[Note: This front page replaces the first two pages of the published article, because those are printed on color pages and do not reproduce well.]

VIDEO AS A TECHNOLOGY FOR INFORMAL COMMUNICATION

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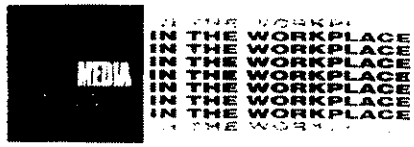
We have prototyped several video telephone systems over the past three years, one of which is now serving about 125 users on a daily basis. Our goal has been to devise new telecommunications applications to support collaboration among members of geographically distributed work groups and to use the insights derived from building these applications to identify communication capabilities that the applications require from a network infrastructure. (See accompanying article by Arango et al. in this issue). The design process we use at Bellcore combines prototyping communication applications with behavioral and social science data collection and analysis. Our designs have often been motivated by theories of social interaction, and our evaluation techniques include both quantitative and qualitative methods to understand use of the systems and directions for change. To assess users' needs for telecommunications applications, we have conducted national surveys, telephone interviews, and field observations in diagnostic work settings. We prototyped, deployed, and evaluated three iterations of video telecommunication systems [4], trying to improve support for collaboration and the balance between privacy and accessibility.



The intent of this article is not to describe our total research program nor to discuss the evolution of the systems we have built. Rather, we will examine in detail a single attempt to use video telephony for the type of informal communication that is common among people who are physically colocated. It presents an evaluation of a desktop video telephony system deployed in 1990. While our recent video telephony prototypes have improved on this early system, revisiting it is informative for two reasons. First, the evaluation points to some of the challenges one faces in designing communication technology to mimic social processes that appear to be trivially easy to accomplish in daily life. Second, the approach we adopted demonstrates some of the benefits and limitations of theoretically motivated system design and empirically based evaluation, in contrast to the less disciplined "build it and try it" approach of much human-computer system design. Thus, one can consider the evaluation we report here as a case study both in using video for spontaneous conversation and in applying social science theory and method to the tasks of system design and evaluation.

The prior literature on organizational communication and our own studies of distributed work demonstrate the importance of informal communication in organizations. Formal communication flows through official organizational channels, is often prearranged, and is typically conducted in a formal style. In contrast, informal communication cuts across these organizational boundaries and often happens spontaneously. In terms of style, informal communication is often more frequent, expressive and interactive than formal communication [6, 13, 25].

These studies show that in the aggregate, spontaneous, informal communication is useful. It is a crucially important method that organizations rely on to accomplish work, transmit organizational culture and knowledge, and maintain the loyalty and good will of their members. It gives organizational members the flexibility to deal with highly uncertain and ambiguous topics, tasks, and decisions. Informal communication is especially important for the less directly task-oriented aspects of organizational membership (e.g., learning the organizational culture, becoming loyal to an organization, making judgments of others, and forming relationships). While informal communication is important in the aggregate, almost any particular episode is expendable. Participants neither seek such episodes out nor willingly incur costs to have them; rather they opportunistically exploit them when they come about by chance.

Typically, informal communication is mediated by physical proximity. The chance encounters and ease of access among people who are physically close to one another provide many opportunities for organizational members to come into contact and communicate [1]. When people are physically close to one another, communication typically occurs through face-to-face conversations or meetings. Compared to other communication channels, face-to-face communication is both socially oriented and rich. According to social presence theorists [24], face-to-face communication highlights the other people in an interaction and interpersonal relationships. From a media richness perspective [6], face-to-face communication is interactive and expressive and is especially useful for dealing with nonroutine and equivocal issues.

Potential of Video/Audio Technology for Informal Communication

Analyses both of the ways the visual channel is used to support informal interaction in face-to-face settings and of early experiments using video to support distributed work groups suggest that video communication systems might be able to substitute for physical proximity and support informal communication at a distance. We will now review the prior literature consistent with the hypotheses that video-based communication is helpful in:

1. increasing the spontaneity and frequency of communication,
2. supporting social relationships,
3. coping with the most complex and equivocal communication problems encountered in work groups, and as a result
4. integrating members into and supporting the work in research and development groups.

Frequency and spontaneity of interaction. Close observation of spontaneous, face-to-face communication episodes [13] demonstrates the importance of the visual channel in initiating informal communication. The visual channel increases the probability of spontaneous interaction by helping people simultaneously identify a partner, topic, and moment for conversation and by helping them ease into interaction. Recent studies of encounters across video conferencing systems show that these systems can lead to spontaneous interaction, although less than in face-to-face settings [7]. A recent demonstration project at Xerox PARC provided a continuous video and audio connection between two of its research facilities located hundreds of miles apart [2, 8]. Usage data indicated that over 70% of the interpersonal communication between the two sites consisted of short, casual, "drop-in" interactions and that most of these interactions would not have occurred without a continuous video link.

Richness and social-orientation of interaction. Both media richness theorists [6] and social presence theorists [24] array communication channels along a continuum anchored by face-to-face interaction at the richer, social end and written documents at the other. Insofar as audio and video communication mimics the features of face-to-face communication in being expressive, interactive, and focusing attention on personal attributes, it should function as face-to-face communication. Thus, the media richness and social presence perspectives both suggest that video

teleconferencing should be well suited for informal communication, and especially good for aiding the more social, the more uncertain, and the more equivocal aspects of communication. There is evidence in the prior literature, however, that the presence of an audio channel makes more of a difference than the presence of a visual channel [18].

