Relating Electronic Mail Use and Network Structure to R&D Work Networks and Performance

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ABSTRACT: This study analyzes computer-monitored and self-reported electronic mail usage and network data collected over time from mentors and their summer interns at an R&D organization. Amount and network measures of E-mail usage were significantly associated with work and work familiarity networks. As time passed, interns communicated through E-mail more outside their formal mentor–intern relations. However, amount of E-mail use and most E-mail network measures (such as centrality) were not related to mentors' assessments of interns' performance several months later. An intriguing exception was how interns were located in the overall E-mail network. Surprisingly, overall, most forms of communication were negatively associated with performance ratings. These results imply that it is not necessarily how much one uses an E-mail system, but how the users are positioned in that system's structural context, that may affect R&D performance.

KEY WORDS AND PHRASES: diffusion, electronic mail, implementation, information systems, network analysis, organizational computer-mediated communication, organizational structure, R&D networks, R&D performance.

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Problem Statement

RESEARCH AND DEVELOPMENT (R&D) ACTIVITIES ARE INHERENTLY UNCERTAIN, equivocal, and difficult to coordinate. Therefore, appropriate group and project communication is crucial to R&D performance [3]. But traditional communication channels—face-to-face conversations and meetings—are too formal, and too constrained by scheduling and distance, to fully support the spontaneous, informal, collaborative communication neccessary for R&D work [26]. Computer-mediated communication (CMC) may help overcome these temporal, physical, and formal obstacles. However, there is little empirical research on the general issue of whether it improves R&D performance.

Further, an important unstated assumption in much prior E-mail research is that these and other effects occur primarily at the individual level, and are due simply to use of the technology. However, a CMC system represents a form of communication among a network of organizational members, rather than simply a technology for accomplishing isolated actions by individuals. As Kling noted [24, p. 87], "The ways in which computer-supported collaborative work systems restructure social relationships at work, if at all, depends on pre-existing patterns of authority, obligation, and cooperation, and an organization's openness to significant change, as well as the technology's information-processing capabilities." And Albrecht and Ropp [1] argue that innovativeness, especially in collaborative R&D groups, is not an individual trait, but a product of complex interpersonal interactions within a system. There is even less research on the particular issue of whether structural patterns (networks) of system use among participants indeed matter.

This study first assesses whether the amount and pattern of E-mail usage in a R&D organization are associated with more general work communication networks and familiarity with others' work, comparing results for mentors with those for interns. Then it considers whether the amount and pattern of E-mail use influence mentors' ratings of the interns' performance.

The Importance of Traditional and Computer-Mediated Communication Channels in R&D Organizations

COLLABORATION WITHIN R&D LABORATORIES RELIES ON BOTH FORMAL and informal communication, within and across project boundaries, and across physical, temporal, and status boundaries [3, 49]. The ability of R&D researchers or project groups to realize their goals depends on how well information is acquired, interpreted, synthesized, evaluated, and understood, and on how well information channels support these processes [2]. For example, Allen [3] found that higher-performing groups and higher-quality solutions involved more internal consultation, greater communication with fellow project members, greater reliance upon colleagues within the organization but external to the project, more diverse contacts, and greater contact with others outside their speciality. In general, satisfying, enduring, and effective work relationships, especially for newcomers to an organization, require the development of "mutual expectations" about the nature of the task, how to work together, and how to work independently on a joint task [3, 15, 25].

The primary and traditional means of acquiring knowledge and becoming socialized in organizations is through face-to-face interactions with co-workers [12]. Initial interactions and assessments are often based upon institutionalized roles such as formal superior–subordinate relations rather than actual working relationships. Formal communication—such as project meetings, scheduled work sessions, and progress reports—tends to be used for coordinating relatively routine transactions within groups and organizations.

Yet, much of R&D research is uncertain and ambiguous—involving managing and reducing the uncertainty in both production and social relations [e.g., 47]. And such processes are more difficult among individuals who are physically distant, experience greater uncertainty and project complexity, do not interact frequently with one another, have different subgroup norms, experience obvious and salient status differences, are limited to formal communication channels, and experience constraints of distance and scheduling [49], or are newcomers.

So, relying solely on formal and temporally or spatially constrained communication can limit the development of realistic mutual expectations, and, further, may emphasize formal, asymmetrical status relations, leading to decreased self-disclosure and trust. Thus, greater, more informal, and more diverse communication seems necessary in the face of such uncertainty, equivocality, and complexity [10]. Informal contacts provide direct solutions and solutions previously developed by others, explanations of procedures, a wider domain of attention, and the opportunity for browsing, which may lead to innovations, verification of answers, and help in defining operational environments [3]. Weak ties, especially between members of different work groups or among those not well acquainted, facilitate greater diffusion of ideas [18, 29].

However, informal and diverse communication typically occurs only if R&D participants are physically close [27]. This is not only because proximate members are more likely to "bump into" each other as they pass through hallways or go to social or formal activities, but also because the costs of intentionally accessing others is lower when there are fewer physical or temporal obstacles [41]. Without such opportunities, many collaborations would undoubtedly not occur and others would break down before achieving their goals [26, 27], while other task-focused small groups would likely become isolated [31].

