Structures that Work: Social Structure, Work Structure and Coordination Ease in Geographically Distributed Teams

Pamela Hinds
Department of Management Science & Engineering
Stanford University
650-723-3843
phinds@stanford.edu

Cathleen McGrath
College of Business Administration
Loyola Marymount University
310-338-4585
cmcgrath@lmu.edu

ABSTRACT
Scholars have recently argued for flatter, organic organizational structures that enable workers to deal more effectively with dynamic and uncertain environments. In a correlational study of 33 R&D teams, we find that although this network form is associated with more smooth coordination in collocated teams, the opposite is true for geographically distributed teams. In fact, an *informal hierarchical structure* was associated with more smooth coordination on distributed teams. These results add to the scant literature on networks in teams and provide insight into important differences in the structure of geographically distributed and collocated teams.

Categories and Subject Descriptors
H.5.3 [**Group and Organization Interfaces**]: Computer-supported cooperative work, organizational design.

General Terms
Management

Keywords
Distributed teams, social networks, global teams

1. INTRODUCTION
An increasing number of work teams have members who are far-flung, often distributed at multiple sites around the globe. Although team members are separated by miles and continents, they must effectively coordinate work and deliver value to the organization. Problem-free coordination, however, can be elusive for these teams and there remains uncertainty about how to optimally structure distributed work to facilitate smooth coordination and effective performance. Anecdotal evidence suggests that dense social networks, dense communication networks [3], and loosely-coupled work structures [33] may aid distributed teams in coordinating their work. However, little systematic research has examined the relationship between these structures and the effective coordination of work on these teams. The goal of the work reported here is to investigate the relationship between social structure, work structure, communication structure, and coordination ease on geographically distributed teams. In doing so, we strive to contribute to nascent research on networks within work teams, particularly adding to our understanding of how structural aspects of geographically distributed teams may differ from their collocated counterparts.

By geographically distributed teams, we refer to teams in which members reside in different cities, countries or continents. Geographically distributed teams, like collocated teams, are groups of individuals who work together interdependently to accomplish a task (e.g., [8]). Attempting to coordinate interdependent work across distances, however, can be fraught with difficulty. Geographically distributed teams experience more miscommunications and misunderstandings [27], have more difficulty sharing information [10,17] and providing feedback [3], and face more challenges in attempting to develop and maintain a shared team identity [30]. Our question, then, is what social and work structures might help geographically distributed teams to overcome these challenges and coordinate their work more effectively.

We argue in favor of using team-level network measures to understand structural aspects of distributed teams. Team-level network measures highlight the dynamics in the team as a whole, enabling us to examine the overall social and work structure within these teams. Using team-level network measures also allows us to examine the relationship between team-level structure and team-level outcomes at the same level of analysis. Previous work that has looked at the performance of distributed teams has focused on the relationships among team members at different locations [23,29]. Although this is an important factor to the performance of distributed teams, we contend that the structure of the whole network linking all members across locations must be accounted for to understand the impact of structure on the performance of distributed teams. We further argue that distributed and collocated teams will gain advantage from different structures because maintenance of those structures brings with it different costs and benefits. Distributed teams, for example, may face significant challenges in establishing and maintaining dense social networks. Therefore, only when social and work structures provide significant value in helping these teams to coordinate their work will these structures result in better outcomes.

1.1 Social Structure
Social networks can foster rapport and trust in work teams [9]. A dense network of social relationships can facilitate group identification and lead to more smooth coordination and collective action [9,37]. On distributed teams, rapport and trust may be particularly important because distance makes monitoring

difficult [21] and scant information about the lives and activities of other team members makes harsh attributions more likely [11]. Geographic distance makes it particularly challenging to create shared understanding [10] and develop rapport. Strong, cohesive social networks, however, may help to alleviate the problems of distance by increasing the extent to which team members give one another the benefit of the doubt and keep one another in mind when making decisions and sharing information [20].

With these ideas in mind, we argue that a dense network of social relationships on distributed teams will be particularly helpful in alleviating coordination problems and improving performance. We anticipate that the benefit of social networks to distributed teams will be greater than the benefits to collocated teams because these networks can alleviate within team conflict and misattributions. We further argue that these benefits will accrue most on distributed teams when links exist between distant as compared with collocated team members, thus building cross-site rapport rather than generating an us versus them dynamic between sites [12].

H1: A dense social network on distributed as compared with collocated teams will be associated with fewer coordination problems, particularly when there are social ties between team members at distant sites.

1.2 Work Structure

Groups and organizational researchers have studied the effects of work structure on team performance for many years. The underlying work structure or structure of interdependence, reflects the flow of work between team members (see [40,43]). Building on Thompson [40], Van de Ven and his colleagues suggested that team work flow can take one of four forms – independent, sequential, reciprocal, or team – each reflecting a greater degree of task interdependence. More organic structures with high levels of task interdependence enable a more dynamic response when teams face ambiguity and uncertainty in their work, when more exceptions arise and when mutual adaptation is required [16,28,40,43]. Burns and Stalker [7], for example, argue that in unstable or dynamic environments, organic, non-hierarchical, informal structure is a more effective way of organizing because it allows workers to communicate based on the changing demands of the task. More recently, Powell [36] argued that this more organic *network form* of organizing is essential for the sharing of know-how, applying the tacit knowledge embedded in workers, and facilitating innovation. He further argued that this form of organizing was most appropriate for a highly skilled labor force. Confirming this, Allen [2] reported that R&D teams were more effective when they were not constrained by a hierarchical structure.