Support for research and development environments. Early trials of telemedicine attempted to use video for medical information transfer, diagnosis, consultation, and patient contact. While the technology had only mixed success in supporting these information transfer and diagnosis tasks, Rockoff [21, p. 1087] offers a "clinical impression that this technology improves the cohesiveness and sense of organizational unity experienced by health care providers in a geographically dispersed system (i.e., it facilitates their functional integration)." More recent studies of video networks in R&D organizations [2, 3, 7, 8, 17] have illustrated the value of video communication networks, as well as showing some of their limitations. For example, the Xerox PARC experiment described earlier suggests that a video link can be barely adequate to promote a shared context and culture to support joint work across two R&D locations, but that audio and video alone will be insufficient for accomplishing tasks. Both sets of findings suggest the most important value of video telephony might be to aid in the formation and maintenance of social relationships.

An Evaluation of Video Telephony for Informal Communication

Our research evaluates the adequacy of audio and video conferencing for supporting informal communication in a realistic setting. Because face-to-face communication has traditionally been the primary mechanism through which organizations conduct informal communication, the evaluation explicitly compares video telephony with face-to-face communication. We were interested in the degree to which visual communication shares some of the attributes of face-to-face informal communication—its frequency, expressiveness, and interactivity—and whether it can serve the same functions.

We addressed this question in the context of a four-week field experiment in which temporary employees and their supervisors and mentors at Bellcore used an audio and video conferencing prototype called the *Cruiser*™ system [22]. Since at its core, the Cruiser system is standard video telephony, it should have the attributes we mentioned that make it appropriate for rich communication with social presence. In addition, this system included features explicitly designed to increase the opportunities for communication and thus increase the frequency of spontaneous conversation.

The experiment was conducted as part of the summer internship program for college and graduate students at Bellcore in 1990. Students in telecommunications engineering, computer science, mathematics, psychology, statistics, and other disciplines worked for 10 weeks with senior researchers in their fields. From a pool of about 50 volunteers, we randomly selected 23 volunteers—11 students and their 12 mentors—to use the Cruiser system. The mentors and students were all housed in a single building, with a mentor-student pair typically located on the same floor. Thus, the Cruiser system simply supplemented the communication they could have by walking to one anothers' offices.

The Cruiser environment in the summer of 1990 consisted of a software-controlled audio and video telecommunications network. Each user received a multiwindowed computer terminal that controlled the Cruiser application and provided conventional computing, including email. Along with the computer terminal, the Cruiser station consisted of a 12-inch color video monitor, a small speaker, and a microphone. Audio connections were full duplex. This allowed both parties to a conversation to talk at the same time with no audio echo or feedback.

For the summer experiment, the Cruiser system consisted of audio and video telephony supplemented by three novel calling methods to encourage spontaneous interactions that might lead to conversation:

Cruises, which consisted of one or a series of audio and video calls. When the caller issued the command, the system opened an immediate audio and video connection to the called party, which timed out after about three seconds unless one party explicitly continued it by issuing a Visit command. A list of people could also be called. If users issued a Cruise command without arguments, the system initiated a series of connections to randomly selected users.

Glances, which were one second video-only connections to one or a series of other people. If users issued a Glance command without arguments, the system initiated a series of Glances to randomly selected users.

Autocruises, in which the system itself initiated calls between users at random times. Except for initiation, the protocol was the same as a Cruise. The intended analogy for the Autocruise was wandering in a corridor and randomly seeing other people with whom one could speak.

The system included two privacy features. First, users could issue a *Private* command, which notified callers that calls were not being accepted. Second, a *Reciprocity Rule* was imposed. If someone else could see and hear a user, the user could see and hear that person in return.

Finally, to increase awareness of the other Cruiser system users, the system included an *Active Directory*, listing the availability status of all other users, and a *Call History*, showing who had called a user.

Results

A maximum of 23 people could place calls on any day. During the 21 business days of the trial, users made 1,295 call attempts to 1,556 recipients[1] or about 2.7 call attempts per potential user per day. As with most innovations introduced into organizations, users showed an early burst of activity as they experimented with the system. Figure 1 shows the distribution of call attempts per potential user per day.[2] The distribution is plotted separately for all users, for five dropouts—users who attempted

[1]Some call attempts were to a series of recipients.

two or fewer calls during the second week of the trial—and for 18 sustained users—users who attempted more than two calls during the second week of the trial. Throughout the trial, the sustained users were placing 4 to 5 calls per business day, with call frequency understandably dropping on the weekends (days 6 and 7, 13 and 14, 20 and 21). These numbers are comparable to the frequency with which staff members across the company placed telephone calls (5.4 calls per day), even though the Cruiser system provided access to far fewer parties.

Cruiser calls were short. The modal Cruiser call was under 15 seconds, and the median call lasted only 27 seconds. Approximately 25% lasted three minutes or longer, 5% lasted more than 30 minutes and the longest calls were over four hours. This distribution of call duration is similar to that of the telephone, where the typical call is short, but the distribution has a very long tail [15]. Long Cruiser calls include both sustained work sessions similar to those conducted by telephone and two interesting behavioral innovations enabled by this technology.

