

Improving Remote Collaboration With Video Conferencing and Video Portals

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The ability of employees to collaborate with remote colleagues is now essential for most large corporations and organizations. Decades of research have identified the conditions that must be present for remote collaboration to succeed. We present a set of studies of remote collaboration within a technology company (Google) that has not only met these conditions but gone beyond them by providing ubiquitous video conferencing (VC). We looked at how well remote collaboration can now work, whether travel is still required, and what impediments still remain. We found that several factors contributed to the success of remote collaboration. Visual real-time communication via VC is ubiquitous and easy to use, VC is integrated with calendar software, and most Google employees have laptops with VC capability. Collaborative tools such as Google Docs, e-mail, and instant messaging make working together, sharing information, and keeping in touch easy. Finally, there is a culture of trust and sharing within Google. We also found that initial face-to-face meetings remain crucial for enhancing subsequent remote interactions. There were two findings of particular interest. First, VC has completely replaced audio conferencing for internal company communications. Second, video portals (always-on video connections between two or more locations) have sprung up spontaneously throughout Google. We categorize their use into four

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different styles of interaction and describe how they can be effective not only in facilitating communication but also in providing presence and status information, helping to establish mutual trust and common ground, and preventing misunderstandings. Video portals reduce the behavioral costs of communication and for the first time allow tightly coupled remote work to succeed. Although there are some lingering problems in technology-mediated distributed meetings, a combination of a collaborative culture with appropriate infrastructure, software, and access to technology can radically narrow the gap between colocated and remote collaboration.

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1. INTRODUCTION

Large organizations of all types are often spread across multiple locations. From an organization’s perspective, this can make it easier to hire the best talent or to form the best temporary teams, as employees or contractors can work from almost anywhere and highly skilled employees can be recruited irrespective of their location. Employees can also live closer to customers, allowing more face-to-face interaction and reducing travel expenses. Work can proceed continuously when handed off to colleagues multiple time zones away, and a distributed workforce can also improve an organization’s ability to deal with disasters.¹ From a team perspective, however, this means that geographically distributed individuals will need to collaborate remotely to complete work tasks, and how to accomplish this efficiently has been the topic of hundreds of studies over the last 30 years (G. M. Olson & Olson, 2000; J. S. Olson et al., 2008; J. S. Olson & Olson, 2006; Powell, Piccoli, & Ives, 2004). G. M. Olson and Olson (2000) summarized much of this work in the title of their article “Distance Matters.” In fact, just the belief that a remote partner is in a distant city versus the same city can have negative effects on cooperation and persuasion and lead to increases in deception (Bradner & Mark, 2002). Distance does matter, but remote collaboration can succeed for loosely coupled work when a set of basic conditions are met and challenges overcome.

What happens, however, when all conditions are met, and in addition new effective technologies are applied that were not available a decade ago? Our goal was to understand how well remote collaboration can work in a company where the

1. Continuity of Operations Plans are becoming increasingly important. For example, to deal with extreme weather, natural disasters, disease outbreaks, or terrorist attacks, Congress passed the Telework Enhancement Act of 2010 (Public Law 111-292), which mandates that all federal agencies “establish a policy under which eligible employees of the agency may be authorized to telework” (Section 6502).

technology is significantly better than that studied in most of the research literature.² How does remote collaboration develop and proceed when a wide variety of technologies and tools are available and it is up to individuals and teams to decide how to use them? What currently works well, what tools and techniques are effective, and how satisfied are employees with their current situation? Will remote collaboration be equivalent to colocated collaboration, and will new tools and technologies eliminate the need for travel? What findings from the research literature can we confirm, and what will we find that has not been reported previously?

To answer these questions, we carried out a set of studies at Google, a widely distributed technology company, by studying individuals, teams, and meetings in a number of settings. We used diverse methodologies, including interviews, surveys, log analyses, and observations of meetings and workplace environments. Our focus was on how distributed teams can collaborate effectively to complete their work tasks, and we refer readers to other research for discussions on different aspects of teams, including management and team composition. Globalization and advances in information technology have led to a changing conception of teams, with new research required on team definition, membership and roles, and leadership (Wageman, Gardner, & Mortensen, 2012). For a review of the issues involved in managing distributed teams, including selecting team members, see Hertel, Geister, and Konradt (2005). Scientific collaborations that involve researchers from multiple universities and organizations have some additional challenges to overcome, especially with respect to management, planning, and decision making, and these are discussed in detail in J. S. Olson et al. (2008).

We confirmed many of the basic findings from the research literature, but also report much that is new. For example, we show that even tightly coupled work can now succeed across a distributed team in some special circumstances. Google is perhaps the first company where ubiquitous and easy-to-use video conferencing (VC) is available to all employees, bandwidth is unlimited for all practical purposes, and a wide variety of technical tools are available. We argue that both VC ubiquity and ease of use are particularly important. In work at Sun on making distributed meetings more effective (Yankelovich et al., 2004), ease of use was “perhaps the strongest theme to emerge” (p. 422). The Sun research focused on audio conferencing, but we argue that ease of use is even more important for VC, which traditionally has had much more complex user interfaces. Saturating facilities with VC-equipped rooms and integrating the VC system with electronic calendars and the conference room reservation system radically reduces the complexity and effort of setting up and joining a VC. This reduction in the behavioral overhead of participating in VC meetings is one of the keys to its success.

How “virtual” or distributed a team is can vary (Hertel et al., 2005), with maximum distribution occurring when each team member is at a different location and everyone communicates only electronically rather than face-to-face. The teams we

2. Consider Cramton’s (2001) highly cited work that involved studying dispersed teams of graduate students who were not able to use videoconferencing or even telephone conferencing, or to travel and meet face-to-face.

studied represent a range along this dimension. For some teams, approximately equal numbers of team members were located at several different locations, whereas for others there were one or two primary locations with multiple individuals as well as remote locations with just one or two individuals. We note where our results apply to a particular distribution of team members over locations, but we have not studied enough teams to generalize.

1.1. Factors Influencing Remote Collaboration

The research literature is very clear that face-to-face meetings and prior experience facilitate remote collaboration. Face-to-face meetings increase trust and familiarity and create “common ground” with respect to shared vocabulary and work practices, and help by clarifying goals and individual roles (see Hertel et al., 2005; Rocco, 1998). Although VC can also be considered a form of “face-to-face,” we follow the standard usage of this term to mean meetings at which people are physically colocated. Distributed teams (also called virtual teams) are more likely to experience conflict (Hinds & Bailey, 2003), but this is mitigated by face-to-face meetings followed by regular VCs, which can help to maintain a cohesive team and a sense of shared identity. Coordination and cooperation among distributed team members are improved in teams with a shared identity (Bos, Buyuktur, Olson, Olson, & Volda, 2010), and team cohesion and trust are related to project success in distributed teams (see Powell, Piccoli, & Ives, 2004). J. S. Olson and Olson (2006) wrote, “If team members have a lot of shared past experience, have worked together before, share a common vocabulary, etc., it is easier for them to work through remote media without a lot of clarification” (p. 101). Cummings and Kiesler (2008), in another study, analyzed 3,911 pairs of collaborators and found that “a prior project with a collaborator predicts greater strength of a current collaborative work tie. Prior experience also reduces the negative impact of distance” (p. 437). Weimann, Hinz, Scott, and Pollock (2010) provided an

analysis of the communication culture and tools of the distributed teams of a large German manufacturer. . . . The findings show that regular face-to-face meetings, email and phone still play a pivotal role in team communications, even though a variety of communication tools is available. The results also indicate that, like non-distributed teams, a need for common ground and shared meaning, or social context, are essential elements for the communications within a distributed team. Face-to-face meetings are still important to create a common ground and shared meaning in distributed teams. (p. 187)

When the complexity of team coordination increases due to an increase in team size and geographical dispersal, then the advantage of familiarity with team members has an even greater impact on team performance (Espinosa, Slaughter, Kraut, & Herbsleb, 2007a).

These interpersonal effects of remote collaboration help to explain much of the early experimental literature on differences in task performance in groups communicating via audio only, audio plus visual, and face-to-face, as well as other conditions

(see McGrath, 1984). McGrath developed a model of group task types and found that many of the differences in experimental results could be explained by the characteristics of the tasks used. Whether there is audio or video connectivity, for example, does not affect performance in simple problem solving or brainstorming tasks but does make a difference in tasks involving negotiation and conflict. In these latter cases, face-to-face interaction and audio plus video are better than audio alone. Veinott, Olson, Olson, and Fu (1999) argued that there are negotiations of meaning in everyday conversations, and they show how video can help in some situations. McGrath (1984) also made a point central to our findings: These lab studies often formed groups for a single experimental session, whereas groups in the real world continue over time and “work on tomorrow’s tasks, and the next day’s, will flow much better if the group has a stable pattern of interpersonal relations, a stable set of functional roles” (p. 180).

The literature on remote collaboration also highlights the importance of knowing about the presence and status information of colleagues: Are they available for certain types of communication exchanges, what are they working on, how busy are they, and so on. Espinosa, Slaughter, Kraut, and Herbsleb (2007b) wrote,

Coordination is important in software development because it leads to benefits such as cost savings, shorter development cycles, and better-integrated products. . . . Our findings show that. . . . geographic distance has a negative effect on coordination, but is mitigated by shared knowledge of the team and presence awareness. (Espinosa et al., 2007b, p. 136)

1.2. Early Prototypes for Improving Presence Awareness and Communication

G. M. Olson and Olson (2000) summarized the research from the 1990s aimed at improving communication and awareness among remote team members. They wrote,

One important feature of co-location that is missing in remote work is awareness of the state of one’s coworkers, both their presence-absence and their mental state. . . . There have been a number of attempts to recreate this sense of awareness remotely [Cruiser, Video Window, Montage, CAVECAT, Portholes, Portland video link experiment]. . . . All of these installations had some success in getting people to communicate more easily, though a number of human factors, social, and organizational issues interfered with their ready use. In all cases they were abandoned after a demonstration period, in part because their cost could not be justified by appropriate benefit. (p. 161)

The human factors, social, and organizational issues have now been solved, we argue, and we report next that many groups within Google are now connecting offices or work areas with an always-on video and audio connection that we are calling a video portal. We briefly review one of the early prototype systems here, and mention some of the others in our discussion of how radically technology and work contexts

have changed in the last 20 years. (Also see Mantei et al., 1991, for a description of CAVECAT; Fish, Kraut, & Chalfonte, 1990, for a description of the VideoWindow system; and Dourish & Bly, 1992, for Portholes; for a more comprehensive discussion of video-mediated communication and the history and prototypes of the broader area of media spaces, see Finn, Sellen, & Wilbur, 1997, and Harrison, 2009.)

Fish, Kraut, Root, and Rice (1992) developed a prototype system called CRUISER. They argued that informal communication is very important within organizations, for example, in “learning the organizational culture, becoming loyal to an organization, making judgments of others, and forming relationships” (p. 37). They went on to speculate “that some form of desktop video teleconferencing could prove useful in preserving informal communication channels for geographically distributed organizations” (p. 47). CRUISER was tested for 21 business days by 23 volunteers at Bellcore, 11 student interns, and their 12 mentors. They were all in the same research and development facility but on different wings and floors. There was no multiperson conferencing capability. There were several modes: Cruises contacted a particular person and immediately opened an audio and video connection but it timed out after 3 s unless one party explicitly decided to continue it. In Autocruises, the system initiated a call between randomly selected users, and in Glances a 1-s connection was established with one or a series of other people.

Not surprisingly, the system did not work very well in facilitating informal communication, given how disruptive it was to normal work. However, there were two results of interest to our findings. First,

On occasion some intern–mentor pairs connected their offices for an extended period, without engaging in sustained conversation. Rather, the pair would work relatively independently, occasionally having conversation to ask a question or to get help on a problem. The open connection reduced the behavioral cost of communication during periods when the participants anticipated they would need multiple episodes of unscheduled conversation. (Fish et al., 1992, p. 40)

Within Google, reducing the “behavioral cost of communication” is a major factor in the success of video portals, as well as in the use of personal VC units. The second result of interest was that

conversations using the CRUISER system involved more greeting and scheduling, but involved less problem solving and decision making . . . a major problem that 90 per cent of respondents mentioned was that they could not share work objects when conversing with someone by using the system. (Fish et al., 1992, p. 41)

That is, they could not examine computer printouts together or use a whiteboard. We have advanced to the point at which sharing documents and computer screens is easy but a shared drawing tool remains elusive. Research systems exist (e.g., Calico; Mangano & van der Hoek, 2012), but they are not yet in wide practice. It is very difficult to reproduce the advantages that whiteboards provide to colocated

groups with electronic tools used by remote groups (Cherubini, Venolia, DeLine, & Ko, 2007).

VC is central to remote collaboration within Google. In what follows, we describe Google's VC system, present the findings of five studies on its internal use, and then discuss how it has enhanced working together over distance. We also note additional opportunities to enhance remote collaboration through technological innovation.

2. COMPANY PROFILE AND VIDEO CONFERENCING SYSTEM

2.1. Company Profile

Google now has more than 70 offices in more than 40 countries. Roughly one third of its employees are now located at the headquarters in Mountain View, California. Other locations with more than 500 people include Cambridge (MA), Kirkland (WA), New York (NY), San Francisco (CA), Beijing (China), Dublin (Ireland), Hyderabad (India), London (England), Sydney (Australia), Tokyo (Japan), and Zurich (Switzerland).

2.2. Google's Video Conferencing System

Google has developed its own VC system built upon its Hangouts offering. The deployment team has saturated Google offices with these systems. There are now more than 6,000 VC³ units throughout the company, and most are located in reservable conference rooms. Given 2012 employee levels, there is one VC-equipped conference room for every six to seven Googlers (the name for Google employees). During this study the VC system used the H264-SVC codec, which supports a main window of 640×360 at 30 fps and additional participant windows at 320×180 , also at 30 fps. Moving forward, the VC system will be enabled to allow higher definition. Individuals can join a meeting from a VC unit, from a phone, or from their personal computer. Using a laptop, a person can join from anywhere in the world that has an Internet connection of greater than 2 Mbit down/600kbps up. The system can support more than 15 different video feeds simultaneously (each can be a conference room or an individual).

