Who Collaborates Successfully? Prior Experience Reduces Collaboration Barriers in Distributed Interdisciplinary Research

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ABSTRACT
Two recent studies of over 500 interdisciplinary research projects have documented comparatively poor outcomes of more distributed projects and the failed coordination mechanisms that partly account for these problems. In this paper we report results of an analysis of dyadic data from the most recent of these studies. The question we asked is, "Does prior experience with a collaborator reduce the barriers of distance or interdisciplinarity?" Analyses of 3911 pairs of collaborators found an answer: "In part, yes!" A prior project with a collaborator predicts greater strength of a current collaborative work tie. Prior experience also reduces the negative impact of distance and disciplinary differences. We discuss the implications of these results for CSCW, given the lack of evidence that today's technology eliminates collaboration barriers in distributed research.

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H.5.3 Group and organizational interfaces. Computer-supported cooperative work. Evaluation/methodology. J.4 {Social and Behavior Sciences} Sociology

General Terms
Management

Author Keywords
Distributed work, virtual organization, interdisciplinary teams, coordination, R&D

INTRODUCTION
Increasingly, teams dominate production in science [34]. These collaborations may be interdisciplinary [28], organize around processes rather than functions [26], create horizontal communities of research workers [10], and use shared computer-based resources such as digital visual representations [5]. Many government agencies, including the U.S. National Science Foundation and National Institutes of Health, and the EU Framework Programme, have sponsored projects involving dozens, and sometimes hundreds, of investigators working together across universities and disciplines in cyberinfrastructure-enabled collaboratories [29].

Collaborations distributed by geography, institutions, and disciplines can experience tensions from the pressures of sheer distance, and from the different ways educational institutions are organized, how faculty are rewarded, and how disciplines are structured [28]. Researchers have reported many barriers to multiple-institution proposals and projects [8]. Resolving conflict and getting on top of problems early is more difficult in distributed than in collocated collaborations; some even end up in court [23]. Given the huge national, institutional, and individual investments in distributed research projects, it is important to understand who works together on these types of projects and what can be done to predict and support their success.

Although CSCW is traditionally concerned with the operational side of group work, a large literature in CSCW (e.g., [17]) and other fields (e.g., [2]) examines how people work together using relationship concepts such as cohesion, interdependence, and team climate. Relationships are important in both collocated research teams (e.g., [1]) and distributed research or R&D [12]. With a few exceptions [3, 21], most researchers examine the group as a whole; they have paid less attention to how each potential pair (or dyad) in a group works together. For example, in a research collaboration, does the computer scientist work with the biologist or only with the other computer scientist on the team? Do those at each university stick together or do pairs work across university boundaries? By examining dyadic relationships in research teams, we might better understand the factors that contribute to collaboration success in distributed research. In this paper, we look particularly at the dyadic relationships in distributed research

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collaborations and how they influence the outcomes of those collaborations.

Problems in Distributed Research Collaborations

We need to be concerned with relationships in research because of changes in the nature of research, particularly today's heavy emphasis on collaboration. These changes have not been smooth and without problems [11]. Some distributed research projects bring multiple partners together as a cohesive whole that attains more than the sum of its parts, but many do not. An example of this point can be drawn from our research on two U.S. National Science Foundation initiatives, Knowledge and Distributed Intelligence (KDI) and Information Technology Research (ITR) [8, 9]. Both of these initiatives supported teams of computer scientists, engineers, and scientists from other fields in research that often spanned multiple institutions.

We examined four kinds of outcomes emanating from the collaborations supported by these programs: *knowledge* (e.g., publications, patents), *tools* (e.g., software, databases), *training* (e.g., Ph.D. students), and *outreach* (e.g., museum installations, school projects). We found that projects involving more institutions were significantly less likely than projects involving fewer institutions to report positive outcomes year over year. For instance, Figure 1 shows knowledge outcomes in the ITR initiative. The figure shows that ITR collaborations involving more universities produced fewer patents, publications, and other knowledge outcomes, especially when more than one discipline was represented in the project. These analyses simultaneously controlled for other factors including number of PIs, project budget, university R&D expenditures, and project length.