The first of these is the *virtual shared office*. On occasion some people connected their offices for an extended period, without engaging in sustained conversation. Rather, the pair would work relatively independently, occasionally having conversation to get help on a problem, ask a question, make an observation or tell a joke. The open connection reduced the behavioral cost of communication during periods when the participants anticipated the need for multiple episodes of unscheduled conversation. Other researchers studying desktop conferencing systems have reported similar phenomena [2, 3, 9].

The second innovative use of long calls is the *waylay*. Here one member of a work team with a pressing communication need makes a connection to another's office. If the called party is not there, instead of disconnecting and trying again later, the caller simply maintains the connection and waits for the absent party to return. The waiter can monitor the other's office through peripheral awareness and still focus attention on his or her own work.

Call Types

As described previously, calls can either be Cruises or Glances initiated by callers or Autocruises initiated by the system, calls can be placed to one or more people simultaneously, and the name of the called party can be supplied by the caller or supplied by the system. Table 1 shows the distribution of call attempts across these call types and the percentage of each call type that was accepted.

As Table 1 illustrates, the most frequent use of the system was similar to telephone usage, to execute a point-to-point call to a single, named recipient. However, some of Cruiser's features had the intended effect of providing users with greater awareness of others and increasing the frequency of spontaneous and informal interaction. For example, 18% of user-initiated calls were Glances, whose sole purpose was to provide information about others' availability. Users informed us they used Glances rather than Cruises to uncover this information because they were quick and relatively unintrusive and thus provided a better balance between convenience to themselves and disturbance of others. In one-fifth of these Glances, users let the system select parties to call. Both in initiating a Glance and in allowing the system to select the partners, they were using the system to increase their awareness of who was around.

Figure 2 shows the distribution of Cruise calls and Glances over hours of the day. These data substantiate the hypothesis that the Cruises and Glances were used for different functions: they have distinctive distributions over time (Pearson $\chi^2 = 21.08$, $df = 11$, $p < 0.5$). Glances were more likely to occur early in the morning, right after lunch, and on weekends, when uncertainty about who was around was highest and perhaps before the callers themselves had become fully absorbed in their work.

While the Glance was used with modest frequency and seemed to improve informal interaction and organizational awareness, the Autocruise did not. The intent of the Autocruise was to mimic the opportunities for conversation that people have when they pass by one another in the hallway. The opportunities these Autocruises provided rarely resulted in conversation. While 54% of user-initiated calls were accepted (i.e., at least one of the parties executed the Visit command), only 3% of 236 Autocruises ended in conversation. For an Autocruise to be accepted two parties needed to be in their offices, needed to notice that a call attempt had occurred, and needed to want to talk to the potential partner at just the moment that the conversational opportunity presented itself. Given the low probability of all these factors being true simultaneously, the low conversion rate for Autocruises is perhaps understandable and may not be much lower than the probability that on a particular occasion two random people would engage in conversation when passing in a hallway.

More telling than the simple acceptance rate for Autocruises, however, are results demonstrating that users found Autocruises highly objectionable. When asked to describe features of the Cruiser system they disliked most, 40% of users mentioned Autocruises. Unlike the random encounters that occur multiple times per day when two people are colocated, the Autocruises did not allow people to conduct the subtle nonverbal negotiations that regulate the entreé into conversation.[3]

While this explicit attempt to cre-

[2]Because of uncertainty about who was present on a given day, the total number of calls per day was uniformly divided by 23, the maximum number of users. Thus, Figure 1 underestimates per person usage on a typical day.

[3]In another version of the system, in which pairs for an Autocruise were selected from among those with a high prior frequency of communication, acceptance rates were still low and the feature was still disliked. This suggests that problems resided in the initiation mechanism, not in the selection of conversational partners.

ate a hallway metaphor failed, the video fostered spontaneous communication in other ways, by enabling more open conversations than conventional telecommunication services. When people saw someone having a conversation on the Cruiser system, they could easily insinuate themselves into these conversations. They used the visual channel to negotiate entreé into these conversations, much as they would enter an ongoing discussion in an office or hallway. As one interviewee reported, "When I'm talking on the phone, nobody would come in, but when I'm talking on Cruiser, people feel free to come in and interrupt . . . I would do the same thing. I would walk into somebody's office if they were on a Cruiser call. It's much more expansive; it's inclusive." Not only do visitors enter Cruiser system calls, but the reverse also happens. That is, a caller happening on a face-to-face conversation often joined in.

Comparisons to Other Media

Self-report data confirmed the previous observation, based on system logs, that the typical Cruiser call was short. During a debriefing interview, users compared a recent conversation held over the Cruiser system with a face-to-face conversation with the same partner. Table 2 summarizes the reported length, content, and outcomes of the conversations.

Respondents reported Cruiser calls lasted about 4 minutes compared to 30 minutes for face-to-face conversations. According to respondents, conversations using the Cruiser system were more likely to have greeting and scheduling as the main topic, but less likely to involve problem solving and decision making. Most reported using Cruiser conversations to inquire about or to inform one another about the status of work activities, to get quick answers to short questions, or to schedule work. In essence, they reported that during Cruiser conversations they mostly prepared for work, while during face-to-face conversations they actually performed the work.