Although we are convinced by these arguments for collocated work, we posit that distributed teams may not be equally advantaged by these organic work structures. Ironically, scholars have argued that the technologies that enable distributed work also will enable the emergence of a network form of organizing (e.g. [47]). These technologies, it is argued, will make it easier to communicate, increase the range of relationships that are possible outside of the formal hierarchy, and increase flexibility (see [32]). The reality, we argue, is somewhat different for distributed teams. As suggested by Nohria and Eccles ([32]: 292),

> The social dimension of organization is especially crucial in the network organization because the type of coordinated action that is required is rarely routine. It has to be novel and imaginative, in tune with the volatile, uncertain, and changing environment confronted by the organization. For this kind of coordinated action, people must act under conditions of great ambiguity of purpose and means to achieve ends. They must negotiate a shared understanding of the context, discover sources of information, decide who can be depended on, distribute work among these people, and develop rules and norms for further action and monitoring progress toward their goals [19].

They further argue that "issues of uncertainty, ambiguity, and risk – the daily fare of a network organization – are difficult to address through electronically mediated exchange" [32: 289-290]. We add that occupying different work and cultural contexts and attempting to surmount time zone differences exacerbate problems for distributed teams. More simply stated, the costs associated with maintaining a network form may overwhelm the benefits that a network form offers to distributed teams. Consistent with this, Ahuja and Carley [1] found evidence of a hierarchical, centralized informal structure in the distributed research network they studied.

In response to the challenges faced by distributed teams, some scholars have argued for *loose-coupling* of work between distant team members [23,33]. Decomposing the task to allow different sites to work independently on different modules may limit the need for frequent communication, thus reducing delays as team members wait to hear back from one another and minimizing miscommunications that might result from interactions about the day-to-day details of the work. Olson and Olson [33] for example, note that distributed teams that modularize their work by site are able to function more smoothly. This observation is consistent with Galbraith's [16] reasoning that self-contained tasks reduce information processing requirements. Based on these arguments, we posit that distributed teams that minimize interdependence between team members at distance sites will experience fewer coordination problems and better performance.

H2a: Distributed teams will experience fewer coordination problems if there is less interdependence between members at distant sites.

Although loose-coupling across sites holds promise as a structural solution for distributed teams, it may not be a panacea. Although teams may not have day-to-day requirements to interact, loose-coupling can mask true interdependences and can lead to more severe problems at the point of handoff [17]. Grinter and her colleagues [17], for example, observed that software development teams that decoupled their work experienced severe integration problems that were extremely costly because they were discovered late in the project. Loose-coupling also may lead to divergent perspectives as team members isolate themselves from one another, making decisions without input or notification. Finally, reducing interdependence between sites may suboptimize one of the very reasons for distributing the work in the first place – taking advantage of distant expertise.

We propose that, in addition to considering the amount of interdependence in distributed teams, it is important to examine how the interdependence is structured. A hierarchical informal work structure, for example, may provide an alternative organizing framework for these teams. Early work suggests that a hierarchical structure of work can increase efficiency [46]. While this early work focuses on formal hierarchy, it is important to note that we are not talking about an authority hierarchy (or bureaucracy), rather an informal hierarchy of interdependence that facilitates the coordination of work among team members who occupy equivalent positions in the formal hierarchy. For example, it would constitute an informal hierarchy if an informal leader emerged who created and managed a project schedule, thus setting up a dynamic in which all team members must go to her to figure out work priorities. Although much of the work on hierarchies refers to authority hierarchies, Simon [39] observed that informal organizations also evolve to be hierarchical. Whether formal or informal, the logic is the same – hierarchy increases efficiency by controlling the flow of information within an organization, reducing redundancy and ensuring that workers have the information they need as they need it [16].

On distributed teams, the costs of communicating are magnified. Distributed teams are known for having difficulties in distributing information evenly, accurately, and when needed [10]. Informal hierarchy can ease the burden by reducing the communication demands on team members. A hierarchy can ensure the flow of information to the right people as it is needed, thus making the flow of work more efficient and effective [16]. An informal hierarchical structure may provide more advantage than loose-coupling because it does not mask interdependence. As Galbraith [16] suggests, when the amount of contact between units increases, a liaison or integrating role, can facilitate the flow of information thus making lateral processes more efficient. Based on this reasoning, we argue that distributed teams will benefit from informal hierarchy whereas collocated teams will have more smooth coordination and better performance when non-hierarchical work structures emerge.

H2b: An informal hierarchical work network on distributed as compared with collocated teams will be associated with fewer coordination problems.

H2c: An informal centralized work network on distributed as compared with collocated teams will be associated with fewer coordination problems.

1.3 Communication Structure

Communication exists alongside and supports the social and work structures within teams. Numerous studies indicate that the emergence of an appropriate communication structure can lead to more productive teams [5,6]. A dense communication structure in a team enables the free flow of information and ensures that knowledge is broadly distributed [38]. The absence of "structural holes" in the communication network also can facilitate team identification and trust [35].

On geographically distributed teams, densely connected communication networks are difficult to maintain. Members of distributed teams rely heavily on communication technologies to facilitate their interactions and often face time zone differences that make it problematic to talk synchronously with one another [44]. Although technologies provide a communication link, people tend to communicate less via technology than when face-to-face [26], enjoy communicating less [23], and engage in less unplanned, spontaneous communication with their co-workers [21,27]. In fact, Van den Bulte and Moenaert [42] demonstrate using longitudinal data that when members of R&D teams are moved closer together, their communication increases. Although distributed team members may interact less than collocated team members, communication remains crucial to the success of distributed teams [3,10,22]. Distributed teams whose members do not communicate frequently and share information evenly with one another are at risk of rampant miscommunications [10], undermining the team's ability to work effectively [22]. Thus, dense communication networks should facilitate coordination and performance on distributed teams, particularly when team members are interacting across sites.

H3a: A dense communication network on distributed as compared with collocated teams will be associated with fewer coordination problems, particularly when there are communication links between team members at distant sites.

