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The (Currently) Unique Advantages of Collocated Work

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Today's technologies promise that remote work can be as good as face-to-face. We disagree. We show that radically collocated teams are twice as productive as teams that are merely nearby. Teams in these situations have interactive, continuous communication, making coordination and learning easier. From this observation, we infer two things: what tools might make their work even more productive, and how remote work could benefit from attempting to mimic some of these features.

In spite of all the new ways to connect remote teams—e-mail, chat, videoconferencing, shared whiteboards, and the others—it is still the case that there is nothing quite so humanly effective as being collocated. We make this as a research claim and back it up with evidence presented in this chapter. The research we report here focuses on the collocated work, in fact *radically* collocated work, and describes its effect on productivity, how people work in this environment, and what aspects of this environment seem to contribute to that success.

We describe this work with a caveat. We do not believe that collocated work is the gold standard and that remote work will succeed only if it mimics it (Hollan and Stornetta 1992). There are many aspects of collocated work that are poor (e.g., many meetings where nothing happens), yet there are some aspects that are excellent and worth attempting to achieve. We take the view that for some of kinds of work, being collocated with colleagues is beneficial.

In this chapter, we describe the nature of collocated work—both its advantages and disadvantages. There are three reasons to examine collocated work. First, we may uncover difficult aspects of today's collocated work and suggest tools (either technology or process) to help overcome the difficulties. Second, once we know what the desirable features of collocated work are, we may be able to develop technologies that support those aspects remotely. Third, if we find that the really good aspects of collocated work cannot be duplicated in remote work, perhaps we can define

better what kinds of work can be done remotely and what must be done face-to-face. This chapter is intended to inform this goal by setting out many of the details about what happens when people are collocated.

What Do We Mean by Collocation?

Allen (1977) and Kraut, Egido, and Galegher (1990) have summarized extensive data that indicate that communication frequency among individuals drops considerably with distance and that after about thirty meters, it reaches asymptote. This means that if two people reside more than 30 meters apart, they may as well be across the continent. After 30 meters, they are mentally distant because they are in a different work state: out of sight, out of mind. Communication beyond thirty meters is difficult.

While most people think of collocation referring to nearby cubicles or offices, the purest, most extreme form of collocation is being within a few feet of each other—in the same cubicle or office, adjacent offices, or a shared study. Indeed, in this chapter we examine two variants of the most extreme kind of collocation: the *project room*, where all the artifacts of a particular type of work reside, though the team members come and go, and the *team room*, which we call *radical collocation*, where all team members and their artifacts are in a room for the duration of the project.

Project rooms include laboratories with specialized, shared equipment over which people coordinate their work; conference rooms taken over by a particular project or engagement, common in the world of consulting; and perhaps training rooms that have specialized equipment and materials. Team rooms, in contrast, are rooms in which people who are engaged in the same project reside as their primary work site. We find them to be more common for projects where there is a high need for coordination: architects, research teams, designers of a family of appliances, and software engineers. These two types of rooms are similar in that both hold the material of the work for the duration of the project. They differ in whether the team members reside exclusively in them.

Is Radical Collocation Good?

To address the value of collocated work, we report on a number of studies, including an interview study of team and project rooms and one in-depth study of one

team room (Covi, Olson, and Rocco 1998, Olson, Covi, Rocco, Miller, and Allie 1998). We start with our most extensive study: a longitudinal study of six teams that used team rooms for software development. The teams consisted of six to eight members: software engineers, a manager, and the customer. Team members were diverse in both gender and country of origin and were mixed in whether they had worked together before. All team members resided in the team room; they did not have other offices to go to or other work responsibilities outside the project. The team rooms were the size of a large conference room with arrays of desks with workstations, a center worktable and chairs, and whiteboards and flip charts arrayed around the room. Bays of hoteling cubicles—offices not assigned to anyone and available as needed for privacy—were nearby for solo work or private phone calls, and conference rooms were available for more formal meetings with outside people. Each team was to produce a software product that was scoped to be completed in six to eight weeks with a team of this size. The products ranged from client-server applications to new Web sites, and they originated from a number of areas in the company, including marketing, manufacturing, and sales.