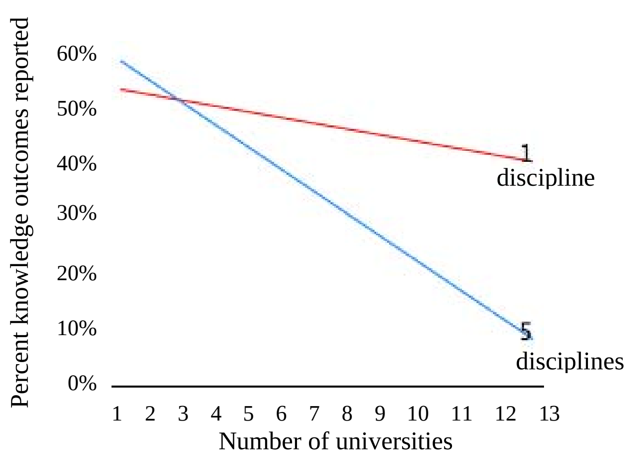

Figure 1. Statistical relationship between number of universities and disciplines, and reported knowledge outcomes. Data from Cummings & Kiesler, 2007.

Why did more distributed projects report fewer good outcomes? We found that the more distributed a research project was, the higher its coordination costs and the more effort it required to sustain strong working relationships. For instance, collaborators at different universities could not depend on running into one another in the hall or a regular face-to-face meeting to share plans and results; they had to arrange travel, plan phone conferences, or exchange frequent email or IM. Other coordination mechanisms they used were to meet at conferences or give talks at each others' universities. Coordination also involved exchanges of information, skills, and knowledge, as happened when collaborators co-advised students or attended each others' research meetings. At a distance, collaborators could send students to a collaborator's lab or even spend a sabbatical at the colleagues' institution, but these steps were often seen as financially burdensome, time consuming, and hard to arrange.

Spiraling Impact of Coordination Failure in Distributed Research

Virtually all of the projects we studied started out with good intentions and a "kick off" meeting. However, relationships in distributed projects at the outset were not as strong as those in collocated projects. In distributed projects as compared with collocated projects, collaborators were more likely to be strangers or mere acquaintances when the project started. (One reason a project is distributed is because the investigators seek out experts from other institutions that they cannot find locally [4].) Thus, distributed team members began with weaker relationships.

Research shows that people who are closer communicate more and gain more from communication [24]. The distributed projects we studied began with an obligation to communicate and coordinate heavily in order to create working relationships. However, due to the costs of coordination, the distributed teams we observed actually reported using fewer of the coordination mechanisms mentioned above (email, meetings, student exchanges, seminars, and so forth). Although they needed to invest in coordination more than collocated teams did, they ended up putting even less effort into coordination. Some distant collaborations fragmented despite good intentions and substantial funding because investigators ended up working mainly locally, with colleagues and students at their own institution. The lack of coordination statistically mediated (explained) poorer outcomes [9].

Importance of Relationships

Prior literature suggests that the use of coordination mechanisms reinforces and sustains relationships. In turn, good relationships foster coordination and the operational side of work. For instance, frequent communication through IM, email, or shared web resources can help team members know what others are doing and what problems they have to solve [6, 33]. Communication also increases attention to others. Without this attention, project management can fall apart and the tasks that team members are doing together may receive lower priority, which can cause further weakening of relationships.

Distributed work tends to disrupt both coordination and relationships. Distance reduces spontaneous interaction, which acts as a kind of "glue" for collaborative relationships [22]. If, on top of distance, the team is made up of people from different universities and disciplines, then team members are likely to feel closer to colleagues in their own department and not as close to those at other universities. They usually belong to local projects (plus teaching and other local obligations) that exert a pull on their time and attention.

We argue that the success of distributed research collaborations is associated with coordination because coordination both determines and signals whether investigators actually work together. Working together means not just putting in time on the task but collaborating in the finest sense of this idea – sharing information and ideas such that the sum of the work is more than the work of both working alone. Although this point has been made before, it is traditionally studied at the group level using statistical averages (e.g., [30]) or exemplary cases [3]). We want to understand how each member of a collaboration works with each of the other collaborators. By doing so, we hope to uncover the reasons why collaborative relationships succeed and fail.