Although dense communication networks can lead to more rapport and trust, they also may be less efficient than a more centralized structure. This is particularly true when problems are complex, embedded in dynamic settings, and require a significant amount of unplanned communication [5]. Thus, density in intrateam communication may be beneficial, but its benefits reach a plateau. In an experiment, Guetzkow and Simon [18] observed that even small groups tend to centralize their communication into a wheel structure because it is more efficient and robust. Tushman [41] also observed that R&D teams whose work demanded external communication performed better when they centralized boundary spanning communication in a few team members. The benefits of a more centralized structure, he argued, resulted from increased efficiency in translating across these different contexts. Particularly on a distributed team, too much communication can be costly because of the effort involved in establishing and maintaining communication links [31]. Because of this, some hierarchy in communication, as with work structure, may be necessary to ensure the efficiency of distributed work. That is, it may be more efficient if there are team members through whom much of the team communication flows. We therefore hypothesize that a hierarchical communication structure will lead to more smooth coordination and better performance on distributed teams, although this same benefit may not accrue to collocated teams.

H3b: A hierarchical communication network on distributed as compared with collocated teams will be associated with fewer coordination problems.

2. METHOD

To test our hypotheses, we conducted a web-based survey of geographically distributed and collocated R&D teams located within a single multi-national corporation in the natural resources extraction and processing industry. The surveys were followed by interviews intended to provide a richer understanding of the teams, their work processes, and the challenges they faced. At the time of our study, the organization had recently (3 years previous) decided to increase the global reach of their teams. The leader of the R&D organization had affirmed that "all teams will be global teams." This dictate, however, was not carried out by all managers; providing an ideal opportunity for a comparative study of distributed and collocated teams. In our interviews with the managers who had chosen to keep their teams at a single site, they expressed no strategic or task specific rationale. In essence, managers' reason for collocating team members in the face of this dictate was a more pervasive belief that working as a geographically distributed team was more challenging for team members and, hence, less effective. One of the reasons we were invited into the organization was to assist the leadership team in determining whether or not their decision to distribute teams was a good one.

2.1 Procedure

Initial contact with teams was arranged through a representative who identified teams and team members for us. We then contacted individual team members via email and provided them with the necessary information to access and complete our web-based survey. We augmented the survey data with face-to-face semi-structured interviews conducted with one to two randomly selected members of each team and with as many managers as possible. The intent of the interviews was to assist us in interpreting our quantitative data by learning more about the type of work being done within the teams and better understanding the issues being confronted by members and leaders of these teams.

2.2 Sample

A total of 455 individuals, situated within 49 teams were initially contacted, with a response rate of 64% (289 respondents). We restricted our final analysis to the sample including only teams with at least a 50% response rate and at least 3 respondents. Our final sample consists of 33 teams, ranging in size from three to twenty-one members. Of the 33 teams in our sample, 16 consisted of members who all were collocated with the remaining 17 teams composed of members distributed between two locations in a single campus in Europe and a single campus in the United States. The average team-level response rate for our sample is 74% (SD=.15) with response rates of 74% (SD=.14) and 75% (SD=.16) for distributed and collocated teams, respectively. Distributed teams were larger, with an average of 12 (SD=5.41) members whereas collocated teams had an average of only 8.25 (SD=4.30) members ($F[1,31]=5.89$, $p<.02$).

The teams in our sample were R&D teams. Although all of the teams were conducting basic research, many also were expected to provide technical services to and solve specific business problems for clients within the larger organization. In our sample, teams spent on average 39% of their time conducting basic research, 41% of their time providing technical services, and 19% of their time solving specific business problems. On these measures, there were no significant differences between collocated and distributed teams.

2.3 Dependent Variables

Our dependent measure in this study is coordination ease. It was created using respondents' ratings of the extent to which they faced a set of coordination challenges on their teams. We provided five known issues such as "team members having different priorities" and team members having "incomplete or inaccurate information about what other team members are doing." We asked respondents to rate each of the 5 issues using a 5-point scale anchored by 1 = not at all and 5 = very much. We calculated a mean of the five items to create an individual-level coordination score with high reliability (α = .76). For a team-level measure of coordination problems, we then averaged across individuals in the team, yielding an interrater reliability score of .78. We then reverse scored this variable by subtracting all values from 6, thus creating a measure of coordination ease.

2.4 Independent Variables

To generate a measure of geographic distribution, we used self-report data (verified against the company database) to identify each respondent's office location. We calculated a dichotomous measure of distribution in which teams were considered distributed (=1) if team members were spread across two locations and collocated (=0) if all team members were based at the same location (building or campus). Although, in some ways, this measure oversimplifies geographic distribution by not taking into account the number of locations, time zone difference, and so forth [13], our sample was intentionally selected to minimize variance on these other dimensions. Most of our distributed teams were split between only two sites that were approximately 3000 miles apart. A dichotomous measure therefore is analogous to more complex measures in this sample.

2.4.1 Network Structure

In all of our hypotheses, we include predictions about the informal networks on teams. We therefore created network-level variables to test our hypotheses. In the section below, we describe how we collected the survey data used to calculate the network variables. In all cases, team members were asked to report only on their direct ties with other team members. From respondents' reports of their direct ties, we construct team level networks.

2.4.1.2 Social Structure

Our measures of social relationship include how well team members knew one another and how close they felt to one another. To measure how well team members knew one another, respondents were asked to indicate how well they knew each of the people on their team on a scale ranging from 1= "not at all" to 5 = "very well." We recoded these values to range from 0 to 4. To measure interpersonal closeness, we used a pictorial measure applied successfully in previous research [4]. We provided team members with a set of six graphical representations in which two circles represented the "self" and "other". If the two circles were overlapping, the relationship was "very close," but if the circles were distant, they represented a distant relationship. We asked respondents to select the number that corresponded to the picture that most closely matched their relationship with each of their team members (1 = very distant, 6 = very close). Here we recoded values to range from 0 to 5.