We administered a survey at the start and end of the project. We observed two of the teams in depth, visiting about eight to ten hours a week for the duration of the projects. At the project's completion, we conducted interviews with the members of two teams we studied in depth. In addition, the company took standard measures of productivity of the six teams, including cycle time and function points per staff month. The company also had the team members, the project sponsor, and the user fill out satisfaction questionnaires at the end of the project. (The details of this study are reported in Teasley, Covi, Krishnan, and Olson 2000.)

In measuring how the work changed in team rooms, we report two measures of productivity that are widely used in measuring software development. The first is the number of function points produced per staff month. Function points are commonly accepted units of complexity in software development (Jones 1996, Albrecht and Gaffney 1983). The second measure is cycle time—the number of months from the start of the project to the end, normalized for the size of the project: the number of months per 1,000 function points.

Teams who experienced radical collocation—pioneer teams—were much more productive than standard teams at both this company and in the industry as a whole. Table 5.1 shows these metrics. These teams produced twice as much as other teams did in their multitasked work, in standard office cubicles, in projects with more variable scoping. The collocated teams got the job done in about one-third the amount

Table 5.1
Comparative statistics on productivity in team rooms

Productivity	Pioneer teams	Company baseline	Industry standard
Function points per staff month (higher is better)	29.49	14.35	20.00
Cycle time (lower is better)	7.64	19.47	24.00

Table 5.2
Productivity of pioneer teams versus follow-on teams

Productivity	Pioneer teams	Follow-on teams	Significance	*df*
Function points per staff month (higher is better)	29.49	51.32	$p < .01$	15
Cycle time (lower is better)	7.64	6.58	N.S.	12

Note: The degrees of freedom were adjusted for unequal variance.

of time compared to the company baseline—and even faster than the industry standard. Both of these differences are significant using a *z*-score against company baseline ($p < .001$).

We worried that we might be seeing a Hawthorne effect (Mayo 1933), in that the newness of this situation and the fact that we were closely monitoring the teams may have made them more productive. To test this notion, we assessed the productivity of the eleven teams that followed the six pioneering teams. Table 5.2 shows the comparative statistics.

Follow-on teams were even more productive than the pioneer teams; function points per staff month doubled again while cycle time stayed about the same. We believe this second increase has to do in part with the fact that some of the team members now had experience (some pilot team members served on follow-on teams), and there was some organizational learning about how to run and manage such groups.

For both of these sets of teams, we have team, sponsor, and end user satisfaction measures. Satisfaction was measured using a standard scale for the company, which ranges from 1 to 5, where 5 is "very satisfied." (See table 5.3.) We have no baseline to compare these scores to, but overall the scores are high and not significantly different between the pioneer teams and the follow-on teams.

Table 5.3
Satisfaction of pioneer teams versus follow-on teams

Satisfaction	Pioneer teams	Follow-on teams	Significance	*df*
Team	4.15	4.30	N.S.	13
Sponsor	4.56	4.29	N.S.	8
End user	3.68	3.97	N.S.	4

Table 5.4
Changes in preferences at entry and exit

Preference	Entry	Exit	Significance	*df*
For team rooms	3.53	4.00	$p < .01$	5
For cubicles	3.86	3.42	$p < .04$	5

From the surveys we did of all members of the six teams, we found that the team members liked radical collocation. They had little experience with this style of work prior to this project, rating it 2.17 on a 5-point scale where 5 is "very frequent use." Working in the facility increased their preferences for working in the team rooms and decreased their preference for working in cubicles. (See table 5.4.)

In summary, the work was more productive, the satisfaction of the work and the product was high, and the team's preferences for working in this intense collocated environment increased with experience.

What Happened in the Team Rooms?

What did radical collocation give these teams? To address this question, we draw on data from two sources: the team room study detailed above and a very similar study of one team in another company in comparable circumstances (Covi et al. 1998). This other study examined a team that consisted of six people doing software engineering while experiencing advanced training in a new computer language. They resided in a large conference room outfitted the same way as the rooms in the team room study. Like the six teams reported above, they worked for six weeks, had no other responsibilities during this time, and were mixtures of genders and background. Some knew each other from previous work, and they developed an internal application for salespeople.

