Walking Away from the Desktop Computer: Distributed Collaboration and Mobility in a Product Design Team

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ABSTRACT

A study of a spatially distributed product design team shows that most members are rarely at their individual desks. Mobility is essential for the use of shared resources and for communication. It facilitates informal interactions and awareness unavailable to colleagues at remote sites. Implications for technology design include portable and distributed computing resources, in particular, moving beyond individual workstation-centric CSCW applications.

Keywords

Distributed collaboration, field study, mobility, communication, awareness

INTRODUCTION

We report on a field study of distributed work at a design consulting firm. We aimed to learn how collaboration was and was not supported by current technology and to seek opportunities for design innovations. What we found was that the work involved far more mobility than we had envisaged. Most of this was not long distance, involving car or public transportation, but rather *local mobility*; simply walking between rooms or buildings at a local site.

While local mobility sets up challenges for technology to support individual design work, it is even more significant for collaboration. In this work setting, designers were seen to move around in pursuit of *resources* and other *people*. Mobility proved to be a means by which people kept up to date with project and other company activity. This meant that they were often away from their desks where their personal resources for distributed collaboration such as email and the telephone were concentrated. Consequently, while local mobility enhances local collaboration, it penalizes long distance collaboration severely. This paper is an attempt to illustrate how and why this happens and to point to some of the implications local mobility has for design.

MOBILITY AND DISTRIBUTED COLLABORATION

Many studies of distributed collaboration, and most existing technology, are dedicated to work that people are assumed to conduct at their desks, such as sending email [e.g., 22] or distributed co-authoring [e.g., 3]. Much effort has also been directed towards the development of new technologies to support collaboration from the desktop. Some systems support communications or synchronous work such as video conferencing, multimedia email, and shared authoring tools, [e.g., 2, 17, 19, 21, 23, 24]. Other tools attempt to support organization of distributed team efforts such as semi-structured collaboration systems and workflow systems [e.g., 1, 7, 16]. While these systems all have many benefits, they tend to be restricted to *desktop collaboration* only.

A growing body of field studies and ethnographic research addresses collaboration within various work settings [e.g., 5, 12, 14]. This research reveals how informal and subtle aspects of social interaction are critical to accomplishing work and need to be taken into account in design of technological support systems. Design work is also known to be a highly social collaborative work domain [6, 18]. This literature, though it implicates the importance of local mobility, has not focused on the important role that mobility plays in determining people's requirements for computational support for distributed collaboration.

In the domain of explicitly mobile collaboration contexts, Hutchins [13] examined teamwork in navigation of large ships. However, his subjects are *locally immobilized* by their consoles. Orr [20] describes mobile service engineers working without sophisticated technology support. These workers were later equipped with radios that were also telephone capable for continuous open-channel, voice and telephone communication, but design for mobile access to computational support was not the focus of this work.

Whittaker et al. [25] offer computing technology design implications in an analysis of informal communications of two mobile professionals. Building on the work of Kraut et al. [14] they show that frequent informal interactions are key to the work of a collaborative organization. Surprisingly though, their design recommendations do not accommodate the mobility that enables those interactions. Rather, they only propose that local mobility might be reduced by communication via desktop audio-video (AV) solutions.

Harper [10] describes a system for allowing receptionists to locate office workers which is very relevant to the issues we raise here. However, Harper's assessment of the impact of this technology is devoted to how the "moral order" of organizations accounts for acceptance or rejection of the system by its users. His analysis is not directed towards the benefits of such a system for mobile collaboration.

Our aims here are to show that mobility may be critical to many work settings that have been traditionally considered non-mobile and that its existence and purpose must be accommodated by CSCW design. Mobility supports sharing resources and communicating in a way that video-conferencing connections or email can't accomplish. CSCW technology must *accommodate* this phenomenon, rather than seek to

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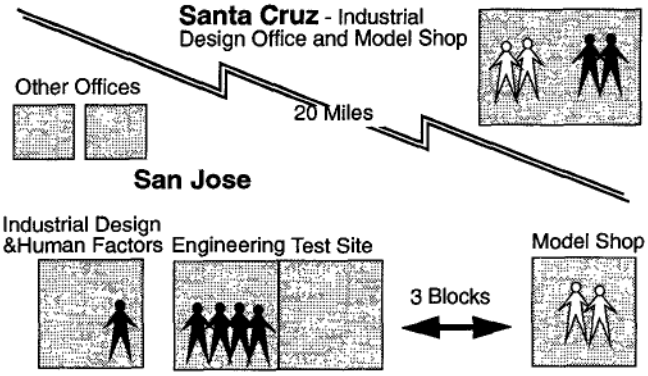

Figure 1. Schematic view of the project team's distribution. Team members are shown in black and model makers, assigned to work with them, in white.

eradicate it. However, little if any research has been dedicated to how workers' requirements for support are strongly shaped by time spent away from their desks.

In the rest of this paper, we describe the design team we studied and our methods. We report on our observations, discussing how mobility is key to their work and valuable for local collaboration. We then describe some of the penalties of local mobility for distributed collaborators. Finally, we conclude with a description of design efforts to provide support for distributed groups which compensates for loss of the benefits of mobility amongst distributed team members or accommodates mobility as part of the work context.

THE STUDY

We studied a team of product designers in a consulting firm distributed over several buildings. We were interested in how they used technology and in how they collaborated with each other, support staff, and with people outside their team. We begin by describing the organizations involved, our team of designers, their project and our study methods[1].