There are two types of VC units:

1. Conference room units are run via a dedicated computer, have either one or more flat screen displays (size varying with the room, up to 65 in.), plus a hard-wired control device with a touch-sensitive screen that sits on the conference room table (see Figure 1). Cameras in this configuration are either fixed or pan-tilt-zoom.

3. "VC" from this point on refers to Google's internal video conferencing system built on Hangouts.

FIGURE 1. A conference room with a dual-monitor video conferencing (VC) system.



Note. Note the touch-screen control device in the right foreground. When not in use, the monitors display information and tips on using the system. The telephone is not used during VC calls; the system has the ability to add telephone users as needed.

2. Personal VC units (see [Figure 2](#)) are used primarily in “phone rooms”⁴ (see [Figures 3](#) and [4](#)) or on an individual’s desk. These are single units with a touch-screen monitor and built-in processor and fixed camera. Users control the session using the touch screen.

When no meeting is in progress, the current and subsequent meeting reservations are listed on the personal VC monitor or, in larger rooms, on the control device. Once a meeting has been joined, the table-top device provides controls for exiting, controlling the camera, selecting a video source for the large display area, reporting problems, muting (both the local and remote site), and more, though not all options are visible all the time.

In VC meetings, individuals can give a presentation to all participants by screen sharing from a laptop (wirelessly) by opening a simple URL. The contents of their PC screen are then projected onto the video display for both colocated and remote participants. Off-site users, or participants who are not in the scheduled conference rooms, can easily join the meeting from any other conference room or phone room by entering the meeting name, or via their laptop with a URL. Scheduling and joining a meeting under VC is integrated with Google Calendar, and users can join from their own device by merely clicking a link in the invitation.

4. Phone rooms are small one- or two-person enclosed rooms with a phone and a video conferencing unit.

FIGURE 2. A personal video conferencing unit, designed for use in a phone room or on a desk.



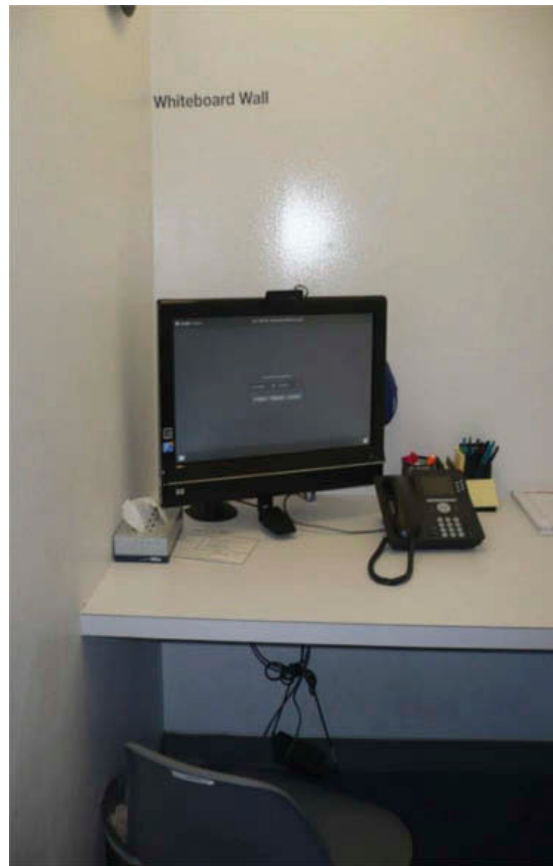
FIGURE 3. A line of phone rooms.



3. METHODOLOGY

Over the course of a year we carried out five different studies. Rather than try to separate out the results from each study, we have combined them to form what we hope will be a fairly comprehensive picture of how remote collaboration currently works within Google, continuing problems, and the need for various enhancements and improvements.

FIGURE 4. The inside of a phone room with a video conferencing unit, a phone, and a marker-writable wall.



3.1. Individuals: Semistructured Interviews

We started by interviewing 24 Googlers. We contacted acquaintances and then used a snowball sampling methodology, selecting respondents based primarily on location and job type. The first two authors carried out the interviews, and in only one case did we interview someone we knew personally. Our goal was to sample a wide range of people from within Google. Participants came from 12 different locations, represented a diverse collection of job types (with about half involved in software engineering and testing), ranged in age from 26 to older than 50, included about equal numbers of men and women, and had worked at Google from less than 2 months to more than 6 years. Educational backgrounds ranged from B.A.s to Ph.D.s. There were eight participants from 20 to 29 years of age, eight participants from 30 to 39, and six participants who were 40 or older.

We used an interview protocol with 33 questions in the following eight areas: (a) background information on the individual; (b) location, nature of work, overall assessment of remote collaboration; (c) video conferencing; (d) social aspects of collaboration; (e) mobile phones and travel; (f) other technologies; (g) physical spaces; and (h) wrapup. The interview protocol is available online at www.tandfonline.com/loi/hhci20. The interviews took 45 min to 1 hr. Most were conducted over VC, a few

face-to-face, and one via phone. As appreciation, participants were given a Google store gift card.

The interviews were recorded but not transcribed. We took detailed notes during the interviews and reviewed the audio when required to complete our notes. For analysis, we used a simplified open-coding technique in which we made repeated passes through the notes to categorize the respondents' statements.

3.2. Teams: The Use of Video Portals

We studied six diverse teams that maintained an always-on VC connection (a video portal):

- Team 1 is a software development team working on Google's internal VC system. Members are located in New York (NY), Mountain View (CA), and a personal residence in Texas.
- Team 2 is a software development team creating websites and backend systems supporting online cultural initiatives. Members are in Paris (France) and Tel Aviv (Israel).
- Team 3 is part of a technical support team with members at dozens of locations throughout the continental United States.
- Team 4 is a software development team working on application programming interfaces (APIs) for Google services. Members are in New York (NY), Chicago (IL), and Chapel Hill (NC).
- Team 5 is a network surveillance team with members in Mountain View (CA), Sydney (Australia), and Dublin (Ireland).
- Team 6 is a two-person user-interface design team in Mountain View (CA). The two members consult and work with multiple other teams that are geographically dispersed.

We interviewed team members, studied their physical office arrangements, and joined the video portal of four teams to observe interactions during the day. We observed for a combined total of 30 to 40 hr.

3.3. Meetings: The Use of Video Conferencing

Nine experienced user experience researchers at Google observed 20 meetings that involved the use of video conferencing between two or more locations. We identified target meetings primarily via peer networking. We selected a diverse set that involved different team members, different disciplines, and different numbers of attendees. We were also limited by the requirement to have a researcher present at one of the meeting locations.

There was a single observer per meeting, except for one meeting that three observers attended, each at a different location. All observers participated in a 3-hr

training session. The first two authors, with input and feedback from several experienced ethnographers within the company, created course materials that covered some of the history and theoretical underpinnings of ethnographic research and prepared guidelines and practice materials specifically for meeting observation. The training was itself conducted via VC in two separate sessions to accommodate varying time zones.

The observers sat in on meetings in Mountain View (CA), New York (NY), San Francisco (CA), Pittsburgh (PA), London (England), and Shanghai (China). All meetings were naturally occurring, the observers did not participate in any way, and approval to observe was obtained ahead of time. Practically all meetings were between 30 and 60 min, and most were recurring meetings. There were a variety of meeting types, including status update meetings, Town Hall meetings, training, and brainstorming meetings. The number of attendees at a single meeting ranged from four to more than 80, and the number of different video feeds ranged from two to 18. For example, in a single large meeting, 18 video conferencing units (in conference rooms or work areas) or laptops could all be connected to the same meeting, and there could be more than 80 people at these different locations.

We developed a detailed coding scheme to help the observers take notes; it included 68 questions in four sections: (a) Pre-meeting (e.g., type and size of room, are there whiteboards?); (b) Room, Timing, Participants (e.g., actual start time, any single individuals at a location, number and location of participants?); (c) Google Video Conferencing & Technology (e.g., any technical problems, were any VC controls used, was anyone participating via phone rather than video?); and (d) Communication & Group Dynamics (e.g., any turn-taking issues, any side conversations?). There was also a postmeeting interview guide. Despite this extensive coding scheme, we instructed the observers that most important was to keep in mind three general questions and areas, along with whether changes in these areas might improve meeting efficiency and remote collaboration: (a) How is technology being used? (b) How is the room itself being used? (c) What is happening with respect to communication and group dynamics?

In addition to documenting what they saw during meetings, observers were instructed to note what happened before and after the meeting officially started, and to interview a meeting participant after the meeting if possible.

3.4. Personal VC Devices

Individuals can request a personal video conferencing unit that can be physically attached to a desk. To find out how these units were actually being used, we created a list of units in New York and then toured the New York office, talking with owners and others in the area and observing where the units were placed. We collected information on 17 units. We also estimated, from usage logs (see next), how many of the total number of personal VC units throughout Google were being used for video portals.

3.5. Surveys

We created a survey to confirm findings from our interviews, to track satisfaction with the video conferencing system, and to explore a variety of issues related to remote collaboration. Some items assessed frequency of use and familiarity with various features of the VC system. The survey was pretested for clarity and time-to-complete (8–10 min minimum). A link was distributed via e-mail to a random sample of 1,250 Google employees around the world, excluding top-level executives and brand-new employees. Demographic data, including job role, department, location, and length of employment, were harvested from company records and correlated with survey responses. Over a 2-week period, and with one reminder e-mail, 496 surveys were completed and another 81 had partial responses.

To gather information on the frequency of conference calls in other companies, we sent a question asking about the relative frequency of audio conferencing versus video conferencing to many of our (non-Google) contacts on LinkedIn as well as posting the question to a usability discussion forum. The sample was certainly not random, but we received responses from 66 people from 55 different companies.

3.6. Log Analyses

Although not a separate study, we performed log analyses as part of several of the preceding studies. Google keeps logs of every network event, such as establishing a video conference, adding another participant, or terminating a connection to the video conferencing system. Analysis of the logs makes it possible to track relevant statistics like the number of units that are in use, the number of video conference sessions, and their duration.

4. RESULTS

The results are divided into four sections. In the first section, we provide an overview of remote collaboration within Google, focusing on video conferencing but also discussing other technical tools, the importance of face-to-face interactions, and a comparison of remote collaboration with collaboration among colocated colleagues in open work areas. We will present data on how video conferencing has increased rapidly within Google, some of the reasons for its widespread adoption, and the different ways in which Googlers participate in VCs. In the second section, we describe some of the issues and problems that arise when meetings are held among two or more locations using VC, whereas in the third section we focus on the use of video portals. Problems in remote collaboration are discussed in the fourth section.

4.1. Remote Collaboration Within Google

Of the 501 responses to our survey question, “Is your core team geographically distributed?” 65.3% replied yes. Although Google periodically attempts

FIGURE 5. Percentage of Time “Actively Collaborating.”

None or nearly none of my time	10.8%
Less than $\frac{1}{4}$ of my time	53.1%
Up to $\frac{1}{2}$ of my time	22.8%
More than half my time	6.8%
Nearly all my time	6.6%

to “defragment” projects or product areas by consolidating them geographically, employee movement and organizational changes tend to counteract those efforts over time. In addition, we know anecdotally that most groups within Google interact regularly with other teams across product, discipline, and organizational boundaries, and these interactions routinely involve people at multiple locations.

To clarify the extent of remote interaction, our survey asked, “How much of your time do you spend actively collaborating with remote colleagues?” The 501 responses broke down as presented in [Figure 5](#).

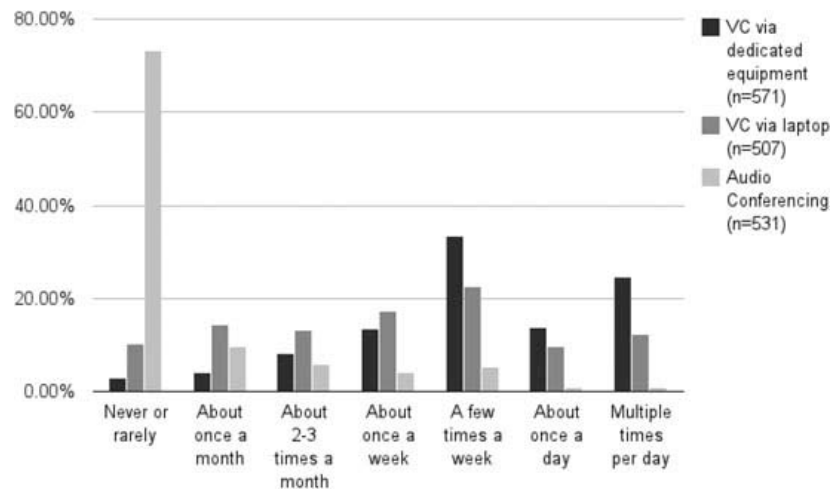
Taking a work week as 40 hr, and assuming these proportions reflect the entire Google population, this translates to around 13% of the company engaged at least 20 hr per week in “active” remote collaboration. An additional 23% spends between 10 and 20 hr per week so engaged. Presumably, this includes all kinds of meetings, discussions, and design sessions, and it represents a significant number of person-hours working with peers located at some distance. The survey data on the prevalence of VC (presented next) suggest that about 38% of employees participate in one or more video conferences a day just from dedicated equipment, and more than 70% do so more than once a week. Although these conferences might be of short duration, they are still a fairly frequent form of remote collaboration.

If a project or task can be divided into separate parts that can be worked on independently and then joined when completed, remote collaboration is easy and can be highly successful. The problems arise when work is tightly coupled, which means that “components of the work are highly interdependent. The work typically requires frequent, complex communication among the group members, with short feedback loops and multiple streams of information” (G. M. Olson & Olson, 2000, p. 162). The Googlers we interviewed all seemed to have an implicit understanding of the difficulty of tightly coupled work and provided examples of tightly coupled work being too difficult to do with groups separated geographically. They recognized the need to reorganize projects so that tightly coupled work was assigned to one location. As we describe in the section on video portals, however, tightly coupled work is now sometimes possible when teams are connected via a video portal, provided the geographical separation does not cross too many time zones.

