Work Group Structures and Computer Support: A Field Experiment

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It is frequently suggested that work groups that have computer technology to support activities such as text editing, data manipulation, and communication develop systematically different structures and working processes from groups that rely on more conventional technologies such as memos, phone calls, and meetings. However, cross-sectional or retrospective research designs do not allow this hypothesis to be tested with much power. This field experiment created two task forces, each composed equally of recently retired employees and employees still at work but eligible to retire. They were given the identical tasks of preparing reports for their company on retirement planning issues, but they were randomly assigned to different technology conditions. One group had full conventional office support; the other had, in addition, networked microcomputers with electronic mail and routine office software. Structured interviews were conducted four times during the year-long project; in addition, electronic mail activity was logged in the on-line group. Although both groups produced effective reports, the two differed significantly in the kind of work they produced, the group structures that emerged, and evaluations of their own performance. Although the standard group was largely dominated by the employees through the extensive reliance on informal meetings, the electronic technology used by the other task force allowed the retirees to exercise primary leverage. We conclude that use of computer support for cooperative work results in both quantitative and qualitative changes but that effective participation in such electronically supported groups requires significant investments of time and energy on the part of its members to master the technology and a relatively high level of assistance during the learning process.

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1. INTRODUCTION

What happens when task groups attempt to couple the advantages of on-line text preparation or data analysis and decision support with computer-based communication capabilities? How, if at all, does networked information technology affect group structures and interaction processes? And do positive answers

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to these questions depend on having a technology-rich environment with computer-sophisticated individuals to start with, or could almost anyone reap significant advantages if provided with basic computer and communications technology?

For the last several years, Rand's Institute for Research on Interactive Systems has been pursuing research about the ways electronic information media may influence work groups—their structures, patterns of individual interaction, and experiences of task and social involvement.[1] Among the questions that have recurred are the following:

—When work groups get access to computer-based media for handling information and communication tasks, do their structures change? Do they move closer to or further from formally established organizational structures? Do group positions (e.g., leader roles, assistant roles) stay the same or change?

—Do computer-supported groups overcome physical barriers to interaction (e.g., space or time constraints)? Do they overcome preexisting social barriers (e.g., status differences)? Do they form tight clusters ("electronic islands"), or are they overlapping and not sharply defined ("loose bundles")?

—How, if at all, do networked information technologies affect the amount or density of interaction in a group? How do they affect the extent of members' integration within a group? Or centralization? Or communication across groups?

—How do these new technologies affect social communication among group members? How do they affect experienced task involvement? Do these media tend to "diffuse," that is, to spread and include other users and other uses? Do these media supplant or supplement other means for exchanging information and coordinating group tasks?

Our research to date has focused largely on the work group as the critical unit of analysis and on the overall context in which such units are embedded. Our findings support Kling and Scacchi's view [12] that any interactive technology introduced into a work group will be more like a "web" than like a discrete entity. When a web of interactive technology is introduced into a work group, the sociotechnical system is altered; work groups increasingly become "directly dependent on their material means and resources for their output" [2, 11, 16, 21, 22]. That is to say, individuals become interdependent not only on one another but also on the technology for accomplishing their tasks; access to and control over the "means of production" assume greater importance [9, 23]. New communication channels can introduce new ways of productive interaction; they can also exacerbate existing differences and force confrontations (they can also, of course, be largely ignored) [17, 18]. Although the avenues for group work and the means for managing it may have multiplied, new challenges are introduced, along with the technology that preexisting social structures may be ill-prepared to handle. New patterns are likely to emerge.

[1] We have previously reported on a number of aspects of this research, including a large cross-sectional study of work groups using computer-based tools [1, 4]; case studies of new information technology introduced into multiple work groups in single organizations [5, 20]; and a developmental project to design, implement, and track an electronic message-handling system [3, 7].

Our previous studies of the effects of electronic communication [7] allowed us to control the type of communications hardware and software, as well as its relationship to other computer-based tools, but it did not permit us to evaluate the extent to which network structures and interaction patterns that emerged over time were influenced by the new technology in comparison to ongoing social relationships, task differences, and other factors. It could not reveal how, if at all, computer-supported work group structures and processes differed from those that would be observed in groups employing standard interaction media.

The most effective method of trying to untangle the causal inferences we sought and still have the exercise carried out in a real-world rather than laboratory context is, of course, the classical field experiment. This procedure would allow us to randomly assign group members to computer-based versus traditional support in the completion of identical work goals, as well as to design and control the introduction of new information and communications technology. An effective experimental design, it seemed to us, should also have the following characteristics:

—If individuals are expected to become familiar with new information technology, accomplish a meaningful goal, and in the process have an opportunity to form or reform work structures and social relations, it would require an intervention of about a year's time.

—Further, if individuals in both the "electronic" and "standard" conditions were to participate in a year-long effort, a strong mission focus was essential—the goal for group activity and the role of communication would have to be highly motivating.

—Also, for noncollocated individuals to agree to take part (and to continue their participation) in randomly assigned groups, they should be selected from a common "community"; that is, they should come from a common culture, share some concerns, and have some reason to think they might want to work with one another (cf. [14]).[2]

2. FIELD PROCEDURES

From one of the older and larger corporations in the greater Los Angeles area, we recruited volunteers for two task forces. Members, half retired and half actively employed, were to work together over the course of a year to consider, deliberate, and develop a set of recommendations about preretirement planning to be addressed to persons nearing retirement, to organizations (including, but not limited to, their own), and to professionals involved in preretirement planning. Meetings, phone calls, duplication, postage, and other supplies were provided by Rand or supported for both groups.

In addition, members of one of the two task forces had the option of communicating with each other and conducting their business with the aid of new

[2] Last, and definitely not least, we needed to find a funding source willing to support a rather costly experiment of this sort! This research is funded through a grant from a nonprofit organization whose two programmatic interests are aging and adult development and social uses of the media—The John and Mary R. Markle Foundation—for whose cooperation we are deeply indebted.

technology. Each member of this "electronic group" had access to networked microcomputers, communications software adapted from the interface to RANDMAIL, built-in modems and hard disks, and local printers. Limited additional software was supplied, including full-text editing and formatting capabilities, a spreadsheet, a database management system, games, and Basic. (A more complete system description is available in [6].)

Because we were interested in the possible advantages and disadvantages of electronic communication compared with more standard media, we randomly appointed task force volunteers to either group. The project enrolled 79 members, all of them male professionals or managers with prior problem solving or decision-making responsibility. The mean age was 62 for retired participants and 60 for employees. Those who were retired had done so in the past four years, and the employees were all currently eligible to retire.

The distribution of participants thus was as follows:

	Computer	No Computer
Retired:	$n = 20$	$n = 20$
Not Yet Retired:	$n = 20$	$n = 19$

Although both groups received the same general orientation to and support for task force work, members of the electronic group additionally were taught to use the computer system. The three-hour training session (and the user manual developed by the research team) focused on fundamentals of operating the computer and using it to send and receive messages as well as to draft and print textual material.

The focus on electronic mail reflected several assumptions. First, the field experiment was concerned with communication and cooperative activity. Although using electronic mail has much in common with other activities users perform with computers, the difference is that electronic mail is a mechanism for dealing with others (most applications involve communication between users and programs within their own computers). Second, we supposed that communication is intrinsically motivating, so that when provided with that capability task force members would be likely to use it. Third, we regarded electronic mail as analogous to wrapping an envelope around whatever other information the user might want to share; although we could not anticipate just what else the task force might want to do, we equipped members with a number of general information handling tools to be used as they thought appropriate.

Highly structured individual interviews were administered to all subjects at the beginning of the project, with interim interviews conducted twice during the task force year and a final interview at its end. Interviews gathered detailed sociometric data about interactions among group members in addition to information about other aspects of subjects' work and social lives, attitudes, and evaluations of task force activity. In addition, for the electronic group, we collected automated usage logs and detailed network data of the sort obtained in the RANDMAIL study, as well as user assessments and diffusion and extension of use.

3. EXPERIMENTAL RESULTS

This research has produced two general kinds of findings. First, it yields the experimental results per se: what differences, if any, can be observed between the standard and electronic groups? Second, it generates a profile of the electronic group's use of technology: an account of how a group initially unfamiliar with interactive systems adapts to and makes use of computer-based work tools. The short answer to the first question is that technology really does make a difference; the two groups differ significantly in many aspects of how they structure and carry out their tasks. Second, although virtually all members of the electronic task force adjusted in one way or another to the system, the adaptation took its toll. Thus, the standard task force was able to begin work on its task immediately, while members of the electronic group spent much of their time in the first project months just learning to use the tools. On the other hand, once a sizeable proportion of the electronic task force had acquired basic skills, the ease of coordination and interaction afforded by the system seemed to permit the group to undertake fairly ambitious substantive efforts, to involve a larger number of its members in carrying them out, and to move fairly rapidly to completion. In the remainder of this paper, we discuss some of the differences between the experimental groups, as well as characteristics that distinguished the emergent electronic network.