Why was this? Time and again users said they used face-to-face communication rather than the Cruiser system because the Cruiser

Table 1. Frequency and outcomes of call attempts

Call type	# of called parties		% calls accepted
	1	>1	
Cruise—caller supplied name	1015	8	54%
Cruise—system supplied name	67	NA	18%
Glance—caller supplied name	174	9	NA
Glance—system supplied name	NA	51	NA
Autocruise—system supplied name	236	NA	3%

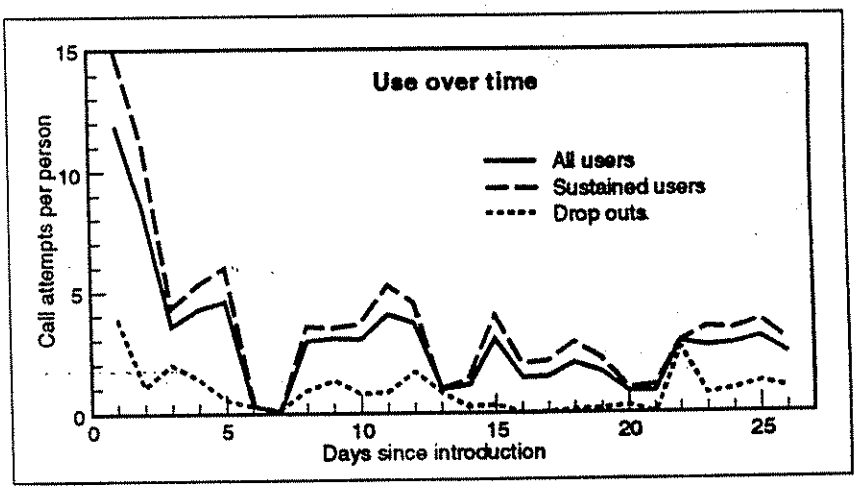


Figure 1. Number of calls over days

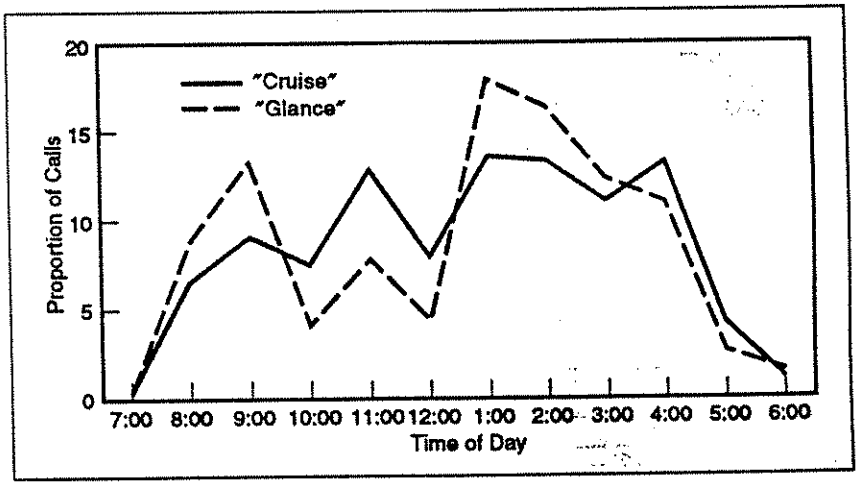


Figure 2. Call attempts by time of day

system was not able to support all the communication demands of conventional work activities. This version of desktop teleconferencing was still insufficiently rich compared to face-to-face communication. For instance, a major problem that 90% of respondents mentioned was an inability to share work objects when conversing with someone over the system. One mentor, for example, called a student just as she was in the midst of trying to understand and solve a problem in a computer program she was writing. Taking advantage of this opportunity, the student sought advice. However, after some discussion, the mentor walked to the student's office so they could jointly work at a computer terminal and examine printouts. Similarly, one student reported that he often called his mentor whenever he was stuck on a problem. By using the Cruiser system, he could quickly tell if his mentor was available for assistance. They would briefly discuss the problem and then schedule an immediate or deferred meeting time, mainly so they could use a blackboard. In a third case, a student had a virtual office connection to his mentor while working on an outline for a presentation. The student noticed the mentor at his desk and opportunistically asked for advice. This led to extended discussion. The conversation progressed to the point where the mentor asked the student to come to his office so they could jointly use the blackboard.

Sometimes the resource needed to continue a conversation was another person. Several respondents complained that while Cruiser communication was appropriate for pairs, it was unsatisfactory for communication in a larger group because the system had no facilities for multiperson conferencing.

Other needs for communication richness occurred when people were dealing with social relationships and ambiguities, rather than work objects. Thus, many of the mentors reported they used the Cruiser system to inquire about project status, but met face-to-face when commenting about interns' personal performance, for example, after a presentation. One mentor said he scheduled a face-to-face evaluation session

Table 2. Duration, topics discussed, and outcomes of conversations

Measure	Modality		
	Cruiser system	Face-to-face	Paired t-test
Conversation length (in minutes, self-report)	3.9	35.7	−3.96***
% meeting work related	90	89	.00
Meeting topic (*Percentage of number of meetings*)			
Schedule meetings and tasks	48	19	2.03
Assign tasks to people	14	19	−.57
Report work status	71	81	−1.00
Solve problems	48	86	−2.61**
Make decisions	33	57	−1.75
Discuss workplace information	0	10	−1.45
Discuss nonworkplace topics	5	5	.00
Greet another	33	19	1.83
Outcomes of meetings (1 = low, 7 = high)			
Did productive work	4.77	5.94	−3.92***
Learned organizational culture	1.88	2.10	−0.81
Maintained relationship	4.29	5.19	−4.26***