2.4.1.3 Work Structure

Because the teams were self-managed and engaged primarily in basic research, the formal organization of work was flat. However, teams structured their work informally in very different ways. The measure of work relationship that we use captures how much they relied on team members to get work done. To measure the *relies on* relationship we asked respondents to indicate the extent to which they relied on each of their team members to accomplish their work on a scale of 1 = "not at all" to 5 = "heavily." Again, we recoded values to range from 0 to 4.

2.4.1.4 Communication Structure

To measure communication structure, we asked respondents to indicate on average (based on their recall) how often they interacted with each member of their team in face-to-face communication as well as using different communication media including email, telephone, video conferencing, AltaVsita Forum, LiveLink, text-based chat, email, fax, and paper based documents. We then calculated the average across each member of the dyad based on their response of how often they communicated each week using each medium. We then calculated a total communication measure which sums across all communication media. We also calculated a synchronous communication measure which sums face-to-face, telephone, video conferencing, teleconferencing, livelink and chat communication. Our final measure of communication was intended to capture more precisely the network for the sharing of work related information. We measured the extent to which team members *received information* from one another by asking respondents to indicate how often they received, "substantive technical or project specific information from each person on the team" on a scale of 1 = "never" to 5 = "always," which we recoded to range from 0 to 4.

2.4.2 Network Measures

We calculated a series of network measures for the relations described above. Specifically, we consider network density, network hierarchy, network centralization and, for distributed teams, the relative number of cross-site ties. In the following section, we define each of these measures.

2.4.2.1 Density

We calculated density for all of our measures – social structure, work structure, and communication structure. Density measures the average strength of connections among members of the network. It represents the degree to which all members of the team are connected to one another. We compute density as the sum of the strength of all connections in the network divided by the total number of possible connections in the network.

$$density = \frac{\sum_{i,j=1}^{n} x_{ij}}{n(n-1)}$$

where x_{ij} is the value of the connection from i to j.

2.4.2.2 E-I Index

To test our hypotheses about cross-site ties for distributed teams, we adapted the E-I index introduced by Krackhardt and Stern [25]. This measure compares the number and average strength of external ties to internal ties within different groups in a network. For our purposes, *external* ties are those that connect team members at different sites; *internal* ties are those that connect team members at the same site. The E-I scores range from -1 (indicating all ties are between people at the same site) to +1 (indicating all ties are between people at different sites). The scores for social, work and communication ties were calculated as the total strength of cross-site ties minus the strength of within-site ties, all divided by the total strength of all ties. It is important to note that this index is intentionally designed to be independent of network size and density. This enables comparison across different networks and captures *relative number* of external to internal ties.

2.4.2.3 Network Centralization

As a measure of the centralized structure of the network, we use the network centralization measure [15] described by Wasserman and Faust [45]. This captured the extent to which each network had high variance in the number and strength of connections that each individual in the team maintained. Network centralization increases as one person (or a few people) have connections to many others while the rest of the team are connected to only a few people, thus those in central positions are the focal points. We calculated network centralization as follows:

$$C_D = \frac{\sum_{i=1}^{g}\left[C_D(n^*) - C_D(n_i)\right]}{\max \sum_{i=1}^{g}\left[C_D(n^*) - C_D(n_i)\right]}$$

where $C_D(n^*)$ is the largest degree

2.4.2.4 Network Hierarchy

Network hierarchy, like centralization, is a measure of order in the network. We use one of Krackhart's [24] dimensions of hierarchy to count the number of times there is a path from one person to another, but no path back. In other words, "members cannot directly or indirectly reach each other in a reciprocal manner" [1: 745]. This measure is calculated on dichotomized, directed network graphs because hierarchy measures the absence or presence of direct and indirect reciprocal paths. For *relies on* and *receives information* – our two directed measures – we use a response of 2 or above to indicate the presence of a directed path between team members. If a team scores high on network hierarchy for *relies on*, it suggests that the team members depend on and are depended on by a different set of people. Although there are similarities between network centralization and hierarchy, along with others [1], we argue that they are distinct constructs. A centralized network is not necessarily hierarchical. For example, if there are reciprocal ties between a focal node and other nodes, then hierarchy is violated, but centralization remains. Although more likely, a hierarchical network need not be centralized. For example, if information is funneled through multiple nodes (without reciprocity), then hierarchy would be relatively high, but centralization would be low.

2.4.3 Control Variables

Previous research suggests that some types of work are more well-suited to geographic distribution [17,34]. We therefore included the percentage of the time teams spent on three types of work (technical development, business services, and technical services).

The efficiency of communication in a team is somewhat predicated on the extent to which the communication structure matches the work structure. In organizations faced with high uncertainty, communication and feedback among interdependent units enable the sharing of new information and mutual adjustment that are crucial to effective coordination [16,40,43]. Thus, problems in coordination are more likely to arise when people fail to communicate with team members with whom they are interdependent. We therefore control for alignment between communication and work networks when testing for the effect of communication networks on coordination ease. We did this by calculating the Pearson's correlation coefficient between corresponding cells of the communication and *relies on* networks for each team. This calculation resulted in network correlation