Thus, other communication channels than formal, status-related relationships, or printed or interpersonal channels that involve temporal and geographic obstacles, are necessary for effective and successful R&D collaboration [17]. Albrecht and Ropp [1] argue that communication with diverse others (e.g., across departments, formal superior–subordinate hierarchies, or other content areas) increases knowledge and resourcefulness and reduces uncertainty about organizational activities. Papa and Papa [28] found that network diversity, size, and integrativeness all predicted the speed with which employees adopted an unofficial but effective way of using a new computer system. Tushman and Romanelli [51] found that one's location in technical, research, and informal networks contributes to one's influence. Thus, individuals who become more central to the overall network are more likely to experience increased influence, and, in turn, satisfaction with and performance from the collaborative process. Groups with more individuals who bridge group boundaries (especially in uncertain or interdependent task conditions) tend to have higher performance [49, 50].

One way organizations might attempt to overcome some of these communication obstacles is by implementing CMC systems such as electronic mail (E-mail) [4, 30, 33, 35, 39, 44, 45] and computer-supported collaborative work and groupware [7, 11, 16, 20, 23, 32]. E-mail can overcome physical and situational constraints associated with face-to-face communication, scheduled meetings, and distributed work environments [33, 37]. E-mail can support an increased amount and diversity of communication with others, and awareness of others' work [20, 44, 46]. Members of E-mail groups communicate more among themselves and therefore should be more likely to know of relevant R&D work in the organization. E-mail can help prevent task fragmentation by allowing individuals to send and receive messages and respond when it is more convenient and they are more prepared. Thus, E-mail use could potentially improve communication, familiarity with others' work, understanding of how work is accomplished, and subsequently R&D performance.

However, increased communication is not an unalloyed good. Project managers may lose direct touch with activities managed through E-mail, E-mail users may experience overload [21] or may become part of isolated electronic "cliques" [31], and increased access to one user by other people "on the network" can lead to a loss of individual control and privacy [48].

Thus, we need to better understand whether and how amount and patterns of E-mail use are associated with traditional communication channels, and with R&D performance.

Focus of Study and General Research Questions

TWO DIFFERENT ASPECTS OF E-MAIL COMMUNICATION and its relation to R&D communication and performance will be considered. If the force of a technology lies primarily in its use by individuals, then simply the amount (total usage) of E-mail communication should be positively associated with work communication, and should positively influence performance. However, if organizational communication structures set the context for the use of E-mail communication, then the structure of E-mail communication networks should be associated with work communication and performance. The prior discussions lead to two sets of general research questions and their specific hypotheses.

RQ1: Influence of E-Mail Use and Network Structure on Other Communication

To the extent that E-mail overcomes physical, temporal, or organizational boundaries (such as status differences), more active and more central E-mail users are likely to communicate more about work-related topics, may become more aware of others' work, and may communicate more outside of formally prescribed roles (such as mentor–intern relations).

H1a: The greater the amount of E-mail messages one sends and receives, the more one will communicate with others about work, and be familiar with others' work.
H1b: The greater centrality in one's E-mail network, the more one will communicate with others about work, and be familiar with others' work.
H1c: The E-mail communication network will be associated with the work communication network and the work familiarity network.
H2: The E-mail communication network will be less associated with formal mentor–intern relationships, compared with the association of the work communication network with formal mentor–intern relationships.

RQ2: Influence of Communication Amount and Network Structure on Performance Ratings

Interns who communicate more and who are more central in communication networks may be more likely to understand the norms, work-related resources, related technical solutions, and knowledgeable others in their organizations, leading to higher performance ratings by their mentors. And members of communication cliques should exhibit higher performance.

H3a: The greater an R&D intern's amount of work communication and familiarity with others' work, the higher the intern's performance rating.
H3b: The greater an R&D intern's centrality in work and familiarity networks, the higher the intern's performance rating.
H3c: The greater an R&D intern's use of E-mail communication, the higher the intern's performance rating.
H3d: The greater an R&D intern's centrality in an E-mail network, the higher the intern's performance rating.
H4: Members of network groups will have higher performance ratings than will nonmembers.

Method

Research Design

DUE TO PRACTICAL DIFFICULTIES AND CONCEPTUAL FLAWS, many studies of organizational CMC systems suffer from weak research designs [11, 52]. This study attempts to overcome some of the typical limitations by analyzing communication among mentors and interns at multiple time periods, and by using multiple sources of data.

The study took place at a technical R&D organization. The particular organizational unit studied brings in advanced student interns from various disciplines for a ten-week summer period to work on specific projects with assigned mentors who are members of the permanent research staff. Interns are expected to make a defined contribution to their project and, at the end of their time, to compile a report on what they did and accomplished. During the program, the interns and mentors get to know each other in both social and work terms, and the interns get an idea of the organization's culture and mores. Both of these mechanisms allow each party to assess, in part, the potential for future employment.

There were 25 *interns* each assigned to one of 23 *mentors* in the present study population (in three instances, two interns were assigned to one mentor, and in two instances, one intern was assigned to two mentors; one other mentor dropped out of the study, and two interns had no assigned mentor in the study sample). "Intern–mentor" relations refers to relations between specific interns and their formally assigned mentors; "newcomer–veteran" relations refers to relations between interns in general and mentors in general.