QED: The Organization

Our study team worked at QED, a large, successful design consulting firm with sites around the globe. Their client, Greenfields, is an even larger international corporation specializing in home improvement products. Greenfields' headquarters is almost 2000 miles away from QED's main site in San Jose. Most of the office spaces at QED are open plan, fostering a relaxed atmosphere and permitting easy access between co-workers for conversation and the discussion and demonstration of design ideas. Informal and frequent interactions seem to be critical to the way the organization conducts its work as a whole.

The Design Team

Figure 1 shows how the 7 members of the team we studied were distributed between two sites in San Jose and Santa Cruz, 20 miles apart. The manager, three engineers (and an engineering student intern who helped out) were all located in a building in San Jose at the firm's main site. Their model shop was located about four blocks down the street from their office. In a building next door, on the corner of the next block, there was a Human Factors (HF) specialist. Two industrial design (ID) team members were located in a single building with their own model shop in Santa Cruz.

The manager, Bob, and the HF specialist, Hugh, each worked on several projects simultaneously. The others were more committed to the Greenfields project during the term of our study. However, everyone at QED tends to work on multiple projects at a time, allocating time depending on varying workloads. The team also worked with four model makers in their associated model shops (see Figure 1).

Technology and Collaboration in QED

Our preliminary meetings with QED, prior to the study, revealed that they think of themselves as 'freeform' operators and attribute much of their firm's success to flexible work practices which might not be tractable to computer support. Despite this view, nearly everyone uses computers heavily. Even in graphical work, only a few preliminary sketches are created exclusively on paper by designers.

The office PCs are mostly Apple Macintoshes for writing text, graphical work and communication. Engineers also use Hewlett-Packard CAD workstations. A dedicated file server and T1 line are shared between the engineers and their model shop so that 3D CAD files can be transferred from HP workstations to drive computer numerically controlled machines that carve the physical models. The industrial designers in Santa Cruz communicate with their model makers by taking pen-and-paper sketches and drawings down to a shop, four floors below their office. Standard public telecommunications lines are the sole means of data transfer between the San Jose and Santa Cruz offices.

QED uses no explicit 'groupware' products. Much communication occurs via phones, faxes, email. For example, proposals are commonly emailed around via Quickmail. Apart from taking or posting hardcopy between sites, the main way to share design work between engineers, industrial designers and HF specialists in different buildings is via fax. Industrial designers also ship some 2D model data created using drafting packages such as Vellum™ between Macs and an SGI machine, and sometimes to engineers on the HP systems.

The Greenfields Project

The QED team's project was to design an electric weeder for a global market. Work began on customer studies in early 1995, followed by detailed product research. When we began our study, in April, the team was refining three initial concepts after an early meeting with Greenfields. Two of these were engineering prototypes; the high powered, self cleaning *Turbo*, and the rechargeable-battery *Portable*. The industrial designers were mainly working on the *Hydra*, a more conventionally engineered prototype which was distinctive in its ID qualities of elegance and reconfigurability.

We intensified our study in June, just prior to a major milestone meeting when the team presented their three refined concepts at a milestone meeting at Greenfields headquarters.

STUDY METHODS

Our primary interest in studying QED was to inform the design of prototypes for distance collaboration which might then be deployed at QED to support its employees. We chose four methods to find out about the design team and its practices: a brainstorming meeting, interviews, meeting attendance, and observations of daily work activity.

1. The **brainstorming meeting** with the QED team was held first to identify problems and solutions for support-

1. In our descriptions we have changed the names of organizations, locations, and the artifacts being designed in order to preserve confidentiality of the product and consulting agreement. With the exception of these changes, our transcripts and descriptions are directly from the data.

Location	Gus	Harry
Personal desk (usually a semi-partitioned space)	13% of time (2 separate occasions)	10% of time (6 separate occasions)
Electrical Eng. (EE) Lab	11% (3)	-
Mech Eng. (ME) Lab	4% (1)	0.5% (1)
Shared workspace area	-	16% (4)
Model shop	32% (2)	2% (1)
Other team member desks	3% (1)	14% (10)
Meeting room A	20% (1)	29% (1)
Reception area	-	2% (2)
Printer/fax/copier	-	4% (2)
CAD station	8% (2)	-
Other in building	1% (1)	-
IDHF building	-	0.5% (1)
Percentage of time travelling between locations	8%	11%

Table 1. Sample of locations and time spent there by two engineers over a 4 hour period of observation during a 4 hour morning

ing collaboration (particularly over distance) as seen by the QED team. This gave us an initial perspective on the team's understanding of their own work and problems with existing technology to support distributed collaboration. It also provided an entry point for communication with designers and developers back at Apple.

2. **Interviews** were conducted with team members to get an overall description of the work, project and views on distributed collaboration from individual perspectives. This gave us rationale for how and why things get done. In addition we conducted similar interviews with three receptionists who have a supporting role in distributed collaboration amongst the designers.
3. Attending all **project meetings** from April to June allowed us to follow the progress of project activity. We recorded what occurred as an important component in giving us project background and status.
4 Finally, 40 person-hours of **close observation** let us track individuals through details of their day-to-day work and through an intensive all-day session just prior to the Greenfields milestone meeting. Because our interest was in team collaboration and communication, we focused on individuals rather than locations or artifacts. These observations gave us detailed experience of the work activity.

We tracked Harry and Gus, two engineers, each for 15 hours, and Leonard, an industrial designer, and Derek, another engineer, for 5 hours each. We did not select these individuals because we thought they were mobile, but, rather, because they were present at the QED sites while we were conducting observations. Their mobility only struck us after our observations were concluded.

Our data include notes and transcribed videotapes of all meetings we attended. We also have transcripts, notes, and videotapes of the six interviews and transcripts, audiotapes, videotapes, photographs, and notes from our observations.