Video Conferencing

The Prevalence of Video Conferencing

One of our most dramatic findings was that nearly everyone in Google participates frequently in video conferencing. As shown in [Figure 6](#), fewer than 3% of survey

FIGURE 6. Frequency of video conferencing (VC) and audio conferencing.

respondents said they “never or rarely” participated in standard VC meetings (i.e., using dedicated VC equipment, as opposed to joining from a laptop). In contrast, 24.5% of survey respondents reported typically having multiple VC meetings a day, whereas an additional 47.1% reported VC meetings “a few times a week” or “about once a day,” via dedicated VC equipment. Almost three fourths of respondents participate in VC meetings a few times a week or more. Analyses of VC system logs confirm these numbers, as there were more than 20,000 VC connections per day in late 2012, where a connection represents each location participating in a VC session. Given conservative assumptions of the number of Googlers per VC meeting, it is clear that the survey results reflect VC usage throughout Google. For meetings joined from a private personal computer, the frequencies are somewhat lower but still quite common. Although we did not directly collect a frequency of participating from either medium, it is common for people to do both (on different occasions), so the overall frequency of using VC is higher than either mode on its own.

The rapid adoption of VC can be seen in [Figure 7](#), which presents the daily total minutes of VC time per day (from VC devices only, not PCs). This is calculated as the sum of connection time of participating locations on all VC calls. Thus, two VC devices (conference room or personal VC devices) connecting for 30 min would be 60 VC min; this does not take into consideration how many people are standing in front of the personal VC device or sitting in the VC-equipped conference room.

Weekly dips represent weekends, whereas the irregular dips in July and December reflect U.S. legal holidays. Daily total minutes for the busiest day each week has proved to be the best growth metric. Using that measure, the steady upward trend in connect time represents a near *quadrupling* of usage from the beginning of 2012 through mid-January 2013.

[Figure 8](#) shows the number of VC devices deployed throughout the company during approximately the same time interval as [Figure 7](#). There was an increase of nearly 50% in the number of rooms equipped with VC during these 9 months of 2012.

FIGURE 7. Number of video conferencing minutes per day (in thousands) within Google from January 2012 to January 2013.

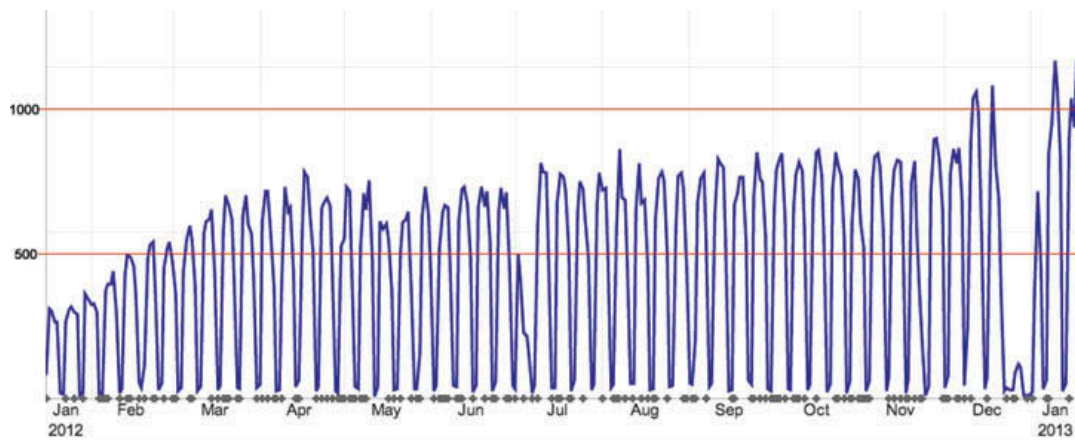
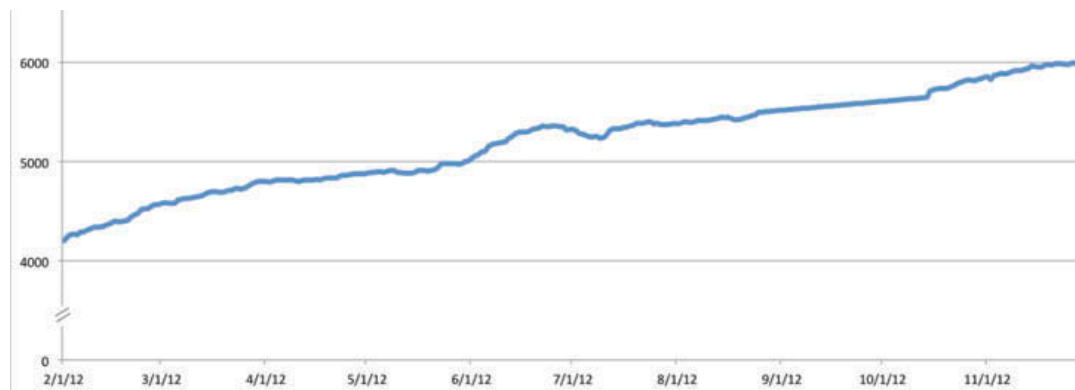


FIGURE 8. Number of deployed video conferencing devices within Google.



In contrast to the high participation rate for VC meetings, 73.3% of survey respondents report that they never or rarely participate in audio-only conference calls—and for those who do, it is typically because there is an external participant involved (e.g., a sales call with a client where VC is not an option). In essence, VC meetings have totally replaced audio conference calls for internal use, a dramatic result made even more so when compared to the situation in many technology companies, where VC meetings are still rare.

Audio conference calls are still the norm in the United States. In our informal survey on audio versus video conferencing, we polled non-Google professionals from dozens of companies. Eighty-five percent of respondents reported that audio-only conference calls were the norm and they participated in few if any video conferences. The remaining 15% of respondents participated in an equal or greater number of video conferences but were much more likely to use Skype or Google+ Hangouts from their PC rather than using specially equipped conference rooms. None of the large companies represented in our sample had plentiful VC-equipped conference

FIGURE 9. A small conference room called a “huddle.”

Note. This unit has a Pan-Tilt-Zoom camera, but most huddles currently have fixed cameras.

rooms. A response from one large technology company was representative of several we received from people working at large corporations: There was only one VC-equipped room in a facility with several hundred people, and due to both unavailability and inconvenience it was used infrequently. Because there were restrictions at this corporation for desktop video conferencing, audio conferences predominated.

VC meetings at Google are typically arranged for 30 or 60 min, and in most locations there are ample conference rooms, phone rooms (see Figures 3 and 4), and “huddles” (Figure 9) where Googlers go to attend these meetings. Huddles are small conference rooms near teams intended for ad hoc use. About half of survey respondents reported that they could find a phone room when they needed one most of the time or always (48.6%). Only 3.8% reported that they were rarely or never able to reserve a conference room. Googlers typically bring laptops to VC meetings, and the ability to wirelessly present or share screens or documents from a laptop was easy to do, worked well, and was very common. In fact, thirty-one people (12.4%) mentioned screen sharing in response to an optional survey question about what they liked best about VC.

The Advantages of Video Conferencing

The advantages of video conferencing and its superiority over audio conferencing were explicitly acknowledged by almost all interview respondents, and the ability to have video conferences whenever needed is a major contributor to the success of remote collaboration. As one Googler summarized it, “Video works really well. It gives, by far, the highest sense of what’s going on—you can see the expressions. . . . I love it.” Another respondent noted that you are more likely to pay attention during

a VC and less likely to engage in multitasking. “The more real it feels, the less likely you are to do anything else.” Many people answered the optional survey question, “What do you like best about video-conferencing at Google” by writing about how it helps remote collaboration. These five responses are representative: “It’s great! I can’t imagine trying to do cross-office collaborations without GVC [the name for the Google internal VC system]”; “Makes remote site work almost as good as being there”; “Overall, it’s incredibly easy to hop on a call with collaborators from other offices and it makes cross-office work SO much easier than dealing with just phone and email!”; “Makes my life 1000 times easier as my team is spread across the country”; Google VC is a “revolutionary improvement. It largely enabled me to manage a team that spanned the SF, MV, NYC, Chicago and Seattle offices.”

A variety of reasons for the superiority of video are mentioned in the literature, and many came up spontaneously in our interviews or were mentioned in response to survey questions. With video it is much easier to tell who is participating in the meeting, there is a greater sense of participation and emotional connection with video, gaze and body movements can help to regulate the flow of conversation, nonverbal cues provide information on emotional state, and from listeners’ facial expressions and body language a speaker or presenter can get feedback about their level of comprehension and engagement (see Mané, 1997). For this reason, as Mané pointed out, it is more important for a speaker to see the audience than the reverse. You can, of course, also show physical objects to other participants. In addition, the visual channel can be used as a backchannel without interrupting the speaker (e.g., by raising hands or shaking one’s head; see Henderson & Henderson, 2009, p. 354).

Some Googlers noted that video conferencing works best with smaller numbers of participants and that the experience deteriorates somewhat as the number of participants and video feeds increases. In a video conference with multiple locations there is a separate video feed from each location. The video of one location (or a presentation) is in a large window while the rest are in a “filmstrip” along the side. When there are multiple people in a room, each person’s image can become so small that it is easy to lose track of who is in which room, it can become hard to see facial expressions, and it is sometimes difficult to determine who is talking. It also becomes very difficult to read body language and nonverbal cues.

Video Conferencing: Quality and Reliability

In our internal interviews, most Googlers thought the video quality was good, and sometimes “surprisingly good.” There were more complaints about the audio, although even here the majority thought the quality was good. In our study of 20 VC meetings, the observers rated both the video and audio quality as good, sometimes fair, or excellent. The survey results from more than 500 Googlers were consistent with these reports, as almost three fourths of the respondents said they were moderately or extremely satisfied with both the video and audio quality (top two responses on a standard 7-point satisfaction scale).

Reliability is the attribute with the lowest rating in the survey. When people complain about VC, reliability is the most typical complaint, and problems with the

touch screen control device are mentioned most frequently. In our survey, more than 200 people provided optional comments about using VC for meetings. In addition to problems with the touch screen, other issues included the need to reboot the PCs controlling VC and broken equipment or the system being down. This is reflected in the only substantive difference in ratings between dedicated VC devices and laptops, where the former is rated less reliable than the latter (see [Figure 10](#)). People sometimes complained about having to move to another conference room, but this points out one of the benefits of saturating the facilities with VC-equipped conference rooms. If one room is out of service, there is often another nearby. If VC is not working in a conference room and only one or two people are involved, another option is to remain in the room and join the meeting from one of the laptops. Despite these comments, twice as many survey respondents chose a satisfied rating compared to a dissatisfied rating on reliability (61.0% vs. 29.9%) and 42.9% were either moderately or extremely satisfied.

Video Conferencing: Ubiquity and Ease of Use

Ease of use and ubiquity are the two main factors behind the widespread adoption and use of VC. This was clear from our interviews and observations and was supported by survey responses, as 70.2% said they were moderately or extremely satisfied with the ease of use of joining a VC meeting from a VC device. Of the respondents, 249 answered the optional question “What do you like best about video conferencing at Google?”; the most prevalent response included statements about how easy it was to use or start a VC meeting (103 responses, or 41.4%). Sixty people (24.1%) mentioned either (a) ubiquity explicitly or the ability to join a VC from their PC or from anywhere or (b) availability on many different devices.

Setting up a VC meeting in advance is very easy and can be done via an internal version of Google Calendar in less than 1 min. A meeting name is automatically assigned, but it can be easily edited (“Q1 Rollout Planning” is the meeting name on the device in [Figure 11](#)). A conference or phone room can be chosen from within the calendar and participants invited. An e-mail with this information is then sent automatically to all attendees. When entering the assigned room for the meeting, the time and name of the meeting are listed on the touch screen device on the table, as shown in [Figure 11](#).

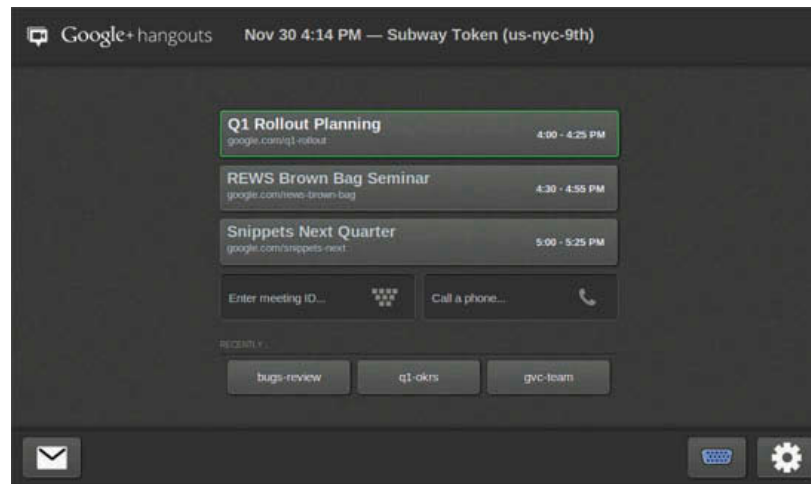
A video conference is established when the first participant joins, which happens when a participant touches the meeting name. During the meeting, the touch screen device has controls for the camera, microphones, speakers, and other elements of the system. If a meeting is not set up via the calendar, then all that needs to be done is to enter an agreed-upon name on the touch screen device in each conference room. Consider a meeting between Mountain View, New York, and London. Someone would typically use Google chat to suggest a video conference and propose a time and meeting name (e.g., “Let’s VC at 4 pm, mtg name Q1 Plan”). Participants in the three cities would then go to any conference room (or use a personal VC unit or their laptops), enter the meeting name on the relevant device, and all parties would be immediately connected.

FIGURE 10. Satisfaction Ratings by Video Conferencing Device (Dedicated vs. Laptop).

Overall Satisfaction		Audio Quality		Video Quality		Ease of Use		Reliability		Features & Capabilities	
Dedicated ^a	Laptop ^b	Dedicated ^c	Laptop ^d	Dedicated ^e	Laptop ^f	Dedicated ^g	Laptop ^h	Dedicated ⁱ	Laptop ^j	Dedicated ^k	Laptop ^l
Average rating	5.6/7	5.6/7	5.7/7	5.8/7	5.5/7	5.8/7	5.8/7	4.6/7	5.2/7	5.5/7	5.7/7

^a $n = 576$. ^b $n = 534$. ^c $n = 574$. ^d $n = 525$. ^e $n = 569$. ^f $n = 527$. ^g $n = 566$. ^h $n = 526$. ⁱ $n = 569$. ^j $n = 525$. ^k $n = 563$. ^l $n = 516$.