Note: $N = 23$
*$p < .10$
**$p < .05$
***$p < .01$

Table 3. Appropriateness of four media for different tasks

Task	Cruiser system	Face-to-face	Phone	Documents
Check project status	4.52	4.86	4.24	4.19
Stay in touch	4.48	4.76	4.81	4.38
Exchange time-sensitive information	4.38	4.19	4.67	3.95
Ask questions	4.38	5.00	4.43	4.19
Exchange information	4.33	4.76	4.19	4.19
Schedule meetings	4.24	4.48	4.57	4.57
Make commitments	4.10	4.86	4.19	4.00
Make decisions	4.05	4.95	3.76	3.24
Generate ideas	3.86	5.00	3.40	3.38
Negotiate or bargain	3.76	5.00	3.67	2.62
Resolve disagreements	3.57	5.00	3.48	2.90
Get to know someone	3.24	5.00	2.76	2.62
Explain difficult concepts	3.10	5.00	2.69	2.67
Exchange confidential information	2.74	5.00	3.62	2.71
Mean	3.91	4.85	3.89	3.54

because he anticipated a long meeting in which the parties would need a "richer" (his term) communication environment, including the ability to see and respond to subtle reactions.

These differences between Cruiser and face-to-face conversations led to differences in their perceived value. As shown at the bottom of Table 2, respondents reported that Cruiser conversations were less useful, both for getting work done and for learning about their conversational partner.[4] These data come from respondents' assessments of the Cruiser and the face-to-face conversations on 7-point Likert items. These items were grouped into three scales, with item assignment based on a principal components analysis with varimax rotation. The scales were *Productivity* (e.g., usefulness for getting your work done; relevance to your ongoing work; Cronbach's alpha = .73); *Organizational culture* (e.g., usefulness for keeping up with company people, politics, policies, and other news; usefulness for providing background information about how things are done at this company; Cronbach's alpha = .75); and *Relationship maintenance* (e.g., usefulness for maintaining a personal relationship with someone at work; usefulness for understanding your partner's point of view; Cronbach's alpha = .53).

[4]While Table 2 shows paired t-tests between Cruiser and face-to-face conversation, the differences between the modalities hold when duration is controlled, primarily because conversation duration was only weakly correlated with the outcome judgments (*r*'s range from −.14 for the relationship scale to .14 for the productivity scale). Rather than length of a conversation, the data show that topic of conversation was the prime determinant of the amount of work respondents reported they accomplished. Respondents reported more work was done when the topic was solving problems ($\beta = .34$, $p < .005$), making decisions ($\beta = .23$, $p < .05$), or assigning work ($\beta = .28$, $p < .05$), but that less work was accomplished when they talked about scheduling work ($\beta = -.20$, $p < .10$; R^2 for the model = .34).

Perceptions of Media

Different media have properties that people perceive to be useful for different tasks [20]. We asked participants in our study to rate the appropriateness of nine different media for a variety of communication tasks. The media were one-on-one face-to-face meetings, group meetings, telephone, email, answering machines, fax, handwritten notes, printed documents, and Cruiser desktop video conferencing. Table 3 lists the communication tasks, based on those used in earlier evaluations of media appropriateness [e.g., 23].

Table 3 also shows the mean rating of appropriateness for these communication tasks for four of the media, including the Cruiser system, one-on-one, face-to-face communication, the telephone, and the exchange of documents. Ratings were judged on a 1 (Inappropriate) to 5 (Appropriate) Likert scale. The tasks are ordered in decreasing appropriateness of the Cruiser system for performing them.

Note that most media, including the Cruiser system, were judged inferior to face-to-face communication for most tasks. This finding is common to many studies of media appropriateness (e.g., [19]). It is more noteworthy that the pattern of per-

ceived appropriateness of the media differs across the tasks. Compared to face-to-face communication, the Cruiser system was judged to be adequate for routine information exchange activities—checking on project status, keeping in touch, and exchanging information of various types. As the tasks became more socially sensitive or intellectually difficult, the Cruiser system became less adequate, although more adequate than either the phone or exchanging documents.

One can examine the appropriateness of different media for various tasks more systematically through multidimensional scaling, which attempts to uncover a small number of dimensions to account for similarities among the media. Two media are similar to each other if they were judged as appropriate for the same communication tasks. To derive similarity measures among the media we calculated the mean appropriateness of each medium for each task, as in Table 3, and then calculated Pearson correlation coefficients between the ratings for each of the media on the 14 communication activities (i.e., the columns in Table 3). This matrix of correlations was input to a nonmetric multidimensional scaling analysis [14, 23] and to a hierarchical cluster analysis [10].

Figure 3 shows the 2D solution from these multidimensional scaling (stress = .008, Formula 1) and hierarchical clustering procedures. The vertical dimension of Figure 3 can be interpreted as the degree of interactivity that a particular medium provides. For instance, group meetings, the Cruiser system, and the telephone are more interactive than fax, handwritten notes, and printed documents. The horizontal dimension can be interpreted as the amount of information exchanged during a typical session. Thus, people exchange more information in face-to-face meetings than in the typical telephone call or answering machine message.

The closeness of the media in Figure 3 is an index of their similarity. The circles show the order with which media clustered (e.g., the Cruiser system and the telephone clustered before either clustered with an answering machine). It is telling that in this analysis, the Cruiser system clustered with the telephone, and not with face-to-face meetings. Both the Cruiser system and the telephone are more interactive than email and answering machines, although all four are in the same low-information region of the plot. In contrast to the telephone, the Cruiser system was perceived to be more informative and slightly more interactive. This pattern makes sense, since the Cruiser system adds visual information to the audio information transmitted by the telephone.