These summer interns were selected for their technical expertise and academic record, and have considerable familiarity with computers. They were provided accounts to a standard UNIX electronic mail system as part of their full complement of office resources upon organizational entry. The system provided standard features such as reply, forward, copy, and delete, but no extended features such as conferencing or voice annotation, and was integrated into the operating system of the desktop workstation. The interns had no difficulty using the UNIX-based system in this configuration.

Data Sources, Measures, and Procedures

Questionnaires containing network rosters were administered halfway through the summer program (T2) and at the end (T3) to all participating veterans and newcomers. Continuous computer-monitored usage data from the E-mail system were also collected.

Reported Networks from Roster of all 48 Individuals, on Questionnaires[1]

Work network: "How frequently do you communicate with this person about work projects? Examples: discuss the project(s) you are working on, actually work together, exchange project information, check up on the status of project-related activities, discuss goals and procedures for accomplishing your project-related tasks, etc." This is an asymmetric matrix with cell values that contain from 0 = not rated, 1 = less than once per month, to 7 = several times per day ($n = 45$ respondents at T2, 46 at T3).

Familiarity network: "To what extent are you familiar with the details of what the following people are working on?" This is an asymmetric matrix with cell values that contain from 0 = not rated, 1 = very unfamiliar, to 5 = very familiar ($n = 45$ at T2, 46 at T3).

Both of these are typical ways of collecting communication and familiarity network data [14, 42, 43]. There is no measure of reliability within a particular network matrix because it is a single measure, and indeed there is even considerable debate as to how accurate self-reported (or "cognitive") network data are compared to observed or archival ("behavioral") network data [5, 34]. However, as noted below, the patterns of these matrices are stable across time and highly correlated with a social communication network,[2] indicating test–retest reliability and predictive validity. Further, we are primarily concerned about relative amounts and patterns of communication, not absolute values. Network accuracy research indicates that respondents' cognitive data fairly well represent typical and underlying communication structures, if not specific interactions at specific times.

Archival and System Networks

Intern–mentor network: Based upon formal project assignment, this is a symmetric matrix that has a cell value of 1 if the mentor and intern are assigned to each other, and 0 if not ($n = 48$).

E-mail network: Each data point collected by the E-mail system included the account name of the sender and of the receiver, and the date the message was sent. All data up to T2, and then between T2 and T3, were aggregated into two asymmetric sender-to-receiver matrices, where the cell value was the total number of messages sent from a particular sender to a particular receiver during that period (diagonal values excluded) ($n = 48$ at T2, T3).

Taking advantage of the computer component of a CMC system, one can unobtrusively collect usage and network data from a full census of users as well as from multiple or continuous time periods, as long as participants have provided permission or the data are inherently public. One disadvantage of such data is the ease with which large amounts can be collected, requiring appropriate programming skills and disk storage space. While self-reported usage and system-collected usage data are usually moderately but significantly correlated, they represent different conceptualizations, aspects and measures of usage (see [31, 34, 41] for more detailed discussions). The implication for the present study is that the present measures of E-mail use and E-mail networks are reliable and complete behavioral measures of system usage and network relations. Thus, threats to the internal validity of analyses involving these data are reduced.

Postproject Mentor Survey

Perceived intern performance was measured by four questions asked of each mentor, about their assigned intern(s), a few months after the summer project ended. The four questions were developed by the organizational contacts for this study, and asked: (1) how the intern compared to other interns, (2) how the intern's project turned out, (3) whether the mentor would hire the intern again as an intern, and (4) whether the mentor would hire the intern permanently (all from 1 = poor, low, or no, to 5 = outstanding, very well, or yes). These items loaded on a single principal component, explaining 72 percent of the variance, with an alpha reliability of 0.74, and a mean of 4.02 (s.d. = 0.83).

For mentors, this measure indicates the *mentors'* ratings given *for* their intern(s) (averaged over multiple interns when necessary). For interns, it indicates the ratings the *interns* received *from* their mentor(s) (averaged over multiple mentors when necessary).

Network analysis methods were used to create several measures and to perform some of the analyses. Network analysis is the study of patterns of relationships (such as communication, superior–subordinate, or awareness of colleagues' work) among entities (individuals, groups, organizations) [40, 42, 43]. Precisely because both R&D project work and CMC involve relationships, network concepts and methods are theoretically appropriate (see, for example, [8, 11, 34, 36, 38]).

Derived Measures

From each network matrix at each time period, three sets of measures were derived—individual-level usage amounts, individual-level network betweenness centrality, and network-level structural measures.

The first set of measures is simply the total amount of communication of each type for each individual (the total of a network matrix's row or column, excluding the diagonal). Thus, we have total work communication, total work familiarity, and total E-mail messages sent or total E-mail messages received. High levels of use and a strong effect of E-mail usage are both probably unlikely within this short period of time. There were about 20 business days within each time period, so average users sent and received about 3.5 messages per day. As is typical, there were high and low users: the range of messages sent was 0–175 at T2 and 1–163 at T3, and the range of messages received was 0–80 at T2 and 2–243 at T3.