FINDINGS

Initially we were focusing on issues of communication and coordination among team members and between team members and external clients. However, this quote from the interview with Gus, an engineer, summarizes what we found most noticeable about our team:

> *I'm all over the place. I'm either at a CAD station trying to fit things out, see how they lay together, either in this room or in another room. I'm next door doing testing. I'm talking to people specifically about. looking for this magnesium guy or whoever it could be at that time. Talking to different people individually [around here], trying to learn as much as I can from them. In stores talking to [a shop owner in San Jose] who knows everything about weed eaters, just buying bags from him and talking to him about what his opinions are...*

Our observations confirmed Gus' summary of his activities. Harry, another engineer, was also frequently on his feet. He might be after some particular resource or place, or looking for someone, either to hand off a piece of work or more often to pass on a message (often involving coordination).

To test our impressions, we have derived the locations for Gus and Harry from observations during a four hour period one morning. The number of separate occasions at each site are shown in table 1, together with the percentage of total time they spent there (these are approximate figures based on our transcripts). Figure 2 shows Gus's movements around the San Jose site during that same period. He spent over half of his time out of the building where his desk was, though he was never further than 4 blocks away.

Whilst Gus and Harry seemed to be on their feet a lot of the time, Derek, another engineer on the team, whom we did not track so closely, seemed to spend less time away from his desk (he is one of the most computer-literate engineers at QED which may explain why he is often found working on his PC). However, even in the smaller office in Santa Cruz, where the industrial designers on our project all worked in a single open-plan office with the model shop in the basement, we saw very frequent local mobility among the two industrial designers. One, Leonardo, described his usual whereabouts as *"I make my way between here and the scanning station, the printer and the [model] shop for the most part."*

The HF specialist, Hugh, spent a lot of time off site at client meetings or doing studies. He was thus very mobile in a more traditional sense. However, he also exhibited plenty of local mobility, walking between buildings in the San Jose site to attend meetings and work with teams on the various projects he was involved in. Whilst his frequent absences made him impossible for us to track, we observed an interesting practice he maintained of marking his whereabouts in the receptionist's paper calendar as he left his building so he could be traced if necessary.

The same pattern of frequent absences was also seen in the manager Bob's movements, though we did not see him (or anyone else) using the calendar. He showed us a timesheet he opted to keep for budgeting purposes. His day was broken into units as small as 15 minutes which he divided between the eight different projects he was working on.

Apart from Hugh and Bob, the other team members tended to be only locally mobile. They frequently moved about to talk to a colleague or find out about a test or model build, to share design material, and to locate artifacts. We even saw several strolls, to local stores to get parts for prototypes or examples of competing or related products. Our observations of this local mobility revealed two categories of motivation:

Use of *shared resources*. Team members often used devices and resources which were not in their personal office space.

Desire for *communication*. Our designers were frequently going someplace to talk to someone.

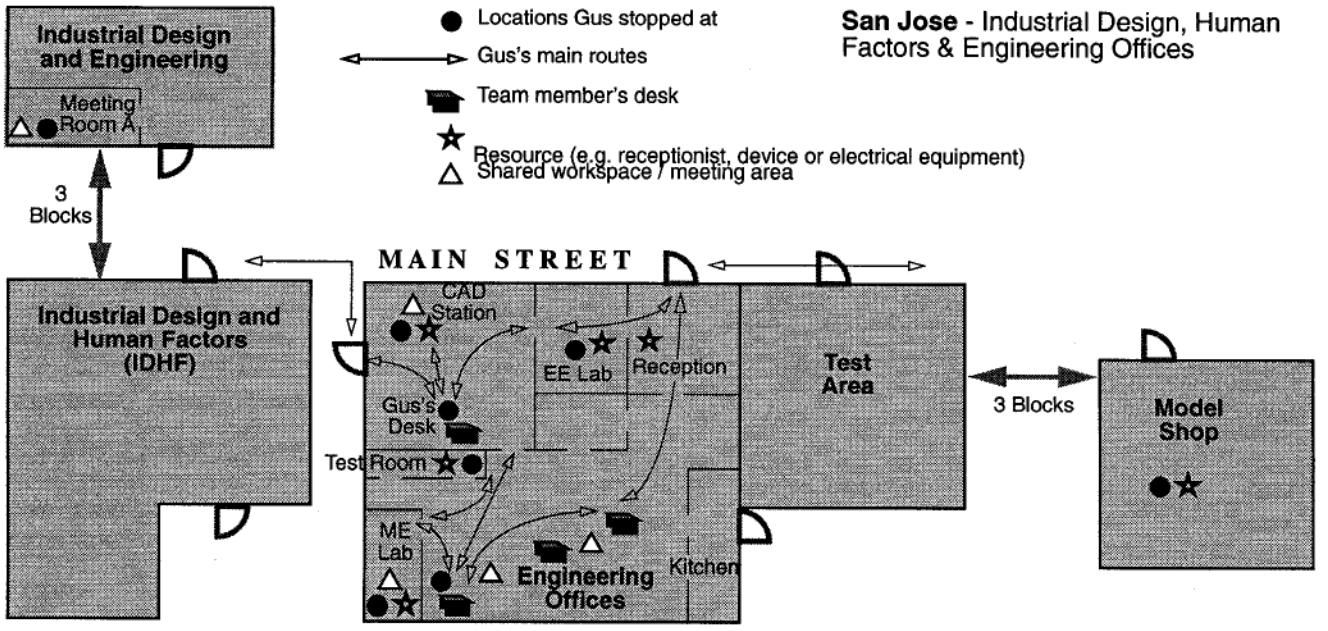

Figure 2. Schematic map showing locations visited by Gus, one of the engineers, over a single 4 hour morning

While communication and shared resources caused designers to leave their desks, the effect of that mobility was an increase in local informal communications and awareness of QED work in general at a local site.