Concept of Collaborative Tie Strength

We draw from theory and research on social networks in organizations to develop a model of collaborative relationships. The model uses the concept of collaborative tie strength – the intensity of working relationships among collaborators on a research project. Tie strength in the organizational literature refers to the intensity of the relationship between two people [14, 31]. Strong ties are characterized by greater frequency of communication and emotional closeness compared with weak ties [25]. Applied to scientists and engineers engaged in research projects, collaborative tie strength is the extent to which two collaborators have engaged in the production of knowledge and new ideas, methods, and resources. It follows that collaborative strong ties have a high level of joint intellectual effort. We operationally define this effort as working directly together on a research project and publishing together. By contrast, collaborative weak ties are pairs who are members of the same research project, but do not work directly together or publish together.

Drawing from the literature, we developed a model to predict collaborative tie strength from three factors that increase or reduce the likelihood of two researchers working closely together. The first two of these explain why distance and interdisciplinarity are likely to reduce collaborative tie strength, and the last explains why prior experience is likely to increase collaborative tie strength.

Proximity

Proximity is defined as the physical distance between two people. When pairs of people reside or work near one another, they have more opportunities to meet face-to-face, to have spontaneous communication, and to interact informally [1, 19, 22]. People in the same location also have access to the same social context, and are more aware of local events and problems that can impede progress in research. They can take advantage of serendipitous events to solve problems, instead of having these problems percolate. For instance, we recently ran into difficulty with the funding of summer undergraduates. One of us happened to run into our provost, and by dint of spontaneous conversation, the problem was resolved. Meanwhile, frustrated distant colleagues at another university sent repeated email messages to unresponsive administrators. When pairs of people work apart from one another, as when they work in different universities, they have fewer opportunities to achieve a level of spontaneous and routine communication that support collaborative tie strength. Thus, we hypothesize that:

Hypothesis 1: Distance will be negatively associated with collaborative tie strength.

Homophily

Homophily is defined as the similarity between two people. People are more likely to interact with others who are similar to them on characteristics such as age, religion, education, and gender [20, 24, 27]. Two researchers who share the same discipline, which often includes common training and education, are more likely to have similar past experiences and goals. Furthermore, researchers who share the same discipline will also read from a similar list of journals, attend a similar set of conferences, and know a similar group of people. Repeated interactions and affirmation of shared interests creates a strong preference for working together. By contrast, two individuals from different disciplines will likely have less in common, which may decrease the likelihood of working together. As a result, we hypothesize that:

Hypothesis 2: Disciplinary differences will be negatively associated with collaborative tie strength.

Familiarity

Familiarity is conceptually defined as how well people know each other, and can be operationally defined as the amount of exposure people have had to each other or the amount of interaction people have had with one another in the past. Greater familiarity reduces uncertainty about how another person will behave in the future [13, 15, 18]. Prior experience can have two effects. First, for those pairs of project members who try to work together and fail to "click," they can abandon their attempt to have a working relationship. This leaves projects with pairs of more successful collaborators because they are the pairs with prior experience (a self-selection effect). Second, collaborators who have had prior experience working with one another in the past become familiar with each other's styles, habits, and preferences, and as a result will more comfortable working closely together in the future (an experience effect). Therefore, because of the self-selection into successful collaborations and the experience gained from working together before, we hypothesize that:

Hypothesis 3: More prior experience will be positively associated with collaborative tie strength.

Moderating Effects of Prior Experience

Above, we argued that physical proximity, similarity of discipline, and prior experience contribute directly to collaborative tie strength. We also predict that prior experience will moderate (interact with) the impact of distance and disciplinary differences on collaborative tie strength. That is, having prior experience will increase the likelihood that when two researchers are in different universities or different disciplines they will work together closely. We hypothesize that:

Hypothesis 4: Prior experience will reduce the negative impact of distance on collaborative tie strength.

Hypothesis 5: Prior experience will reduce the negative impact of disciplinary differences on collaborative tie strength.

Figure 2 summarizes the model of collaborative tie strength, including the hypothesized relationships in the model.

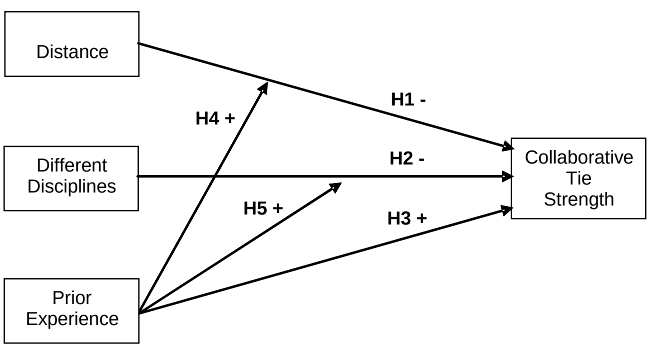

Figure 2. Model of collaborative tie strength.

