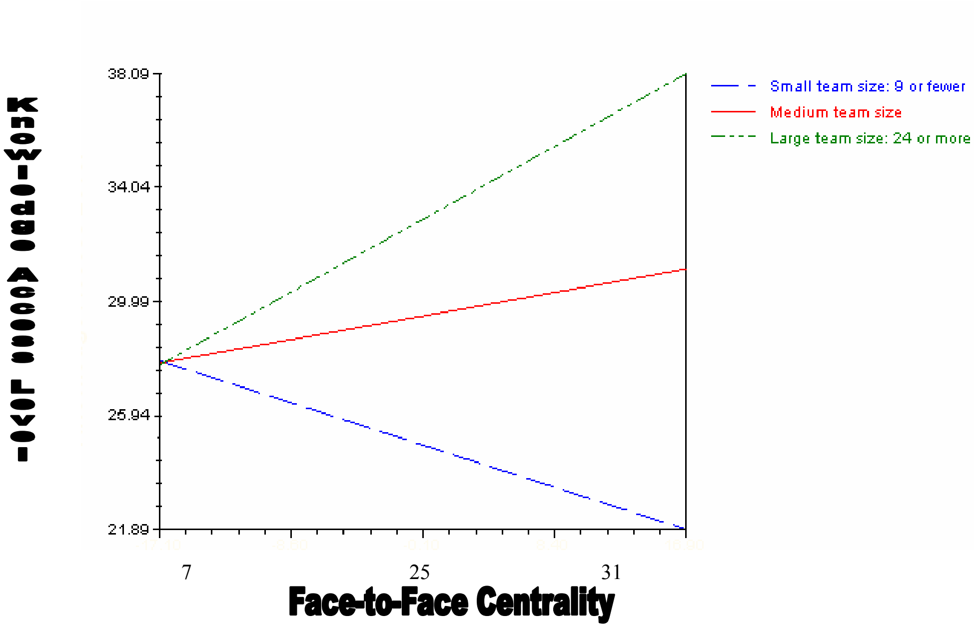


Figure 3b
Face-to-Face Cohesion and Knowledge Access Level by Team Size

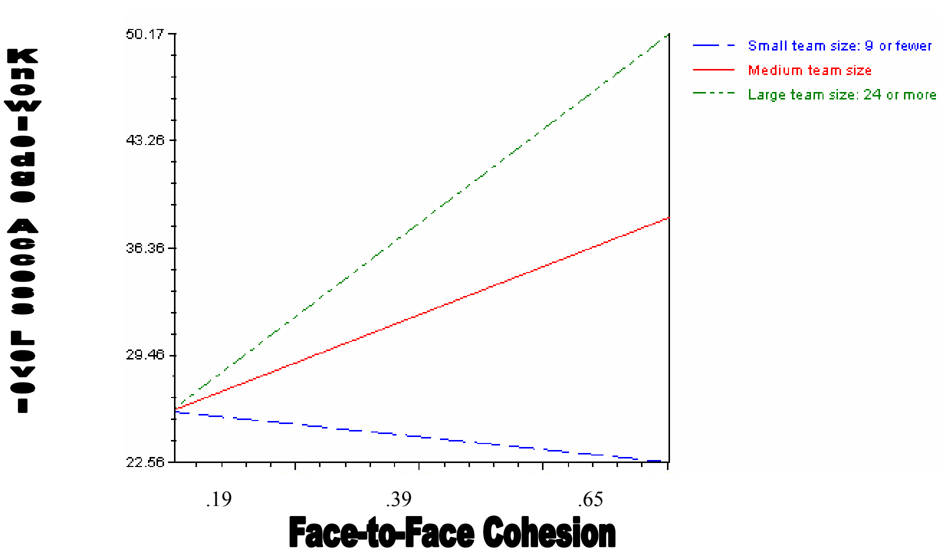


Figure 4
Electronic Diversity and Knowledge Access Level by Team Size

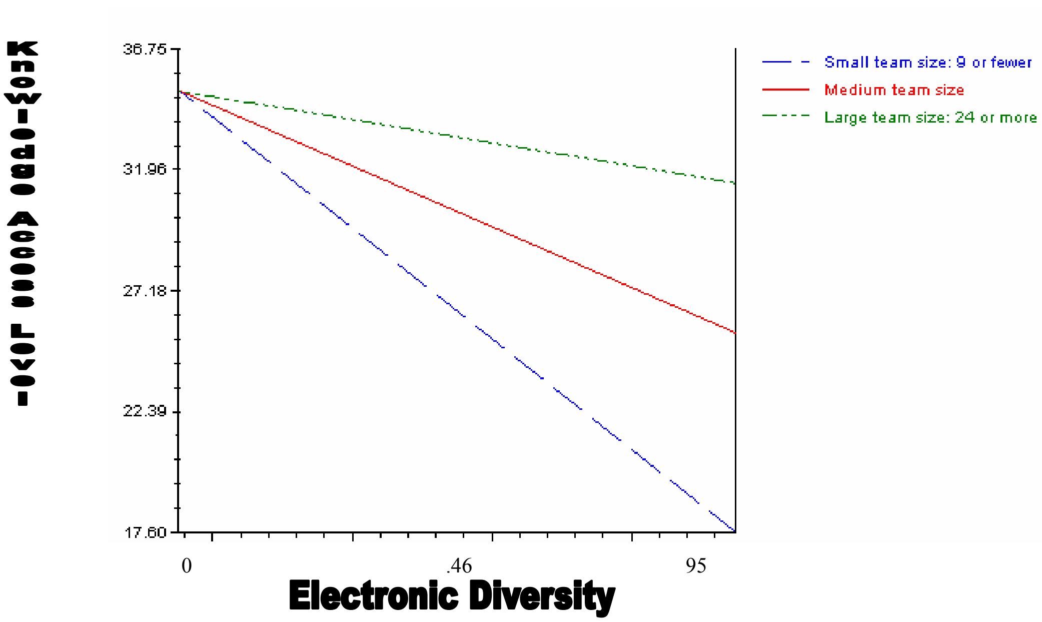
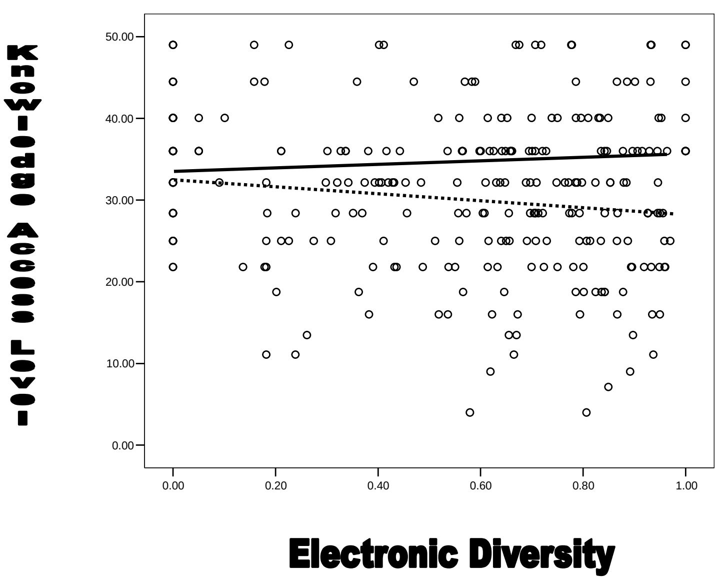


Figure 5
Electronic Diversity and Knowledge Access Level by # of People Collocated

-------- Collocated with fewer than 9 team members

——— Collocated with 9 or more team members



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