Mobility for Using Shared Resources

The team members were all involved in creating artifacts, most of which required resources and/or space that was shared. These included meeting rooms, test facilities, electrical and mechanical engineering labs, model shops, spray painting sites, shared CAD stations, common work areas, and the usual array of printers, copiers, fax machines, and scanners. Each time any designer or engineer in QED wanted to work on a prototype or manipulate hardcopy, he or she had to travel to the appropriate lab or equipment.

Design work involved a range of ways in which ideas were articulated and tested. These included drawing (both manually and electronically), checking previous related work, keeping abreast of other current project, and building models (CAD or physical artifacts). Drawing seems to be one of the most obvious parts of the design process, but it was surprising how much mobility this too involved. In particular, the drawings rarely (if ever) consisted of a single medium. As Harry, an engineer, put it:

> *Well these take time... and so you do something like this and then you photo reduce it down so it fits on an 8.5 by 11...*
>
> *... You do a lot of overlays so you do one drawing and you don't really like it so you put a new sheet over the next and overlay draw it...*
>
> *...you may even do a CAD drawing rough, print it out, then overlay draw on top of it.*

These different treatments of drawings require the use of various devices and frequent fetching of extra material.

We saw several team members go back and forth to devices like scanners, printers, CAD workstations and so forth. For example, one morning about 11am in Santa Cruz, Leonard, an industrial designer, decided he needed to include hardcopy drawings in a package he was sending to a client. He selected the appropriate plotter on his PC and walked to the device to set up the correct pens. Back at his desk, he began setting up the print parameters. By 11:20am, he was back at the plotter to start the job. Jennifer walked by and they discussed sketches needed for the Greenfields model. Leonard went back to his PC. Ilse came by with a letter that required a response so he went to the cupboard to get a sheet of letterhead. At 11:55am he noticed that the PC was still busy trying to print so he went to the scanner to begin another task. Ultimately, he discovered that the printing wasn't working and that he would have to walk back and forth between the plotter and his PC to feed the paper manually one sheet at a time.

While the industrial designers in Santa Cruz spent nearly all their time moving around in a single building, team members in San Jose spent a lot of time going to and from the model shop, four blocks away, and the test site next door. Gus, Harry and Ian, the intern, made at least one or two visits a day to the model shop (lasting from a few minutes to an hour or more) while the model that they were designing was being made. They told us in interview that this was fairly typical. Model makers, in turn, would often come to the design office to look for engineers if they needed to talk to them urgently or to talk about designs and project background information before beginning work on a new model.

The engineers in San Jose could also often be found in the test site evaluating their models and making modifications, or wandering around the various design offices or laboratories in their building.

Mobility for Communication

During interviews our team members told us that they spent much time away from their desks, talking to others. We were told that talking face-to-face was preferable to the telephone wherever possible, even if it meant crossing the street. Generally, trips away from the desk were motivated by things like curiosity, a desire to consult with or help someone, to coordinate and plan presentations and reports, to obtain client requirements, to integrate project components and so on.

For example, Harry would walk to a person's workspace, if necessary asking others if they'd seen them. Occasionally he

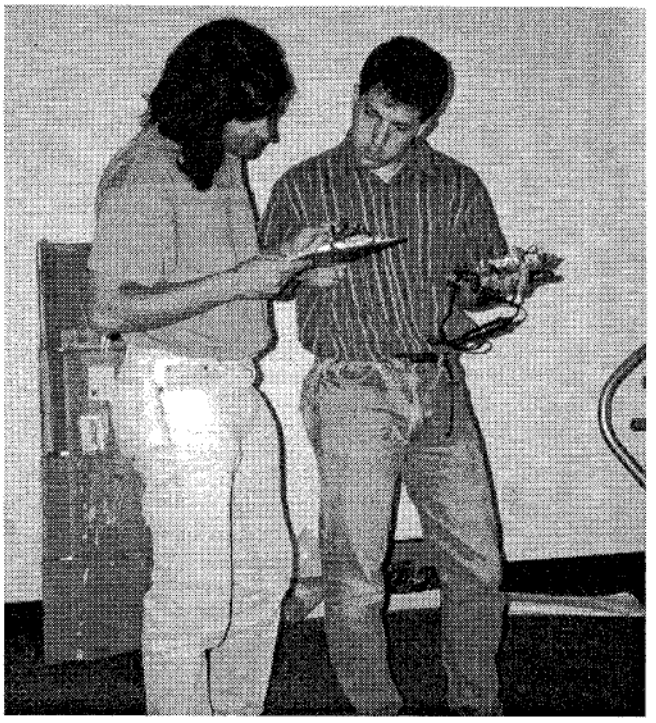

Figure 3. Ian the student intern gets Gus (on the left) to look over his test data as he finds him on his way out of the design office.

would leave notes; more often he would leave a message with someone else the person was likely to see. He rarely used the phone for locating people. Although he received calls regularly, he seemed to phone out only if there was a particular question to be answered by someone not available locally (e.g., a Greenfields engineer or staff at a Kinko's printers). Walking to the receptionist's desk, one time, Harry said *"I could call but I prefer to walk..."*.

A typical sequence can be seen from details of the first hour of Harry's movements summarized in Table 1. At 8:30am Harry went to the receptionist's desk to arrange a meeting room, walked back to Bob's office to check on the time, back to the receptionist to confirm, off to the kitchen for a drink and a hallway chat, back to his office to call the client and check messages, a pass by Bob's office on his way to the intern, Ian's office to start him on a task, down to the model shop to check with Gus and offer help, by the test lab to show Gus the results of a weeding test, back to his office to get his notebook, and past the bathroom to pick up his wallet which he left there earlier. Then he goes off to a meeting.