METHOD

We analyzed social network data in a dataset from our study of the Information Technology Research (ITR) Program of the U.S. National Science Foundation [9]. The ITR program lasted for 5 years, and supported interdisciplinary information technology research and education. The program was a major NSF initiative, growing from U.S. $90M in 2000 to U.S. $295M in 2004. We analyzed data from the Medium projects (up to US $1M per year for five years) and Large projects (up to US $3M per year for five years). Because there was substantial overlap in the actual number of senior personnel and project funding for Medium and Large ITR projects, we combine them into a single analysis. Seventy percent of the ITR projects were funded through the Computer and Information Science and Engineering (CISE) directorate of NSF, and over 50% of principal investigators' disciplines were computer science or electrical and computer engineering.

Sample

The dataset was created from an online survey that asked senior personnel about their working relationships with other senior personnel on their ITR project. The National Science Foundation gave us a list of the "senior personnel" on each project. One senior person per university was surveyed from each project, avoiding duplication so that any one person completed only one survey. Each university involved in an ITR project was sampled. For example, on a project with 3 universities, the most senior personnel at each university answered questions about his or her project. If there were six senior personnel spread evenly across three universities, in the dataset we would end up with 15 pairs (3 senior personnel times 5 other senior personnel) rather than 30 pairs (if all 6 senior personnel responded about all other senior personnel).

There were 2692 senior personnel across 549 ITR projects, including duplications (people on more than one project). Of these, 1302 of the most senior personnel on each project were sent one survey (48%). Responses were received from 885 of those sent a survey, for an overall response rate of 68%. The final sample included 3911 pairs of senior personnel from 475 ITR projects.

Measures

Tie (relationship) strength. Based on survey questions, we calculated collaborative tie strength on a 3-pt scale (1= on ITR project together, but do not work directly together or publish together; 2 = work directly together on ITR project, but do not publish together; 3 = work directly together on ITR project and publish together).

Prior experience. To establish prior experience, we asked "Did you work directly with this person prior to your ITR research?" and "Did you publish a peer-reviewed paper with this person prior to your ITR research?" These questions are a proxy for whether or not the pair had actually collaborated. We measured prior experience on the same scale as tie strength (1 = on prior project together, but did not work directly together or publish together; 2 = worked directly together on prior project, but did not publish together; 3 = worked directly together on prior project and published together).

Distance. We asked project members to tell us how far they worked from others on their team: "Please indicate how far away each person works from you: 1-same room, 2-same hallway, 3-different hallway, 4-different floor, 5-different building, 6-different city, 7-different country." We did not find meaningful differences when looking at pairs within the same building, so we created a 3-point measure (34%

same building; 5% different building, same university; 61% different university). Note that the majority of research projects were distributed across institutions.

Interdisciplinarity. We asked respondents to use a pull-down list of NSF discipline codes to select a "primary discipline" and a "secondary discipline" (over 75% of investigators only selected a primary discipline). Disciplines included computer science, engineering, physics, biology, mathematics, geology, and others. To capture subfield differences we asked, “Please indicate how similar each person's discipline is to yours: 1-same subfield, 2-different subfield, or 3-different field.” We calculated disciplinary difference on a 3-pt scale (1 = same subfield; 2 = different subfield, same field; 3 = different field).

Control variables. Control variables at the project level included project year (2000-2004), number of universities involved in the project (1-13), number of disciplines represented in the project (1-5), proposal funding (logged: US$1,500,000-$15,000,000), R&D expenditure of universities represented in the project (1- 5 ranking based on yearly grant revenue), and whether or not the project was funded through the CISE directorate (1 = yes, 0 = no). Control variables at the relationship level of analysis included whether or not the pair of senior personnel was both male (1 = yes, 0 = no), both PIs (1 = yes, 0 = no), and both full professors (1 = yes, 0 = no). Only four percent of the pairs were both female. The survey did not include a question about when respondents earned their degrees, but we expected that respondents’ academic positions (62% full professor, 16% associate professors, 9% assistant professors, 13% administrators or research scientists) would control for tenure.