Findings from the research are qualified by a number of limitations that may bear on their generalizability. First, the sample size is small; resource constraints limited us to only two task forces of about 40 members each. Second, all the members are older men whose careers led to midlevel management or professional positions; we do not know how the inclusion of younger employees, women members, or representatives of the top or bottom of the organizational hierarchy might have affected the results. Third, participation in the task force was voluntary; results might not be the same for collaborative activities that are part of regular job assignments. As we see it, the main strength of the research design comes from random assignment to experimental conditions plus control over other potentially interfering variables (type of task, type of technology, prior experience with electronic mail, preexisting group structures, and the like). Any differences between the two task forces on the dependent measures reported here can, we believe, validly be interpreted as effects of networked interactive systems.

3.1 Baseline

The random assignment to experimental conditions, in fact, produced two quite similar groups. In both electronic and standard task forces, over 50 percent of participants had attained a college degree or higher level of education. Standard task force members appeared to have slightly higher incomes and occupation levels than their counterparts in the electronic group (especially within the employee category); however, this difference seems to be purely an artifact of random selection, and there is no evidence that it materially affected most of the outcomes. Prior computer experience was much the same across conditions. About half in each task force had had some sort of contact with batch-processing mainframe computers at work, and about a quarter had tried using a small

home computer (typically for games). None had ever used computer-based communications.[3]

Both the conventionally supported and the computer-supported task forces had the same general charge and initially structured their approaches to it in much the same way. Each divided the basic mission into smaller issue areas for work by subgroups; the subgroups elected chairs, with the chairs forming a task force steering committee.[4] Interestingly, although both task forces generated six subcommittees related to specific concerns (health, finances, and so on), the standard task force spent considerable time arriving at a felicitous assignment of members to subgroups (e.g., balancing size and employee–retiree representation while accommodating individual interests).

In the electronic task force, by contrast, subgroup assignment did not arise as a problem. We suspect it was assumed that, given electronic means for overcoming space and time constraints on multiperson activity, members could work on as many subgroups as interested them. No one in the standard task force became a member of more than one subgroup, while most of those in the electronic task force started off with two or more subgroup assignments; the mean size of the subgroup in the standard task force initially was 6+ (range = 6–7), while it was 10+ (range = 6–15) in the electronic task force. It is reasonable to suppose that the availability of electronic media can affect people's expectations about how group work will proceed.

From items in the interview tapping relationships among respondents, we constructed three measures reflecting varying degrees of interpersonal attachment.[5]

(1) Recognition, or reflecting other task force members with which a subject is familiar at least by recognizing the name or face;
(2) Knowing, or a reciprocal acknowledgement between pairs of subjects in the task force that they know each other well;
(3) Contact, or having been in touch with any of the other task force members (in person, by phone, by memo, and/or by computer) in the past two weeks. At baseline (i.e., prior to the experiment), subjects on average "recognized" over a third of the other members of their task force but "knew" only about ten percent of them. Very few instances of actual contact were reported.

In general, we found few differences between the two experimental groups on these measures. Members of the standard task force tended to be slightly more widely recognized and better known, which we interpreted as a reflection of their

[3] An open-ended item at the end of the initial interview asked subjects why they had agreed to participate in the project. In both conditions a similar pattern emerged: Retirees were interested in giving information, and employees were interested in getting information about the transition to retirement; the task force topic itself was thus a strong incentive. Another often cited motivation was curiosity about research procedures. Access to the technology was infrequently cited—only ten percent of the standard group and five percent of the electronic group mentioned they were interested in computers.

[4] An experienced group facilitator was retained to help the task forces get started. She worked with both groups at several points during the study.

[5] See the Appendix for details on how these and other measures were constructed and used.

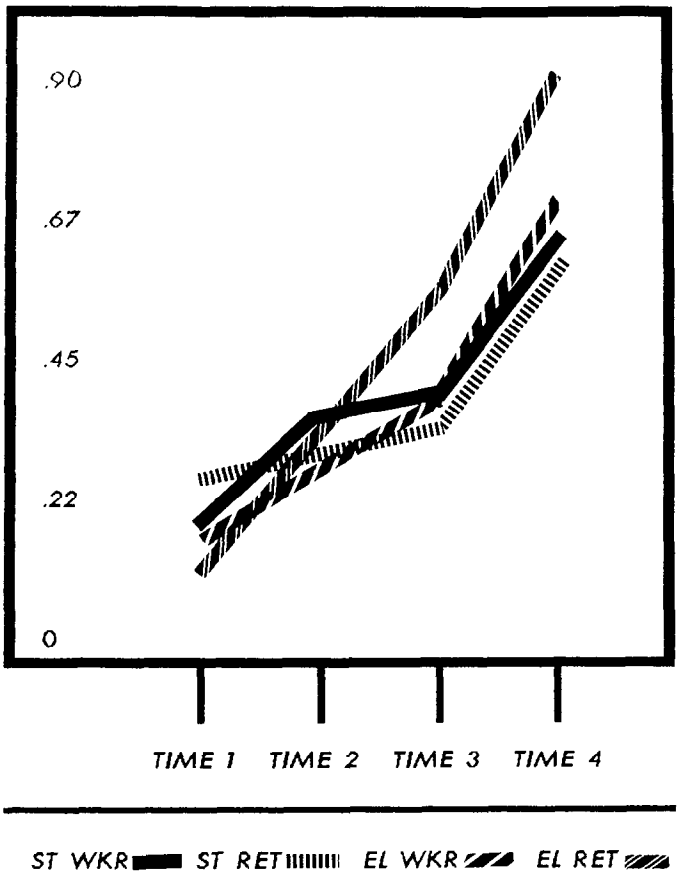

Fig. 1. Recognition density. Standard and electronic groups overall.

higher status in the parent organization (differences were not statistically significant). Much stronger differences, however, were notable between employed and retired members across the task forces; measures of recognition and knowing, and especially of contact, were lower for retirees than for those still employed. Retirees in both electronic and standard groups were relatively peripheral.[6]

3.2 Structural Changes During the Project

The issues-oriented subcommittee structure persisted for both task forces throughout the project. In the electronic group, however, a second procedurally based work structure was also created to facilitate task completion. For instance, each subgroup sent members to a content coordinating committee whose job it was to determine how the issues examined by each subgroup fit together, to

[6] The proportion of the population with whom contact is reported (the "integrativeness" index—see the Appendix) for retirees in both groups averaged about .08. This contrasts with about .12 for electronic workers and about .20 for standard workers. An analysis of variance shows the only significant difference to be that due to employee–retiree status ($F = 15.87, p < .001$); neither condition nor interaction effects are significant).

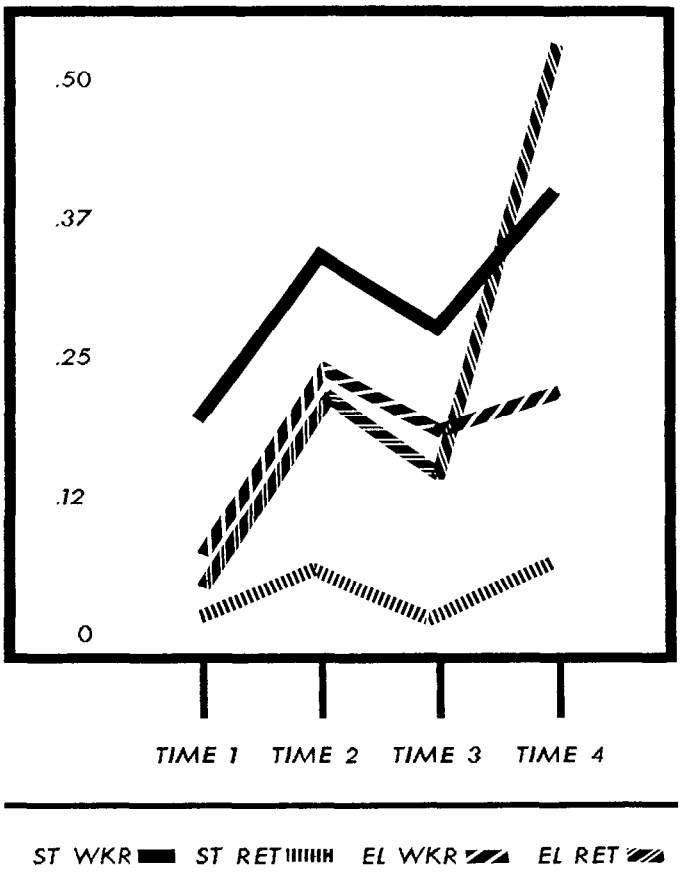

Fig. 2. Contact density. Standard and electronic groups overall.