The second set is the individual-level network structural measure of betweenness centrality in each network, which is the proportion of all the geodesics (shortest binary paths from i to k) that pass through j, summed over all i's and k's for a particular j [13]. Betweenness centrality is a theoretically appropriate measure of network position for this study because it represents the extent to which each individual lies along the paths of communication among the network members, and thus indicates the extent to which each individual is more or less likely to become aware of useful information, resources, norms, or contacts.

The third set of measures includes four network-level structural measures (computed from the network matrix). One is the mean network betweenness centrality, the average centrality for the network as a whole. The second is network density or the percent of present links relative to the maximum links possible. A third network-level measure is the location of individuals in multidimensional space. The fourth is identification of network cliques of densely connected individuals.

Network Analysis Procedures

Betweenness centrality and density were calculated using the UCINET network analysis package [6]. These individual-level usage and network measures were then used in correlation and multiple regression analyses.

Parametric statistics are inappropriate for comparing network matrices, however, because the rows and columns are not necessarily independent. The accepted approach is first to re-organize each matrix into a vector and then to compute the correlation between the two vectors, to produce a familiar measure of the strength of association. Then, UCINET's Quadratic Assignment Procedure (QAP) [22] is used to determine the significance of the association by means of a nonparametric gamma association significance test (derived from a distribution of possible associations between one matrix and all permutations of the other matrix).

Multidimensional scaling (MDS) was used to portray the relative positions of users in the E-mail network space, based on their similarity of communication patterns with all other users. At each time period, first the E-mail network was transposed and concatenated to the original matrix. This allows both sending and receiving of messages to be taken into account. Then the columns of this $2N \times N$ matrix were correlated (ignoring diagonals). The resulting $N \times N$ correlation matrix was reversed to convert it into distances, and then submitted to MDS. Results include the two-dimensional coordinates for each E-mail network participant, for use in plotting and regression analyses.

The linkage-based NEGOPY network program was used to identify cliques because it is based specifically on strength of relations between pairs of individuals in a network [40, 42]. First, the weakest links were dropped (here, those with a strength of only one) and then the remaining links between pairs were made symmetric by using the mean of the frequency of messages sent by each pair. Based upon the clique results, individuals were assigned a nominal code indicating that they belonged to a particular network clique, or were nonmember isolates.

Results

Research Question 1: Associations of E-Mail with Other Communication

Means Tests of Differences in Total Amount of Communication over Time

TOTAL WORK COMMUNICATION (mean of 26.5 at T2, 29.6 at T3), familiarity with others' work (20 and 33.3), and E-mail messages sent (16 and 31.7) and received (16 and 41.4) all increased significantly over time ($p < 0.05$).

Differences between newcomers and veterans for the changes over time were nearly identical for E-mail messages sent (an increase of 16.7 for newcomers versus 14.5 for veterans), but greater for messages received (20 versus 31.3), likely due to the growing use by veterans of distribution lists or group messaging. No differences between newcomers and veterans concerning changes across time in E-mail communication or work familiarity were statistically significant, except for total work communication (5.42 for veterans, 0.38 for newcomers, $p < 0.05$). A plausible explanation for this difference is that veterans increased their work-related communication with their own as well as with other mentors' interns, and thus also had new reasons for communicating about work with other veterans.

Differences in E-Mail Network Structure over Time

Over time, individual-level (mean) betweenness centrality did not significantly change for the familiarity or work networks, but was higher overall and decreased for the E-mail network. All the networks slightly increased in network-level density, although the E-mail network was at most only half as dense as the work and familiarity networks (see Table 1). The network-level betweenness of all the networks stayed about the same over time, but the E-mail network was about twice as centralized as the other networks. That is, fewer people were connected in the E-mail network, but those who did communicate were more closely interconnected compared with the other networks. We'll come back to this issue of dense E-mail relations.

Visual Portrayal of Network Relationships at Each Time Period

Each mentor–intern pair was plotted in two-dimensional scaling space, then given the same consecutive letter (upper case for mentor, lower case for intern) to show the relative closeness of mentor–intern pairs, and a line connecting them. Then cliques and isolates resulting from the clique analysis were identified in this scaling plot (see figures 1 and 2).

There was somewhat of a divergence from one large set of users with a small outlier set at T2, to two sets and no one in the center at T3. At T2, one clique of ten (four veterans, six newcomers) resulted, with all others too weakly interconnected (network density = 0.06) to constitute a group. Within the clique, mentors A, M, B, and Q were all close to their interns. Indeed, all interns of mentors in the clique also belonged to the clique.

By T3, linkages were dense enough (0.10) to constitute two cliques and a residual set of "isolates." In the smaller clique, only the B–b mentor–intern pair remained (not especially close), and the other two mentors (L and W) were not grouped with their interns. While all other mentors except for O were included in the larger clique, some pairs were quite distant (M–m, E–e, T–t, V–v).

These results indicate a slight divergence of the 48 E-mail users into two cliques. There is also an overall decrease in the association of the intern–mentor relations with the formal intern–mentor messaging patterns (from $r = 0.46$ to $r = 0.34$, as noted below). A subsequent section will return to the clique memberships and dimensional coordinates in a more formal attempt to detect network influences on poststudy performance ratings.