Analyses

Because pairs of senior personnel were nested within ITR projects, we used Hierarchical Linear Modeling (HLM) to account for the non-independence of observations [32]. In our 2-level model, we examined pairs of senior personnel on one level (e.g., collaborative tie strength), and the characteristics of their ITR projects on another level (e.g., project year). HLM corrects the degrees of freedom in the model, so depending on the number of variables in the model, there were roughly 3911 degrees of freedom for the relationship-level variables and roughly 475 degrees of freedom for the project-level variables. We examined the statistical significance of the coefficient estimates to determine whether or not the hypotheses discussed above were supported by the models.

RESULTS

The ITR projects made it possible for researchers across the U.S. to work together. Fifty-eight percent of the senior personnel pairs had not worked or published together before their ITR project. Seventy-two percent of senior personnel pairs on ITR projects were separated by distance, and thirty-six percent of the pairs were in different disciplines.

A surprising number of investigators on these projects ended up not actually working together with their collaborators. Pairs of senior personnel were evenly split across those with collaborative weak ties (did not work directly together or publish together = 29%), collaborative moderate ties (worked directly together on project, but did not publish together = 39%), and collaborative strong ties (worked directly together on the project and published together = 32%). See Figure 3 for a comparison of collaborative tie strength by prior experience, which

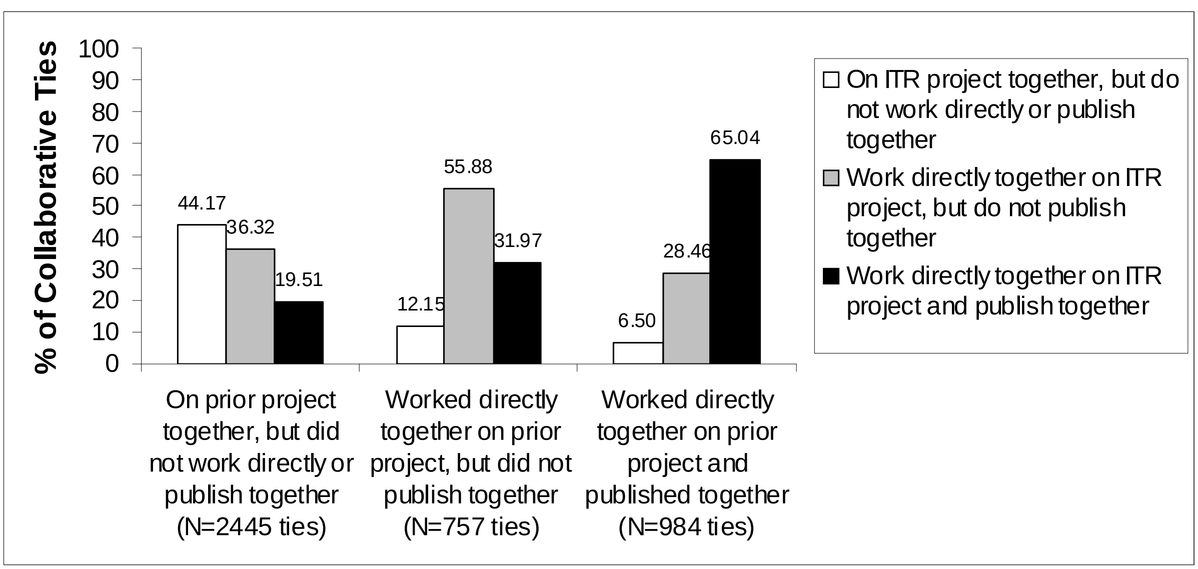

Figure 3. Relationship between prior experience and collaborative tie strength.