locate overlaps, and to eliminate redundancies. Eventually six such groups were matrixed through the original six subcommittees. No structural additions or changes were instituted within the standard task force.[7]

An overall look at network patterns (based on the three measures outlined above) indicates increasing amounts of communication (measured by the "density" index; see the Appendix) over time for both task forces. Figure 1, for instance, shows changes in recognition density; for all groups, recognition increased by Time 4 to well over 50 percent. The increase is most striking for the electronic retirees, who went from recognizing less than 10 percent of their group at baseline to over 90 percent by the project's end. Figure 2 shows the changes in actual contacts. Again, electronic retirees evidence the greatest overall change with contact density increasing to over 50 percent.[8]

[7] See Section 4 for further data on the evolution of this group.

[8] Figure 2 shows declines in actual contacts between Time 2 and Time 3. The Time 3 interviews were conducted in late summer when vacation schedules had significantly reduced participation in the project for the two-week period surveyed.

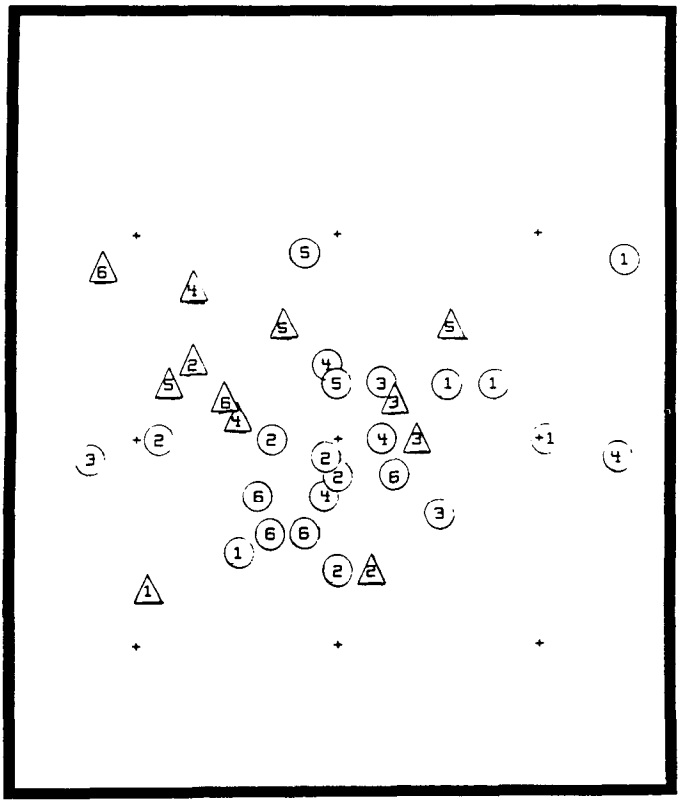

Fig. 3. Contact relationships. Standard group—time 1 (at baseline).

A repeated measures analysis of variance confirms the significance of these trends. The largest main effect, not surprisingly, is for time (recognition: $F = 22.4$, $p < .001$, contact: $F = 28.5$, $p < .001$). For recognition, the electronic–standard condition is also a significant source of variation ($F = 9.9$, $p < .01$), as is the time/status/condition interaction ($F = 3.5$, $p < .05$). For contact, condition is significant ($F = 3.9$, $p < .05$), as is status (employee–retiree)—($F = 18.9$, $p < .001$) and the condition–status interaction ($F = 15.6$, $p < .001$).

Both task forces saw their patterns of interpersonal contacts quickly change in response to task group activity. Figures 3 and 4 show "contact maps" (see the Appendix for details on how these "maps" were constructed and interpreted) representing the pattern of interactions at baseline; no particular clustering of members emerges within either task force. That is, there is no evidence that individuals chose to join particular issue-oriented subcommittees because of prior relationships to others in their task force.[9] In both tables, the relatively peripheral position of retired members is apparent.

[9] The numbers on the figures indicate the location of persons as well as their subcommittee membership (subgroups are arbitrarily numbered 1–6). Workers are indicated as circles; retirees are shown as triangles.

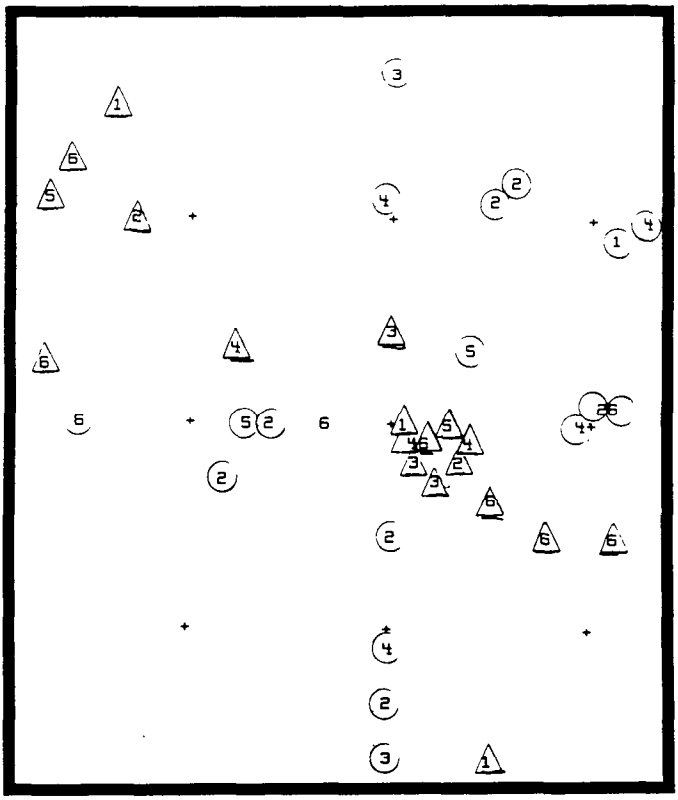

Fig. 4. Contact relationships. Electronic group—time 1 (at baseline).

By Time 2, only three months later, the patterns of contact shifted substantially. In the standard task force (Figure 5), what had begun as a rather formless collection now exhibited relatively well-defined relationship clusters that tended to reflect subcommittee boundaries. In the electronic task force, in contrast, the map shows much less sharply defined clusters (Figure 6), probably reflecting overlapping subcommittee memberships plus new group formation.[10]

The task forces also differed in terms of overall levels of contact their members experienced during the experiment. Figure 7 shows the number of people an average task force member reported contact with at each time period. Again, there is a strong interaction effect. At baseline, workers in both task forces reported contacts with 5–6 others on average; retirees reported contacts with 1–2. For the standard group, both levels remain essentially static across the experiment, with retiree contacts actually declining somewhat. For the electronic group, worker contacts also remain basically stable, but retiree contacts increase

[10] Contact maps for Times 3 and 4 are generally similar to those for Time 2. By Time 4, the tightness of clusters in the standard group has decreased somewhat but not so much as to resemble the electronic group.