FIGURE 11. The touch screen device shows the names and times of scheduled meetings.



Note. Touching a meeting name starts the conference, and the screen then lists various video conferencing controls.

The Use of Personal Video Conferencing Devices

Googlers can join a VC meeting from phone rooms, conference rooms, PCs, or from a personal⁵ VC unit. As depicted in Figure 2, a personal VC unit is a one piece computer-monitor combination dedicated to video conferencing. Although in the past these were rare, and used only by upper managers, they are becoming more common, and individuals can now request a personal video conferencing unit that is attached to a desk. Of the 2,072 personal units within Google (March 2012), 1,555 were used in phone rooms and huddles, whereas 517 were used as personal units and assigned to individuals. About 30% of the personal units were used as video portals (153), which we defined as units that were in two 3-hr periods of continuous use during a week. This finding that 30% of personal units are used for maintaining a video portal is in accord with our findings from the small sample of 17 units that we identified, for five of these were used as video portals. The remaining 12 units were divided evenly among those used primarily by an individual for personal use and those used primarily by a team, as described next.

Personal Use

Most Googlers who had a personal device were in an office (private or shared) or small team conference room, but not all; some were in open areas. Generally, the people who use a device for their own personal use are at a higher level of responsibility within Google, manage others, or are product managers who need to communicate almost constantly.

5. As earlier, the label “personal” refers to the dedicated, single-unit VC configuration as opposed to the standard conference room setup; no implications regarding ownership are intended.

The units are used for both scheduled and spontaneous meetings, and sometimes to join existing video portals for a short time. For spontaneous meetings, a common scenario finds two collaborators in the midst of an extended e-mail or chat exchange when one senses that VC would be more efficient. The personal VC owner typically suggests a video meet-up and proposes a meeting name, and then joins that meeting on the VC unit, continuing to work on his or her computer for a few moments while waiting for the other person to join. The meeting will begin quickly and will often last only a few minutes. Without a personal VC unit, it would require more time to locate and get to a free conference room, or more inconvenience to join the meeting from one's desk computer—losing context, sharing screen real estate, and having reduced access to the computer during the VC. In fact, a theme we heard repeatedly is that behavioral overhead is a critical factor. The ease of connection on a dedicated device—compared even to using a laptop—increases the likelihood of use. As one person said, “It’s very valuable, it makes a big difference. If I didn’t have it on my desk I would use my laptop, which isn’t as convenient . . . overhead matters.”

Everyone in our sample who had a personal unit also used phone and conference rooms, typically for private meetings (e.g., dealing with direct reports), so as not to disturb neighbors, or for times when the VC owner wanted to be in the same conference room with local colleagues for a VC with Googlers at another location. Conference and phone rooms were also used when there was a need to attend closely to the meeting content and the Googler preferred the quiet and seclusion of a conference room. For the rare Googlers with private offices there are no worries about disturbing others (or privacy concerns), and these owners spend a significant part of their day in their offices participating in VC meetings. They all report that it is “incredibly useful” to be able to take most of these calls from their desks. Although a few of these owners may use conference or phone rooms for more than half of their meetings, they still find their personal units extremely valuable.

Units that are primarily personal are sometimes used for group meetings. For example, a senior person or manager may share an enclosed office with others who report to her or are on the same project, and the owner may invite them to stand or sit in front of the unit for quick team meetings. This also happens for owners with private offices, who may occasionally invite in team members who have their desks in an open area outside. Because these units are typically placed on a desk, the camera field of view (FOV) is fine, as is the audio, whether or not headphones are used.

Team Use

About one third of “personal” VC devices are used as a team device, typically in an enclosed office but not always. Two or more team members regularly use it for meetings with single or multiple remote participants. It may also be used occasionally by an individual. In practically all cases that we observed, when multiple people share an enclosed office they are working on the same project or team, and so it makes sense to use the device for team meetings. The VC unit is permanently situated on a small table, rather than a desk, and the Googlers in the office move to the unit when

they want to use it, rather than participating from their desks, which is difficult or impossible given camera FOV issues. It may also sometimes be placed on an individual's desk, using an arm that allows it to be swung out and viewed easily by multiple people. Teams vary in how often they used the units, ranging from several times a day to several times a week. The units are used for both scheduled and spontaneous meetings.

Some teams use their personal VC device to maintain a video portal with one or more remote groups. We describe four different modes of using a video portal in a later section, and this captures the video portal usage we found here, with one exception. We observed one large group in New York that has a video portal in a spacious open area outside of their work area (but still part of the group's private area). It seems to serve more of a social function rather than for focused collaboration (it is, after all, far from the individual work areas). The other end of the portal is in London, and members of both locations often interact informally using the video portal. It is also used for group meetings between the two locations, which we were told can be fairly large.

Laptops and Technical Tools: Docs, E-mail, Instant Messaging, Calendars, Sites, Groups

Although we made no effort to systematically investigate the workplace communication ecology (see Turner, Qvarfordt, Biehl, Golovchinsky, & Back, 2010), it was clear that different teams and different types of job functions communicated using a different mix of technologies. Some groups, for example, used Internet Relay Chat (IRC) and other group chat tools as a replacement for some e-mail, although we saw nothing like the almost complete replacement of e-mail by group blogging and IRC reported by Johri (2011).

Based on our interviews, we found that other tools are available and widely used in addition to VC. E-mail and Google docs are essential, whereas Instant Messaging (IM; e.g., Gchat) is also widely used. Everyone uses Google Calendar extensively. Google Groups is used to distribute information and discuss issues. The ability to look at others' code and builds is critical, and easy to do. Google Sites is widely used to collect and share information about projects. In our respondents words, these websites are used "for keeping track of projects, milestones," "as a repository for information," "weekly updates," "as our primary form of documentation," "as a way to keep everyone informed," "to document everything," and "for release documents, instructions, specifications, tips, etc."

The fact that most Googlers have personal computers capable of VC and can share documents using Google Docs means that Googlers can work, and collaborate, anywhere in the world that has an Internet connection. The ability to easily share and coedit documents, spreadsheets, and presentations facilitates remote collaboration, and there is evidence that being able to coedit documents improves group performance (J. S. Olson, Olson, Storrosten, & Carter, 1993).

For finding an expert, getting a question answered, or learning about what other groups are doing, Google's intranet is effective, but not as effective as asking

a colleague. From our interviews we found that Googlers will typically first ask colleagues, then look in the intranet or Groups, or ask a question in Google+.

Travel, and the Importance of Face-to-Face Meetings

Our results are in complete agreement with the research reviewed in the introduction that finds face-to-face meetings essential for facilitating remote collaboration by increasing trust and creating common ground. Hinds and Bailey (2003) mentioned the importance of creating similar contexts: “Distributed teams moderate the negative effects of distance by meeting face to face, purposely conveying contextual information, and creating similar contexts at distant sites” (p. 628). Practically all Googlers who collaborate with people at other locations do some traveling to have face-to-face meetings. Some groups have annual global conferences, and smaller quarterly face-to-face meetings seem to be common. In addition, some groups have rotation programs, and it is fairly common for Googlers to spend a week at another office working face-to-face with remote colleagues. Our respondents considered a week long enough to accomplish significant work and get to know colleagues yet short enough to minimize disruption to personal life. For managers who mostly check in with team members for progress and planning, shorter visits may be optimal.

The importance of meeting people face-to-face was one of the key factors we heard in facilitating remote collaboration, and helps in many ways, as the quotes from our interviews demonstrate.

- “The quality of remote collaboration is multiplied by 10 or more after at least one face-to-face meeting. Communication is based on trust, built as a result of physically meeting. This is almost a prerequisite for working together. That said, VC relationships can be somewhat effective to establish initial trust, but not as effective.”
- “Already knowing the people and knowing them fairly well; that’s what is critical” [for remote collaboration to work well].
- “After a meeting, they [her colleagues] get more responsive to emails. You should always travel and meet others and be on the same page.”
- [After a group summit] “It was easier to work with people after I got back home. I definitely understood how they worked and how to work with them. I understood the dynamics of the group. The group adapts, and knows better the skills of each member of the team.”
- Meeting face-to-face is essential for “establishing guidelines for behavior and understanding and norms.”
- “It’s always important to meet in person when building a new team. Also, people will say things to you in person that they won’t in VC.”
- “If I establish rapport first, then collaboration is much easier. The social aspects are important, so meeting first is good.”

In addition to establishing rapport and common ground, many people feel more comfortable discussing sensitive work-related issues face-to-face, such as those having to do with pay, promotions, individual performance, and some organizational issues.

Presence and Status Information of Colleagues

Presence awareness is provided by video portals, which we discuss in a later section. Status information includes information on the projects that colleagues are working on. When assignments do not completely overlap, this contextual knowledge can be helpful (e.g., in understanding delays in shared projects). Typically, Googlers had detailed information about what their closest collaborators were doing, and less information (although it was typically sufficient) about those not on their direct team with whom they were more peripherally involved. Googlers found out what others were doing via group meetings and by looking in “snippets” (a widely shared write-up of the week’s activity), at another’s code base, and sometimes by looking within the intranet at an individual’s Objectives and Key Results and related data. Online calendars can also be an effective way of learning what others are doing as well as getting information about meetings or events that may be of interest. Sharing calendars is the norm at Google, and it is general practice to look at someone else’s calendar when scheduling a meeting. Nevertheless, Googlers are hesitant to “stalk” others’ calendars. Openness and trust come into play here: In a spirit of openness it is fine to look at my calendar to see when I am free for a meeting, but I trust that you will not go snooping around without a good reason.

Colocation and Open Workspaces

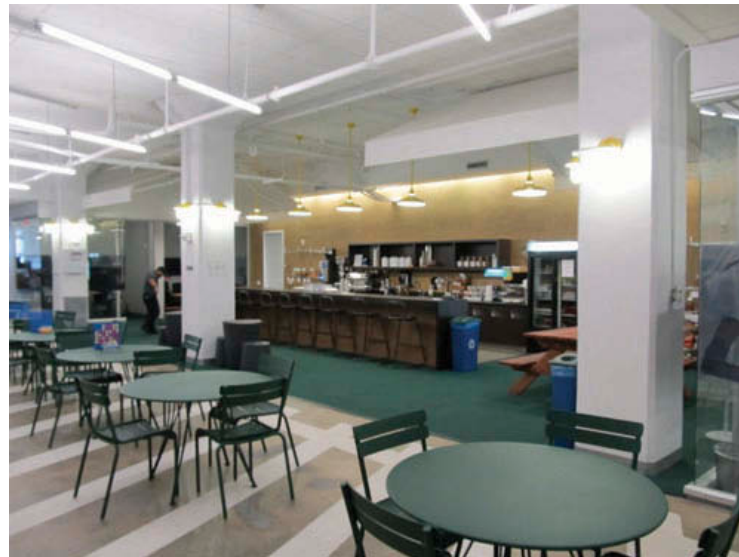
Office layouts can have dramatic effects on collaboration and communication, as well as employee satisfaction and productivity (Vischer, 2008; see also Hua, Loftness, Kraut, & Powell, 2010). Because Googlers evaluate the effectiveness of their remote collaborations with respect to their collaborations with colocated colleagues, it is important to describe the open workspaces in Google facilities where teams are colocated. The Google open workspaces are called multispace offices by some researchers (e.g., Boutellier, Ullman, Schreiber, & Naef, 2008) because they include a variety of diverse places for working. Workspace quality depends on physical comfort, functional comfort (e.g., support for users’ tasks), and psychological comfort (including feelings of belonging, ownership, and control; Vischer, 2008). All these factors are considered in the design of Google open workspaces. For example, open areas typically have natural light (see Figure 12), and there is both individual and group control and autonomy with respect to the design and construction (from modular parts) of individual workspaces and team areas, which can help to create a sense of both individual and group territory. Given the lack of privacy in an open environment, shared spaces away from one’s desk are essential for informal conversations, spontaneous meetings, and chance encounters with people from related teams. Google provides many such spaces; see, for example, the “micro-kitchen” (an area with drinks and snacks) and its surrounding area in Figure 13.

FIGURE 12. An example of an open work area in the New York office.



Note. Note the natural light to the right. Shared spaces with tables and chairs, as well as enclosed conference rooms, are out of sight along the left side of the picture.

FIGURE 13. Tables by a micro-kitchen provide a popular spot for informal meetings and relaxing.



The distance between individuals is critical. Teasley, Covi, Krishnan, and Olson (2002), referring to research going back to Tim Allen's work at MIT in the 1970s, write that "there is a logarithmic decline in communication with increased distance between collaborators, where any distance over 30 meters produced the same low probability that team members would talk to one another" (p. 672). (See also Boutellier et al., 2008, for research on the impact of office layout on communication.) As one person we interviewed put it, "I don't discuss things with people who are way far off, but I do collaborate more with people sitting near me."

The presence and status information that is so difficult to obtain among geographically dispersed teams is very easy to achieve when groups are colocated. Teams within Google are generally located together in open workspaces. When one is located physically next to colleagues, it is easy to interact with them and stay in the loop. One can turn around to ask a question or overhear project-related conversations among others. A person can stand up, see where all the team members are, and then quickly walk to any one of them. Serendipitous conversations are another advantage of colocation: Discussions occur outside of scheduled meetings, and informal interactions take place at meals and while working on other projects (three free meals a day are provided at the larger Google facilities). Googlers pointed out to us that it is much easier to interrupt colleagues sitting nearby compared to those who are remote because one can tell when they are busy and when they are likely to have time to answer a question. Even a quick question to a remote colleague might require an e-mail, with the corresponding overhead and delays. One manager also mentioned that it was much easier when colocated to assess whether a new employee was managing all responsibilities well or was overwhelmed.