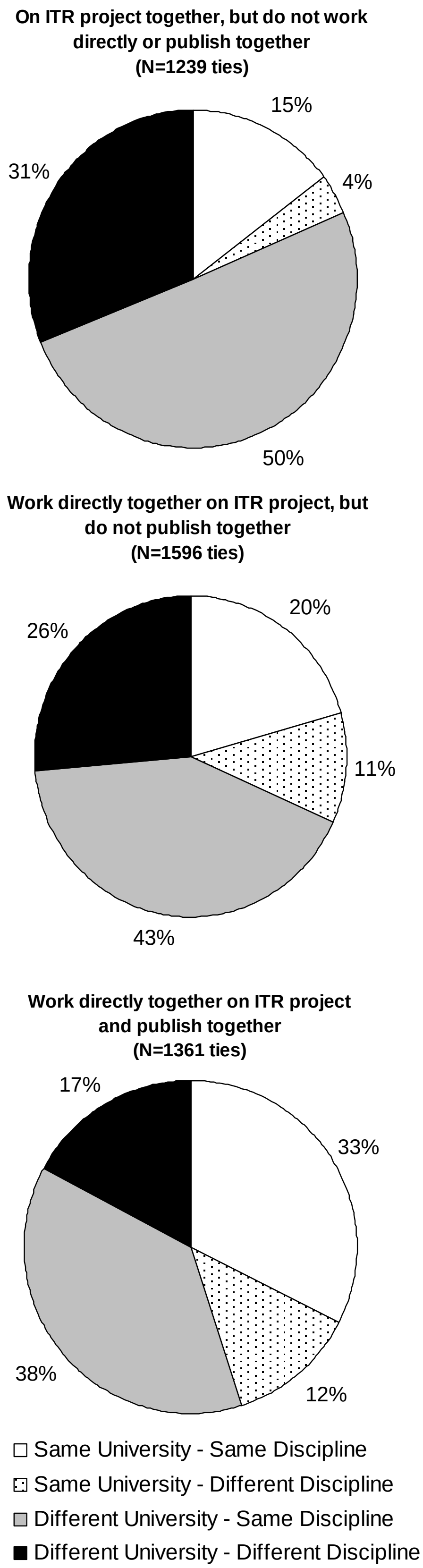

Figure 4. University and disciplinary differences by collaborative tie strength

highlights the positive correlation between having worked together in a prior project and stronger collaboration in the ITR project (r = .44).

In support of H1, distance was negatively associated with collaborative tie strength (H1: B = -6.04, p < .01). In support of H2, disciplinary differences were negatively associated with collaborative tie strength (H2: B = -2.47, p < .05). In support of H3, prior experience was positively associated with collaborative tie strength (H3: B = 23.82, p < .01). See Figure 4 for a comparison of collaborative tie strength by distance and interdisciplinarity, which illustrates that stronger ties are more likely to come from the same university and/or same discipline than weaker ties.

In support of H4 and H5, prior experience reduced the negative impact of geographic distance (H4: interaction B = 3.70, p < .01) and prior experience reduced the negative impact of different disciplines (H5: interaction B = 2.56, p < .05). Furthermore, though not hypothesized in the model, we also observed a three-way interaction such that prior experience reduced the combined negative impact of geographic distance and different disciplines (B = 4.78, p < .01). Overall, the model of collaborative tie strength was supported (see Figure 5).

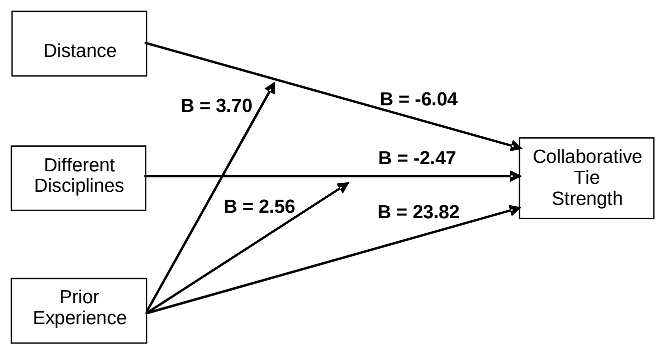

Figure 5. Direct and moderating effects of prior experience on collaborative tie strength.

DISCUSSION

Technology has made it possible to work with others on important problems at a distance. However, forming a team is not the same as being productive. This study followed up on previous findings showing that distance reduces the productivity of interdisciplinary research teams (see Figure 1). To understand this finding better, we used a large dataset to investigate who formed strong ties with others on interdisciplinary research teams and who did not. We found that nearly a third of the senior investigator pairs in the ITR research teams represented in our data did not work with their collaborators or co-author a paper with them.