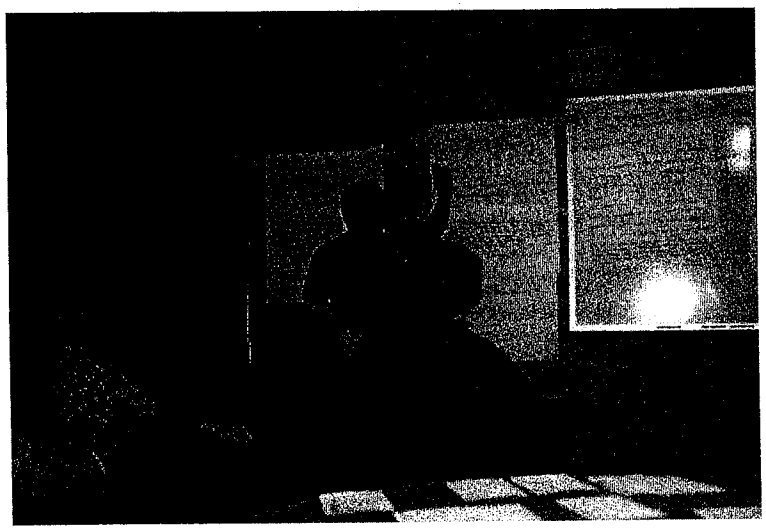

Figure 5.1
A team working using an object-oriented development method, creating, editing, and referring to the material on the flip charts throughout the six weeks.

Figure 5.1 shows a typical situation for collocated teams. The team members in this group lived among their artifacts. The group depicted produced a large number of flip charts in the early part of their work (the artifacts represented use cases, object hierarchies, to-do lists, and so forth). As the group worked, they referred to the posted lists and diagrams often, occasionally moving the artifacts so that comparisons could be made and marking on them to reflect mutually agreed-on changes.

Team Room Process

The team rooms supported interactive, continuous communication. The close quarters of the team rooms supported impromptu communication and allowed people to overhear each other. Subgroups could form and re-form. Over time, this physical reality produced a number of advantages. First, team members found it easy to develop common ground (Clark 1996), engaging in standard procedures or methods without having to talk explicitly about them. Furthermore, the team members knew each other. They had transactional memory (Moreland, Argote, and Krishnan 1996; Moreland 1999) and expectations about each other's talents, working style, and moods. They could read each other moment by moment to know, for example, whether someone was having trouble or was deep in thought while coding (and therefore should not be disturbed). They could use various aspects of the context to assess what was going on at this moment—the position, sound, and gestures of the teammate; the recent history; and the shared local context (some from non-task-related conversation as they enter or take breaks, for example).

While being collocated, each member had local control over what he or she was attending to at each moment, so that different people were paying attention to different people or artifacts to suit their current goals. This situation contrasts sharply with videoconferencing, when everyone sees the same thing because there is only one camera. And typically the team members responded immediately to each other. When someone looked at another with a question, the natural reaction was to respond immediately, even if only to say that he or she would look something up or work on something and get back to the person making the inquiry. This situation is in marked contrast to working remotely through e-mail or voice mail, where responses are most commonly delayed, and the sender has no information about when to expect a response.

In the broad interview study reported in Covi et al. (1998), there were numerous stories about the value of being aware of each other's work. One room we visited housed an emergency response team that helped salespeople worldwide broker special large pricing and packaging deals for important customers. Team members had desks about fifteen feet apart. They were close enough to overhear other team members' conversations if they chose and note for future reference what customer was involved, what salesperson called, and what kinds of deals were eventually made. The desks were far enough apart, however, to make this attention a matter of choice. Also, when one person was inundated with calls, others in the same room could seamlessly take over with nearly the same knowledge of the situation as the key person.

The awareness afforded in collocation also allowed people to engage in informal training sessions. In the study of the single team (Covi et al. 1998), trainers could see over students' shoulders, allowing them to monitor progress over time and intervene only when necessary. Similarly, people learned implicitly by imitating others in the room. They learned quickly from the more experienced people "how things are done," how to make a request by phone, and how to gauge the progress of others.

People learned routines from each other without instruction that made the work proceed smoothly (Cohen and Bacdayan 1994).