H1a and H1b: Correlations of E-Mail Amount and Centrality with Total Work and Familiarity Communication

Individual-level total amount of E-mail usage (messages sent or received) and E-mail network betweenness were positively correlated with the total amount of work

Table 1 Differences in Network Structures over Time

Network	Time	Network: Density	Network: Betweenness	Individual betweenness: Mean	Individual betweenness: Significance of T-test, T2–T3
E-mail	T2	0.06	0.40	0.31	
	T3	0.10	0.42	0.29	*
Work	T2	0.20	0.18	0.24	
	T3	0.25	0.17	0.21	n.s.
Familiarity	T2	0.20	0.19	0.24	
	T3	0.24	0.21	0.21	n.s.

* $p < 0.05$.

Note: Each network was first symmetrized by union, then dichotomized at "1" to provide a common basis for comparison over networks with different metrics, and to allow the computation of density and betweenness. Sample size includes 45 at T2 and 46 at T3 for the reported networks and 48 for the E-mail network.

communication and work familiarity, at T2 or T3, all from $r = 0.43$ to $r = 0.56$, $p < 0.01$, providing support for H1a and H1b. The correlations within and across time periods are sufficiently similar that there is no convincing evidence of direction of causality between E-mail and the other communication.

H1c: Associations among E-Mail, Work, Familiarity, and Intern–Mentor Networks

As Table 2 indicates, all the communication networks (matrices) were at least moderately associated, with the work and familiarity networks strongly associated. All the networks were strongly associated (about $r = 0.85$) with themselves across the two time periods. The E-mail networks were weakly but significantly associated with the work and familiarity networks, providing support for H1c. However, these associations were weaker at T3 ($r = 0.35$ for work, 0.30 for familiarity) than at T2 ($r = 0.46$, 0.37), again indicating the E-mail communication network was diverging somewhat from the more general work communication relationships. The networks were all more strongly associated with each other during the same time period than they were across time, again providing no conclusive evidence concerning causal direction.

The only apparent differences between newcomers and veterans in all these correlations involved the associations between the work networks and the E-mail networks. Newcomers' communication via the E-mail network increasingly diverged from the work communication relations more than did veterans' communication (the correlations were $r = 0.35$, 0.42 at T2, and $r = 0.11$, 0.32 at T3, respectively). This implies

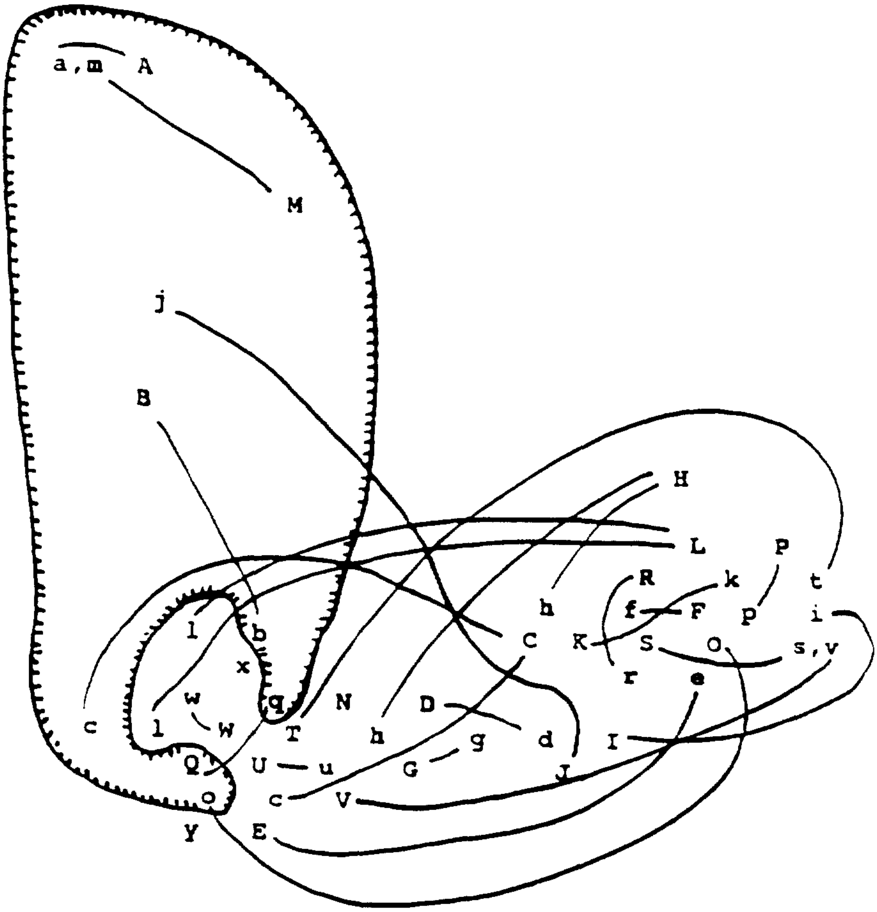

Figure 1. Metric Multidimensional Scaling of E-mail Network, Time 2 (Note: Same letters are mentor [upper case]–intern [lower case] pairs. Two small letters with comma indicate same intern for two mentors [two instances]; two separate but same small letter indicates two different interns for same mentor [three instances]. Variance explained by two dimensions: 22%)

that newcomers to an organization may use an E-mail network to augment or extend their communication patterns beyond the formal work network [46] more than will veterans, who are already members of the organization, and thus are more embedded in their ongoing relations (reinforcing Kling's comments [24]). This may be to the interns' benefit or detriment; wandering too far afield from their formal intern–mentor or work communication network might harm their performance, as discussed below.