An effect of Harry and Gus's mobility was that Ian, the intern who depended on them for supervision and advice, spent a lot of time walking around hunting them down and would solicit help wherever they happened to be when he found them. Occasionally he would encounter them en route to some other place themselves. Figure 3 shows a typical scene where Ian catches Gus on his feet and asks for feedback and guidance on the evaluation tests he's running on Gus's model in the test site.

As well as engaging in frequent informal communication, the team held two or three scheduled meetings per month in San Jose where project reporting took place and decisions were made. It was necessary for the industrial designers to travel 20 miles from Santa Cruz to take part. The manager, Bob, used these meetings for round table reports. These face-to-face encounters provided the only explicit forum for ensuring that everyone from both sites was up to date on each other's activities and that plans could be coordinated.

Figure 4. Seeing something that someone is working on offers an occasion for unplanned interaction Here, Harry is making one of his frequent stops at Derek's desk which provides an unplanned opportunity to chat about Derek's current work.

How Mobility Benefits Collaborators

An important benefit for collaboration of the mobility which we observed seemed to be to do with maintaining *awareness*; keeping up-to-date with things going on, both on and off one's own project.

Awareness for distributed groups at QED was supported at the desktop by what one engineer called "blanket email" messages with requests for information and answers such as, who is the manufacturer of a particular part. However, we saw that time spent at the PC reading and sending email was minimal compared to the amount of time dedicated to building awareness of ongoing activities through face-to-face encounters. This was obviously one of the key benefits of the scheduled team meetings, but was mainly achieved on a day-to-day basis through local mobility.

We sometimes saw people wandering around just to see what was going on, apparently with no other motive. Gus called this doing a "walkabout". In fact, useful information seemed to be obtainable *passively*, just by coming into close proximity to others. Conversations could be overheard and people seen working together at PCs or on design models or showing each other documents.

QED employees often *actively* pursued things they became passively aware of, especially by initiating *informal communication*, showing interest in others' activity to find out more about its *significance* or to offer advice or help. A conversation, or a new theme in an ongoing discussion was often prompted by an observation on a current activity (as shown in Figure 4) or on some item in the local vicinity. Awareness of someone's current work focus provided an entry into a topic of mutual concern. It also allowed people to solicit or spontaneously offer feedback on designs which we were told repeatedly in interview was a key advantage of working in close proximity to one another.

To illustrate the above observations from our study, we provide an example from one of our transcripts:

Harry is sitting in an open workspace putting parts together for the Turbo breadboard model. Another QED employee, Ted, enters the space and overtly bends over Harry's shoulder to stare closely at what he is doing. Harry waves a part close to Ted's face and Ted steps back. Harry turns from what he is doing to look at Ted.

Harry: These are our air filters to replace those switch filters. I think the switchings even work.

Ted: Why not use them?

Harry: They are way too small.

Ted: Oh really?

Harry: The switch works, we got that working... which is really cool.

Ian the intern arrives at the table and stands listening.

Ted: What did you do to make it work?

Josh is passing and walks over to the table to listen for a moment.

Harry: I put something with the same end view, just like underneath it.... got it so that it just stopped at the right point. It worked really well. Thanks for your help on that actually.

Josh: Is this for your Landrover?

Ted, though not a team member, is clearly interested in this project and has even helped out in the past. Seeing that Harry is working in a public workspace he approaches and makes a show of looking at what Harry is doing. Harry, who has the option of ignoring this play, instead willingly offers information on what he is doing and why he's doing it (the significance of his activity). He assumes familiarity on Ted's part, with the context of the filters, since the weeder is never mentioned. Ian, the intern, arrives followed by yet another non-team member, Josh, who also shows curiosity about what's going on and who soon asks a question which implies he knows about at least some of Harry's work.

Being within earshot afforded an entry into relevant or interesting discussions or enabled people to learn things which they might not otherwise have done. Visual and auditory accessibility clearly provided the awareness which facilitated or prompted spontaneous communication. In this way people sharing office space learned great deal about one another's ongoing activities and were more likely to interact informally as a result. Outside of walking distance, awareness dropped off considerably and the telephone did not seem to be a good substitute for the casual face-to-face encounters enabled by local mobility. As Harry put it:

It's a real pain to be in different places. There's something about working with a group of people in the same building when I can just walk by somebody and say "How's it going?" and keep up to date on what they're doing. See if I see anything. Recently I've been working as a senior person with more experience than the others. It's easier to keep track when you're supervising if you're in the same room. There's a lot of inertia even in just having to pick up the phone.

To sum up, mobility was beneficial to collaboration for all of our team members because they were working with other members or with people outside the team who were distributed over distances from a few feet to hundreds of miles away. Local mobility, in particular, afforded *awareness* of ongoing team and other activity as part and parcel of day-to-day work. This was achieved both passively and through concerted effort involving frequent *informal communication*. Awareness and informal communication not only support projects, but also increase personal experience and expertise in support of the consulting firm as a whole.

PROBLEMS FOR DISTRIBUTED COLLABORATION DUE TO MOBILITY

In this section we consider specific problems which mobility imposes for distributed collaboration at QED. It seems likely that these problems will be apparent in many distributed workplaces where people tend to leave their desks.

Locating People

We first noticed the location problem when we discovered that most of our team members were difficult to catch when we telephoned them. This was also true when team members called one another. In fact, *mobility propagates further mobility*. People spent a lot of time wandering around just looking for each other and, while it was often difficult to find someone locally on foot, it was a great deal harder to do so from a remote site with only the telephone.