We also noted that typically projects involve a number of subactivities—some that seemed best done in the whole or subteams and some that required individual work. For example, conversations with the customer, problem solving of major architectural issues, and status meetings involved a lot of both dissemination of information and clarification and negotiation. The left side of figure 5.2 shows an activity involving the whole group, where they are understanding the overall function of the software they are building and the architecture that will support it. The right side of the figure shows the same group gathered to be tutored on an issue that is needed in the next step of their design, called just-in-time learning. At other points during the project, people worked individually. Figure 5.3 shows people in the same room working individually on their pieces of code. In these situations, team members are quiet, concentrating on their own work. But even in the quiet individual work, however, learning is happening. The man in the middle is looking to his neighbor on the right to find out how to do something.

One of the advantages of being collocated, then, was the ability to move between these various subactivities of work—some requiring individual work and some group interaction. When people had questions, often the person who could answer it (e.g., the customer, the tutor, a fellow worker who had more experience or expertise on a topic) was at hand.

Figure 5.2
On the left, a team working huddled around a table with cards on it, attempting to understand the architecture of the whole system they are designing. On the right, the same group huddled around a computer for a just-in-time tutorial.

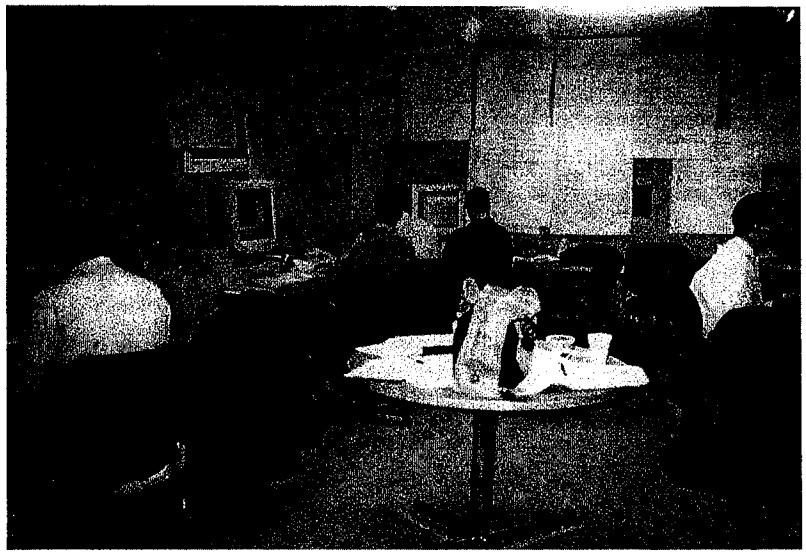

Figure 5.3
The same team using the room to work individually.

On the other hand, the fact that the team members were in interactive, continuous communication had several disadvantages. First, people reported that the room was strikingly chaotic, with visitors and team members coming and going. Overhearing was distracting for those who were trying to concentrate. Informal nearby meetings can interrupt the "flow state" of those team members doing programming. Team members requiring quiet often left the room to go to nearby hoteling areas, but they left reluctantly, knowing they might miss something important. Some team members came in early or left late, hoping to have some uninterrupted time but in the room with posted shared artifacts available when they needed them. We also noted, however, that collocation works well when the team is in a large enough room, with about fifteen feet between people, and when the group develops norms of behavior about being sensitive to the state of the person someone wished to interrupt.

An additional limitation of team room work is that there is no privacy in the room. Team members reported feeling uncomfortable making private telephone calls in the team room. They also reported discomfort having the customer constantly in the room; programmers worried about revealing half-baked ideas or inelegant

Table 5.5
Changes in reported attitudes about activity in the team rooms

Attitude item	Entry	Exit	Significance
I am susceptible to distraction.	3.37	2.68	$p < .001$
People should work near each other.	3.86	4.27	$p < .009$

solutions. Also, since the manager resided in the room, many team members felt their work could be too closely monitored. Furthermore, the fact that everyone lived in such close quarters affected motivation. The psychological literature has documented this phenomenon well (Allport 1920, Forsyth 1998). We could document social impact, both positive and negative. Five of the six teams were high-energy teams; motivation indeed rose by contagion. In one team, the contagion was negative; motivation dropped very quickly because all behavior was visible to everyone. Nevertheless, even in the low-motivation team, productivity was still remarkably higher than the company norm.

Questionnaire results showed how attitudes changed over time. The questions asked the degree to which the respondent agreed with a statement such as, "I am personally susceptible to distraction," with 5 being high agreement. As shown in table 5.5, team members coming in to the team rooms thought they would be distracted by such close quarters. At project completion, however, people were significantly less distracted by the presence of others in the room. They also increased their reported value of being near each other in getting their work done.