H2: Associations with Formal Intern–Mentor Relations

The E-mail network matrices at T2 and T3 were less strongly associated with the intern–mentor matrix ($r = 0.46, 0.34$) than were the work communication matrices ($r = 0.61, 0.55$), providing support for H2 (see Table 2). In every case, the intern–mentor

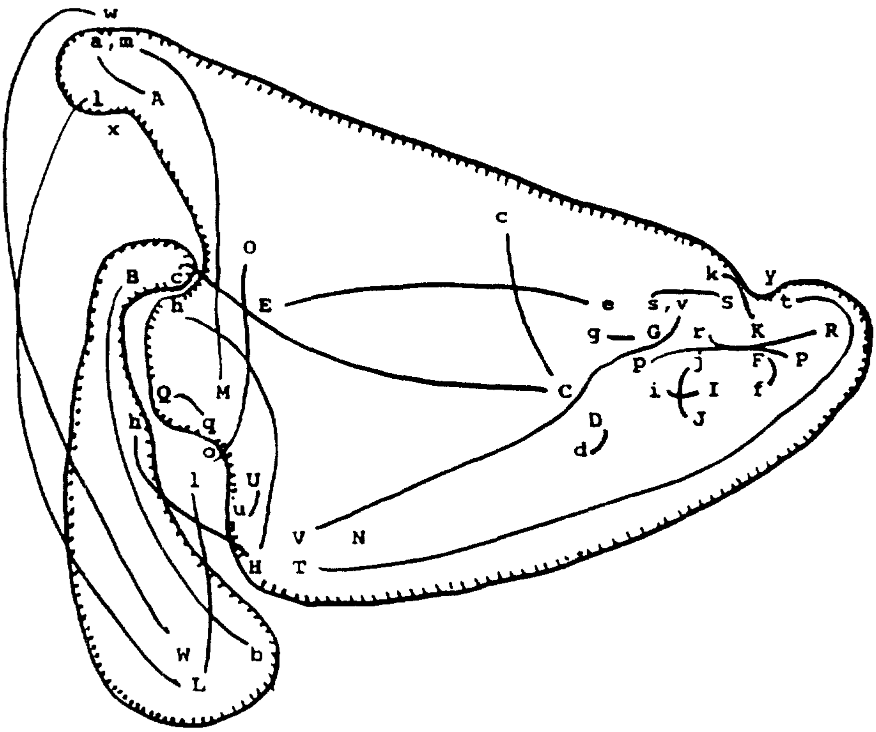

Figure 2. Metric Multidimensional Scaling of E-mail Network, Time 3 (Note: Same letters are mentor [upper case] intern (lower case) pairs. Two small letters with comma indicate same intern for two mentors [two instances]; two separate but same small letter indicates two different interns for same mentor [three instances]. Variance explained by two dimensions: 58%)

matrix was slightly more strongly associated with the other matrices at T2 than at T3, indicating that over time communication in general among this set of R&D members included more than the formally assigned mentor–intern relationships, especially so via E-mail.

Research Question 2: Does Use of E-Mail Influence Performance Ratings?

H3a–H3d: Influence of Amount and Structure

Only total work communication at T2, total work familiarity at T2 and T3, and total amount of E-mail messages sent at T3 were significantly correlated with performance ratings given by mentors a few months later (see Table 3). However, counter to H3a through H3d, these associations were all negative.

H4: Influence of Network Structural Position

The above analyses use rather global measures of network structure. The following analyses turn to more specific aspects of the participants' position in the E-mail network.

Table 2 Correlations among Network Matrices

		Wor2	Wor3	Fam2	Fam3	InMe	E-mail2
Work	T2	—	—	—	—	—	—
Work	T3	0.85	—	—	—	—	—
Familiar	T2	0.88	0.79	—	—	—	—
Familiar	T3	0.77	0.87	0.85	—	—	—
Intern/Mentor		0.61	0.55	0.44	0.40	—	—
E-mail	T2	0.46	0.43	0.37	0.36	0.46	—
Newcomers		0.35	0.22	—	—	—	—
Veterans		0.42	0.42	—	—	—	—
E-mail	T3	0.37	0.35	0.31	0.30	0.34	0.84
Newcomers		0.17	0.11	—	—	—	—
Veterans		0.33	0.32	—	—	—	—

Note: all correlations are significant at at least $p < 0.01$. See text for explanation of Quadratic Assignment Procedure for tests of significance of associations between matrices.
$N = 43$ for all tests.

We have seen that there is a moderate association between specific intern–mentor pairs and their E-mail communication. Does just the E-mail communication between specific interns and mentors influence their performance evaluations? Here, the performance evaluations given by each mentor were correlated with the total number of messages sent to the mentor's intern and received from the mentor's intern (each of these values averaged across multiple interns if necessary). The converse was done for interns. None of these correlations was greater than $r = 0.10$. So total E-mail communication between specific mentor–intern pairs is not behind the influence of E-mail communication on performance ratings.

To expand this emphasis on detailed E-mail network position, we return to the MDS and clique results (figures 1 and 2).