In interview, Gus said that he dislikes stepping away from his desk and then coming back in two minutes to find voicemail. It is annoying to him that clients don't realize that he is not far away or only gone for a moment. They end up leaving a message whereas he could have talked to them directly a moment later. The problem of locating someone by telephone results from the lack of contextual information or awareness that can be gained locally on foot. In order for Gus to be found easily by remote colleagues he *has to be at his desk*. By contrast, if someone looks for Gus physically, then they often find out if he's in the vicinity or has gone far away (by looking around, listening or asking).

Lack of Awareness

Mobility, which supports local communication and mutual awareness, makes it hard for distributed team members not only to locate remote colleagues but to stay in touch more generally. This we characterize as a *lack of awareness*. Awareness provides a background of common knowledge and shared understanding of current and past activity. Lack of awareness means lack of the *context* and *familiarity* necessary for the essential, lightweight interactions and communication which are key to collaboration.

Distributed collaborators cannot do anything like a "walk-about" to survey current work at a remote site. Nor can they easily track the activity of their colleagues through the technology they have, since that technology is tied to the desktop, whereas people are not. Furthermore that technology only affords *explicit communication* (discussed in the next sub-section) rather than the kinds of *implicit communication* available through co-presence and mutual awareness.

The lack of implicit communication between remote collaborators meant that people at QED had almost no opportunity for gauging what remote colleagues were up to (if they were busy, in a meeting, reading a magazine, etc.) or for serendipitous learning to take place. It was also impossible to find out (by spontaneous query) the significance of others' ongoing activity unless one came across that subject in email or on the phone. Through the existing technology available to remote collaborators at QED there is *no casual or lightweight entrypoint into discussion* about current work; nothing to prompt the passing remark or enquiry.

Lack of Communication

While face-to-face communication was clearly preferred by our designers when they were within walking distance of others, this was not possible between team members who were 20 miles apart or with people outside QED. This meant that people had to rely on the phone, email, faxes and paper-

mail. We observed some, but not many, instances of use of only the first two of these media. Since the two industrial designers were situated 20 miles away in the Santa Cruz office, the only chance they got for spontaneous communication with the rest of the team was prior to or after pre-arranged team meetings for which they travelled to San Jose.

We were told that communication over the telephone was difficult and awkward. It was not possible to be as spontaneous as one could be face-to-face. The problems with communication seemed to be a great deal to do with a lack of mutual awareness. Apart from never knowing when the callee would be at their desk, it was also hard to know what they would be doing or thinking about, even if they were there to receive the call. As a result phone conversations between remote team members were infrequent compared to the local interactions and people tended to save up a number of things to talk about for when they actually made a call. Gus, for instance, told us, *"I talk to the two ID people in Santa Cruz more now, less before. Hooking up with each other is problematic at times. We talk probably every other day. It's hard because when you call they are not always thinking about the project we're working on together and vice versa."* Contrast this statement with the fact that team members at the same site would see each other at least several times each day, either by explicitly visiting each other's desks or by happening upon one another in other places. Clearly, much more coordination took place amongst team members who were located near to each other.

Coordination

The telephone and email provide resources for making arrangements and coordinating activity between remote collaborators. However, we found that, as with other acts of communication, people preferred to do this face-to-face where possible. This was true both for the preparation of the project report and presentation which we observed and for the arrangement of scheduled events.

While walking back and forth takes time and effort, people seem to feel more comfortable negotiating face-to-face. Furthermore, when co-present they have shared access to resources. For example we observed Bob, the manager walking around to show people on their PCs how he wanted the client report to be written and how to add their contribution to the on-line template he had prepared.

Coordination over distance, without the advantages of co-location and mobility is highly complex by comparison. We observed the difficulty of organizing resources for a phone-conference between the three engineers and the manager at the San Jose office and three of the Greenfields reps the day before the team set off for the major milestone meeting at Greenfields' headquarters 2000 miles away.

In the following example, Harry walks to the receptionist, Kay's desk to negotiate setting up a room for the conference. Kay has to stay at the front desk, to staff the phones, and keeps a conference room booking schedule there. This schedule covers rooms at each of two of the San Jose site buildings and is constantly updated and coordinated between the receptionists at each of these two buildings.

Harry: I am looking for a place to do a Greenfields phone conference at 9:30.

Receptionist (Kay): Oh, you have it. It's supposed to be at 2nd floor. It appears 9:30 to 10 o'clock.

Harry: Man, we're on top of things!

Kay: You really are this time.

Harry: Someone is; Derek is, I think; not necessarily me.

Kay: I was going to send reminders to all of you but then QuickMail went down but you do have 9:30 to 10, 2nd floor.

Harry: Thanks. That would be really nice if you could do it in the future too... reminders.

Kay: Well, it's real tight there today also; it's like back-to-back.

Harry: Okay.

Kay: Okay?

Harry: All right, we'll keep that in mind. [He leaves reception]

5 MINUTES LATER

Harry: We'd like to change to the Smithson office.

Kay: For the whole thing?

Harry: Yes.

Kay: That's perfect. I'll have Norm set up...

Harry: I assume you call Smithson's phone? That's the phone that's in there?

Kay: No, they'll call us, reception, first and we'll transfer you.

Harry: Okay.

Kay: Right? It's a client calling you?

Harry: It's a client calling us.

Kay: Yeah, they'll call reception and then I'll transfer the call to you guys...So, he's 332 up there but that doesn't matter...

Harry: When Derek and Gus come in, could you also try to pass the word on?

Kay: Yeah. Okay?

Initially Harry doesn't realize that the meeting has already been scheduled by someone else. Later on, a comment by Kay ("it's real tight...back-to-back") leads him to reschedule the room, knowing 9:30-10am won't be long enough. Finally, they talk about access to and coordination of the resources needed for the phone conference which is handled by Kay.