Table 1. Descriptive Statistics for Distributed and Collocated Teams

	Mean	Std Dev	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Distribution	--														
2. Density of knows well	2.44	.48	-.26												
3. Density of closeness	2.09	.54	-.21	.72^											
4. Density of relies on	1.76	.66	-.35*	.59^	.76^										
5. Cent. of relies on	2.06	.72	-.11	.14	-.24	.07									
6. Hierarchy of relies	.47	.36	.27	-.41*	-.22	-.40*	-.36*								
7. Density of total comm.	10.45	11.08	-.02	.46*	.53*	.45^	-.04	-.14							
8. Cent. of total comm.	26.87	24.05	-.02	.43*	.28	.34	.22	-.17	.78^						
9. Den. of receives info	1.92	.66	-.42*	.57^	.75^	.89^	-.01	-.36*	.39*	.30					
10.Cent. of receives info	2.02	.76	-.14	-.01	-.24	-.01	.65^	-.10	-.07	.17	-.13				
11. Hier. of receives info	.50	.34	.14	-.57^	-.37	-.59^	-.32	.43	.21	-.33	-.54^	-.35*			
12. Den. of synch comm	6.35	6.45	-.15	.33	.45^	.50^	.12	-.31	.78^	.74^	.47^	.03	-.21		
13. Cent. of synch comm	18.27	18.67	-.05	.33	.23	.29	.28	-.18	.65^	.91^	.28	.18	-.28	.85^	
14.Coordination ease	3.22	.43	-.46^	.32	.51^	.47^	.02	-.15	.48^	.26	.42*	.12	-.08	.64^	.35*

[†] p < .10, * p < .05, ^ p < .01

scores that represent the degree of alignment between teams' networks of communication and networks of interdependence.

Previous research also has indicated that larger teams may experience more difficulty in coordinating their work [14]. We therefore examined the role of team size as a control in all of our analyses. Finally, we examined team tenure (the average number of months the team members had worked on the team) reasoning that teams that had worked together longer would find coordination easier. Our examination of team size and team tenure, however, indicated that neither of these variables was significant in any of the models reported in the tables, nor did they change the pattern of results. For parsimony of presentation and to protect degrees of freedom, we therefore removed team size and tenure from the results presented in the tables. In contrast, in the E-I analyses, team size proved to be a significant predictor of coordination ease. Team size was therefore included in all regression models with E-I indices.

3. RESULTS

Table 1 provides the descriptive statistics for and correlations between our primary variables of interest. As indicated in the correlation table, geographic distribution is associated with less dense work ties (r=-.35, p<.05, for relies on) and less dense information sharing (r=-.42, p<.05, for receives information). There also is evidence that coordination was more fraught with problems on distributed teams (r=-.46, p<.01).

In our first hypothesis (1), we argued that a dense social network would be particularly important to distributed as compared with collocated teams. Our data, however, do not support this. Table 2 contains the regression models with social structure predicting coordination ease. As indicated in table 2, teams in which members felt close to many of the other members reported more ease of coordination (β=.64, p<.05, see model 1b). Although positive, the interaction terms (table 2, models 1c & 1d) predicting coordination ease are not significant, suggesting that distributed teams do not benefit significantly more than collocated teams from dense social ties. Taken together, these analyses provide little support for the argument that social ties will be particularly important on distributed as compared with collocated teams as a means of coordinating work and improving performance.

The forgoing analysis does not examine social ties between distant versus local team members for distributed teams. We argued that it was the cross-site ties that would be most beneficial to distributed teams in facilitating work across sites. To test this, we used the E-I index comparing the number of cross-site and within-site ties on distributed teams only. A high E-I value indicates more and stronger cross-site relative to within-site ties. Our hypothesis suggests a positive relationship between the E-I indices for social ties and coordination ease. In regression analyses with E-I indices predicting coordination ease, however, we found no evidence that cross-site social ties facilitated coordination (β=-.17, n.s. for knows well and β=-.15, n.s. for closeness).

Our second set of hypotheses (2a-2b) focused on the way that the teams we studied structured their work. We examined who relied on whom in our analysis of work structure. In hypothesis 2a, we argued that distributed teams would face fewer coordination problems if they limited the amount of interdependence between members. To test this hypothesis, we examined the density of *relies on*. Density enabled us to investigate the number of work ties among members of the entire team. As indicated in table 2 (model 2b), we found some support for our hypothesis. Although a dense network of interdependence was positively associated with coordination ease on collocated teams, it was negatively associated with coordination ease for distributed teams (β=-.93, p<.10, see model 2b interaction term). As with hypothesis 1, we also argued that cross-site versus local ties are particularly important in distributed teams. We therefore used the E-I index for *relies on* to examine the

Table 2. OLS Estimates for Regression Analyses of Team Social Structure and Work Structure Predicting Coordination Ease

	Social Structure				Work Structure			
Independent Variables	1a	1b	1c	1d	2a	2b	2c	2d
Technical development activities	-.07	-.17	-.17	-.17	-.11	-.10	-.12	-.19
Business services activities	.03	-.23	-.29	-.24	-.07	.05	-.07	-.02
Geographic distribution	-.47^	-.32†	-1.03	-.37	-.34†	.56	.51	-.86^
Density of knows well		-.17	-.31	-.17				
Density of closeness		.64*	.69^	.64*				
Density of relies on					.40*	.60^	.54^	.39*
Centralization of relies on					-.01	.10	.24	-.02
Hierarchy of relies on					.08	.07	.05	-.33
Interaction terms:								
Distribution x density of knows well			.73					
Distribution x density of closeness				.05				
Distribution x density of relies on						-.93†		
Distribution x centralization of relies on							-.86	
Distribution x hierarchy of relies on								.80*
Adj. R^2	.13	.32	.32	.30	.18	.25	.24	.31
F	2.65†	3.79*	3.23*	3.03*	2.19†	2.51*	2.47*	3.03*
Df	*3,29*	*5,24*	*6,23*	*6,23*	*6,26*	*7,25*	*7,25*	*7,25*

† p < .10, * p < .05, ^ p < .01

extent to which ties were cross-site versus within-site (on distributed teams), finding a marginally significant effect predicting coordination ease (β=-.31, p<.10). These data provide weak support for the idea that when distant team members are interdependent, it is difficult to coordinate work and problems result.