At T2, clique members gave and received lower performance ratings than did nonclique members: for mentors (3.3 versus 4.1, $p < 0.07$) and interns (3.6 versus 4.2, $p < 0.07$). This result at T2 is counter to H4, but reinforces the results for H3a–H3d. However, by T3, the significance and the effect size of the differences in mean performance evaluations among the isolates and cliques disappeared (although these results are very tentative due to the extremely small sizes of some of the isolate and clique groupings). Further, the larger clique at T3, which for both newcomers and interns included most of the T2 isolates, did not have the lowest mean performance.

These results suggest that it is neither membership in a clique per se nor size of clique that distracts or lowers performance. Rather, it may be communication with other low-performance members and being distant (in terms of multidimensional

Table 3 Correlations of Mean Performance with Amount and Betweenness of Network Communication, for Mentors and Interns

Communication and betweenness variables	Performance scale: Given by mentors	Performance scale: Received by interns
Total work communication		
T2	−0.63***	0.15
T3	−0.21	0.22
Total work familiarity		
T2	−0.40*	0.22
T3	−0.40*	0.25
E-mail messages sent		
T2	−0.29	−0.20
T3	−0.40*	−0.05
E-mail messages received		
T2	−0.35	−0.04
T3	−0.13	−0.04
Work betweenness		
T2	−0.34	0.19
T3	−0.18	0.32
Familiarity betweenness		
T2	−0.32	0.22
T3	−0.23	0.25
E-mail betweenness		
T2	−0.31	−0.03
T3	−0.33	−0.02

* $p < 0.1$; *** $p < 0.005$.

scaling space) from the bulk of users early on in the development of the R&D newcomers' social structuring that negatively affects their later performance ratings. That is, becoming overly embedded early on in a small, dense structure apart from other users may hinder a newcomer's later performance evaluation. And E-mail may foster such early cliquishness by a small number of users.

Table 4 shows correlational and mean difference analyses, relating structural position in the network (here, the MDS scaling coordinates) to the performance ratings. At T2, interns' coordinates on the vertical dimension were negatively associated with their performance evaluations received several months later ($r = -0.66$, $p < 0.001$). The association between mentors' coordinates and performance evaluations given by mentors was lower and only marginally significant ($r = -0.36$, $p < 0.1$). By T3, the

Table 4 Correlations and Mean Difference Analyses Predicting Mean Performance, for Mentors and Interns

Analysis		Veterans	*N*	Newcomers	*N*
Correlations with coordinates of scaling dimensions:					
T2	1st (horizontal) dimension	0.16	23	0.02	25
	2d (vertical) dimension	−0.36*	"	−0.66***	"
T3	1st (horizontal) dimension	0.23	"	0.09	"
	2d (vertical) dimension	−0.26	"	−0.34*	"
Mean differences in performance ratings across groupings:					
T2	Nonclique members	4.1	18	4.2	19
	1st clique	3.3	4	3.6	6
	T-test *T*-ratio	1.9*	1.9*		
	Adjusted R^2	0.11	0.09		
T3	Nonclique members	3.3	1	4.4	5
	1st clique	3.9	18	3.9	17
	2d clique	4.3	3	4.7	3
	ANOVA *F*-ratio	0.5 n.s.		1.5 n.s.	
	Adjusted R^2	0.00		0.00	

* $p < 0.08$; *** $p < 0.001$.

correlations for interns dropped to $r = -0.34$, $p < 0.1$, and for mentors, $r = -0.24$, n.s.

The (weak but negative) role of early clique membership is reinforced when comparing performance of interns located in similar scaling space, but in and out of the clique. Many of the interns with lower coordinate values on the vertical dimension at T2 (figure 1) have the highest performance ratings: y = 5, c = 4.75, u = 5, h = 5, g = 5, d = 4.75, r = 4.5. Yet those interns who belong to the clique but are also in that same general location in the scaling space do not generally have such high ratings: o = 3.5, l = 3.75, x = 4, q = 3.75, c = 4.5, b = 4.5 (and the interns in the clique and highest on the dimension have quite low ratings [a, m = 2.4, j = 2.75]).

H3 and H4: Summary Multiple Regression

Because many of the total and network communication variables are intercorrelated, a stepwise multiple regression of performance on all of the independent variables was run for mentors and interns separately. Only one variable remained as a significant predictor for each subsample. For mentors, total work communication at T2 (beta coefficient = −0.63) explained 35 percent of the variance in performance ratings given to their interns ($F_{1,18} = 10.9, p < 0.005$). For interns, the vertical coordinate at T2 (beta coefficient = −0.66) explained 41 percent of the variance in performance ratings received from their mentors ($F_{1,24} = 18.9, p < 0.001$).

Summary and Conclusions

RQ1: Association with Other Relations

TOTAL E-MAIL COMMUNICATION, NETWORK BETWEENNESS, and the network matrix were all moderately associated with corresponding work and familiarity measures, although the full matrices were less associated at T3 than T2, and noticeably less for interns than for mentors. To some extent, E-mail messaging mirrored both the formal intern–mentor pairings as well as the veteran–newcomer relations. However, both of these associations declined somewhat over time and were less strong than those involving general work communication. Interns, without preexisting structural relations, seemed freer to use E-mail to communicate across status boundaries and to diverge from formal intern–mentor and work relations. Further, as E-mail usage and network density increased, the average E-mail user became slightly less central to the network, and two groups of users emerged. Unfortunately, even with data from two time periods, it is difficult to find compelling evidence for a specific causal relationship among the networks.