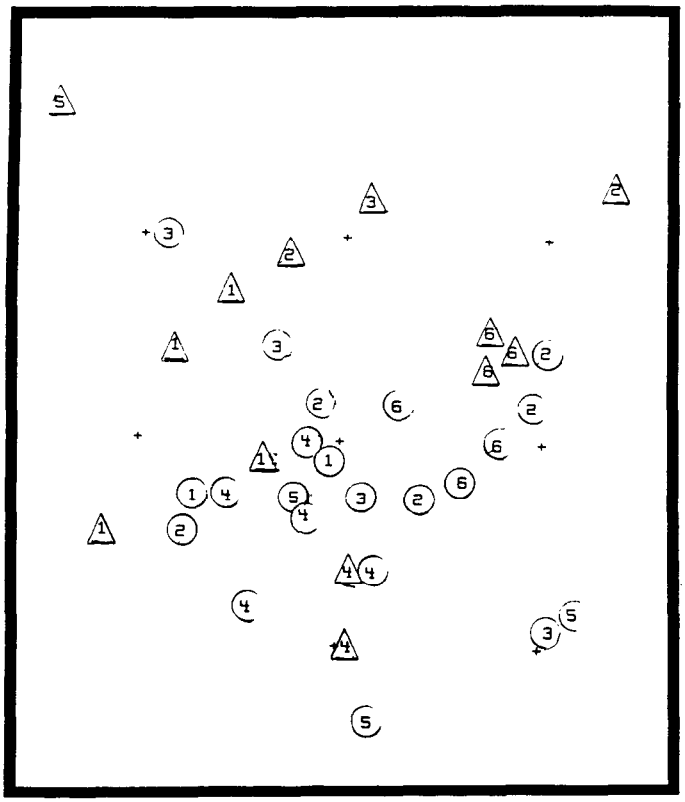

Fig. 5. Contact relationships. Standard group—time 2 (about three months).

dramatically. This is consistent with other evidence about the salience of retiree participation in the electronic task force.[11]

Different individuals often prefer to interact through different communication modes at different times, depending partly on personal preferences and partly on situation and task characteristics. No single mode is likely to be effective in all circumstances. As noted, both task forces had access to a full range of meeting, correspondence, and telephone capabilities, as well as electronic mail for the electronic group. Table I shows the number of contacts reported involving various media.[12]

For the standard group in this last time period, contacts tended to take the form of unscheduled meetings. Not surprisingly, retirees tended to be out of the

[11] Repeated measures of analyses of variance (ANOVAs) confirm the significance of these trends. For task force by time, $F = 6.81$, $p < .001$; for status by time, $F = 6.35$, $p < .001$; for task force by status by time, $F = 5.51$, $p < .001$. There are also main effects for task force by status ($F = 19.9$, $p < .001$) and for time ($F = 6.07$, $p < .001$).

[12] Unfortunately, the question about media use was only asked at Time 4. See the Appendix for details on question wording. The table shows the number of actual contacts reported as using each medium; a few contacts were reported as using more than one medium and are logged here as separate contacts. The maximum possible number of contacts in any one cell would be $(N(N-1)/2)$ or 780 for the 40 individuals in each group.

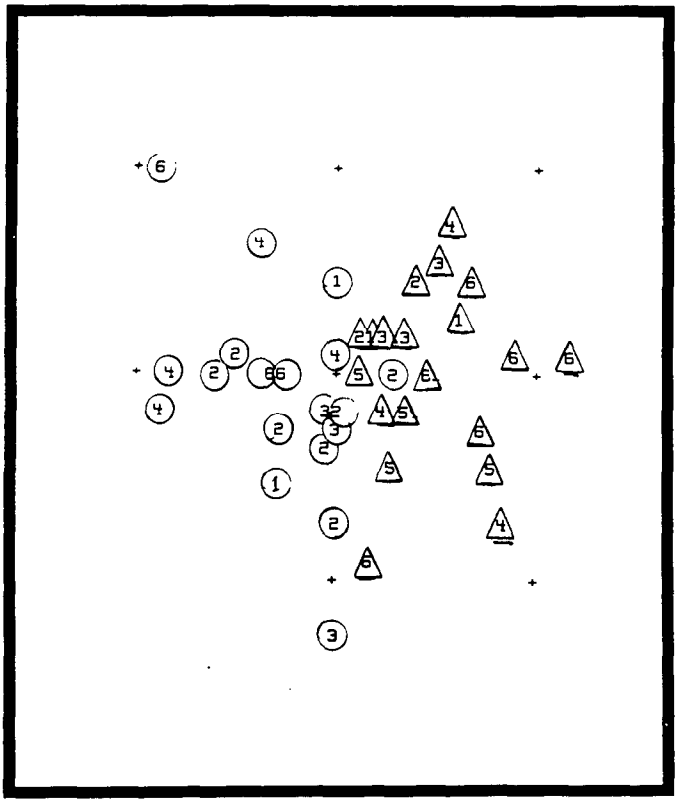

Fig. 6. *Contact relationships. Electronic group—time 2 (about three months).*

unscheduled meeting loop since these apparently took place largely at corporate headquarters; retirees participated in only 12 percent of the unscheduled meetings in the standard group and 25 percent of those in the electronic group. For the electronic group, by contrast, contacts tended to be primarily in the form of scheduled meetings with less reliance on unscheduled meetings and relatively heavy use of electronic mail. Retirees participated in 19 percent of the scheduled meetings in the standard group and 75 percent of those in the electronic group. Retirees also used 80 percent of the electronic mail that was sent.[13]

The standard group experienced significantly greater stability of leadership roles during the experiment than did the electronic group. Table II provides intercorrelations among "betweenness" scores obtained for the four time periods.[14] A repeated measures ANOVA shows significant main effects for task

[13] The electronic group set up a series of scheduled in-person meetings at the end of the study to coordinate preparation of their final report. This emphasis on scheduled meetings is probably not representative of the entire period of work.

[14] *Betweenness* is a measure of the relative centrality of a person in a network (see the Appendix for the construction and interpretation of this index). Because of high skewness in betweenness scores, logs of raw scores were used in these correlations.

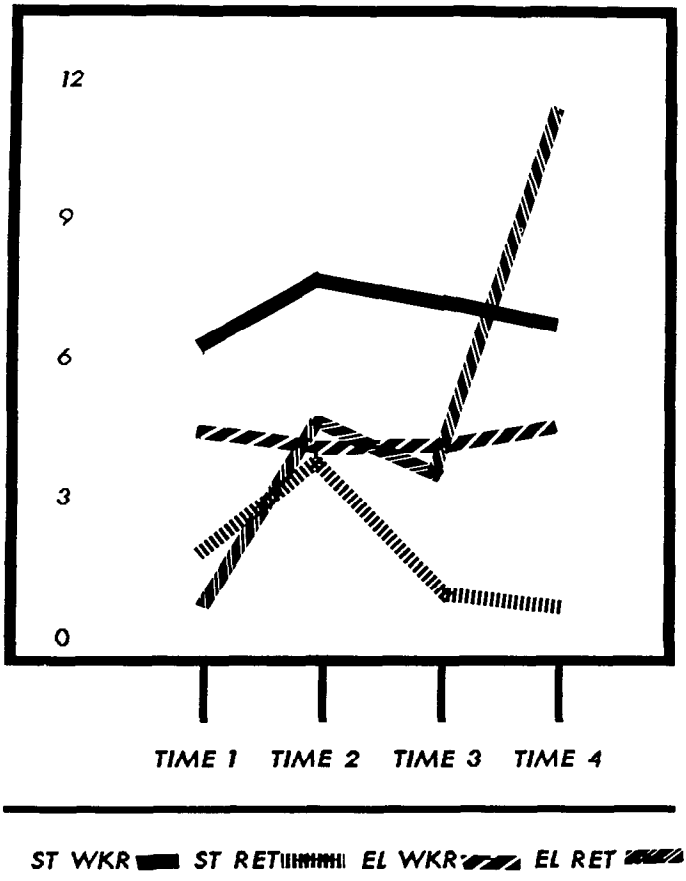

Fig. 7. Average contacts per group member. Standard and electronic groups overall.

force ($F = 7.7$, $p < .01$) and for status ($F = 33.9$, $p < .0001$), as well as for task force by time interaction ($F = 4.6$, $p < .01$). For the standard group, the betweenness scores at each time point are significantly predicted by the betweenness scores at the preceding point (F's range from 11.5 to 18.6, $p < .01$). For the electronic group, this is not the case; betweenness scores are not significantly related to the previous period's scores.

If we take the 5 most central people in each contact network at each period to be a sort of "leadership cadre" for that time period, there are a total of 20 possible leader slots. For the standard group, 13 people fill those 20 leader slots (with 7 repeating the role at more than one time period); all but 1 are workers. For the electronic group, there are 16 leaders (4 repeaters); 7 are workers and 9 are retirees. The basic point of all these analyses is that the leadership of the electronic group is a much more fluctuating and diverse group and much less dominated by the workers than is that of the standard group.