In general, Googlers found the open office layout to work well, and they use and appreciate the informal meeting spaces, micro-kitchens, huddles and phone rooms. When we asked specifically, “Does this open area work for you?” the general refrain was, “I’m happy with what we have.” This directly contradicts prior survey findings that office workers are dissatisfied with open office environments (Vischer, 2008). According to Vischer, people who move to an open space from enclosed offices are typically unhappy, at least initially. We attribute Googlers’ satisfaction to many Googlers never having experienced more private arrangements, the high value on sharing and collaboration, the egalitarian Google culture, and the availability of alternate spaces for quiet and privacy. The many ways in which Google’s open workspace environment facilitates collaboration sets a high standard against which to compare remote collaboration; despite this, the ability to collaborate with remote team members is rated highly.

There are, of course, some negatives associated with the open office layout, primarily related to noise and distractions. It is easy to get distracted by nearby conversations, and people near conference rooms or micro-kitchens sometimes complained about the noise. Several people mentioned the need to get away to a quiet area: “Sometimes I want to work on something quietly but it’s hard in an open environment.” This individual would grab a free room and work from his laptop.

4.2. Meetings Using Video Conferencing

For any type of collaboration, whether colocated or remote, meetings are necessary, and vary widely in both size and function. Size can range from two people to more than 100, whereas meeting functions also vary widely, and include regular status update meetings, various types of planning meetings, design and brainstorming meetings, presentations, tutorials, training meetings, personnel and performance review meetings, and Town Hall meetings. How effective are meetings when they involve video

conferencing between two or more locations, and how can meetings be improved by changes or innovations in technology, physical spaces, and communication or behavioral practices? These are large, complex questions that we cannot hope to answer fully, but we do have some interesting findings from our study that we expect will generalize to many other settings.

In practically all cases, our nine meeting observers judged that the meetings were run efficiently, participants were engaged, and meeting goals were met. There were, however, a variety of areas in which problems occurred and opportunities for improvement existed. In some cases, solutions were obvious. For example, poor illumination or backlighting in some conference rooms results in faces on remote VC monitors being in shadow or dark and thus not recognizable. Simply adding more lighting or drawing shades would typically solve this problem.

Difficulty Identifying Presenters, Speakers, and Locations

In the large meetings we observed it was often difficult (or even impossible) to tell who the presenter was and where he or she was located, as the presentation occupied the largest part of the display area on the monitor and the speaker was relegated to a thumbnail image. When someone other than the presenter spoke, it was still very difficult to see who was talking based on mouth and body movements, because with multiple rooms and often more than a dozen people in a room, individual images were tiny. Because presentations are often used with large audiences, this problem surfaced regularly. Automatically zooming in on the speaker would help in many large meetings, and using face recognition to identify individuals and display their names would also help. The situation is now somewhat better given system upgrades that allow rooms with dual monitors to show a presentation on one monitor and a view of the speaker's room on the other. In this case, the video window with the speaker is much larger than the other windows.

Field of View Problems

Even in small meetings there were sometimes problems related to the camera's FOV. One person reported after the meeting that "the layout is ok but if people sit at the side of the table the camera does not capture them. We all need to sit close to each other to be in the frame." In another room where we observed a meeting, there was a bench along one wall, and those sitting on the bench were out of the camera's FOV and were thus invisible to the remote participants. These problems typically occur in only a small percentage of conference rooms, but when they do occur they can be quite disruptive.

VC Controls

In about two thirds of the meetings no one used any of the VC controls, aside from initiating and ending a meeting. In the other third, only the mute control was used

(to mute locally, not remotely, which is also possible). In many cases, other controls would have definitely helped. In particular, panning to people on the side or out of view when they speak or present, and selecting which video stream to display in the main window would have made dramatic differences in some cases. More than 90% of survey respondents were aware of the most common features (e.g., muting the local mic, presenting from a laptop), so lack of knowledge was not a factor in the low usage frequency. The Google VC system has a rich feature set, however, and 20% to 30% of respondents did not even realize that less commonly used features existed (e.g., viewing chat messages on the VC monitor).

The VC touch screen control unit is typically reachable by only one or two people. In large meetings people typically mute the mics in rooms when no one is speaking to prevent distracting noises, but this means that a person who wants to speak may have to repeatedly ask someone else to unmute, and then to mute again. It is likely that this will result in less participation by some people, who may question whether what they have to say is worth the trouble of requesting someone to unmute. The fact that only a few can reach the touch screen control may also account for the rarity with which people use the pan or zoom camera controls. Because practically all meeting attendees arrive with a laptop, providing VC controls via a laptop application would allow any person to activate VC controls from their seat. In addition, the system now supports up to four touchscreen controllers for large conference rooms.

Meetings Run Late

Many meetings continue past their scheduled endings and stop only when interrupted by the next occupant. To attempt to solve this problem, meeting times were changed to 25 and 50 min from 30 and 60, but this did little to solve the problem. It is still the case that those coming in for the next meeting are often rushed setting up and getting started, and people leaving the meeting for another are often late, creating a vicious cycle that is hard to break. One solution under evaluation is to provide on-screen alerts and warnings, increasing in intensity as a subsequent reservation approaches. The alerts would differ depending on whether there is another meeting scheduled, and if not an option could be presented to extend the room reservation.

“Primary Room Dominance,” System Delays, and Turn-Taking

Observers were unanimous in judging that single remote individuals did not have trouble participating in meetings, but this does not mean that they were able to participate in the same manner as members of a colocated group. Consider the following scenario, which happens frequently when there is a primary room with many people and one or more remote rooms with only one or two people. The people in the primary room start having an animated discussion, with many people participating, and the discussion swings back and forth quickly. There are two consequences: First, it is easy for the people in the primary location to forget about the remote participants; second, it is often very difficult for the remote participants to enter into the

conversation in a natural way. We observed this in several of the meetings, and in other meetings where we were participants rather than observers. A distributed meeting with a single conference room and remote individuals is a fairly common occurrence in many companies. At Sun, for example, 60% of distributed meetings were of this type (Yankelovich, Simpson, Kaplan, & Provino, 2007).

A simple but radical approach can eliminate primary room dominance when equality among participants is paramount: force colocated individuals to join the meeting individually rather than together from a conference room. Although drastic, this technique could be used as a training exercise to help colocated employees appreciate the situation of remote team members.

Several people mentioned the problem with system delays and how this makes it difficult to participate. There may be lots of lively back and forth within a location, but this is generally not possible between different locations. Speaker turn transitions can occur with no gaps between speakers; this is possible because people can predict the end of a speaker's turn based on prosody, grammar, body language, and other cues. This is often not possible in the Google VC system, where round-trip delays in some locations can exceed 150 ms. This is actually very fast, and not generally noticeable, yet can affect turn-taking. There is experimental evidence that people are often unaware when delays of 600 ms are added to a conversation, and even though the delays do not affect subjective speech quality ratings or task performance, they can significantly increase interruptions (Karis, 1991). In our initial interviews, one observant Googler made this point about turn-taking explicitly. He said, "There is a small delay; it's really small, but sometimes significant. When you want to get into the conversation, that small fraction of a second may be annoying." Although there are cultural differences in the average gap between turns, there are also "striking universals" in turn-taking (Stivers et al., 2009).

Whether small system delays cause problems depends on the type of meeting and the type of interaction. Problems are less likely to occur when the participants are more equally spread out over multiple locations, and less likely to occur in status meetings where a team leader calls on people to provide updates. In our interviews after the meetings we asked, "Do you think it was harder for people at some locations to participate?" One person responded, "No, since it is a recurring meeting, people know the process and each other." In large meetings, the leader may explicitly manage the turn-taking, including resolving verbal collisions when multiple people start talking at once. In meetings where there are more free-form discussions, however, system delays will present more of a problem.

4.3. Video Portals

Multiple teams within Google now use video portals, an always-on video connection. Some have been using them for several years. We found this surprising, because in all the cases we were aware of, the decision to set up and use a video portal was made independently, without any special support or direction from management, and because no one we spoke with was aware of any of the research literature in this area.

Team members reported hearing about some other team that was letting their video meetings continue for long periods, or just started doing this themselves.

Although there are no official statistics available, based on an analysis of VC usage logs of personal VC devices, we estimated that approximately 50 teams were using video portals during this study. Now that VC units can be ordered online via the intranet, their numbers are increasing dramatically (there has been a 75% increase over the last 7 months of 2012), and we expect that the number of teams using video portals will increase steadily. Creating a video portal is simple, as it just involves setting up a video conference and leaving it on. Although any type of VC unit can be used for a video portal, the vast majority use personal VC units, as anyone can order one for use in their work area. Cost was not an issue and was never mentioned. Setting up a video portal requires equipment, a network, and continuing use of bandwidth. The network is already in place, bandwidth is plentiful and not a constraint, and the equipment is relatively inexpensive (the cost of a VC unit is comparable to a well-equipped desktop PC).

We were interested in learning how the six teams we studied were using their video portals, whether they felt it improved team efficiency and product velocity (in the Agile Programming sense), how the effectiveness of the portals could be improved, and whether it would be beneficial if they were used more widely within Google.

We were surprised at the different ways in which video portals were used, with different teams developing their own unique modes of interaction. For some teams it has become essential, whereas for others it is useful but not critical. The frequency of interaction over a video portal also varies dramatically, but even when it is used sparingly (e.g., once a day) it is still considered useful and worthwhile. The primary use is facilitating direct communication among team members, whereas a secondary, but still important function is to allow team members to learn and keep in touch by overhearing conversations in other locations. Maintaining a video portal also allows people from outside the team to join and ask questions or seek help. All they need to know is the name of the VC meeting used to establish the video portal. Improving and maintaining team cohesion and identity is another benefit. However, as should be clear from the upcoming brief descriptions, there are variations in the importance on all of these dimensions. For all teams, travel is still critical, and the importance of getting together physically for face-to-face meetings is acknowledged by everyone. As one member of the Network Surveillance Team said, “VC is great for keeping relationships, but that initial meeting in person is really quite helpful for getting the relationship going.” Another person noted that “design fights” stopped after they had an in-person meeting. Having meals together and getting to know each other is critical for facilitating future remote collaboration.

Teams that maintain a video portal still often join other meetings over VC, either from their own VC units or from a conference room. For most teams, especially the larger ones, when a discussion over the portal gets technical and is unlikely to be of interest to the entire team, those involved leave the video portal and start a separate VC.

We categorized the six teams that use a video portal into four different styles of interaction:

1. Facilitating spontaneous communication (Teams 1, 2, & 3)
2. Integrating remote team members into the core team (Team 4)
3. Facilitating handoffs or other discrete events (Team 5)
4. Facilitating easy access and consulting services (Team 6)

We discuss each of these four styles of interaction in the following sections, followed by some observations on how communication practices evolve over time, and on the commonalities across teams with respect to team building, travel, physical spaces, and privacy. Based on our observations, we then present some of the lessons learned and design implications.

Facilitating Spontaneous Communication

Software Development Team 1 works on the development of the Google VC system and is spread over three locations: Mountain View, New York, and a personal residence in Texas. Members interact over the system more than any other team we studied, and they value it highly. Interaction varies widely over days and weeks, but typically there are multiple interactions each day of all types, including technical and coding questions between individuals, requests for feedback, group discussions, and various types of meetings. In addition, people from outside the team occasionally join to ask questions or to get help. The team is divided into three subteams, and members often benefit from overhearing conversations among other subteam members. There are nine people on the three subteams: three in California, five in New York, and one working remotely from his home in Texas. In addition, there were several other members in New York who are involved as Quality Assurance engineers and product and project managers. The team members form a highly cohesive group that gets along well, and this facilitates their use of the video portal.

A major factor in the successful use of the video portal is the fact that the team has multiple VC units. There are many personal units on desks, plus some large wall-mounted units. This reduces the overhead of using the system, as there is no need to get up and move to a unit; in all cases, team members can interact over the video portal from their desks. A screenshot is presented in [Figure 14](#). Note that the video includes both the head and upper body. Nguyen and Canny (2009) examined measures of empathy (using both questionnaires and behavioral measures) and found that empathy was higher in a video condition that included both the head and upper body compared to a head-only condition. Empathy in a face-to-face condition was also higher than the head-only condition but not significantly different from the head and upper body condition.

Members of one subteam often hear conversations related to another, and this helps them to keep in touch with what the other teams are doing. In addition, people sometimes jump into conversations they overhear with comments or suggestions. This

FIGURE 14. A snapshot of Team 1's video portal.



Note. When a person speaks, the corresponding video feed is placed in the large window. However, each individual can override this and choose which video feed to display in the main window by selecting one of the images in the filmstrip on the right.

works well because the team members know each other very well and have developed trust and respect for each other.

Team members made the following comments about their use of the video portal (paraphrased except where there are quotes):

- It does a pretty good job of simulating hallway conversations. A keyword catches your interest, and you jump in and participate, you feel more like a team, and knowledge sharing is definitely better. This would not have happened over chat or e-mail.
- Overall it works great. Really good for communicating quickly: “Hey, Steve, quick question, quick response.” Can get a lot more information than over IM.
- The best thing is not having to schedule VCs. Being able to look over and see if others are there and available. Steve’s camera is on, but his chair is empty, he’s having lunch, and I can ping him when I see him.
- The good thing about having a live video stream is that you can always talk to someone and get information faster—compared to IM, for example. What are the details of turning on an experiment? It’s easier to understand when someone tells you something rather than putting it in writing. It’s more convenient, and if there are any misunderstandings you can ask questions right away.
- It’s easier to ask a question than to write an e-mail. Having the video portal shortens the build process by 2 or 3 hours compared to the past.

Sharing Screens

Screen sharing over VC is easy, and team members often review colleagues’ code this way. They also share the build process in real time, displaying the release scripts,

which can take more than 1 hr. When verbal description becomes challenging, engineers may rely on screen sharing to show code so that everyone can understand the issue or problem.

Software Development Team 2 helps to promote culture online by creating projects such as an online archive for Yad Vashem and the Digital Dead Sea Scrolls. Like Team 1, they are located primarily in two locations (10 people in Paris and five in Tel Aviv), and team members at each location are in their own room. Although the subteams are spread across the two locations and collaborate closely, they only interact over the video portal about one to three times a day (less for some subteams) and do not typically use it for informal banter and chatting the way Software Team 1 does. Note, however, that it is still left on continuously. Maintaining a video portal between Paris and Tel Aviv is seen as useful but not a dramatic improvement.