An hour later, the problem of coordination over distance further highlighted the lack of awareness and lack of communication across QED sites. During the meeting, it became clear that the industrial designers should also have been involved. Either they should have been present or the engineers should have been better informed about their recent activities. The Greenfields reps asked about the ID models and the engineers had to admit that they hadn't seen them. They were also reluctant to admit that several members of the team had not seen a fax Greenfields had sent.

After the meeting, the engineers explained that they had found this interaction embarrassing because they didn't want to appear ill informed of their own team members' activities in front of their client. *"That was the major slambo of that phone-call actually, was that they asked us how the Hydra looked and did it look like this thing and none of us had seen them, they are all being done in Santa Cruz."*

When we asked if it would have been would have been useful for ID to attend they said *"very"* but that ID had conflicts in their schedule which kept them in Santa Cruz. When we asked why they had not been patched into the phone conference the manager said *"yeah, if I had thought about it for more than about a minute I probably would have worked harder to get them into the call."* It is possible that, if the industrial designers had been in the same building as the engineers, it could have been easier to coordinate with them on the phone conference arrangements. At the very least, if the team had been in the same building, the lack of mutual awareness and communication would probably not have arisen in the first place.

To sum up these disadvantages of mobility, it is important to distinguish between local and longer distance collaboration (anywhere outside of walking distance). Local mobility is

key to the former, but has severe penalties for the latter. We note two types of disadvantage that we observed for remote collaborators. The first is the *lack of advantages* that local mobility provides. The second is difficulties due to the fact that remote communication and collaboration *resources* which might help to overcome the first problem are largely only *present at the office desk* while their users often are not.

DESIGN IMPLICATIONS

Overall, our findings echo those of Whittaker et al. [25]. Spontaneous interactions facilitate frequent exchanges of help and useful information, and that awareness of ongoing activity creates shared knowledge and provides a key context for the interactions that occur. These aspects of the work of our designers are supported by mobility and poorly supported by existing technology. The lack of these resources makes it difficult to collaborate successfully over distance.

Since mobility is so important for local collaboration and use of resources it seems misguided to try to eradicate it from a workplace. If our aim is to support a range of group work, including distributed collaboration, we must design *for* mobility and not *against* it. The implications for CSCW drawn from our study suggest two design goals:

1 To replicate for remote colleagues some of the opportunities for building awareness and for informal communication and coordination that local mobility enables.
2. To reduce the penalties for distributed colleagues of trying to communicate, collaborate and coordinate with others who are away from their desks.

In the rest of this section we describe our ongoing design efforts to achieve these goals.

Replicating Benefits of Local Mobility for Remote Colleagues

Our designers in San Jose were very much more aware of local activity than they were of activity in Santa Cruz and vice verca. This difference is underlined by some of the quotes in this paper. They told us that local design interactions are valuable and occur frequently while it is easy to walk up to local colleagues and watch or talk about what they are doing. However, they dislike discussing design on the phone, partly because they can't tell what people are up to and if it's appropriate to interrupt. They prefer to walk over and talk face-to-face if possible. Consequently distributed design teams suffer a loss of mutual awareness.

Harrison et al. [11] demonstrated how video communications technology can provide a useful resource for remotely collaborating designers. However, in Harrison's study, expensive analogue video technology was used which our designers do not have access to. We did see some effort at QED to communicate multimedia design information over distance with more mundane technology when Leonard sent Gus an email attachment with annotated Connectix™ camera snapshots of his latest models. This is a new practice at QED, but it shows that our designers are willing to expend some effort to use technology as a substitute for local design interactions when these are not possible. As a result, we have been thinking about how to replicate some of the benefits of local mobility and co-presence for remote collaborators. One idea is to make design work more visible by supporting its capture on-line in some way, as Leonard has done in his email attachments to Gus.

In addition to making work more visible on-line, collaborators also need opportunities to communicate easily and spontaneously *about* that activity as they do in physical space. These kinds of interactions are the life-breath of QED with its frequent informal exchanges of ideas and design feedback. Currently these are only available to those who are within walking distance of one another.

For this reason, in addition to providing on-line access to design work, we are trying to provide opportunities for spontaneous interaction between remote colleagues who cannot move around each others' sites to survey the ongoing work. Previous efforts to provide this kind of opportunity have been made with AV communication infrastructures [e.g., 4, 8] however, we believe that such systems will be much more attractive if people have some *occasion* for spontaneous interactions. It is easier to start a conversation if there is something to communicate *about* and if both parties are aware that each other is interested in it (as was the case in our excerpt of the transcript of Ted's encounter with Harry).

One idea, which we are exploring with prototypes at Apple, is to provide a 'virtual site' for design or any other content of interest to a distributed community. Users can take pictures of sketches or prototypes with a camera connected to their machine or at a shared installation. These images can be annotated, stored on a server and distributed to remote software clients which can display them. People running client software can 'hang-out' at the site if they are interested in communicating about the subject matter.

Our initial virtual site prototype was a World Wide Web server system which we tested in our coffee bar at Apple. This system grabbed images of the goings on in the coffee bar taken from a FlexCam™. It then displayed them on an internal Apple web page which employees 'visited' through their web browser. The server also displayed updated information provided by the coffee bar staff about what was currently on sale (cookies, ice-cream, etc.). Visitors to the virtual site were invited to identify themselves and provide a 'gif' photo of themselves if they wished. The server then displayed the name and photo on the web page with the coffee bar camera image and information from the staff.