We also found that prior experience working closely with another project member in the past predicted working closely with that person again. This effect plausibly results from self-selection, whereby poorly matched collaborators abandon their relationships. It also happens because familiarity increases the ease of working with another person. In our study, not only was prior experience the best predictor of collaborative tie strength, but it also facilitated relationships that crossed university and disciplinary boundaries. These findings suggest that when assessing the forces that promote strong collaboration in interdisciplinary and distributed projects, it is important to consider the connections among all project members. If pairs of senior personnel have had no prior experience with one another, then coming from different universities and different disciplines will reduce their chances of developing strong working relationships in subsequent projects.

Limitations

The nature of the data somewhat limit the generalizability of the results. The data from the ITR program are biased toward distributed interdisciplinary research projects that, at least in part, involve computer science. Thus we cannot generalize to all distributed research teams, for example, those purely in physics or biology. (On the other hand, the ITR project teams did have access to some of the most advanced computer-based technologies to support distributed work.)

Another limitation is that geographic distance and being at a different university are confounded in our data, as they are in real life. However, we conducted some internal analyses of projects in which investigators were at different branches of the same university. Being at the same university but separated by branch did not increase collaborative tie strength. Similarly, we looked at collaborations among investigators at institutions in the same city, and still found a negative impact of being at different institutions on collaborative tie strength.

Finally, because we examined within-project relationships, our analyses control for variation in the extent to which projects are collaborative in nature. However, our analyses are limited to the members of research projects who chose one another and to projects that were funded. Our analyses do not speak to the relationships that were not pursued, or to the biases entailed because researchers chose to work on one project rather than another. For example, possibly the best researchers choose each other and left isolates to work with other isolates. Without knowing about senior personnel who were not invited to participate in the proposals, or senior personnel who chose not to participate in a particular ITR project, we cannot say much about the selection of senior personnel into projects. We also have cross-sectional data from one point in time, thus our results are limited to projects with senior personnel who have already been selected, and we cannot speak to the likelihood they will collaborate again in the future.

Implications for Project Organization

Our results should not be construed as implying that researchers should avoid new relationships or that research teams should include only people who have worked together in the past. There are benefits to weak ties and there are risks to avoiding new relationships that our data did not address. Weak ties, new relationships, and newcomers increase the likelihood the project will pursue innovative directions and methods [16]. If all members of a project have prior experience with one another, by definition there are not any newcomers to bring new knowledge and ideas to a project.

We speculate that research projects need to strike a balance between weak and strong ties. Projects need relationships with sufficient prior experience to overcome distance and disciplinary and institutional barriers. They also need to avoid too much inertia in the membership that constrains potential creativity and innovation. Future research is needed on the issue of how much prior experience, or alternatively how many newcomers, are optimal for projects in science and engineering.

Implications for CSCW

Much prior work in CSCW assumes a common set of tools and technologies that groups or teams use together ("groupware" being a prime example). We speculate, however, that in the case of research projects, distributed project members are likely to use different tools and technologies with different members of their research project. People in the same discipline will share tools that others do not use. Collaborators at the same university, due to the kinds of common computer systems, applications, and networks their department or institution has adopted, are likely to use the same technologies and common tools. Collaborators at other universities are less likely to be as comfortable using these tools, if they don't use them routinely at their own institution. It follows that instead of a common suite of software for the entire project, pairs of members are likely to adopt and use software with each other in familiar ways.

Shifting the lens of CSCW research from group technology use to dyadic technology use could shed light on why prior experience for dyads (rather than groups) can have a strong impact on the success of distributed projects. Pairs of people with prior experience (compared to pairs without prior experience) will have established norms of use, types of computer-mediated interactions that work for them, and effective patterns of communication and coordination. This argument also suggests that CSCW researchers, without abandoning their focus on groups, should also be looking at how pairs of people within groups use technology to support group work, and the linkages between dyads and the larger group.