What is striking about all of this is how effortlessly human perceptual and cognitive capabilities come into play in order to support the easy flow of interactions in such situations (Hutchins 1995a, 1995b). Participants working face-to-face seldom feel disoriented or without context. These features of the process are hard to duplicate in today's distance technology, but are key to successful conduct of tightly coupled remote work (Olson and Olson 2000).

Team Artifacts

The artifacts generated by the teams we studied were easy to create (flip chart and pen) and were placed on the walls for everyone to see and use. Their spatial arrangement was important, since artifacts were often put up in the order in which they were produced. People knew where to look for something because they knew when it was produced, and they could tell something about another person's attention by

seeing where that person was looking. These artifacts also served various meetings. People would huddle around an artifact to clarify their understanding and make changes with everyone's knowledge. Whittaker and Swartz (1995) noted the same kind of advantage when developers used a large-scale project plan on the wall with notations and cards affixed to it to monitor and meet about the project.

A second key feature of the artifacts in the team rooms was that they were constantly visible. When the team members wanted to access information generated, in some cases weeks previous, they merely glanced at the portion of the wall where the diagram or list was posted. They lived in the interface. The group members so valued this visibility that they covered even the pictures used to decorate the room and asked for a ladder to post new artifacts high on the wall. Figure 5.4 shows the group using the wall surface for the diagrams. When these people were asked about the design of new rooms, they wanted more tackable surface instead of windows.

At another site, human resource people used a project room to plan various moves in the organizational staffing. Two long walls of the room, covered with whiteboard

Figure 5.4
People working in a team room with the organizational chart made of magnets and connectors in electrical tape—a nondigital editable large display.

material from floor to ceiling, displayed the entire organizational chart of the organization, from the top down to four layers of management. (See figure 5.4.) The people on the chart were represented with small magnets (1 by 4 inches) with their pictures, names, and some other notations. The connectors in the chart were indicated with narrow electrical tape. The whole chart was thus physically editable, though not electronic. Career paths of managers were planned in this room. The magnet of the manager under discussion was removed from the chart and held on the table, while the planners gazed at the entire display to decide the implications of various moves of that person (for example, whom this person would replace and which positions were currently vacant). They reported that holding the magnet of the person in hand while the discussion ensued was important; there was something compelling about the materiality of the magnet representing the magnitude of the decision on peoples' lives.

In another of our field studies (Olson and Olson 2000), we noted that at an automobile manufacturer, a competitor's model was permanently displayed on the hall wall, "exploded" so that each piece was examinable and related parts were near each other. Engineers gathered around the wall display to consider issues and possible alternative designs in informal meetings, aided by the parts and their locations on the wall.

We also have seen an extreme form of the spatial location being important for artifacts. On occasion, people explain things to others by drawing in the air (the "air board" referred to in Olson and Olson 1991). Later in the conversation, people referred to "that idea" by pointing to the spot in the air where the first person had "drawn" the idea.

When everyone focuses their attention on the same object and points to the various places on it, they can easily come to a shared understanding. In our early work on design meetings (Olson, Olson, Storrøsten, and Carter 1992), we noted an example where the meeting participants lacked this ability. All people in the meeting were given individual copies of a system diagram at the start of the meeting. As they discussed and agreed to things, they took notes on their own copy of the diagram, adding things and crossing things out. We noted at the end of the meeting that different people had made different marks, implying different understandings of what they had agreed to. This group could have benefited from referring to the same object, perhaps on a whiteboard, because without it, they ended up not "singing from the same sheet of music".

The Interaction of Artifacts and Process

Room sizes are limited and human perception is limited, and thus one cannot have all the information needed in a project visible. But when artifacts are limited, it affects the process. For example, we witnessed a brainstorming meeting in which the emerging ideas were recorded on the whiteboard. The brainstorming stopped as soon as the board was full. Furthermore, because the board was not editable without a great deal of effort, some synergies and similarities among the ideas were lost. Flexibility and editability were important for this task, but there may be other situations in which inflexibility is important and annotations (not cleaned-up versions) are important to the task. For example, the editing marks may signal to someone not present at the moment of change that something has changed. The point is that different situations call for different features of the artifact, and getting these features right is important.