RQ2: Influence on Performance

Contrary to traditional theory about the importance of R&D communication, more frequent, diverse, and dense communication is not always better for R&D performance. Further, while use of an E-mail system did complement general work networks, and provided more diverse and less formally aligned relations, it did not positively contribute to R&D performance. If mentors are involved in extensive work communication, they may either be distracted from paying attention to their interns' performance or may have more exemplars to which they may (negatively) compare their own interns.

For interns, it is not simply the amount or even the centrality of one's E-mail communication but their position in the E-mail network that affects the performance ratings they receive. Referring back to the discussion about clique membership and network location, even though some interns in the clique are close to the high-rated interns (lower on the vertical dimension), they may have received their lower ratings because of their early dense E-mail relations with other lower-rated interns and membership in the initial clique. This does not imply, or require, that their mentors are aware of the interns' E-mail relations. It may be that interacting via E-mail too intensely with other interns (and mentors) who are not well integrated into the rest of the overall network distracts or narrows one's focus and establishes an early negative impression that cannot be easily shaken in spite of different communication patterns and more equal communication later on.

What this means is that interns (here, limited-term organizational newcomers assigned to very small project groups) may typically use an E-mail system to complement their work communication networks, but those networks should not overlap too much with their mentor's network or with lower-performing interns, should not be centered around an initially emergent clique, and should not diverge too greatly from the more general work communication and work familiarity networks. Put another way, successful use of E-mail involves finding the "right partners"—those who can provide the resources to properly socialize one into project and organizational goals and resources [31] and with whom one can develop influential and nonredundant relations [9].

There seem to be at least two intriguing aspects of these results. The first is that while neither measures of *amount* of E-mail usage nor simple indices of E-mail network *structure* (betweenness) were associated with performance ratings, more detailed network measures of clique membership and network *position* were. The second is that, curiously, T2 network measures, rather than the more temporally proximate T3 measures, are better predictors of performance ratings several months later. Thus, even though mentors and interns may "migrate" to different network positions over time, early network connections establish resources, project procedures, technical knowledge, socialization patterns, and impressions that continue later on to influence performance ratings in spite of changing relationships. Other research also shows that early occupation of specific network roles in a CMC network may influence more enduring role occupancy [31].

Qualifications

While we received nearly complete responses from all the 48 participants in the study, the sample sizes are small, so standard statistical significance levels will be hard to achieve. In this particular setting, usually each intern worked closely with one mentor on a limited-duration project, so this context may not only be atypical but in fact may require less, and more focused, communication in order to accomplish the specific project. The short time period (three months) and the temporary nature of the interns' participation both might have contributed to smaller and less consequential effects than in a study of actual new-hires and veterans. As Hiltz [19] found in a study of four CMC systems, it may take a long time to discern productivity benefits from the use of such systems, and such benefits might be more associated with additional CMC features such as online interest directories, public conferences, and ad hoc groups and distribution lists [44]. Further, because of the highly selective nature of the intern program, the newcomers may have already been fairly well socialized into the technical and organizational norms, so that additional communication during the intern program would not have much effect on obtaining new information, mutual knowledge and contacts, and thus performance. However, it seems that the initial processes of acclimation of, and participation in organizational communication networks by, potential newcomers to an R&D organization offers a useful research context.

The work networks are reported and therefore susceptible to recall error and bias, while the E-mail networks are behavioral (monitored by the system) and therefore highly reliable. Because we have no measures of the content of E-mail communication, the messages represent some unknown combination of work-related and social, formal and informal communication (see note 2). Further, while the E-mail networks are obviously medium-specific, the work networks do not discriminate among channels used. Therefore, the E-mail network and the work networks are not conceptually independent.

Conclusions

A simple conclusion might be that while the amount and position of one's E-mail usage complements as well as extends work communication and work familiarity networks, E-mail communication in particular is not strongly, and may be negatively, associated with performance ratings. What is clear is that interns communicate in increasingly diverse patterns using the E-mail network, and diverge from the formal mentor–intern and work relations between T2 and T3. However, it seems possible that a more fundamental implication of the role of computer-mediated communication in R&D organizations is that it is not the amount of system usage, but one's structural position in that system's communication network—especially participation in peripheral cliques early on—that influences performance ratings. Although these findings reaffirm the importance of pre-existing and complementary structures as Kling [24] suggested, use of E-mail can also support interaction beyond those pre-existing structures, and embed one in new, but not always beneficial, relationships.

Notes

1. A variety of other control variables were also measured on a T1 questionnaire and analyzed, such as prior experience with E-mail and perceived appropriateness of E-mail, but are not discussed here, both for parsimony and because they did not influence performance ratings.

2. We did, in fact, also measure social communication networks (reflecting friendly and non-work-related communication as well as communication about norms and culture of the organization), but they were highly correlated with the work networks (from $r = 0.79$ for work T2 and social T3 to $r = 0.92$ for social T2 and work T3), so were not included in these analyses.

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