Table I. Frequency of Use of Different Media for Contacts (Time 4)

	Standard $N = 178$	Electronic $N = 408$
Scheduled Meetings	$N = 36$ .45	$N = 220$ .80
Unscheduled Meetings	$N = 116$ .83	$N = 84$ .47
Telephone	$N = 23$ .36	$N = 41$ .32
Letters/Memos	$N = 2$ .11	$N = 8$ .14
Electronic Mail		$N = 55$ .38

Table II. Continuity of Leadership Structure. (Pearson Correlations)

	Standard	Electronic
Time 1 To Time 2	.47	.19
Time 2 To Time 3	.69	.28
Time 3 To Time 4	.57	.21

3.3 Satisfaction

To understand the perceived effectiveness of computer-based and conventional media for carrying out group tasks, we asked subjects to make a number of evaluations using 5-point rating scales. In particular, task force members were asked to judge the level of their own task involvement, the effectiveness of their subcommittee(s), how well the task force as a whole was working, and the extent to which their experimental condition helped or hindered the accomplishment of the task force mission.

Repeated measures ANOVAs show that the electronic group became increasingly more positive about task involvement as well as subgroup and task force effectiveness, even though the standard group initially scored higher on most measures. The effect is primarily attributable to retirees in the electronic condition. Most informative, perhaps, are responses to the very direct question about the influence of the medium on the task (Table III). Ratings yielded a very strong work status-by-condition effect, with retirees in the electronic condition and employees in the standard condition giving their experimental assignments very high marks. Assessments were just the opposite for employees in the electronic condition and retirees in the standard condition, with the latter judging themselves by far the most disadvantaged.[15]

When asked about their general satisfaction with the overall accomplishments of their task force, participants showed the same pattern (Table IV). That is, the

[15] Repeated measures ANOVAs show a significant main effect for task force ($F = 7.6$, $p < .01$), as well as for task force by status ($F = 16.5$, $p < .001$) and task force by time ($F = 10.3$, $p < .001$).

Table III. Evaluation of Experimental Condition

	MEANS		
	TIME.2	TIME.3	TIME.4
Retirees			
Electronic	3.9	4.0	4.6
Standard	3.1	2.9	2.7
Employees			
Electronic	3.3	3.5	3.9
Standard	3.8	4.1	3.7

Condition: $F = 7.58$***
Condition x status: $F = 16.51$***
Condition x time: $F = 10.32$***
Note: Higher numbers mean the condition is perceived as more helpful to task completion.

Table IV. Evaluation of Overall Task Force Performance

	MEANS		
	TIME.2	TIME.3	TIME.4
Retirees			
Electronic	2.8	3.2	3.7
Standard	3.5	3.4	3.3
Employees			
Electronic	2.8	2.9	3.8
Standard	3.7	3.6	3.4

Condition: $F = 2.99$†
Time: $F = 5.53$**
Condition x time: $F = 13.7$***
Note: Higher numbers mean better performance ratings.

electronic group showed increases, while the standard group showed stagnation or even declines.[16]

Correlating network participation (integrativeness[17]) with these effectiveness assessments in Table V shows, not surprisingly, that those who participate more in the communication network feel more involved in the task force. Effectiveness ratings do not, however, always follow involvement. Rather, the association between participation and perceived task force effectiveness is essentially zero at Time 2 and has become negative by Time 3; that is, those taking more active roles judge their task force as a whole to be less effective than do members who are less involved. By Time 4, the pattern is reversed, and task force effectiveness is again positively associated with participation.

[16] Repeated measures ANOVAs here showed significant main effects for task force ($F = 2.99$, $p < .05$) and time ($F = 5.53$, $p < .05$), as well as the time by task force interaction ($F = 13.7$, $p < .001$).
[17] *Integrativeness*, as noted earlier, is a measure of involvement (the proportion of actual links reported to possible links).

Table V. Correlations Between Involvement, Satisfaction, and Contact (Integrativeness Index)

Time 2	Involvement	.17
Time 2	Satisfaction with task-force performance	−.09
Time 3	Involvement	.21*
Time 3	Satisfaction with task force performance	−.15
Time 4	Involvement	.33
Time 4	Satisfaction with task force performance	.32

Table VI. Total Message Traffic Over Project Year

Recipients	Messages Sent	Messages Received
Individuals (total)	1,745	2,906
Single	1,160	1,160
Multiple	585	1,746
Staff (total)	1,266	—
Aliases (total)	1,080	11,590
Task Force Alias	434	—
All Chairs	407	—
Task Force	239	—
Overall Sum of Totals	4,091	14,496

4. ELECTRONIC NETWORK STRUCTURE

As we explained, the project retained a log of the headers of all network messages exchanged among electronic task force participants over the project year. This log included the sender's ID, the receiver's ID, the message date and time, and, if the message was a reply, the date and time of the original message. Topic identifiers were not retained for confidentiality reasons.[18]

Table VI describes how many messages were involved. During the project year, 4091 messages were sent by the 40 people taking part in the electronic network.[19] Given the various "aliases" (multiple recipients addressed by a single name that expands into a distribution list) employed, this number translates into 14,496 messages received. About 40 percent of these messages were sent point-to-point, sometimes to multiple addresses; and about 30 percent were messages to project staff, either for substantive assistance or computer help.

These messages were not evenly distributed across group members. As several similar studies have reported, approximately 25 percent of the people accounted for about 75 percent of the messages sent. The 10 "high senders" in this case included the 6 subcommittee chairs (all retirees); only one employee emerged as a heavy sender. Figure 8 shows percent of participation (i.e., percent who sent at

[18] Advance consent to message header logging was obtained prior to the start of the project.

[19] This figure does not include messages sent by the project staff to task force members either as originals or replies; they were routed through another host and were not logged.

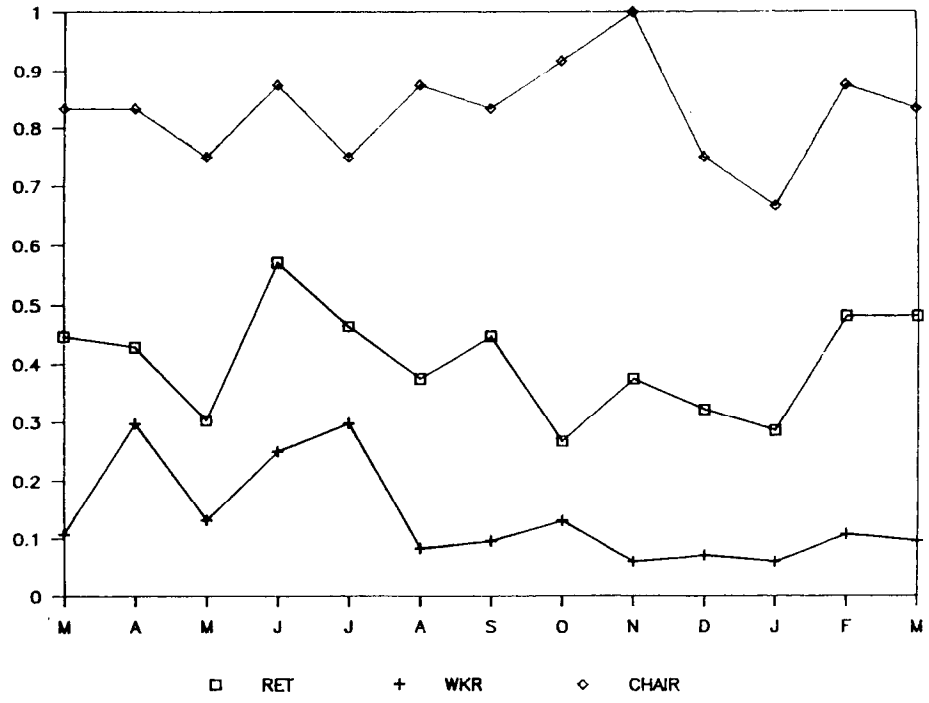

Fig. 8. Participation in network. Percent of groups participating.

least one message) during each project month by employment status. Retirees averaged nearly 50 percent participation each month; workers averaged closer to 20 percent, dropping to only about 10 percent during the last months.

Figure 9 shows the messages sent by the average individual in each group by month. On average, chairs sent 4 to 5 times as many messages as other participants. Of course, as Figure 10 indicates, chairs also received considerably more messages than other people; much of this information was apparently exchanged among themselves. Figure 10 also shows that, while retirees tended to send more messages than workers, they tended to receive just about the same number.[20]

In our first electronic mail study [7], we noted that users tend to divide early into heavy and light senders, with heavy senders getting heavier and light senders, lighter. Figure 11 shows sending patterns for the 10 "high users" in contrast to the remaining 30 network members. Here, too, this pattern is observed: High users got off to a fast start initially and their usage increased over time; light users started slow and changed little over time. The consistency of these trends suggests that they should be taken into account in implementation and training plans for electronic communication systems.

The availability of logged data for the electronic task force provides an opportunity to examine the relationship between computer-based communication and overall contact (structured self-report data). In general, we expected total reported contacts to exceed electronic contacts—and it would not have been

[20] This figure is based on the 14,000+ expanded-alias message set.