At yet another site we observed, a project room contained three full walls of tack boards. On the walls were plastic sleeves 8½ by 11 inches with Velcro on the back, holding paper artifacts from various project presentations (like printouts of PowerPoint slides) of successful engagements of the past. New clients could come to the room with project planners to discuss these past projects, pulling down the various relevant "pages" to discuss, but seen in the context of the entire project and of other projects. The whole context was afforded by the entire room; they could walk around the room and focus in on various points (Covi et al. 1998).

Other artifacts in the team room helped in the coordination of the group's individual work. The software development team constructed a to-do list consisting of the objects and modules to be built, with individuals' names assigned to each. Tick marks indicated which items were completed, and new items were added as they were discovered to be necessary. As people worked individually in parallel, they could keep track of their upcoming workload and monitor the progress of others. This provided both a coordination aid and a subtle motivator. If others had ticked off their modules and one had not, that person knew that he or she might be responsible for delay. That knowledge was a motivator to work harder and perhaps encourage others to help out.

We were surprised at how many of the rooms had artifacts intended to motivate the occupants. In one project room at an appliance manufacturer, the walls were covered with posters of their planning principles, similar in spirit to Deming principles. Another touted the company slogan about being fast on their feet, adapted to being fast in producing software. The rapid response team for closing large sales

deals had the same motivational poster in each of the walls, viewable from anywhere in the room.

In the settings where we were able to observe teams, we saw that the work in team rooms varied. Sometimes all team members focused on a single issue, sometimes they worked in small subgroups, and sometimes they divided the work into modules they could work on individually in parallel. In all the cases, however, the team member had control over the view and editing of the artifact. Several people held pens when working with a use case (a scenario of the anticipated use of a to-be-built software) on a flip chart; work proceeded in parallel in both the subgroup and individual work. Neither solely individual views nor always WYSIWIS (what you see is what I see) is the solution. One has to move flexibly from co-reference to separate views and back. People naturally gravitate to these styles the best they can with the artifacts that are available. There is likely some newer technology that can help even more.

In summary, radical collocation affords a great deal of ease in coordinating the work among people. People have common ground and information about the current and recent context. They can control what they see as well as what they do, and their teammates command rapid responses by virtue of being so close. People share artifacts that are spatially meaningful and constantly visible and can coordinate easily about references to the artifacts. The artifacts are often large, displaying a huge amount of information accessible at a single glance. Some of the artifacts are editable and flexible, adding to their support of emerging, changing work. Individuals can move around the artifact space as their needs change, seeing the large-scale overview or zooming in on aspects they want to focus on, either individually or in small groups. The artifacts also help coordinate the work of individuals through editable to-do lists with tick marks indicating progress. Today's technologies (flip charts, individual workstations) do not yet support well all the activities we seen in radical collocation.

Designing Effective Resources for Collocated Work

Effective teams embody a lot of tacit knowledge that is difficult to articulate and requires extensive observation to tease out, and artifacts play a critical role in shaping the social and cognitive interactions among teams (Hutchins 1995a, 1995b; Suchman 1996; Olson, Olson, Storrøsten, and Carter 1992). The design challenges

are to understand the process and artifacts of skilled work and the ways in which new tools might help.

Optimal Design of the Work Space

Hunt and Poltrock (1999) redesigned a workspace at Boeing with the goal of enhancing the environment for collaborative work. Their redesign was guided by a work flow analysis coupled with innovative thinking about how to reconfigure the space. They looked at who needed to work with whom, who needed access to whom, and how the overall flow of work activities proceeded. Their redesign created more collaborative space and eliminated dedicated private spaces such as enclosed offices. In the first seven and a half months following the redesign, they found marked improvements in productivity, as well as increases in job satisfaction. In recent years, there has been increased attention to the issues of how to design space to facilitate collaboration. Two recent Cooperative Building conferences contain a number of references to designs and studies of these issues (Streitz, Konomi, and Burkhardt 1998; Streitz, Siegel, Hartkopf, and Konomi 1999).