It is instructive to examine some of the differences between Teams 1 and 2, which we think explain the differences in how the two video portals are being used and evaluated by team members. First, there are language issues that prevent team members from benefiting by overhearing remote conversations: although English is the common language, Tel Aviv team members speak Hebrew among themselves, whereas half of the Paris group speaks French and the other half speaks English. Second, the room in Paris is quite large, and because there is only one VC unit it cannot be used by several team members from their desks. This reduces the opportunity for spontaneous interactions; people in Tel Aviv often need to schedule an interaction by IMing a colleague, and people in Paris must leave their desks and walk over to the unit in order to use it. Third, this team is relatively new, and team members have not developed the familiarity and trust seen in Team 1. Fourth, this team is larger than Team 1, and there is more of a concern about disturbing those not directly involved in the current question or issue. This is also related to the fact that the work between subteams is more tightly coupled in Team 1 than on Team 2.

Team 3 is the technical support group that runs “Tech Stops,” where Googlers go for help with a variety of computer and technical issues. We observed the three Tech Stops in NY (each has two to four techs), which are connected during open hours via a video portal. The VC mics are typically muted, but the speakers are left on. If someone wants to ask a question of another location they unmute and call out, either to a location or a particular person. The questions are often about whether the other location has some piece of hardware, or questions about a problem the tech cannot solve. Sometimes questions are directed at an individual with special expertise or information. The system is used multiple times a day and is considered very useful. Without it, techs in one location would need to set up a VC with another location or identify an individual to contact.

During this project many Tech Stops changed the way in which they used an always-on connection. Rather than connecting just with the other Tech Stops at their location, they connected to a much larger video portal composed of all Tech Stops in the Americas outside of Mountain View (which itself has about a dozen). Techs at one New York location still call out to one of the other two, even though all the

other Tech Stops can hear. The number of questions to a New York Tech Stop from another location is fairly low, and probably fewer than five per month, but participating in the portal is still considered useful (the number of total interactions per day is of course much higher). When a problem arises that no one in New York has seen before, they might ask whether anyone else has noticed it. Group chat is used much more frequently than the portal, typically 10 times a day or more.

The change from a local video portal to a much larger national one influenced interactions in some interesting ways. It was a serendipitous change because it highlighted issues in video portal usage that we saw in less dramatic fashion in other teams. Simple queries—such as about equipment inventory—continue as before, whereas a dramatic change occurred in seeking help for problem resolution. Suddenly, there was a stigma attached to asking “stupid” questions. Typically, before asking a question to everyone connected to the nationwide video portal, a tech will ask another tech in person. Then he or she will probably use the Party Chat (a group chat similar to IRC). If there still is no resolution, they will then ask the question over the video portal. We attribute this reduction in questions about problems to the larger number of people involved, and the lack of familiarity and trust among the much larger group of participants.

Another counterintuitive difference involves the mix of work-related and social communication. When the video portal involved just the three Tech Stops in New York, almost all interaction over the connection was work related. Because the techs rotated through the three locations and saw each other face-to-face frequently, there was no need to use the portal for social interaction. Now, however, there are some informal nonbusiness interactions that help to maintain remote relationships (techs travel and meet other techs as part of rotations or field tech meetings).

Integrating Remote Team Members into the Core Team

Software Development Team 4 helps other Google groups build APIs and develops the API serving infrastructure. There is a video portal between a primary group in New York (eight people) and two remote individuals, one in Chicago (IL) and one in Chapel Hill (NC). The remote team members are fairly autonomous in their work projects, and there is only direct interaction over the system about once a day. The main advantage is for them to listen in to the informal conversations happening in New York (both use headphones). In fact, the remote individuals often just listen to the audio and do not even have the video turned on. Several times a week they hear something important, and occasionally jump into the conversation. At other times, hearing what is happening in the primary office helps them keep up to date on the range of activities within the group and makes them feel more a part of the team. Despite this connection with the main office in New York, they still make short visits every month or two.

The primary group in New York is located in an open area, and it is not possible to place the camera of their VC unit such that it captures the entire team. They ordered

a cart on wheels to put the VC unit on. This way they could move it around, both for variety and so those more involved in a conversation could see and be seen better.

Facilitating Handoffs or Other Discrete Events

Team 5, the Network Surveillance Team, monitors Google's production network 24 hr a day 365 days a year. There are three teams: Mountain View (CA), Dublin (Ireland), and Sydney (Australia), and they maintain a video portal primarily to coordinate handoffs at the beginning and end of each 8-hour shift. Each team works 10 hr, however, to permit a 1-hr overlap of teams before and after each handoff. The video portal makes communication during these times much easier. Team members report that maintaining a continuous connection is very helpful. Similarly, when coding or design teams hand off work across time zones so it can continue 24 hr a day, maintaining a video portal before and after the handoffs should be useful. Other groups might find video portals useful for periods of days or weeks during event planning, major releases, or other situations when coordination across geographically dispersed teams is required.

Although the Network Surveillance Team interacts over their video portal primarily right before a shift change (the duration typically ranges from 5 to 20 min), they find it enormously valuable. The team handing off summarizes what happened during their shift and discusses any continuing issues with the receiving team. After the handoff is completed, the receiving team may have additional questions and the open connection makes this easy, as the team that just handed off will still be around for 1 hr. The receiving team just unmutes their mic and calls out to catch someone's attention. This is much easier than trying to figure out who is still around and available and calling an individual. If something happens just before the handoff is scheduled, the team handing off may need to focus on the problem and delay the official handoff, and having an open connection makes it easy to communicate what is happening.

Because the video portal is just used at the beginning and end of each team's work day, there is no need to be able to use it from one's desk. During the handoff, anywhere from five to 10 people crowd around in front of the VC unit. "We have a routine," one member wrote us, "where each person at the site finishing their shift makes their comments and we largely don't interrupt or ask questions unless it's critical." In an emergency situation, other groups may contact the Network Surveillance Team by joining their video portal. This may only happen once every few months, but it is a useful feature of maintaining a video portal.

Facilitating Easy Access and Consulting Services

Team 6 is a two-person user-interface design team sitting together in Mountain View (CA) and provides an example of yet another variation of a video portal: There is only one unit, not two or more, constantly connected! This allows others to join whenever they want to ask questions or collaborate in some way, but unlike the other teams, there is no constant connection between two or more locations. The user-interface

team members typically interact with the Team 1 developers anywhere from several times a day to several times a week, as interaction goes up and down in irregular cycles. They have also distributed the name of their portal to almost 150 other people who join occasionally to discuss other projects. The use here is an outlier in the sense that there is no continuous connection with other people, and because the connection is not used within a team but across teams. We have heard that this type of video portal is now used by several other groups for office hours consulting; they set up a VC meeting during a period when they have said they will be available for consulting, and others join at will.

Emergent Communicative Practices

The use of a video portal developed over time to meet the needs of each team, and “emergent communicative practices” evolved. Dourish, Adler, Bellotti, and Henderson (1996) provided an example:

Where Heath and Luff . . . point out the loss of eye contact in video environments and subsequent confusion in conversational regulation, we observe the use of gaze awareness and consequent recreation of effective conversational practice. When the medium changes, the mechanisms change too; but the communicative achievements remain. (p. 51)

Some face-to-face behaviors may not be possible, but other effective behaviors will emerge over time. “Real-world” interaction should not be the baseline by which video-mediated communication is judged, and so the fact that gestures and gaze don’t serve the same conversational roles is not a problem. This is why the added “reality” of telepresence videoconferencing is rarely required. The two pairs of authors of Dourish et al. (1996) had connections between their offices from 2 to 3 years, and they argued that “a set of communicative practices, tailored to the nature of the medium, arise over time as familiarity with the medium increases. These are related to the specific people and work practices involved—a case of co-evolution” (p. 34). We saw examples of coevolution in the teams we studied. Over time, each team developed its own culture and communicative practices with respect to using a video portal.

The six teams varied dramatically across multiple dimensions. In terms of spontaneity, some teams interacted at any time from their desk, whereas others scheduled interaction via IM or e-mail, or interacted only at preset times of the day. Spontaneous interaction generally happened from one’s desk, while when movement was required to get into the camera’s FOV, interactions were often scheduled in some way. Each team also developed its own *modus operandi* with respect to the use of mics and speakers. When both mics and speakers are left on, team members can overhear remote conversations and can just call out to start an interaction. They can also temporarily turn off local speakers to stop following remote conversations. Some teams, however, turned the mics off and left the speakers on. To start an interaction they would first turn on the mic and then speak up to get their colleagues’ attention. In one

case, both mics and speakers were turned off, and those wanting to join the portal would wave to attract attention. In some teams, interaction was directed to an individual, a subteam, or the team as a whole, whereas in others it was more often directed to a location and not an individual. When interaction was directed to an individual, the video was first consulted to determine if the individual was present and appeared to be free. There was generally no need to consult the video when interaction was directed to a location, as someone would generally be there. For some of the larger teams, it was not even deemed appropriate to address one individual, out of respect for disturbing others not directly involved in the conversation. For these teams, the portal was used primarily for meetings and for conversations involving more than two people. The culture of video portal usage varied among teams. For some, interaction was almost exclusively work related, while for others there was a much more prominent social dimension, with chatting, jokes, and other non-work-related conversations.

Team Building

Seeing each other during the day helps to maintain a cohesive team and a sense of shared identity. As one person from Team 1 noted, “It helps when you see the person all the time. You feel as if you’re more of a team.” Video portals work better when used by established teams. Individuals know each other well, and feel comfortable jumping into a conversation they hear among other team members. Video portals can also help in developing and maintaining a team’s shared identity, which is important for achieving optimal team performance. “When individuals see themselves as part of a group, they are more willing to make individual sacrifices, work harder toward collective goals, allocate resources more fairly, and coordinate work more smoothly” (Bos et al., 2010, p. 89; see also Venolia et al., 2010, for how video can help to integrate a single remote team member). Another member from Team 1 described two psychological benefits of maintaining an always-on connection to us in an e-mail:

1. Increased exposure to team members. It’s easier to forget about people, underestimate their contributions, or even think ill of them if you decrease your exposure to them. Inversely, increasing our exposure to team members helps us remember how hard everyone is working and strengthens our team bonds. Direct communication is not necessary for this. A silent, video-only connection provides a constant baseline level of exposure to others.
2. The “Study Hall” effect. When you see others working, you’re more likely to work. Seeing James working hard over VC reminds me that I should be working hard as well. This is a simple but powerful effect.

There is, in fact, substantial research supporting the notion of a study hall effect, although it is more typically referred to as social facilitation; the effects, however, are complex (see Bond & Titus 1983; Zajonc, 1965).

Privacy

In the teams that we studied, privacy was not a serious concern. Because the person sitting next to you can turn his head and see you, why not a remote person? This was a common refrain. When the person watching you is a trusted colleague, then privacy concerns recede even more. When video is accepted, there is no need for abstract awareness displays for determining a colleagues' readiness for communication (Dabbish & Kraut, 2008). One person pointed out that the most serious privacy issue is with microphones and not cameras. If you are in a large shared office or open area, you know who else is there and can hear you, but when you are participating in a video portal you do not know who else could be listening. It can be difficult to determine who could be listening, as it is impossible to know if there are any remote people outside the camera's FOV. People noted that they can mute the mics and turn off the video when they need privacy. Another person noted that privacy problems arose when he was at home, because he had no home office and the camera could see his private living space. For this reason he joins the team's video portal from home only when he needs to, rather than maintaining an always-on connection. If he had a home office this would not be an issue, he reported.

Video Portals: Lessons Learned and Design Implications

Teams That Can Benefit

We learned several lessons from the teams we have studied that may help others decide whether teams in their organizations might benefit from a video portal. Consider these points:

1. The team should benefit from improvements in one of the styles of interaction that video portals can provide: spontaneous communication and collaboration, the integration of remote team members into the core team, the facilitation of handoffs or coordination during event planning, and easy access for consulting services.
2. Team members should have a fairly substantial overlap in their working days.
3. There should be familiarity and trust among team members, built over time through periodic (or at least initial) face-to-face meetings and activities. Ideally, team members should feel comfortable asking each other questions, getting feedback, jumping into a conversation, and so on.
4. For teams that want to improve spontaneous communication, the team needs to be relatively small, with everyone interested to some extent in all aspects of the team's work, whereas for teams that will be using the video portal in other ways, larger teams are possible.

When work is very loosely coupled, or parts can be worked on independently at each location, then there is typically less of a need for a video portal. Also, to the extent that team members are working on other unrelated projects, the usefulness of a portal devoted to one project is reduced.

The size of the team using a video portal is one of the most important characteristics, and will have significant implications for how the portal is used. When the primary purpose is in facilitating communication, the team needs to be relatively small, probably no more than 12 to 15 people across all locations. The critical question is whether people will feel hesitant in using the portal for fear of disturbing team members not directly involved in the interaction. Ideally, team members will be working closely enough such that they will be interested in conversations between other team members that do not directly involve them. In this case, overhearing these conversations can be useful, and people not initially involved may jump in with comments or suggestions. To the extent that team members reduce their portal use so they do not disturb noninvolved team members, the usefulness of the portal is reduced. There is no minimum number of team members per location, as a video portal may be worthwhile even when there is just one individual at a location. When the primary purpose is integrating remote team members into the core team or facilitating handoffs or other discrete events, then much larger teams are possible.

Duration

Video portals do not need to be left on continuously to be effective. Team 5, for example, used their portal primarily during handoffs at the beginning and end of each shift. Other teams may find it effective to maintain a portal during certain hours of the day, or days of the week, depending on the communication needs of the team.

Physical Location and Setup

Although we initially thought that an enclosed office would be needed so as not to disturb neighbors, four of the six teams maintain effective video portals in open areas. Whether an enclosed office is needed depends in large part on how the video portal is used, in particular how much verbal interaction there is over it, but other factors are important as well. In some cases, team members may use a portal only at specific (and infrequent) times, or it may be used primarily by individuals using headphones. In these cases, there are usually no problems in maintaining a video portal in an open area. The characteristics of the available open areas are also important, as is the local culture with respect to how much talking is acceptable. A member of a New York team that uses a video portal in an open area told us, "This is NY and everyone is noisy." Some open areas are fairly well isolated from other teams because they are at the corner of a floor, and this is obviously conducive to maintaining a video portal. Thus, whether an enclosed office is required depends on how the video portal is being used, the type of open office space available, the local culture with respect to talking in open areas, and other factors.