In our second hypothesis relating to work structure (2b), we argued that a hierarchical work network on distributed teams, but not collocated teams, would be associated with improved coordination. To test this hypothesis, we examined the degree of informal hierarchy of interdependence as well as centralization of interdependence. Freeman's [15] network centralization index provided a measure of the extent to which ties were concentrated within a few people. Centralization, however, does not consider the direction of the ties, e.g. who is dependent upon whom. Degree of hierarchy, in contrast, considers the direction of the relationship, measuring the extent to which ties are non-reciprocal, with no direct or indirect links back to anyone in the chain [24]. We conducted regression analyses with centralization and degree of hierarchy predicting coordination ease. As with our previous analysis of work structure, we examined who relied on whom. Although we found no significant effects for centralization, we did find strong effects when examining the interaction terms between geographic distribution and informal hierarchy. When predicting coordination ease, the interaction between distribution and informal hierarchy for *relies on* was significant and positive (β=.80, p<.05, see table 2, model 2d), suggesting that distributed teams that structure their work hierarchically may experience more smooth coordination. These data, however, also could indicate causality in the opposite direction. That is, teams whose coordination is going smoothly may tolerate a more hierarchical organization of work.

Our next set of hypotheses (3a-3b) address communication structure in distributed teams. We argue that a dense communication structure will aid coordination and performance in distributed teams (3a), but that hierarchy of communication also might be beneficial (3b) because of its efficiency. To test these hypotheses, we examined total amount of communication among team members as well as amount of synchronous communication among team members, reasoning that team members would be more adept at working through problems and sharing information when engaging in synchronous communication. We also examined the networks for who received substantive project specific information from whom. This measure, unlike the communication measures, allowed a directed graph which enabled us to examine hierarchy of information flow. As indicated in table 3, we did not find support for hypothesis 3a. In fact, the results for our analyses of total communication and receives information suggest that more dense communication among members of distributed teams may interfere with coordination (β=-.58, p<.10, see model 3a and β=-1.26, p<.05, see model 3c interaction terms).

As part of hypothesis 3a, we argue that cross-site communication will be particularly important to distributed teams. Contrary to what we expected, the E-I indices for total communication and asynchronous communication were negatively correlated with coordination ease (β= -.33, p<.10 and β=-.36, p<.05, respectively), suggesting that having relatively more cross-site communication is associated with more coordination problems. Taken together, these analyses also could indicate that more cross-site communication is required on distributed teams because resolving coordination problems takes added effort.

To test hypothesis 3b, we examined the centralization and hierarchical nature of communication on these teams. As with work structure, we found that a more hierarchical structure of *receives information* was associated with more coordination ease on distributed teams (β=.78, p<.05, see table 3, model 3e interaction term).

TABLE 3. OLS Estimates for Regression Analyses of Team Communication Structure Predicting Coordination Ease.

Independent Variables	3a	3b	3c	3d	3e	3f	3g
Alignment [a]	.02	-.01	-.02	.12	-.05	.04	.03
Technical development activities	-.13	-.06	-.38*	-.28	-.32†	-.10	-.10
Business services activities	-.06	-.15	-.03	-.02	-.01	-.02	-.03
Geographic distribution (GD)	-.16	-.34	1.10†	.63	-.89*	-.36†	-.41*
Density of total communication	1.2^	.85^					
Centralization of total communication	-.46†	-.34					
Density of receives information			.77*	.77*	.19		
Centralization of receives information			.46*	.65*	.30		
Hierarchy of receives information			.17	.39	-.33		
Density of synchronous communication						1.13^	1.16^
Centralization of synchronous communication						-.65	-.72^
Interaction terms:							
GD x density of total comm.	-.58†						
GD x centralization of total comm.		-.13					
GD x density of receives info			-1.30*				
GD x centralization of receives info				-.85			
GD x hierarchy of receives info					.82*		
GD x density of synchronous comm.						.05	
GD x centralization of synch comm.							.14
Adj. R^2	.44	.36	.35	.23	.40	.56	.56
F	4.58^	3.62^	3.12*	2.18†	3.56^	6.74^	6.91^
df	***7,25***	***7,25***	8,23	8.23	8,23	***7,25***	***7,25***

† $p < .10$, * $p < .05$, ^ $p < .01$, [a] Alignment is a control variable representing a correlation between the *relies on* network and the relevant communication network (e.g. tot. communication, receives information or synchronous communication) in each team.

4. DISCUSSION

As far as we know, ours if one of the first studies to investigate social and work structures on geographically distributed as compared with collocated teams. Our data provide some support for the argument that loosely-coupled distributed teams will be better able to coordinate their work. Our data also suggest, however, that an informal hierarchical organization of work on distributed teams may ease coordination more than a strategy of decomposing and modularizing the work. These findings illuminate some of the limitations of the *network form* as described by Powell [36]. That is, a more organic, network form of organizing that relies heavily on technology to mediate coordination across distance may be inefficient because ambiguity and uncertainty are difficult to negotiate through existing electronically mediated exchange [32]. Thus, distributed teams, in contrast to collocated teams, may not be able to manage this flexible, organic way of working and may be better served by a hierarchical structure that enables more efficient coordination. Of course, our data are correlational, so cannot establish causality. It is equally plausible that teams that coordinated successfully evolved to a more hierarchical model and not the reverse. Longitudinal studies are needed to better understand these dynamics.