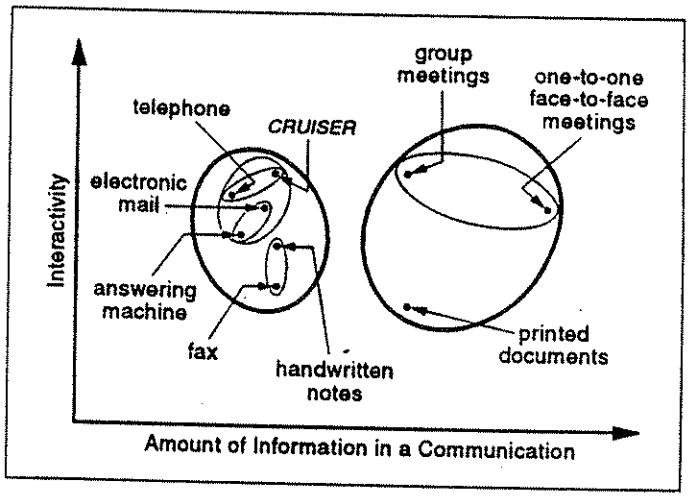


Figure 3. Similarity of communications media

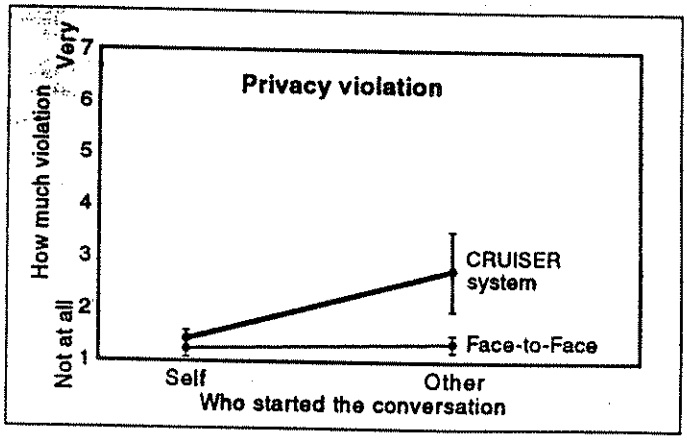


Figure 4. Perceptions of privacy violation

Privacy

Users discussed their privacy concerns during debriefing interviews. In contrast to strong concerns expressed before the system was introduced, in retrospect most users did not think privacy was a problem, especially within a small, collaborative community. However, when users contrasted recent face-to-face and Cruiser conversations, interesting privacy issues emerged. For each conversation they were asked, "How much did this conversation violate your privacy?" Since people are likely to feel more intruded on when they are the recipient rather than the initiator of a conversational attempt, the interview ascertained who started the conversation.

An analysis of variance of these data shows that recipients of a conversational attempt felt more intruded on than initiators ($F = 2.85$, $p < .01$), but that on average, Cruiser conversations and face-to-face conversations were equally invasive of privacy. However, there was a significant interaction between initiation

and modality ($F = 2.39$, $p < .05$), showing that the recipients of conversational attempts felt substantially more privacy violation when the attempt was made via the Cruiser system than when it was made face-to-face. These results are displayed in Figure 4, which shows the mean and standard error of the mean for each combination of media and initiator.

Users took several actions to discourage interruptions and ensure their privacy. They used the built-in commands that signalled to calling parties that they were unavailable, they logged out of the system when they did not want to be disturbed, and on at least two occasions, when managers were dealing with sensitive personnel issues, they physically disabled microphones by disconnecting cables.

Among researchers on the social impact of new technology, there is general concern that those with more social power will benefit most from new technology. In terms of the summer experiment, this reasoning would lead one to expect that mentors would use the system to keep their interns under surveillance but that their low social status would inhibit interns from using the system in a similar way. According to their reports, mentors did indeed use the system to check up on their students, but the reverse was also true. Indeed, interns as a class were about twice as likely to place calls to mentors and to hold conversations with them than the reverse. These results suggest that the Cruiser system follows a common pattern of communication in organizations: communication is more likely to go up the status hierarchy than down.

Surprisingly, the privacy of outgoing messages was as large a concern as the fear of others snooping into one's office. Because cameras have only a fixed field of view, typically narrower than the human visual system, users were concerned that other people might be present at the called party's location but invisible when they were having a conversation. They also were aware that the hands-free audio in the Cruiser system meant that others near a conversation could overhear it. As a result, employees sometimes held face-to-face meetings when they wanted to ensure that they were not disturbing others or that others could not overhear them.

Discussion

In summary, our evaluation found that people used the Cruiser system frequently, almost as much as the telephone, even though it provided access to many fewer people. This suggests that customers judged the system as both useful and convenient. Because it was on the desk top, it was used far more frequently than special-purpose, video teleconferencing rooms examined in prior research [e.g., 7].

The use of the system and perceptions of it were more similar to intentional telephone calls than to the spontaneous and informal communication supported by face-to-face interaction. The Cruiser system was adequate, but only marginally for the support of spontaneous conversations. Glances encouraged exploratory behavior, and the visual channel enabled Cruiser conversations to be more open than telephone conversations. However, users judged Cruiser interactions to be more invasive of privacy than face-to-face interactions. The system did not support the subtle visual and verbal mechanisms that allow users in face-to-face interaction to negotiate the starts and ends of conversation.