Shared Electronic Objects

Artifacts of various kinds, such as whiteboards, flip charts, printouts, and paper, are critical elements of work. Driven by our observation that the physical limits of the artifacts constrained the work of the groups, we built software, called ShrEdit, that allowed shared access to the same editable document. To test ShrEdit's efficacy, we had groups of three work on a design problem that was modeled on those we had studied in the field (Olson, Olson, Storrøsten, and Carter 1992, 1993). Half of the thirty-eight groups worked in the traditional way. They discussed their design and captured it on a large whiteboard along with paper and pencil. The other half used ShrEdit with networked computers that were embedded in the tables of the same meeting room the other group used. The results showed that the groups using ShrEdit produced better-quality designs in the same amount of time as the groups using traditional media. ShrEdit fit the work of these groups quite well, although the ShrEdit groups reported less satisfaction with their work processes than the traditional groups. Undoubtedly, the relative newness of working with ShrEdit played some role in this.

Elsewhere (Olson and Olson 1996) we have argued that simple artifacts with a few well-chosen features can be powerful tools in the hands of groups. There is a

tradition of group support systems that have developed much more structured and complex suites of tools for the support of group work. These tools have had some limited success in certain kinds of formal situations (Nunamaker, Dennis, Valacich, Vogel, and George 1991), but on the whole they have not had a big impact on teamwork. Group processes are subtle and delicate, and providing flexibility through simplicity seems to be a better design strategy. But we still lack the kind of deep understanding of group processes and the role of artifacts in their mediation to develop more detailed design guidelines.

Large High-Resolution, Editable Objects

ShrEdit provided a number of desirable features but lacked constant visibility and spatial arrangements that seemed helpful in team rooms. Others have explored variants of the digital wall. Colab (Stefik et al. 1983) had both individual workstations and a shared large display. Tivoli on LiveBoards allowed writing directly on the surface of a large wall-mounted display with a light pen, and operated with handwriting and gestures that do sensible things on the marks by recognizing their structure, not their content (Elrod et al. 1992; Pederson, McCall, Moran, and Halasz 1993; Moran, van Melle, and Chiu 1998a, 1998b; Moran, Chiu, and van Melle, 1997; Moran et al. 1996, 1997; Moran, Chiu, van Melle, and Kurtenbach 1995; Moran, McCall, van Melle, Pederson, and Halasz 1995). The ZombieBoard and Collaborage allow easy transfer to and from paper and remote access, using cameras and digitized images (Saund 1999, Moran et al. 1999). Flatland is an electronic marker board designed for use in an individual's office (Mynatt, Igarashi, Edwards, and LaMarca 1999). Dynawall in I-Land (Streitz et al. 1999) has extended the size of the digital surface to a wall and allowed more than one pen to be operative at a time. I-Land also extends the information access to personal laptops and a group table.

Some of these ideas have made it into the commercial world. Xerox made a commercial product out of the LiveBoard through a spin-off company, LiveWorks. Other large pen-based interactive displays exist, including MicroGraphix SoftBoard and Smart Technology's SmartBoard (Martin 1995). Others are exploring novel hardware solutions (Winograd and Guimbretiére 1999). With the advent of Microsoft's NetMeeting, some of the boards are being used with audioconferencing to support remote work as well as collocated meetings, with some success (Mark, Grudin, and Poltrock 1999).

Moran and associates (1996) conducted a two-year longitudinal study of the use of Tivoli for regular intellectual property management meetings at Xerox. The LiveBoard was combined with audiotaping of conversations, a linked laptop for note taking, and a thoughtful arrangement of the physical space. Special tailored features were developed in Tivoli to support the specific tasks that were carried out through these meetings. More than sixty meetings were observed. While much work went into developing the specialized tools and to keeping the technology working, the work process was facilitated by the innovative way in which the display and the capture of process linked the meetings with the interspersed solitary work of the intellectual property coordinator. His task of mining the meeting material ("salvaging") to create documents for management seemed to be particularly facilitated by these tools.

We had an opportunity to study the Xerox LiveBoard running Tivoli in our laboratory. We ran groups of three on a task that required a fair amount of sketching and problem solving. We compared Tivoli to two other tools, the whiteboard and a workstation-based drawing tool called Aspects, which was similar in a number of respects to ShrEdit. In our comparisons of both process and outcome, Aspects finished a distant third. In this study, we wanted to focus on the comparison of Tivoli and the conventional whiteboard. Figure 5.5 shows examples of teams working at these technologies.