As an illustration of the dyadic perspective, Figure 6 shows collaborative tie strength among pairs of project members on one research project in our dataset. In this example, a solid line indicates a collaborative strong tie, a dashed line indicates a collaborative moderate tie, and no line indicates a collaborative weak tie. Here, E.F., the principal investigator of the project, has a collaborative strong tie with A.B. and C.D., a collaborative moderate tie with G.H., and a collaborative weak tie with I.J. What is clear from the figure is that some members (e.g., I.J.) are comparatively isolated from the other members, whereas other members (e.g., A.B., C.D., E.F.) are well connected and form a subgroup. Aggregating collaborative tie strength to the group level of analysis misses out on the nuances of who is successfully collaborating with whom on the research project, and the procedures, norms, and technologies they are using to coordinate their work. In some cases, a dyadic perspective will better capture the frequency and quality of interaction among project members, and the ways in which they are supported by their use of computer-based technology.

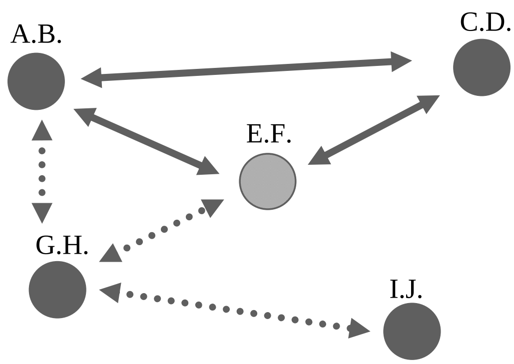

Figure 6. Dyadic perspective on work in groups.

What the above argument also suggests is that the diffusion and adoption of technology is likely to be very uneven across institutions, projects, and individuals. This heterogeneity in availability and use of new communication tools (e.g., high resolution video, wikis, conferencing websites) and other shared tools (e.g., manipulable visualizations) poses a problem for distributed projects. When project members have not met or worked together before, the chances increase that their previous exposure to various tools and technologies is non-overlapping. When coming together for the first time, instead of exploring the use of new technologies, it is more likely that project members shift to the lowest common denominator (such as email and phone) to meet their communication needs. By understanding the tools that members use with collaborators within and outside of the projects, we get a broader sense of which tools were adopted as a result of working in new collaborations.

Dyadic technology use and its relationship to group technology use can be studied in the same way that collaborative tie strength was studied in this paper. The above issues raise a number of interesting questions for future CSCW research on these linkages. When does dyadic technology use support the group as a whole rather than cause the dyad to split off? When does dyadic technology use lead to greater group effectiveness, and when does it undermine the group effort through escalation of use by different pairs of members? When does dyadic technology use lead to adoption by the rest of the group, and when does it cease to exist? When new members enter the group, how is dyadic technology use negotiated with the old members?

From CSCW to Virtual Organization

Virtual organizations that involve large-scale cooperative work across people employed by different institutions are going to be more popular for doing some kinds of research that could not be done before. They will bring together talented specialists who would be otherwise separated into their so-called “silos” of research and allow for the joint use of otherwise expensive common resources.

Our research suggests that for virtual organizations to be effective at bringing together diverse sources of expertise, it will be important that members freely share ideas and perspectives. Differential use of technology within a virtual organization can present a barrier to open exchange and discourse. For example, if only some members of the virtual organization have easy access to large screen video conferencing, or only some of the members check the wikis, or only some of the members use IM regularly, then the distribution of knowledge will be uneven. This problem is exacerbated even further when some pairs of members within the virtual organization have stronger working relationships than other pairs of members. It is unrealistic to think that all pairs of members will be equal in their prior experience. Thus a virtual organization (and accompanying technology use) can be fractured further by the tendency for individuals to pair off rather than focus on the larger collective.

We believe that research on innovation in virtual organizations, and technology to support innovative teams, is critical to the future success of this type of work. Innovation in a virtual organization is the product of generating and implementing new ideas. Ideas that are generated but not implemented do not add value to the virtual organization as a whole. To maximize chances for innovation, it may be important to have some pairs of members who are diverse in their background (e.g., different disciplinary training) and other pairs of members who have a common understanding (e.g., prior experience working together). Having diverse background without common understanding could lead to new ideas without the follow-through to implement. Alternatively, having similar backgrounds with a common understanding could lead to productivity that is not very innovative. Today’s technology may be better for supporting the generation of ideas from pairs of members with different backgrounds, but may not be as effective for implementing these new ideas. In other words, there may be different phases of the innovation process in virtual organizations in which technology is best suited to achieve desired outcomes. Focusing on pairs of members, and how they achieve their goals through technology despite barriers to collaboration, will move us towards a better understanding of success in virtual organizations.

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