Speakers and Microphones. Audio requirements for a conference room are different from those in an open office environment, and VC units are not typically designed for use in open spaces. Some groups complained about the microphones, and one group used

both a table mic and a handheld microphone, which they passed around to those who wanted to speak. Some experimentation may be required to optimize the placement of speakers and microphones.

Camera Placement. Camera placement is often difficult and problematic. Ideally, it should be possible to see everyone at a location, but this is rarely possible. Cameras are typically attached to the VC units, but in some cases it would be better to have them separate from the units and placed at a higher location that makes it easier for remote colleagues to see more of the local team. In other situations, it may help if the entire VC unit is mounted high up on a wall to improve visibility for the local team. It will be advantageous for some groups to attach a VC unit to a moveable cart, and carts with an adjustable height control will help in some situations. Although it would add expense and complexity to the system, the use of a mobile remote presence system (basically a camera and monitor on a robot that can be remotely piloted) might help in some situations (Rae, Takayama, & Mutlu, 2012).

Using Personal Computers. Individuals may choose to join a video portal using G+ Hangouts from their laptops or desktop PCs. This has the advantage of allowing the individual to remain at his or her desk, but it is often difficult to effectively timeshare between the video portal and one's other work using a single display. In some cases, individuals joining from their PCs may listen to the meeting audio via headphones and ignore the video portion of the meetings. The parameters of using one's own PC versus a dedicated VC device require more investigation.

Using Multiple VC Units. If a video portal is very useful for a team, and a single unit per location does not provide an optimal experience, it may be worth providing two or more VC units at each location. This can provide better audio and video for both local and remote team members, although if there are multiple units those not speaking may need to mute their mics. With multiple cameras, the view for remote team members will be improved, and with multiple monitors local team members will typically be closer to a monitor and thus able to see remote locations better.

4.4. Problems in Remote Collaboration

“Temporal Dispersion”

There are two problems that came up repeatedly. First, there are time-zone problems, which can be insurmountable unless people change their work–sleep schedules. Distance matters, as the Olsons concluded after summarizing the research on remote collaboration. East–west distances matter more than north–south distances because they may require coordination across multiple time zones, constraining meeting times to overlap in the work day or requiring attendance outside of normal hours. As Cummings (2011) wrote, “Spatial dispersion should be treated as a separate dimension than temporal dispersion” (p. 24). For this reason, some Googlers (particularly those in Europe and the Far East) are frequently forced to schedule meetings early in the morning or late at night. Several people mentioned the problem of achieving a good work–life balance given this type of schedule. As improbable as it seems,

researchers are working on technical solutions that can help to some extent in certain circumstances, such as the Time Travel Proxy developed by Tang et al. (2012). Their system, which uses a touch-based tablet, allows a colleague located multiple time zones away to “participate” in daily status update meetings via prerecorded reports and comments and then receive video feedback from those present in the meeting. This does not entirely solve the time-zone problem, but it can help in a few specific situations, such as with daily meetings common within Agile software development.

Design Collaboration

The second problem involves difficulty in design collaboration. This problem came up repeatedly in interviews and in our studies on VC meetings and video portals. People complained that there were no good tools to facilitate designing, drawing, and brainstorming. People told us that screen sharing works well for sharing existing designs, but trying to design collaboratively over VC is a pale imitation of face-to-face interaction. This limitation applies more generally to any activity requiring sketching or planning using a whiteboard. Although most people said they would use a physical whiteboard if all collaborators were together in the same room, few used a whiteboard during VCs due to the difficulty of having it visible to everyone. We confirmed this in our observations of 20 VC meetings, for despite the fact that all the conference rooms had whiteboards, they were never used. When Googlers do use whiteboards during a VC, they reported that it was necessary to zoom the camera onto the whiteboard so that remote participants could read what was written on it. In several cases, people reported taking a picture of the whiteboard at the end of the meeting and e-mailing it to remote participants. Even if all can see the whiteboard clearly, this does not solve the problem of how remote colleagues can simultaneously draw and edit. In describing why travel was important, one person told us, “I got a much better feel for the product after we all sat next to each other and had them draw flowcharts.” This type of interaction was clearly missing in their VC meetings. Another said, “It’s easier to establish a closer professional relationship in person. It’s easier to explain things, and I can use a whiteboard.”

Developers and designers in multiple disciplines rely on sketching, and it is particularly important for many software designers (Cherubini et al., 2007). Yankelovich et al. (2004) conducted a survey with 325 Sun customers and were surprised that the importance of being able to do freehand drawing during a meeting was rated so highly, with only the ability to share web pages or browsers rated higher. Software developers use whiteboards frequently to create various types of diagrams and sketches, primarily to support face-to-face communication (for understanding, designing, and communicating), but existing electronic tools do not provide appropriate support (Cherubini et al., 2007). As Gutwin and Greenberg (2002) also pointed out, it is very difficult for such tools to provide workspace awareness, the “up-to-the minute understanding of another person’s interaction with the shared workspace” (p. 9). Prototype software design tools such as Calico (Mangano & van der Hoek, 2012) support sketching and the exploratory aspects of design, and may go a long way toward solving the design

collaboration problem, especially if such tools are available not just on electronic whiteboards but also ubiquitously from multiple devices. Innovation is also occurring rapidly using tablet PCs and mobile phones, and we expect to see multiple new collaborative tools in the next few years. See, for example, the system for collaborative annotation on iPads by Pearson, Buchanan, and Thimbleby (2012), and how Lucero, Holopainen, and Jokela, (2012), created an application using multiple mobile phones and public displays for creating and sharing comics. Within Google, an internal tool development team is now investigating several potential solutions, including a document camera so that people could draw on paper and easily transmit the image, plus drawing tablets or smartboards integrated into the VC system.

Miscommunication and Lack of Awareness

Communication issues and problems are more likely to occur between remote colleagues because they are less likely to share as much information and to develop as much mutual knowledge compared to those who are colocated. For example, one Googler we interviewed described a situation in which he told local people about a system change in person but sent an e-mail notification to the remote people. They ignored this notification, not realizing how important it was, and then were surprised when the system changed. This is an example of one of the five types of problems that can arise when there is a failure of mutual knowledge, “difficulty communicating and understanding the salience of information” (Cramton, 2001). Jang, Steinfield, and Pfaff (2002) described several different ways in which problems often arise within virtual teams: People do not know what their remote colleagues are doing on a day-to-day basis (lack of awareness of activities), they lack awareness of availability (can we communicate now?), they lack awareness of process (deadlines, task requirements), and they lack perspective awareness (differences in how others are thinking stemming from differences in training, background, or the work context). From our data, regular VCs and use of the software tools described in an earlier section generally prevented any of these problems from becoming serious. With the use of video portals, awareness of remote colleagues reaches a level commensurate with colocated colleagues, and the problems described by Jang et al. (2002) essentially disappear.

The Effects of Isolation

In discussing various ways in which groups could be divided across different locations, one situation was mentioned by several individuals as especially important to avoid. This is the situation in which an individual is the only collaborator at one location, with the rest of the team elsewhere. One person said that he always felt isolated and removed from the group when he had been in this situation. Another said that it is just hard to stay in the loop and requires five times as many e-mails, whereas a third said, “It makes a huge, huge difference if you have another member with you at your location” because you can share tasks and information. The psychological effects

can be significant: Perceived respect is lower in isolated individuals, and they tend to identify less with the organization (Bartel, Wrzesniewski, & Wiesenfeld, 2012). In addition, individuals working remotely have to overcome a number of other challenges, such as creating visibility for evaluation and satisfying the need for social interaction (Koehne, Shih, & Olson, 2012).

The use of frequent video contact can help to integrate a single person into the main group. This was one of the main findings of Venolia et al. (2010), who developed a system that allowed a remote individual to maintain a video presence within the main group. It can also help with some of the problems discussed by Koehne et al. (2012), such as providing visibility to remote colleagues. Simple behavioral techniques are also useful. During meetings, for example, it helps if the leader ensures that remote participants are engaged and solicits their input. The leader should make sure everyone has a chance to participate and no one is marginalized.

5. DISCUSSION

There is a general consensus among the Googlers we talked to that remote collaboration works very well, although it could still be improved. The key factor is the effective use of visual real-time communication via video conferencing, which is ubiquitous throughout Google and has completely replaced audio conference calls for internal use. Ubiquity and ease of use are key because they reduce the “behavioral overhead” of using the system. Video conferencing units can be found in almost every conference room, which are available in all work areas, and Googlers can also join VCs from their laptops. Having a personal VC unit on your desk or in a shared office reduces the behavioral overhead even further. Joining a VC meeting typically involves a single click or touch, and the integration of calendars, room reservations, and VCs make setting up meetings easy. To our knowledge, Google is the only large company that currently supports ubiquitous video conferencing. Google Docs and other technical tools make sharing information and keeping in touch easy, and there is a culture of trust and sharing within Google. In addition, remote collaborators within Google typically have regular face-to-face meetings, which are critical in facilitating subsequent remote interactions (see the review of the literature in Powell et al., 2004). Face-to-face meetings can also prevent the types of information problems described by Cramton (2001), such as the difficulty in communicating and understanding the salience of information and the failure to provide and retain contextual information (see Table 3, p. 360).

G. M. Olson and Olson (2000) reviewed a decade of field and laboratory studies on remote collaboration, and concluded by focusing on the central challenges that must be met: “Groups with high common ground and loosely coupled work, with readiness both for collaboration and collaboration technology, have a chance at succeeding with remote work” (p. 139). As we have shown, these basic challenges have been met throughout Google. Common ground is established via frequent video conferencing and face-to-face meetings, and there is an implicit understanding among employees that tightly coupled work is better assigned to colocated teams. Cooperation

is a central part of the culture, and given the nature of Google's work and its hiring practices, the technical competence of employees is very high, as is the technical infrastructure.

5.1. VC Meetings

Meetings are a "necessary evil" in any organization, and there are special challenges in having meetings with remote colleagues. In observing VC meetings, we identified a number of problems and challenges, some with easy technical solutions and some that are seemingly intractable. Dealing with lighting and camera FOV problems require good planning when designing conference rooms, but there are no major challenges here. Overcoming issues concerned with the difficulty of controlling the VC in large rooms is also not technically challenging but requires new designs and applications. When meetings run late, they often create a cascading set of problems for subsequent meetings, and here both technology and a change in the organization's culture are required. Alerts and warnings can be built into the system to let people know that their time is about to end, whether the room is reserved in the next time slot, and to provide options to extend the reservation or move to another nearby room if necessary. The alerts must be acted upon, however, and the rules followed, and this involves changes to the local culture.

There are no easy technical solutions, however, to what we call primary room dominance, because it results from basic aspects of attention and social interaction. It is inevitable that meeting participants will attend more to an active discussion within their own room and easily forget about a silent remote colleague. This can occur even when there is a close-up of a remote colleague on a large monitor. Similarly, increasing the salience of remote colleagues by representing them via some type of dedicated physical device is unlikely to solve this problem (but see Venolia et al., 2010). Remote colleagues may then be more noticeable, but it will be just as hard for them to participate fully in fast-moving conversations, given the difficulty in effectively using all the subtle cues required for rapid turn-taking.

Meetings vary widely in size, interactional style, and goals, and problems arise more in some types of VC meetings than in others. In large meetings, for example, with many participants and more than a dozen locations, it may be difficult to identify speakers or locations, but both behavioral and technical solutions are available. Simply announcing one's name and location can help, while automatically zooming in on a speaker and supplying name and location information after facial recognition is a technical solution. No amount of technology can help with a poorly run meeting, and there are many resources and guides for how to run meetings, which we do not discuss here. We observed many of the same problems with distributed meetings reported by Yankelovich and her colleagues (Yankelovich et al., 2007; Yankelovich et al., 2004), although their research was focused on audio conferencing. Although there are many similarities between distributed audio and video meetings, additional research is needed on the particular problems that arise when VC becomes ubiquitous throughout an organization.

If remote collaboration becomes more effective with new tools, productivity and the speed of product development should improve. As one example, collaborative design, flowcharting, and brainstorming would probably become more common over VC if a good shared drawing tool were available. There are many current candidates, but it is exceedingly difficult to replicate the advantages of a whiteboard in an electronic device that is used simultaneously in multiple locations (Cherubini et al., 2007). Improvements in video quality and the reduction of system delays will also certainly help, as it will be easier to see facial expressions, and turn-taking should improve.

5.2. Video Portals

Not only does real-time visual communication now form the backbone of remote collaboration within Google, but what is especially striking is the spontaneous emergence of video portals. These can provide presence and status information on par with being colocated. Over the last several years, multiple teams within Google have set up and maintained video portals, with their use evolving to meet each team's needs. We identified four different styles of interaction: facilitating spontaneous communication, integrating remote team members into the core team, facilitating handoffs or other discrete events, and facilitating easy access and consulting services. As in the Dourish et al. (1996) study, "emergent communicative practices" evolved in each team to fit the group's needs and situations. What is important is creating effective communicative practices and not necessarily trying to recreate face-to-face interaction. It is for this reason that telepresence VC systems are rarely required; you do not need to feel as if a remote colleague is actually in the same room with you in order to communicate effectively and also connect on an emotional level. This could account for a lack of demand for telepresence features.

Video portals are a natural extension of the research prototype systems built 20 years ago, and it is interesting that the video portals within Google are now working effectively in a variety of situations. We think the change is due primarily to three factors:

1. Improvements in technology, increases in available bandwidth, and decreases in cost have led to vastly superior multilocation video systems with large displays. Contrast this with the RAVE system developed and used in EuroPARC, which could only make a local two-office video connection: "for technical and financial reasons, we cannot make connections to our overseas colleagues, nor can we connect to more than one node at a time" (Gaver et al., 1992, p. 33).
2. Video portals are used primarily within relatively small teams at Google to improve communication and collaboration on primary work tasks, rather than to facilitate awareness, informal communication, and serendipitous communication among a much larger group of employees.