Once conversations started over the Cruiser system, they were less adequate for accomplishing work than face-to-face conversations. Cruiser conversations were substantially shorter and were used more for administrative discussion than for substantive work. When compared to other media, the Cruiser system was perceived to be more similar to the telephone than to face-to-face conversations. Interviews suggest the Cruiser system was inadequate because users could not have multiparty conversations and could not share data and other artifacts (e.g., shared blackboards and editors).

On the other hand, users exhibited some behavior that transcended face-to-face conversation. Some users established virtual offices they shared when they had a high but intermittent need to communicate. The open connection enabled them to maintain a background awareness of one anothers' progress and minimized the behavioral cost of starting any given conversation. The waylay was another novel use. Here one user with a pressing need to communicate with someone who is away from the office simply connected to the latter's office and "stayed there" until that person returned. The waylayer can monitor the other's office through peripheral awareness, but can also focus on his or her own work.

Some of these findings are undoubtedly specific to the Cruiser prototype, but others are applicable to video telephony systems in general. In particular, inadequacies in the Cruiser system in enabling spontaneous conversations and in supporting task-focused work point to generic issues worthy of further discussion.

Spontaneous Conversation

In the workaday world, when people walk by each other, they have subtle, but well-practiced mechanisms to signal or assess readiness for communication and to manage the transitions from lack of engagement to engagement and from engagement to disengagement [11, 12]. For example, if one party does not wish to communicate with another, he or she can use gaze aversion and other nonverbal displays to signal this, which in turn often aborts the conversational attempt. Moreover, a potential initiator can often assess another's concentration on a task without the other's being aware that an assessment took place. In these cases, the decision to take advantage of a conversational opportunity and start a conversation is a cooperative act, in which neither party explicitly rejects the other. The visual channel is central to these negotiations. Video telephony systems can support this negotiation when the communications link has already been established, as in the conversations over already open links described previously [e.g., 2, 7, 8].

As the Autocruise feature of the Cruiser system illustrated, though, it is far more difficult to engineer serendipitous conversational mechanisms into a video telephony sys-

tem. The mechanisms we tried were abrupt, intrusive, and lacking in subtlety. The instantaneous appearance on the screen of someone at speaking distance announced a conversational opportunity and this sudden onset was disruptive. Converting an opportunity into a conversation required explicit and one-sided action, with one party to a potential conversation explicitly issuing a command to extend or curtail the call. These conditions placed too much pressure on the parties to acknowledge each other before they have conducted any negotiation about doing so. In the case of the Cruiser system, users complained that being suddenly confronted with another person compelled conversation, even when they didn't want one. In these circumstances, a failure to have the conversation became an explicit rejection, as well. As one user stated, "There is no halfway with Cruiser."

Communication technology to support spontaneous interaction must provide *lightweight* opportunities for interaction In social interaction, a lightweight opportunity would be one in which getting into a preconversational attitude is a side effect of other activity and thus allows conversation with little incremental effort. From the preconversational state, potential interactants, by small adjustments and subtle cues, can cooperatively determine whether an acknowledgment, greeting, conversation, or nothing will take place. The failure of the relatively gross techniques we tried highlights some of the subtlety of everyday conversational coordination and implies that providing analogous mechanisms through technological means will require substantial ingenuity.

More generally, supporting informal communication will require balancing the costs of providing opportunities for communication with the benefit of any particular opportunity. To support informal communication, systems must balance users' desires for accessibility to others, and protection of their own privacy and solitude. Accessibility is the ability of one individual to have easy access to another. This is one of the essential properties of informal communication. Privacy is the ability of an individual to control the information about him- or herself available to others. Solitude is the ability of an individual to control others' intrusion into his or her space or consumption of his or her time. Individuals would like to have all three, but at the level of the group, they are incompatible. Having access to other people at a convenient time often violates their solitude; providing information about people's readiness for conversation potentially violates their privacy. The use and abuse of telephones, open offices, and private secretaries have shown that even in conventional environments achieving this balance is neither automatic nor static.

Task-Focused Work

A characteristic of informal communication is that people often convert serendipitous encounters into occasions in which they get real work done. Using the Cruiser system, for example, interns often reported attempting to use the occasion of running into their mentors as an opportunity to seek help on a problem. Yet they were stymied because they could not access the resources they needed to deal with the problem; they could not illustrate their dilemma with diagrams, share the objects they were laboring over, or easily bring a consultant into the conversation. This lack contributed to the brevity of their conversations. Our experience with the Cruiser system suggests that even communication systems intended for informal communication must also support sustained task-focused work and must allow graceful transition to it.

Managing the transition between casual conversation and sustained task-focused work will require the integration of *conversational props* [5]—the artifacts and resources needed to sustain group work. For these props to be used spontaneously in the support of ongoing conversation, they must be easily and quickly accessible during the conversation and must be easily shared. All members of the conversation must be able to view, point at, and if appropriate, modify objects—data, diagrams, and files, for example.