We also examined the structure of communication on these teams, finding that dense communication was associated with *more* coordination problems. Consistent with our findings about work structure, hierarchy of communication was related to smoother coordination on distributed teams. Communication, however, is most efficient when it supports the underlying work structure within the team. Because of the communication challenges faced by geographically distributed teams, we anticipated that a better match between the communication and work structures within distributed teams would ease coordination. To test this, we examined the correlation between the network of total communication and the network of *relies on* for each team. We then ran a regression model with the correlation score, geographic distribution, and the interaction term between the correlation score and geographic distribution predicting coordination ease. Although not statistically significant, the results suggest that alignment between the communication and work structure may be more strongly associated with coordination ease on distributed as compared with collocated teams (β=.70, p<.10), indicating that extraneous communication be more disruptive to coordination on these teams.

Although many have argued for the importance of social ties among members of distributed teams, our data suggest that social ties are not significantly more important than on collocated teams. Social ties were associated with more coordination ease across all teams, suggesting that knowing one another well and feeling emotionally close to one's team members may ease coordination (or that coordination ease creates fond relationships between team members) regardless of distance.

Consistent with the direction of much research on geographically distributed teams, we argue in most of our hypotheses that cross-site ties will be particularly important. To evaluate this, we adapted the E-I index developed by Krackhardt and Stern [25] to enable an examination of cross-site ties relative to within-site ties. We found that cross-site (relative to within-site) interdependence on distributed teams was associated with reduced coordination ease. Similarly, cross-site communication was associated with less smooth coordination. These analyses provide support for the arguments underlying our hypotheses – that cross-site ties on distributed teams may be associated with coordination difficulties. These findings also suggest that focusing on the entire team when examining the structure of distributed teams may be a fruitful avenue for research. The cross-site dynamics are merely one aspect of the way that the structure in these teams plays out and, we argue, without examining the entire team structure, critical interactions are missed. For example, an informal hierarchical structure of work may indicate that liaisons have emerged who direct traffic across sites. Although this is a cross-site phenomenon, it is supported by the funneling of information from the liaisons to workers within sites. Thus, cross-site and within-site networks operate together to facilitate the coordination of work. These findings provide support for arguments in favor of conducting network analyses with team-level network measures, particularly when attempting to understand the relationship between networks and team coordination.

Our findings surface recommendations for managers of distributed teams and for technologies to support these teams. First, our data suggest benefits from an informal hierarchical work structure. In the interviews we conducted with team members, we discovered that some teams found success by assigning liaisons or allowing liaisons to emerge within each site. These liaisons were then responsible for orchestrating cross-site coordination and communication; ensuring that all team members had the information they needed. We also talked with teams that structured their work to minimize interdependence between sites. They often complemented this loose-coupling strategy with informal leaders who were aware of the activities at both sites so that work remained coordinated. A knowledge management system that makes this information available to team members also may help, in essence acting as the cross-site coordinator of information sharing. Second, our findings suggest that a match between the communication network and the informal work network is particularly important on distributed teams. This highlights the importance of making the work structure transparent to team members and encouraging team members to communicate directly with those with whom they share interdependence. This second managerial suggestion suggests an opportunity for technology to support distributed collaboration. CSCW systems that help to track and make visible work interdependencies as they emerge might help distributed workers to better align their communications with the evolving structure of the work itself.

5. ACKNOWLEDEMENTS

This research was supported by NSF Grant #IIS-9872996 to the first author. We thank Mark Mortensen and Jim Blythe for their help with data collection and analysis, respectively, and David Krackhardt, Dan Brass, & Judy Olson for their comments on earlier versions of this paper.

6. REFERENCES

[1] Ahuja, M. K. and Carley, K. M. Network structure in virtual organizations. *Organization Science,* 10, 1999, 741-757.

[2] Allen, T. *Managing the Flow of Technology*. MIT Press, Cambridge, MA, 1977.

[3] Armstrong, D. J. and Cole, P. Managing distances and differences in geographically distributed work groups. In P. J. Hinds, S. Kiesler (Eds.), *Distributed Work*, MIT Press, Cambridge, MA, 2002, 167-186.

[4] Aron, A., Aron, E. N. and Smollan, D. Inclusion of other in the self scale and the structure of interpersonal closeness. *Journal of Personality and Social Psychology,* 63, 1992, 596-612.

[5] Back, K. W. Intervention techniques: Small groups. *Annual Review of Psychology, 25*, 1974, 367-388.

[6] Bavelas, A. Communication patterns in task-oriented groups. In D. Lerner and H. D. Lasswell (Eds.), *The Policy Sciences*. Stanford University Press, Stanford, CA, 1951, 193-202.

[7] Burns, T. and Stalker, G. M. *The Management of Innovation.* Tavistock, London, 1961.

[8] Cohen, S. G. and Bailey, D. E. What makes teams work: Group effectiveness research from the shop floor to the executive suite. *Journal of Management,* 23, 1997, 239-290.

[9] Coleman, J. S. Social capital in the creation of human capital. *American Journal of Sociology,* 94, 1988, S95-S120.

[10] Cramton, C. D. The mutual knowledge problem and its consequences for dispersed collaboration. *Organization Science*, 12, 2001, 346-371.

[11] Cramton, C. D. Attribution in distributed work groups. In P. J. Hinds, S. Kiesler (Eds.), *Distributed Work*, MIT Press, Cambridge, MA, 2002, 191-212

[12] Cramton, C. and Hinds, P. Subgroup dynamics in internationally distributed teams: Ethnocentrism or cross-national learning? *Research in Organizational Behavior*, 26, 2005, 231-263.

[13] Cummings, J. N. and O'Leary, M. B. The spatial, temporal, and configurational characteristics of geographic dispersion in work teams. Paper presented at the Meeting of the Academy of Management, Denver, CO. 2002.

[14] Cummings L.L., Huber, G.P. and Arendt, E., Effects of Size and Spatial Arrangements on Group Decision Making. *The Academy of Management Journal*, 17, 1974, 460-475.

[15] Freeman, L.C. Centrality in social networks: I. Conceptual clarification. *Social Networks*, 1, 1979, 215-239.