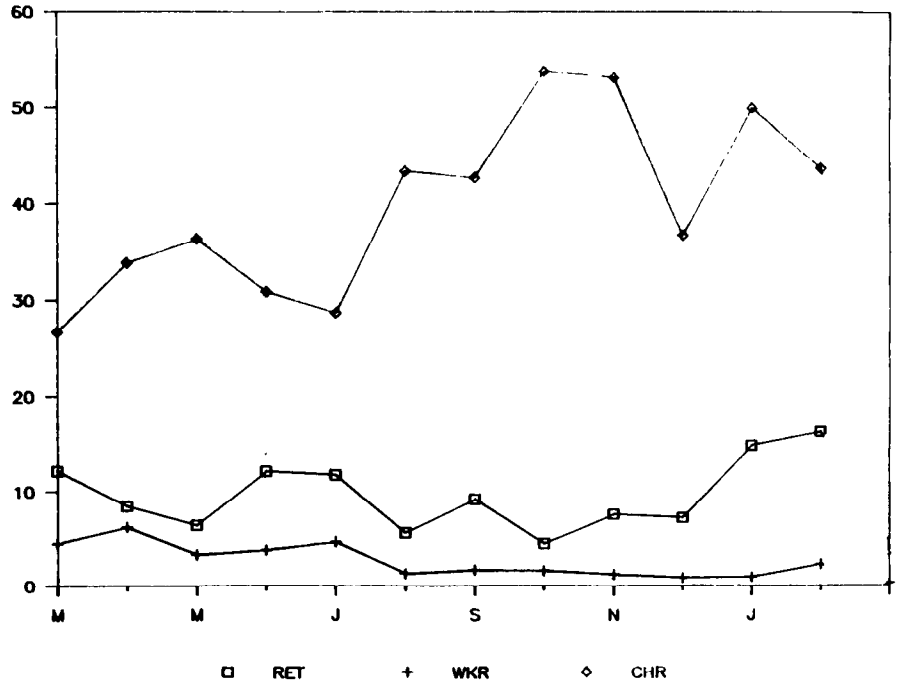

Fig. 9. Messages sent per capita by group.

surprising to obtain reports of contact between people who do not exchange electronic messages. However, it is quite surprising to find the reverse. Figure 12 shows the proportions of contacts that are associated with the exchange of electronic messages.[21] The first part of this figure shows that, if we look at all messages exchanged, about 8 percent of the individuals reported having NO contact with people with whom they had in fact exchanged electronic communication.

If we look only at "message loops" (i.e., messages that have received an answer), the proportion in this category drops to about 5 percent. Further restricting the definition of "what constitutes an exchange"—to a message loop that is addressed to only one person rather than a group—does result in largely, though not entirely, eliminating this category.[22]

In any event, we believe that this question of just what it is about an electronic exchange that defines it as a "contact" for reporting purposes is an interesting one. The issue is significant, particularly in terms of the presumed ability of logging systems to capture the electronic message exchange. Although logging systems clearly can capture the messages actually exchanged, the question

[21] These data are from Time 4; however, similar patterns exist in each of the preceding time periods. The proportions are based on the 780 contacts possible among a group of 40 people. The first two parts of the figure are based on the expanded message set; the third part is based on the point-to-point limited message set.

[22] The overall contact matrix and the "all loops" matrix correlate at .03 only. The point-to-point electronic loop matrix and the overall contact matrix correlate at .15.

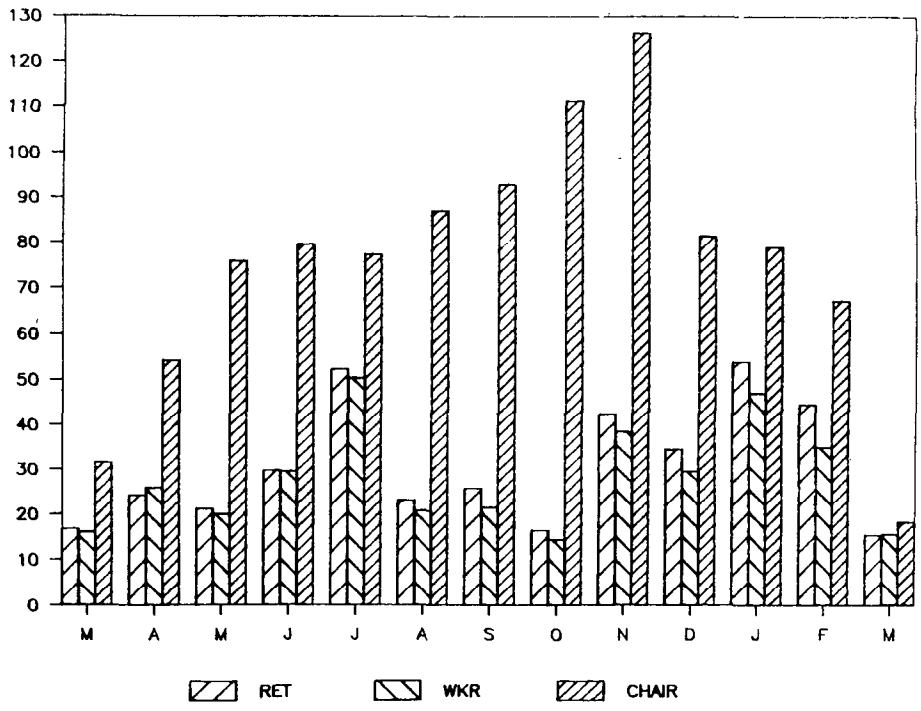

Fig. 10. Messages received by the average person by month.

remains what has actually been measured. Certainly it is not contact as perceived by the messagers. The issue of the relationship between perceived contact and electronic message exchange, we believe, deserves further investigation.

On balance, we think the task force experiment demonstrates that an electronic network can provide an effective infrastructure for sustained collaborative activity, even among people who are not computer sophisticated initially. We believe, however, that we have much to learn about how and why it works and about networked interactive systems generally. First, electronic mail does not serve as a replacement for other interaction media; rather than substituting for them, it may reinforce them instead of reducing their use (see Table I). Second, providing electronic communication cannot be construed just as the provision of an application; it might better be regarded as providing a way of sharing other applications that are individually used (see Section 2).

As a multipurpose avenue of exchange, the system played a significant role in the administration and coordination of task force activities (as evidenced by its use in arranging scheduled meetings shown in Table I). It also figured heavily in the shared development, review, and dissemination of the group's substantive work. For example, the task force decided to survey a broad range of retirees and employees so that its white paper would be more representative than its own membership: questionnaire items were prepared on-line and iterated for review until a final version was accepted; responses to the survey were entered into the database program, datasets were divided and distributed for analysis to the

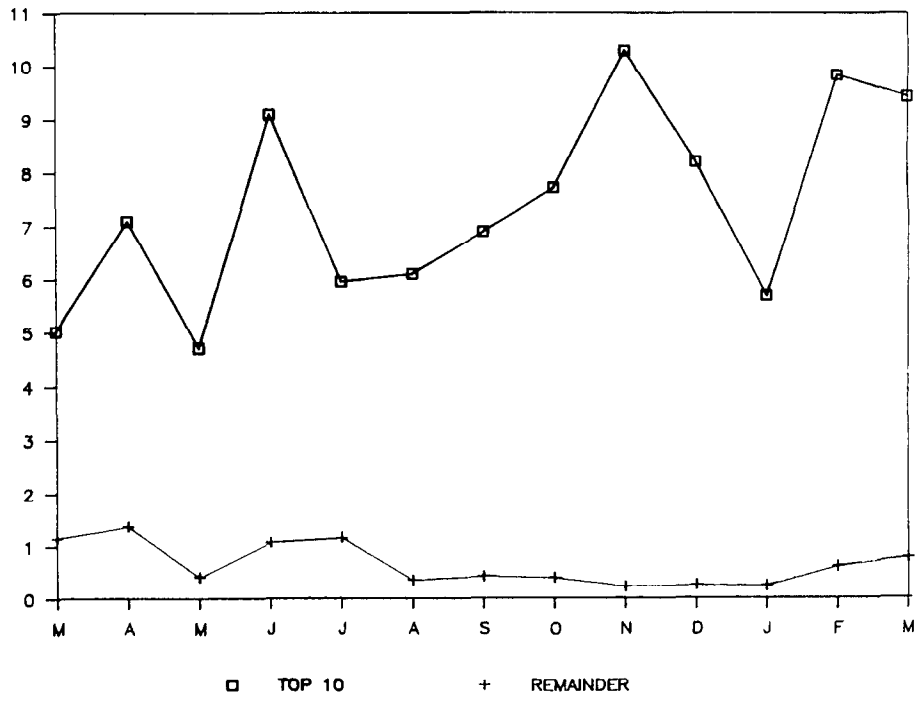

Fig. 11. High versus low users over time. Average messages sent per week.

appropriate subgroup, and results were made available to the task force as a whole. Interpretation and reporting were carried out using the text editor and, after each subgroup had an approved draft of its topic area, the several sections were concatenated to create the final white paper.