In this way, people around Apple were able to remotely visit the virtual coffee bar and spontaneously meet others who were also interested in the site. Informal experimentation with this prototype over a period of a few months suggested that it was regarded as quite acceptable to make a phonecall for no other reason than because one 'encountered' someone else (even a stranger) at the virtual site. This benefit could address Gus's complaint, quoted earlier, about the awkwardness of timing phonecalls to remote colleagues.

A second non-web-based prototype involved computer-and-camera touch-screen installation in the coffee bar itself which allowed people in the coffee bar to take pictures of themselves, or anything they chose to show, and then to annotate these pictures by drawing on the screen with a pen or finger. Once again, visitors were indicated by picture icons but, in addition, visitors could also post messages to one another. Whilst people enjoyed taking and drawing on pictures, this prototype was less successful as a virtual site. This was partly because it was not accessible through a web browser so few people went to the trouble of downloading the client software over the several months that the installation was present. A far worse problem was that the client software tended to slow down any machines it ran on to the point of frustration on the part of users.

A third prototype is currently under development which will once again be web-based and computationally lightweight. This system, which we hope to evaluate more formally at QED, will allow designers to show pictures of, and annotate, their design ideas. A dedicated computer-and-camera installation of the kind used in our Apple coffee bar could be shared by designers, or designers who have easy access to a digital camera can submit images from their PC. Images may be submitted explicitly or automatically grabbed from a camera in a public workspace. Anyone in QED will then be able to visit web pages to find out what design work is going on or show ideas they are interested in discussing with remote colleagues. Presence at the virtual site should indicate a willingness to discuss design content in much the same way that physically hanging around while someone is working on something seems to do now.

Getting Away from the Desktop

Our virtual site offers a means for distributed collaborators to benefit from spontaneous interactions about design work as they do from local mobility. However, it still depends upon people using a stationary PC. So a further challenge is to make locally and remotely distributed colleagues more accessible to one another, given that they move away from their desks a lot. We observed that mobility propagates further mobility as people spend a lot of time looking for one another. We also saw that people were irritated by the fact that phonecalls often just missed their intended target as they stepped away from their desk for a few minutes. Thus a system which provided information about whether people are at their desks or not could be very useful.

One solution could be portable computing devices with wireless communications capabilities for locating designers [cf., 10, 15] but this might seem intrusive and would certainly be expensive to implement. We are exploring other alternatives in the form of further prototypes currently under development in Apple. One system makes it easier to know when people actually *are* at their desk. This is reminiscent of the Portholes 'awareness server' system, [9]. Portholes allows users of an audio/video-based communications infrastructure to see updated images of each other in their offices which reveal ongoing activity, making it possible to tell if people are present, busy, hosting visitors and so on.

QED does not have an audio-video infrastructure, so our system relies only on networked PCs. Information is displayed on a screensaver that appears when a machine goes idle. This displays how long it has been idle and lets the owner leave a message to say where they are or when they'll be back. Further, users can save messages in a list that they can quickly select from. They can also see the state and messages of everyone else's machine from their own PC (this brings some of the functionality available from Unix xchat to Mac users, with a simple graphical interface). Anyone running the software can get an idea about whether now is the time to make a phonecall, or walk over for a chat with a colleague. People walking around also benefit from seeing where others have gone as they pass vacant desks.

We tried out an early version of this prototype for two weeks at QED and discussed experiences with a group of users. They approved of the idea and suggested many design refinements. They also suggested that an improvement would be to let them register their location on any machine, wherever they happened to be. They proposed a personal key-chord which they could type in at any PC keyboard which the system would identify as their current location and update their own PC's message. This would enable others to find them easily, or direct phonecalls to the right location and would obviate the need to predict where one is going to end up before one leaves one's desk (most of the interactions and movements of our designers were unscheduled and unplanned, so ad hoc updating of one's whereabouts would work better for them than preparing messages in advance). We plan to make further improvements to our prototype on the basis of this and other feedback that we obtained.

Since this system only requires vacant screen space and some software, it is considerably cheaper than purchasing portable devices and a wireless infrastructure. It is also less potentially intrusive, since people can decide when and when not to give out information about their whereabouts. The downside is that we rely on users to remember and take the time to provide extra information beyond the automatically broadcast fact that they are not at their own PC.

Another related prototype we are testing supports opportunistic communication through lightweight chat-style messaging amongst groups. It exploits the information about whether or not people's machines are idle to display whether they are available for communication (via the chat facility or by phone). The system automatically infers that people are available if their PC is not idle. However, users can override this possibly incorrect inference by indicating explicitly that they are busy. Our hypothesis with this system is that continuous visibility of a display of presence, availability, unavailability or absence affords a prompt for users to communicate spontaneously when they notice someone has just become available, or when they know someone is around to receive a chat message. This kind of prototype could be useful for supporting lightweight communication such as queries or chat between collaborators at distributed sites and for helping to coordinate more heavyweight communication such as phonecalls or video-conferencing.

CONCLUSIONS

Our study at QED focused upon a wide variety of collaborative activities in a project team distributed over a wide area with a client organization over 2000 miles away. We found that much of the work done by the designers in both of the QED sites we studied took them away from their desks which benefitted local collaboration greatly while hampering remote collaboration. Our main conclusion is therefore that CSCW system designers must take this phenomenon into account and should strive to overcome its associated problems when providing support for remote collaborators.

We are currently exploring a number of prototypes at Apple to provide support for distributed collaboration which could help to overcome some of the difficulties arising with respect to mobility. Our hope is to support opportunistic and serendipitous communication about design work for remote colleagues as this seems to be a key advantage of local mobility which they would also benefit from. We also aim to provide CSCW technology which enhances awareness of people's whereabouts and availability for communication, addressing the fact that people may often be away from their desk. Our suspicion is that such technologies will also be useful in other professions where teams need to collaborate over distance and where people frequently leave their desks.

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