[16] Galbraith, J. *Designing Complex Organizations*. Addison-Wesley, Reading, MA, 1973.

[17] Grinter, R. E., Herbsleb, J.D. and Perry, D.E. The geography of coordination: Dealing with distance in R&D work. SIGGROUP Conference, Phoenix, 1999.

[18] Guetzkow, H. and Simon, H. A. The impact of certain communication nets upon organization and performance in task-oriented groups, *Management Science*, 1, 1955, 233-50.

[19] Hackman, J. R. and Morris, C. G. Group tasks, group interaction processes, and group performance effectiveness: A review and proposed integration. In L. Berkowitz (Ed.), *GroupProcess.* Academic Press, New York. 1978, 1-55.

[20] Hinds, P. J. and Bailey, D. E. Out of sight, out of synch: Understanding conflict on distributed teams. *Organization Science,*14*,* 2003, 615-632.

[21] Hinds, P., and Mortensen, M. Understanding conflict in geographically distributed teams: An empirical investigation. *Organization Science*, 2005, 290-307.

[22] Jarvenpaa, S., and Leidner, D.. Communication and trust in global virtual teams. *Organization Science*, 10, 1999, 791-815.

[23] Kiesler, S. and Cummings, J.N. What do we know about proximity and distance in work groups? A legacy of research. In P. J. Hinds, S. Kiesler (Eds.), *Distributed Work*, MIT Press, Cambridge, MA, 2002, 57-80.

[24] Krackhardt, D. Graph theoretical dimensions of informal organizations. In K. Carley and M. Prietula (Eds), *Computational Organization Theory*. Lawrence Erlbaum, Hillsdale, NJ, 1994, 89-111.

[25] Krackhardt D. and Stern, R.N. Informal networks and organizational crises: An experimental simulation. *Social Psychology Quarterly*, 51, 1988, 123-140.

[26] Kraut, R. and Streeter, L. Coordination in software development. *Communications of the ACM,* 38, 1995, 69-81.

[27] Kraut, R.E., Fussel S.R., Brennan, S.E. and Seigel, J. Understanding effects of proximity on collaboration: Implications for technologies to support remote collaborative work. In P. Hinds, S. Kiesler (Eds.), *Distributed Work*, MIT Press, Cambridge, MA, 2002, 137-162.

[28] March, J. G. and Simon, H. A., *Organizations*. John Wiley, New York, NY, 1958.

[29] Moon, Y. and Sproull, L. Essence of distributed work: The case of the Linux kernel. In P. J. Hinds, S. Kiesler (Eds.), *Distributed work*, MIT Press, Cambridge, MA, 2002. 381-404.

[30] Mortensen, M. and Hinds, P. Conflict and shared identity in geographically distributed teams. *International Journal of Conflict Management, 12,* 2001, 212-238.

[31] Nardi, B. and Whittaker, S. The place of face-to-face communication in distributed work. In P. J. Hinds, S. Kiesler (Eds.), *Distributed work*, MIT Press, Cambridge, MA, 2002,

[32] Nohria, N. and Eccles, R. Face-to-face: Making network organizations work. In N. Nohria and R. G. Eccles (Eds.), *Networks and Organizations: Structure, Form and Action,* Harvard Business School Press, Boston, MA, 1992, 288-308.

[33] Olson, G. M. and Olson, J.S. Distance matters. *Human Computer Interaction,* 15*,* 2000, 139-179.

[34] Olson J.S. and Teasley S. Groupware in the Wild: Lessons Learned from a Year of Virtual Collocation. *Proceedings of the Conference on Computer Supported Cooperative Work*. ACM 1996, 419-427.

[35] Portes, A. and Sensenbrenner, J. Embeddedness and immigration: Notes on the social determinants of economic action. *American Journal of Sociology,* 98*,* 1993*,* 1320-1350.

[36] Powell, W. W. Neither market nor hierarchy: Network forms of organization. In B. M. Staw and L. L. Cummings (Eds.), *Research in Organizational Behavior,* 12, JAI Press. Greenwich, CN, 1990, 295-336.

[37] Reagans, R. and Zuckerman, E. Networks, diversity, and productivity: The social capital of corporate R&D teams. *Organization Science,* 12, 2001, 502-517.

[38] Rulke, D. L. and Galaskiewicz, J. Distribution of knowledge, group network structure, and group performance. *Management Science,* 46, 2000, 612-625.

[39] Simon, H.A. *The Sciences of the Artificial* (2nd. Edition). MIT Press, Cambridge, MA, 1981.

[40] Thompson, J. D. *Organization in Action*. McGraw Hill, Chicago, IL, 1967.

[41] Tushman, M.L. Work characteristics and subunit communication structure: A contingency analysis, *Administrative Science Quarterly,* 24, 1979, 82-98.

[42] Van den Bulte, C. and Moenaert, R.K. The effects of R&D team co-location on communication patterns among R&D, marketing, and manufacturing. *Management Science*, 44, 1998, S1-S18.

[43] Van de Ven, A. H., Delbecq, A. L. and Koenig, R. Determinants of coordination modes within organizations. *American Sociological Review,* 41*,* 1976*,* 322-338.

[44] Walther, J. B. Time effects in computer-mediate groups: Past, present, and future. . In P. Hinds, S. Kiesler (Eds.), *Distributed Work*, MIT Press, Cambridge, MA, 2002, 235-258.

[45] Wasserman, S. and Faust, K. *Social Network Analysis: Methods and Applications.* Cambridge University Press, New York, NY, 1994.

[46] Weber, M. *The Theory of Social and Economic Organization*. Free Press, Glenco, IL, 1947.

[47] Zuboff, S. *In the Age of the Smart Machine: The Future of Work and Power.* Basic Books, New York, NY, 1988.