These examples should help clarify why there was such a high level of interaction within the electronic task force: It had undertaken a very ambitious route to fulfilling its charge. The course it set upon required intensive use of the technology and substantial work commitments from the members. In facilitating their frequent contact, the network seemed also to enable subgroup restructuring as the subtasks at hand required (e.g., to arrive at a final nonoverlapping set of items for the survey, the task force thought the most efficient course was to form a committee composed of representatives from each subgroup; they would negotiate a draft among themselves and then circulate it more broadly after redundancies had been removed, wordings agreed upon, and so on). In that process, it seemed relatively easy for individual members to change roles (e.g., some people were not particularly interested in defining and wording issues for the questionnaire, but they were extremely interested in developing a database and analyzing its contents. They, therefore, acquired the necessary DBMS skills and led this effort). Finally, while different activities dominated task force work at any point in time, there was always need for within-group expertise; although the research team provided a help line, there is no substitute for the local "guru" who speaks the language of the group, is in touch with its tasks, and has a special affinity for

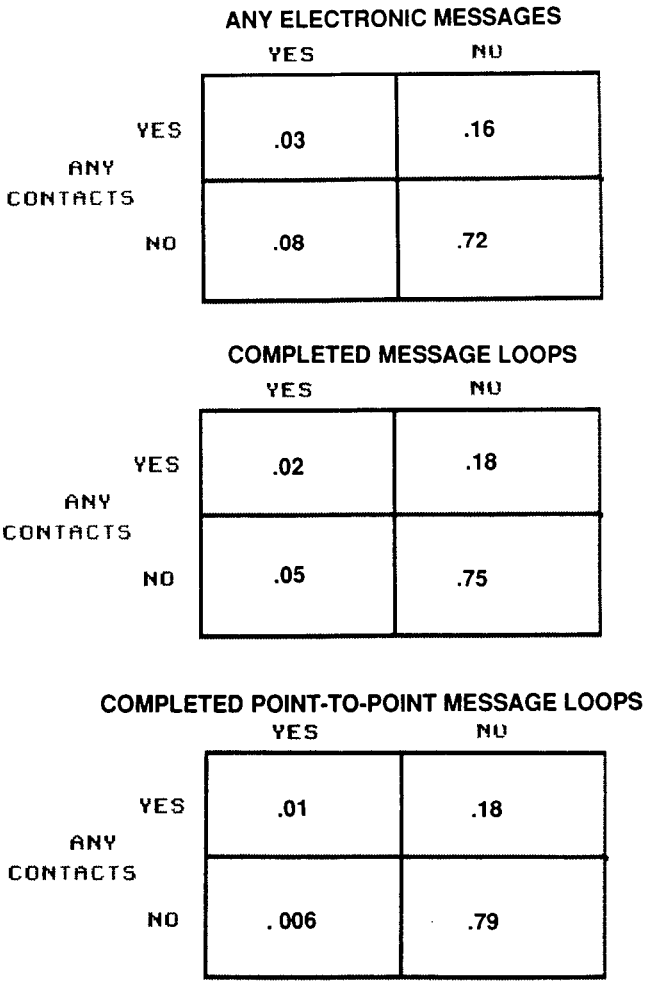

Fig. 12. Proportion of contacts associated with exchange of electronic messages.

the tools. Such local experts emerged within the electronic task force and provided a strong complement to official Rand help.

For all these reasons, a sizeable proportion of network interactions crossed initial subgroup boundaries, and their members had many opportunities both to maintain old social ties and to form new ones. Although the discussion above emphasizes instrumental exchange, it was evident that the network also became an important avenue of social exchange. Messages shared with the research team made it clear that even task-oriented interactions were conducted in a highly sociable manner, and the system was also used for interactions of an exclusively social nature. It is worth mentioning that the Bulletin Board facility remained notably underused—participants seemed to prefer sending a message to the electronic task force alias rather than to a Bulletin Board accessible by all,

perhaps because the former seems more like a social interaction. In any case, analyses of variance (see above) confirm that those in the electronic task force think they have formed significantly more lasting social ties than those in the standard condition.

The picture that emerges of the electronic network is one of a vigorous and effective group in which some individuals take the lead and others take part in differing degrees. There is extensive communication both within and across specific subgroup lines. Patterns that emerged early in its evolution characterized its later operation, but not rigidly; individuals moved both into and out of active messaging over time. In short, it looks very much like a computer-supported cooperative group in which a lot of work gets done.

5. DISCUSSION

At the beginning of the paper we posed a series of questions that we hoped this experiment would illuminate. Although not all of them have been answered definitively even within the compass of this study, we think the following conclusions have been corroborated:

—The electronically supported group developed a structure significantly different from that developed by the standard group, one that appears to take advantage of electronic media in terms of both breadth of access and opportunity to participate. While maintaining its formal organization, it developed a set of alternative structures not apparent in the standard group. The standard group had a generally consistent set of leaders, mainly employees; the electronic group had a much more fluctuating leadership pattern, dominated largely by retirees.

—The electronically supported group allowed different people to work at different times of the day according to their own schedules and certainly increased the ability of noncollocated retired members to take an active role in the project.

—The electronically supported group maintained a significantly higher degree of contact than did the standard group and had considerably less communication isolation. It was generally less centralized both overall and in its task group interactions, although the extent of centralization fluctuated over the project year. Further, in the electronic group, not everyone uses the medium with equal facility, and early experiences with it tend to be carried over into later time periods.

—Members of the electronically supported group appear to experience significantly more involvement in the work of the group, and to be more satisfied with its outcomes. But electronic communications are not simply substituted for traditional media; rather, the electronic task force maintained higher levels of communication in general through all channels.

—Keeping an electronically supported work group up and running is a relatively labor-intensive effort. A good deal of staff time was required to devise and maintain the hardware–software configuration; even more effort was required to respond to user needs and support them as they made the technology their own. The "humanware" demands of such systems cannot be discounted.

What this project demonstrates is that electronic media can constitute a major component of the "means of production" for an information-intensive work group. Control of the means of production tends to mean control of the group's directions and purposes. In the standard group, production-relevant resources (e.g., colleagues, meeting opportunities) were more readily accessible to employees on a regular and usually informal basis; retirees had a more limited ability to shape the work process. In the electronic group, by contrast, the computer-based information and communication system offered a major new production technology, one that proved critical in the emergence of quite different work group structures. Employees, for varied reasons including job demands and time pressures, generally lacked the opportunity to acquire the level of knowledge of this technology that many of the retirees developed; accordingly, it was the retirees in that task force who controlled work group production processes.

Access to tools also clearly shaped the products of the task forces. Although both groups produced effective and insightful reports on the transition to retirement, the standard group's product was about 15 pages in length, composed largely of anecdotal advice gathered through conversations. The electronic group's report, by contrast, was about 75 pages in length, composed primarily of tables describing the results of an opinion survey that the group designed and analyzed on-line. This is not to say that one product is better as a function of length or of its qualitative or quantitative nature; rather, it is to suggest that work tools really do condition how groups define their work goals.

It is also interesting to note that although the task forces have achieved their goals and the field experiment has formally ended, the electronic group is continuing with a communication network. Although the network operates officially under the auspices of the parent organization, it will be managed and supported (and, perhaps, controlled) by electronic task force participants themselves. Additionally, there is considerable demand on the part of some former standard task force participants to become part of the electronic network, and plans are underway to broaden its membership as soon as feasible.

There are, we believe, a host of important questions to be answered about how computer-supported cooperative work tools shape and interact with task demands. This research has contributed clear evidence that both the outcomes and the processes of cooperative work are significantly and directly affected by the tools themselves, and that these effects are systematic and pervasive. We have also established that it is feasible to conduct controlled field experiments in computer-supported cooperative work and to develop a substantial base of information about the structure and performance of such groups through relatively unobtrusive methods. We think the understanding to be gained from such procedures outweighs the effort they entail. Consequently, we hope that future research in this arena includes careful field experimentation with work groups and computer tools.