Groups did a series of tasks to familiarize themselves with whatever tool they were using. In our analysis, we focus on the third, longest, and last task they did

Figure 5.5
Groups working at the whiteboard, Tivoli, and Aspects, respectively, from left to right.

in the series: the design of the interface to an automatic post office. We videotaped these sessions for analyzing group process and captured their final design. Five groups used Tivoli, and seven used the whiteboard.

The performance conditions of whiteboard and Tivoli use were quite close. The whiteboard was easier to use (as evidenced by the increased amount of time the Tivoli groups spent on technology management), but both tools produced the same number of features in the design, and participants reported equal levels of satisfaction. It is clear from an analysis of details of performance, however, that the limited display size and resolution of the Tivoli system were drawbacks to its effective use. A contemporary whiteboard has very high resolution, and we found our subjects writing and drawing very small things on it. Combined with the large spatial layout of many whiteboards, it is possible to put a lot of information on a visually accessible layout. With Tivoli, there were no space limitations in principle, but this was achieved through large numbers of relatively low-resolution layered pages. Thus, the electronic whiteboard allowed people to talk while referring to the same object (by being large) and it was editable, but visibility was not constant. Furthermore, teams using the true whiteboard were able to write in parallel at various points in their work. That was impossible with Tivoli.

Large, editable displays are a winning idea for collocated work. As the resolution of such displays approaches the whiteboard and as it becomes economically feasible for such displays to cover entire walls in the same way that whiteboards do, these will become powerful tools for group work. Furthermore, being electronic, editable displays offer the immediate advantage of being able to interface with other devices (file systems, mobile devices of various kinds) and of being able to share displays between remote meeting rooms. Where collocated work has the distinct advantage of process, there is room to improve the artifacts used by collocated groups.

Virtual Collocation: Tomorrow's Promise

As Olson and Olson (2000) reported, today's distance technologies fall short in supporting the tightly coupled work of remote groups. In the future, some technologies might be able to support the features of communication and artifact sharing that we have highlighted here as being important in radical collocation. Figure 5.6 shows a conceptualization of what a virtual team room might look like. Artifacts are large, editable, and shared, as well as under individual parallel control, shown

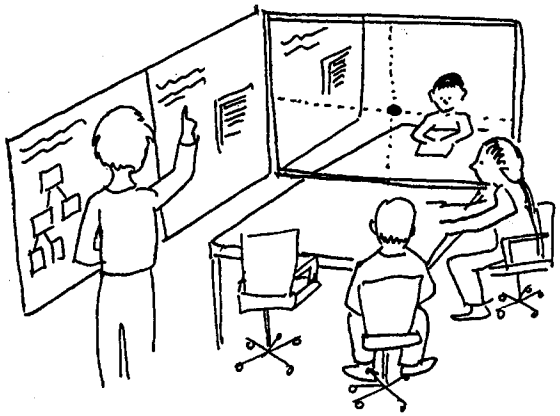

Figure 5.6
Conceptualization of a virtual team room with a video wall and digital walls.

on a wall-size display with various views on individuals' laptops. Remote participants have life-size views of each other, with good stereo audio adjusted to conform to natural physical space. Although there may not be the flexibility of moving around wherever you wish to congregate with remote partners, this configuration goes a long way to produce riche, large, multiple channels of information. If people work in such a room over longer periods of time, aspects of common ground would strengthen as well, making the whole interaction smoother yet.

Before we build such a room, however, we must realize that there still are some limits. We have argued elsewhere (Olson and Olson 2000) that even with the best of tools, there are some major complications to work at a distance. All of them arise from the fact that the more remote the partner, the more likely cultural boundaries will be crossed, with all its concomitant effects on trust, common ground, and different local contexts. However, with training on cultural variations in work practice and with extra effort to ensure that people are working with a common understanding, a number of the features of awareness and shared work flow that are easy in radical collocation are possible over long distances.

We close this chapter with one final point. Several people have asked us whether the people who experienced radically collocated work would be better able to conduct distance work. We do not know. There is certainly widespread belief that a period of face-to-face interaction to facilitate team building is important for distributed groups. In fact, Rocco (1998) found that a few minutes of face-to-face

interaction prior to playing a competitive social dilemma game under distributed conditions led to cooperation, whereas purely distributed interactions (via e-mail) led to competitive behavior. We are currently studying whether such facilitation can come through video interactions. Clearly, the interaction of collocated and noncollocated work needs further analysis and investigation.

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