3. The change from private, enclosed offices in most of the studies from the 1990s to an open work environment today eliminates most of the privacy issues discussed in great detail in the 1990's research.

Many of the early systems were somewhat effective in providing awareness of remote colleagues but were failures in promoting informal communication because they were so inferior to face-to-face interaction. In addition, they required some effort, and in some cases a degree of interruption similar to placing a phone call. For example, in Montage (Tang, Isaacs, & Rua, 1994) a person could “glance” into another’s office, which was announced by a sound to the recipient—a potentially distracting event. In contrast, when a VC connection is left on, awareness of colleagues comes naturally (without interrupting them) and facilitates interaction among team members.

In an update to their 2000 paper, J. S. Olson and Olson (2006) analyzed more than 200 organizations that work remotely and added a second set of challenges for remote collaboration (verbatim, p. 102):

- Alignment of incentives and goals
- Trust is more difficult to establish
- Awareness of colleagues and their context
- No motivational sense of presence of others
- The need for explicit management

We have shown how the use of video portals can help to overcome these additional challenges, except for the need for explicit management. The need for explicit management is much less of an issue when the collaboration takes place within a single organization rather than across multiple organizations. In much scientific collaboration, however, management issues need to be explicitly addressed (J. S. Olson et al., 2008).

An important use of video portals relied solely on the audio portion in two situations. First, overhearing remote conversations that are relevant to one’s work and jumping into the conversation when there is something to add. Second, the integration of remote team members into the core team by establishing an almost constant connection and listening to what is happening at the primary location. Video portals work best when there is familiarity and trust among team members, but using the portal can also help to maintain the connection and appreciation of remote team members. This helps to overcome two of the preceding challenges: awareness of colleagues and their context, and the lack of a motivating force generated by the presence of others. Video portals provide presence and status information, and we heard explicitly about how team members are motivated by seeing their colleagues hard at work. Video portals also help to maintain and improve the common ground among team members, and “the more common ground people can establish, the easier the communication, the greater the productivity” (G. M. Olson & Olson, 2000, p. 161). All of

these aspects of video portal use help to reduce group conflict, which arises more frequently in distributed groups (Hinds & Bailey, 2003). One of our survey respondents whose team used a video portal wrote, “It makes working with my team remotely so much easier. I feel like we have a better working relationship because we can see and hear each other daily even when we don’t have a planned meeting.” This is exactly what Venolia et al. (2010) reported when they created an “embodied social proxy.” The frequent, and often spontaneous, interaction this afforded facilitated the social integration of the remote individual into the main team⁶.

The size of the team, the nature of the work, and the physical location of the team and the VC units all determine how the video portal will be used. A relatively small team working closely together will use the video portal extensively. Use will drop off as the team expands, and it becomes possible to divide the work into discrete and independent components. The difficulty of completing tightly coupled work with remote colleagues is something that all our respondents who had experience working with remote colleagues knew well. Because video portals drastically reduce the overhead associated with communication, and allow frequent exchanges and easy screen sharing, more tightly coupled work is now possible.

In the research on prototype video systems from 20 years ago, privacy was a major issue with interoffice video systems, in large part because the researchers involved typically had private offices. There was recognition of the “fundamental tradeoff between providing awareness information and preserving privacy” (Hudson & Smith, 1996, p. 249). As open office environments have become the norm, expectations with respect to privacy have changed, and having video in addition to visible coworkers is less of a problem. When individuals also have control over the video connection, believe in its efficacy, and have developed familiarity and trust with those on the other end, then acceptance is almost universal.

Cummings and Haas (2012) noted that it is becoming increasingly common for major companies to set up geographically dispersed teams to work on knowledge-intensive tasks and that team members often allocate their time among multiple projects. In their study of 285 teams, they found that the advantages on team performance of allocating more time on the primary team was greater for dispersed teams, “because they are less likely to suffer from the cognitive, motivational, and behavioral costs of attention diffusion” (p. 321). In the geographically dispersed teams using video portals that we studied, almost all individual effort was focused on the primary team. However, when several people on a team are all working on multiple projects, then having a video portal as part of the work environment can be difficult. This is especially true for teams that use it to facilitate spontaneous communication, because the video portal then becomes a pervasive aspect of the environment, and may become distracting when an individual needs to switch and work on another project. Given that 65% to 90% of knowledge workers belong to more than one team (Wageman et al., 2012), this may limit widespread deployment of video portals, unless separate work areas are set up for each team.

6. Video portals are now also used to maintain intimate and family relationships (Judge, Neustaedter, Harrison, & Blose, 2011; Neustaedter & Greenberg, 2012).

Why are video portals springing up spontaneously throughout Google and why are they so effective? We discussed earlier the importance of knowing presence and status information about colleagues, and the constant video connection of a portal certainly provides this. Consider also the description of shared work provided by Gaver et al. (1992): “Shared work involves fluid transitions among general awareness, focused collaboration, serendipitous communication, and division of labour.” It is much easier to make these fluid transitions within a collocated team, and it is instructive to consider the studies of “maximally co-located” teams reported by G. M. Olson and Olson (2000) in which members are all located in a single large room (also called a war room; this is sometimes called “radical collocation”). In this situation there was a

fluidity of participation [that] was rated as very important to the timely completion of their work. They could move from one subgroup to another, or to a meeting of the whole, by merely overhearing others’ conversations, seeing what someone was working on, and being aware of how long they had worked on it with or without progress. (p. 146)

In a field study, Teasley et al. (2002) confirmed the advantages of team collocation with respect to both higher productivity and shorter schedules. Although video portals do not fully re-create the colocated experience, they go a long way toward it, and we found that maintaining a video portal can facilitate the fluid transitions between general awareness, focused collaboration, and serendipitous communication. Colocated teams in a war room may spontaneously form subgroups in a corner of the room, and this also happens with video portals when two or more individuals leave the portal and set up a new VC, then return to the portal when they are finished.

Video portals also facilitate the maintenance of mutual knowledge among coworkers. “Mutual knowledge is knowledge that senders and receivers of communication share in common and know they share in common. Mutual knowledge helps people frame their messages in ways that are likely to be understood without confusion” (Cramton, 2002, p. 356). The combination of maintaining an always-on video connection plus regular travel for face-to-face meetings and working sessions results in the establishment of a high degree of mutual knowledge, which is essential for effective remote collaboration. As Cramton explained, without mutual knowledge dispersed partners are likely to make dispositional rather than situational attributions about remote partners when disappointed or when expectations are not met. That is, they will conclude that problems result from the personal failings of a remote partner (dispositional attribution) rather than from the nature of the situation (situational attribution).

Video Portals: As Good as Colocation?

Although several of the teams consider their video portals to be extremely valuable, no one considers them as good as being colocated. As one person noted, it is still easier to interact in person than over VC. The overhead is not significant, but it is

still there, such as having to check to see if the system is muted and the other person is available for a conversation. Everything just takes a little more effort when you are remote. A team located together in a project room can spontaneously break up into subteams spatially separated throughout the room. As previously described, there is an analogue with video portals when individuals leave the portal and set up a separate VC. They are then totally separate, however, and are not aware of what is happening in the video portal until they return to it. The “behavioral cost of communication” is much lower with a video portal than when using other forms of computer-mediated communication but not as low as being colocated. Based on our observations, we agree that it is more efficient and natural to be in the same room, but for many types of meetings the impairments from having geographically distributed participants are minor. The most serious problem with video portals is the lack of a shared drawing tool that approximates the ease of use and efficacy of a physical whiteboard.

There are also a variety of sound quality issues. Some noises may be enhanced, and at times there may be issues related to the loss of directional cues over VC or changes in the mechanisms of selective attention. For example, tapping on a table can be more disturbing over VC, and multiple conversations are a problem, especially when there are conversations happening both locally in the room and across the video portal. The overall auditory quality is typically good, or even excellent, but when it is only fair, and occasionally poor, this certainly contributes to a less than optimal experience.

G. M. Olson and Olson (2000) provided a figure with the key characteristics of colocated synchronous interaction, which we have adapted to create [Figure 15](#) (we added the Video Portal column plus the last characteristic, Physical artifacts). Video portals provide six of the 10 characteristics at equal or almost equal levels to collocation, three at partial levels, and only one is not supported at all (shared local context). The lack of a shared local context is mitigated, however, by regular travel, which provides information about the local context of each team member.

5.3. Limitations and Future Work

We have used multiple sources of information to present a fairly comprehensive picture of remote collaboration within Google and why it is often so successful. We think our findings will generalize to other companies, but more research is needed. The employees at Google tend to be younger and more technically sophisticated than at most other companies, although we did hear from a number of people in their 40s, 50s, and 60s. It is also easy for Googlers to travel and visit other remote team members and to order extra equipment such as dedicated VC devices. We realize that travel and purchasing extra hardware are much harder at many other companies. There is also a strong culture of sharing and cooperation. We do not yet know what the relative importance is to remote collaboration of all these characteristics of Google, and how easily other companies will be able to replicate some of our findings.

We are convinced that the ubiquity and ease of use of video conferencing is key to the success of remote collaboration within Google, and we have downplayed the advantages of the highly realistic telepresence systems that are now available. It would

FIGURE 15. Key Characteristics of Collocated synchronous Interactions. © Taylor & Francis. Adapted with permission of Taylor & Francis. Permission to reuse must be obtained from the rightsholder.

Characteristic	Description/Implications	Provided by Video Portals
Rapid feedback	As interactions flow, feedback is as rapid as it can be; quick corrections possible when misunderstandings	Equal to collocated synchronous interactions
Multiple channels	Information among participants flows in many channels—voice, facial expressions, gesture, body posture, and so on; many ways to convey a subtle or complex message	Almost equal; slight loss of gestural and vocal expressiveness
Personal information	The identity of contributors to conversation is usually known; characteristics of source can be taken into account	Equal
Nuanced information	The kind of information that flows is often analog or continuous, with many subtle dimensions (e.g., gestures; very small differences in meaning can be conveyed)	Almost equal
Shared local context	Participants have a similar situation (time of day, local events); allows for easy socializing as well as mutual understanding	No shared local context
Informal “hall” time before and after	Impromptu interactions take place among subsets of participants on arrival and departure; opportunistic information exchanges take place, and social bonding occurs	Almost equal; social interaction is common upon arrival and departure
Coreference	Ease of establishing joint reference to objects; gaze and gesture can easily identify the referent of deictic terms	Sometimes possible; dependent in part upon camera setup
Individual control	Each participant can freely choose what to attend to and change the focus of attention easily; flexible monitoring of how participants are reacting to what is going on	Almost equal; however, selective attention to one of multiple remote conversations can be difficult
Implicit cues	A variety of cues as to what is going on are available in the periphery; human attention provides access to important contextual information	Partial; auditory is good, but only partial field-of-view is available
Spatiality of reference	People and work objects are located in space; both people and ideas can be referred to spatially	Partial
Physical artifacts	Multiple people can easily (and even simultaneously) use physical artifacts, such as a whiteboard; design collaboration, flowcharting, and sharing designs are easy and natural	Many tools exist, but none approach the ease of use and effectiveness of a physical whiteboard.

be interesting to compare collaboration over telepresence systems with the lower fidelity (and much lower cost) system used by Google. Given their expense and the need for specially designed rooms, telepresence systems are unlikely to be available whenever needed by any employee, so the question is one of trade-offs: What is better, a few telepresence systems, or ubiquitous systems like the one used by Google?

When ubiquity is the goal, VC meetings will take place in all types of rooms, and we have outlined a number of problems and some potential solutions. There are still many unanswered questions, such as how to provide a shared drawing tool, how best to use multiple monitors, and how much control to give to meeting attendees to customize what is presented on each display. When individuals are separated from the main team, how important is it to provide a physical embodiment of the remote worker in the main team's conference room or work area? Our opinion is that it is the video connection, and not the physical representation of the remote person, that provides the positive effects reported by Venolia et al. (2010), but this is clearly an area for future research. And is it worth the expense to provide remote workers with a mobile remote presence system in the main team location that they can move around themselves?

Perhaps one of our most interesting finding was the spontaneous emergence of video portals throughout Google. We interviewed team members and joined several of these continuous video connections to observe the interactions, but we did not systematically record, count, and analyze the frequency or type of interactions that occurred. Our observations and conclusions need to be validated by more rigorous investigations. For example, we really do not know how well our classification of video portals will apply when a larger number is studied across different types of organizations. There was also a potential conflict in that one of the teams we studied was involved in the development of the Google VC system. Because they were developing VC, however, there were many VC devices per location, and this allowed us to observe how the number of devices influenced collaboration. Again, this is an area for more rigorous, or experimental, investigation.

We studied collaboration within a single organization, rather than across organizations, and this is yet another limitation. J. S. Olson et al. (2008) emphasized the importance of managing remote collaboration in scientific work that involves the participation of multiple scientists from many different organizations, and they listed a large number of problems that can occur. For example, there can be legal and intellectual property issues in scientific collaboration (e.g., consider the issues in biomedical research when millions of dollars are at stake and there are collaborators from both industry and academia). There can also be resistance to dedicated project managers (because their salaries could be used to hire more scientists), and sometimes problems arise because a scientist may become overcommitted when another grant is approved. An explicit communication plan may also be required so that expectations across organizations are similar. Most of these problems essentially disappear when the collaborators are under one management structure within a single company. When collaboration crosses organizational boundaries, however, management problems are more likely to arise.

6. CONCLUSION

Despite the improvements in technology and available tools, distance still matters. However, under the right circumstances involving easy-to-use video conferencing and video portals, it can now matter a lot less than it used to. Ubiquitous video conferencing connects people and creates common ground in a way that audio conferencing cannot. In fact, when it comes to internal communication within the company, video conferencing has completely replaced audio conferencing. Technical tools make keeping in contact and sharing information much easier than in the past. The advent of video portals has opened a new promising chapter in remote collaboration, allowing tightly coupled remote work a chance to succeed for the first time. Although there is no effective solution to the time differences involved in long distance East–West collaboration, the other challenges are slowly decreasing, and the advantages of having a distributed workforce can now be more fully realized.

NOTES

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