APPENDIX. RESEARCH AND ANALYTICAL METHODS

The bulk of the specific measures used in this study were derived from the four rounds of questionnaires. At each time point, respondents were shown pictures

(ID photos) of each of the other participants.[1] They were asked first to indicate how well they "knew" the person, scaled as "know well," "know a little," or "don't know." "Know a little" was defined as "recognized by name or by face." If they "knew" the person at all, they were then prompted for whether they had had any "contact" with the person in the last two weeks, where contact was defined as including in-person interaction (in meetings or by classes), phone calls, memos, or electronic mail. If a contact was reported, they were asked if the purpose of the contact was "chance," "social," "general business," or "task force business" (more than one response was acceptable). In addition, at the last interview, respondents were asked how the contact took place: "scheduled meeting," "unscheduled face-to-face encounter," "telephone," "written letter or memo," or (for the electronic group) "electronic mail."

The three attachment measures were constructed from 40-by-40 matrices summarizing the knowledge degree and contact responses. Each matrix had the individuals as both row and column headers. Each row represented the answers of a given individual; each column, the people with whom that attachment was being reported. For "knowledge," values could range from 0 (no knowledge) to 2 (know well). For contact, values were either 0 (no contact) or 1 (contact). The matrices were initially not symmetric, since it was not necessarily the case that the two parties would agree on their connection.

The matrix of "recognition" relationships was constructed as a symmetric matrix by allowing the relationship between two people to be coded as "1" if *either* person reported knowing the other even a little ("0" otherwise). The matrix of "knowing" relationships was constructed by coding "1" only if *both* parties reported knowing the other "well." The contact matrix was merely made symmetric; that is, a contact was presumed to exist if *either* party reported it. There were thus three matrices of relationships for each task force for each of four time periods.[2]

The structural indices were largely constructed from these matrices. The "density" of a network of interconnections summarized in a matrix is simply the proportion of actual relationships reported relative to the total possible (in a 40×40 matrix, this would be 780 or $(N(N-1)/2)$. If everyone were connected to everyone else, the index value would be "1.0"; if there were no relationships, it would be "0" [13].

Integrativeness and *betweenness* are indices relating to an individual's position relative to others in the network (matrix). Integrativeness is related closely to density and is simply the proportion of others in the network to whom one is connected. Betweenness is a related but distinct concept reflecting one's centrality in a network; specifically, it measures the proportion of all the links between network members that pass through a given person [8]. It is an approximate measure of power or control vested in a given person. Both measures reflect higher values for a person the more significant that person's participation in the

[1] At Times 2 and 3 they were asked only about their own task force; at Times 1 and 4 they were queried about the participants in the other task force as well.

[2] Matrices reflecting the purposes of contacts were also constructed but are not reported here. For Time 4, five matrices, reflecting the contacts through different media, were also constructed by coding "1" if a contact was reported and a given medium was mentioned.

network might be. Scalar values for each individual in the network were calculated for each matrix and time period and used in correlational and regression analyses. The satisfaction and involvement measures used in these analyses were derived from questionnaire items that used a 5-point scale from high to low.

The "network maps" or "sociograms" (Figures 3–6) were constructed by decomposing the various matrices through multidimensional scaling, resulting in a two-dimensional representation of the more complex matrix [19]. In these "maps" people more central to the network tend to be closer to the center, while those less involved tend to be toward the periphery. People who interact with each other, and with others in similar ways, tend to be closer together in clusters on the map. For most purposes, visual inspection of the map is enlightening. For more rigorous analyses of social structure, there are tests for clustering and group formation; this stage in our analysis is still under way at this reporting.

The message header analyses are based partly on the "expanded" message set and partly on the more limited set of original address messages (see Table VI for how aliases translate into expanded messages). Figures 8, 9, and 11, dealing with message sending, use the limited set; Figure 10 (receiving messages) is based on the larger set. Figure 12 uses the expanded set for the "any message" section and the limited set for the communication-loop data.

Any other inquiries on data or analytical issues are welcomed by the authors.

REFERENCES

(Note: References [10] and [15] are not cited in text.)

1. BIKSON, T. K. Understanding the implementation of office technology. *Technology and the Transformation of White-Collar Work*, R. Kraut, Ed. Lawrence Erlbaum Associates, Inc., Hillsdale, N.J., 1987, pp. 155–176; also The Rand Corporation, N-2619-NSF, June 1987.
2. BIKSON, T. K., AND EVELAND, J. D. *New Office Technology: Planning for People*, Work in America Institute's Series in Productivity. Pergamon Press, New York, 1986.
3. BIKSON, T. K., EVELAND, J. D., AND GUTEK, B. A. Flexible interactive technologies for multiperson tasks: Current problems and future prospects. In *Technological Support for Work Group Collaboration*, M. Olson, Ed. Lawrence Erlbaum Associates, Inc., Hillsdale, N.J., pp. 89—112.
4. BIKSON, T. K., GUTEK, B. A., AND MANKIN, D. Implementing computerized procedures in office settings: Influences and outcomes. The Rand Corporation, R-3077-NSF, Oct. 1987.
5. BIKSON, T. K., STASZ, C., AND MANKIN, D. A. Computer-mediated work: Individual and organizational impact in one corporate headquarters. The Rand Corporation, R-3308-OTA, Nov. 1985.
6. BIKSON, T. K., EDEN, R., GILLOGLY, J., HAHM, W., PAYNE, J., AND SHAPIRO, N. How to use the task force microcomputer. The Rand Corporation, N-2670-MF, Sept. 1987.
7. EVELAND, J. D., AND BIKSON, T. K. Evolving electronic communication networks: An empirical assessment. In *Office Technology and People*, Elsevier Science Publications, Amsterdam, The Netherlands, 1987, pp. 103–128.
8. FREEMAN, L. A set of measures of centrality based on betweenness. *Sociometry 40* (1976), 35–41.
9. HILTZ, S. R. *On-Line Research Communities: A Case Study of the Office of the Future.* Ablex Publishing, Norwood, NJ, 1983.
10. HUFF, C., SPROULL, L., AND KIESLER, S. Computer communication and organizational commitment: Tracing the relationship in a city government. *J. Applied Social Psychology*, In press.
11. JOHNSON, B. M., AND RICE, R. *Managing Organizational Innovation: The Evolution from Word Processing to Office Information Systems.* Columbia University Press, New York, 1987.
12. KLING, R., AND SCACCHI, W. The web of computing: Computer technology as social organization. *Advances in Computers 21* (1982), 2–60.

13. KNOKEM, D., AND KUKLINSKI, J. H. *Network Analysis.* Sage Publications, Beverly Hills, Calif., 1982.
14. MARKUS, M. L. Toward a 'critical mass' theory of interactive media: Universal access, interdependence and diffusion. *Communication Research 14*, 5 (Oct. 1987), 491–511.
15. MCEVOY, B., AND FREEMAN, L. *UCINET: A Microcomputer Package for Network Analysis.* University of California, Irvine, Calif., 1986.
16. PAVA, C. H. P. *Managing New Office Technology.* The Free Press, New York, 1983.
17. RICE, R. E. Mediated group communication. In *The New Media: Communication, Research and Technology*, R. E. Rice and Associates, Sage Publications, Beverly Hills, Calif., 1984, pp. 129–154.
18. RICE, R. E., AND CASE, D. Computer-based messaging in the university: A description of use and utility. *Journal of Communication 33*, 1 (1983), 131–152.
19. ROGERS, E., AND KINCAID, D. L. *Communication Networks: Toward a New Paradigm for Research.* Macmillan, New York, 1981.
20. STASZ, C., BIKSON, T. K., AND SHAPIRO, N. Z. Assessing the Forest Service's implementation of an agency-wide information system: An exploratory study. The Rand Corporation, N-2463-USFS, May 1986.
21. TAYLOR, J. C. Job design and quality of working life. In *Technology and the Transformation of White Collar Work*, R. Kraut, Ed. Lawrence Erlbaum Associates, Inc., Hillsdale, N.J., 1987, pp. 211–235.
22. TRIST, E. L. The sociotechnical perspective: The evolution of sociotechnical systems as a conceptual framework and as an action research program. In *Perspectives on Organization Design and Behavior*, Andrew H. Van de Ven and William F. Joyce, Eds. Wiley and Sons, New York, 1981, pp. 19–75.
23. ZUBOFF, S. *In the Age of the Smart Machine.* Basic Books, New York, 1988.

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