Social Science-Based System Design

The Cruiser experiment provides insight into the benefits and limitations of theoretically motivated system design and empirically based evaluation as well as into the requirements for video telephony systems. Theories of informal communication and its importance in organizations strongly influenced the Cruiser design, and its evaluation employed a variety of social science empirical methods. This approach contrasts with more heuristic approaches to system design and evaluation, in which the issues attended to are more inclusive, evaluation is more impressionistic, and changes to the system are more rapid. The Xerox PARC Media Space project reported in this issue is representative of the heuristic approach [2]. We believe the focus on a single issue—informal communication—and adoption of a theory-based design and empirical evaluation slowed short-term progress in creating a fully functional system to support distributed collaborative work. At the same time, though, we believe it improved understanding of the degree to which system features were successful and the reasons for their success or failure, thus guiding improvements in the technical systems being developed and in the underlying social science theory and research.

Heuristic design and evaluation of video telephony systems is not new, as Noll's [16] review of the AT&T's picturephone service reveals. Using a heuristic approach, the early research identified some capabilities that video telephony needs in order to be useful, such as an ability to share graphics and display documents. Yet current commercial video telephony services and products are very similar to the services provided by AT&T in the early 1970s, suggesting that unguided iterative design and development may be insufficient for fundamental improvements in

The *Cruiser* System Today

What does the Cruiser system look like today? How has the system changed in response to the lessons learned from this experiment?

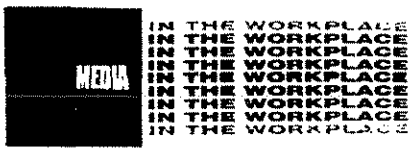
First, the experiment clearly showed that compared to face-to-face conversations, video conversations were short and used for administrative functions rather than substantive ones. To actually accomplish work, users need to bring other resources—both objects and people—into ongoing conversations. To this end, the current implementation of the Cruiser system adds the ability for people in a conversation to share computer applications and to have unplanned multiparty conversations. The shared computer applications include those explicitly built for multiple, simultaneous use through the use of the Rendezvous system (see accompanying article by Hill et al.) and single user programs running in a shared XWindow. The dynamic reconfiguration of calls from two-party to multiparty was made possible through the highly flexible applications-programming interface of the Touring Machine (see accompanying article by Arango et al.) network operating system. Together these enhancements have made it much easier for people to meet their changing conversational needs during the course of a conversation.

The experiment also revealed a need for less intrusive mechanisms for fostering awareness of coworkers and their availability for conversations. To this end, the current Cruiser system includes a mechanism called the Gallery. The Gallery, which is conceptually similiar to the Polyscope and Portholes systems of XeroxPARC, distributes to interested users reasonably current digitized still pictures of other users or their offices. This allows users to maintain a small gallery of images on their workstation of other users or places. The Gallery also serves as an alternate calling interface to the system. The Gallery provides a much less intrusive way than a live audio/video call of evaluating whether a potential conversational partner is busy, disturbable, or even present. For privacy reasons, the images that any user receives are determined by the images the user requests and the permissions that others have placed on their own images.

Moreover, the experiment revealed that users desired better and more precise ways of controlling access to themselves. The current Cruiser system includes privacy controls that can be easily changed for brief periods of time and tailored for particular individuals and groups. For example, with the new system, users set up their preferences so that communication with some people is via a traditional call model, where the called party receives a call notification with calling party identification, and then answers or not. With other people it is through a direct connection model, where the notification phase of the call is replaced by an automatically accepted connection to the called party. The permission system for the Gallery is another example of how users can customize others' access to them.

An additional feature that developed out of our observations is what we call the Virtual Auditorium. In the trial described in the accompanying article and in other trials, users could employ video telephony for information retrieval as well as for interpersonal communication. They would connect to talks that were being broadcast from an auditorium, or to a time-shifted recording of the talk available on a VCR connected to the system. The goal of the Virtual Auditorium is to enable remote viewers of these events to see, hear, and talk to one another as well as to see the broadcast source. This allows the impulse for information gathering to become an occasion for social behavior with its attendant possibilities for work and coordination. The Gallery is one mechanism through which people discover who else is attending a Virtual Auditorium event.

We hope that together these system enhancements will lead to behaviorial changes in the use of the system. To evaluate this and continue our cycle of iterative design on interpersonal communications systems, we are currently running an experimental trial evaluating how approximately 125 people are using the latest implementation of the Cruiser system. These users are distributed across two sites 50 miles apart, and are members of organizations that are split between the locations. As part of this experiment we are continuing the sort of data collection described in the accompanying article. This larger-scale experiment will provide an even better opportunity to see whether communication within physically distributed organizations can be improved through technological means.



communication systems.

Using a more theoretically based approach, we were able to identify a new meeting type—spontaneous encounters—for which video telephony should be appropriate, and we designed several features to encourage them. Yet the evaluation described here shows that these features were, on balance, only marginally successful. One problem with our approach is that while the social science literature was a useful basis for functional requirements, it did not provide a basis for detailed design. In the case of spontaneous encounters in organizations, for example, it is well known that frequency of exposure, typically mediated by physical proximity, controls their rate. The Cruiser system shows, though, that simple exposure is not sufficient to encourage spontaneous encounters. To use the literature as a guide to design requires more complete understanding of the mechanisms by which opportunities are converted into conversations. Even detailed descriptive studies of greetings, for example [13], reveal information about how a process currently occurs, but not general principles that transcend medium. The Cruiser experiment points to a need for additional research on basic human communication processes. It also points to the value of theoretically guided designs and evaluations of new media.

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