Beyond Talking Heads: Multimedia Artifact Creation, Use, and Sharing in Distributed Meetings

Jennifer Marlow, Scott Carter
FX Palo Alto Laboratory, Inc.
{marlow, carter}@fxpal.com

Nathan Good
Good Research
nathan@goodresearch.com

Jung-Wei Chen
UC Berkeley & Good Research
jennifer@goodresearch.com

ABSTRACT
Distributed meetings can be messy, particularly when the task requires collaboration around multimedia artifacts. Teams must not only share a variety of materials related to the work in real time, but also need to refer back to information after a meeting ends. While video tools make it relatively easy to have conversations at a distance, they are less adept at sharing and archiving multimedia content. We conducted a survey of and interviews with members of distributed teams to investigate how they create, use, and share multimedia content before, during, and after distributed meetings. Our findings shed light on decisions made and rationales used in selecting technologies to prepare for, conduct, and archive the results of a video-mediated distributed meeting. The results suggest a need for flexible interfaces for information sharing in multiple meeting contexts so content can be both easily referred to in the moment and also found again later.

Author Keywords
Remote collaboration; Communication tools; Video conferencing; Survey; Interview

ACM Classification Keywords
H.5.2 [Information Interfaces and Presentation]: User Interfaces - Interaction styles.

General Terms
Human Factors; Design; Measurement.

INTRODUCTION
Collaboration technologies such as video conferencing are increasingly essential tools for modern remote workers. As new communication tools have been increasingly adopted in the workplace, fewer completely face-to-face teams exist in modern organizations [8]. A 2014 survey of large companies found that over half (54%) of meetings included remote participants attending via audio, video and/or web conferencing [24]. As workforces evolve, video streaming and communication tools are struggling to meet the increasing demands of modern distributed teams. It is thus important to understand how this rich and evolving medium can be better harnessed to support creation and collaboration from afar.

Current studies of video collaboration and usage primarily focus on "talking heads" or person-to-person communication (e.g., [4]). However, much remote collaboration also involves people generating and sharing digital content such as documents and other types of media files [14]. Sharing content with both local and remote participants was a prevalent behavior mentioned by 60% of respondents to a recent survey about team meetings [24].

While video conferencing tools that support conversations between people are becoming well established, there is limited support for integrating information and media sharing within these tools [6]. As a result, sharing content during video-mediated distributed meetings remains difficult [18]. People have a variety of tools from which to choose, but technical and social challenges with sharing information often dictate which one(s) they must use to achieve their goals.

Our goal in this work is to understand why this is so. Specifically, we focus on the following questions:

How, when, and why do distributed teams integrate content sharing into video-mediated meetings?

What challenges exist in sharing meeting content across locations?

To answer these questions, we studied a diverse set of remote collaborations of varying sizes and in different industries, focusing on those which involved creating some sort of digital or physical artifact together. We conducted a multi-method study around the process of sharing content in various types of distributed meetings in small to medium sized companies.

Our work expands upon prior studies of distributed team communication by considering multimedia flow over multiple stages of distributed meetings among teams involved in creating a digital or physical artifact. In contrast to prior CSCW research on use of one type of communication system in a single organization, we

CSCW '16, February 27-March 02, 2016, San Francisco, CA, USA

ACM 978-1-4503-3592-8/16/02…$15.00
DOI: http://dx.doi.org/10.1145/2818048.2819958

examine small companies that assemblage a variety of tools and applications to serve their information sharing needs on an ad-hoc basis. We focus particularly on the factors that influence tool choice for sharing multimedia content in a synchronous distributed meeting, the work-arounds that are established to circumvent the limitations of these tools, and the implications for re-finding this information afterwards. Additionally, this paper identifies a set of challenges that arise when sharing and accessing multimedia content across different meeting types.

Our findings suggest that current tools and approaches are inadequate for meeting scenarios that require participants to not only converse but also to share and co-reference different types of multimedia content across distance. Participants use a mixed set of tools to support different needs within different types of meetings, as no single video conferencing tool includes sufficient functionality to address all their demands. While this approach may currently work "well enough" for many teams, comments made by study participants suggest there are still gaps in effective support for real-time media sharing, archiving and access. We suggest opportunities for the design of video conferencing tools that better integrate real-time communication with presentation materials from a variety of sources, that can be reconfigured based on meeting purposes and goals, and that allow individuals or groups to easily access and return to content after a synchronous conversation has ended.

RELATED WORK

Current state of remote collaboration

Collaboration technologies have been around for many years and are in widespread use [1]. A large body of related literature has studied how distributed teams use such tools to communicate, build trust, and so on. However, little work has focused particularly on the details of teams' needs for and practices of artifact creation using these tools, including the sharing of multimedia material in real time using synchronous tools such as video conferencing.

Recent surveys of business professionals in large corporations have provided some overall insight into the prevalence of collaboration tools [e.g., 19]. However, there is still a lack of detailed information about how and why people use tools across a variety of professions, work contexts, and tasks.

Related work examining the role of video conferencing tools at a large tech company looked at the role that video technology such as "always-on" portals and dedicated conference rooms played in enabling distance collaboration. This work suggests that large corporations with the resources to support real-time communication can reduce the behavioral costs of communication and for the first time allow tightly coupled remote work to succeed [12]. However, it did not analyze meeting-specific practices and behaviors and the tools required to assist and support creation in those contexts; rather, the study focused on high-level sharing and awareness needs.

As a result, little is known about how teams in smaller organizations can use video and other tools to assist them in creation and to facilitate communication and sharing of multimedia information. Similarly, little is known about how video does or does not help distributed teams who are involved in creating digital or physical artifacts perform different types of tasks. We were interested in exploring the choices people in less resource-rich settings make in terms of selecting technology for remote collaboration both to communicate and share content, and in examining factors influencing these choices.

Sharing media in remote collaboration

Synchronous sharing

Prior work has looked at how people share content in the context of synchronous communications in both personal and professionally-oriented contexts. On the personal side, work by Forghani et al. [6] investigated how and why people currently share media such as pictures or web pages in a call among friends/family, and developed a tool to enable co-referencing of common artifacts of interest such as personal photos or Facebook posts.

In the professional arena, distributed design teams have provided fertile ground for study of how people share and create design artifacts across distance. Prior work has also focused on creating specialized technological setups to support this process for collocated groups, such as whiteboards and shared display spaces [7, 11, 16]. However, design teams present just one context for collaboration, which may not generalize to other areas.

Asynchronous sharing

Other efforts have addressed the potential need to collaborate asynchronously by allowing people to review the results of past conversations. Prior work has looked at the methods by which remote teams choose to communicate and highlight the importance of tools that provide affordances such as persistence and reviewability [20]. For example, chat records such as those found in Skype groups may be more lightweight than email when it comes to traversing and finding relevant past information — serving, in a way, as "hallway conversations with a history" [9] that can be useful both during a meeting and for later reference.

Again in the design context, the TeleBoard system was developed to record and store the results of design discussions (and artifacts) for later perusal [7]. The Procid tool was developed to help summarize design discussions and help distributed groups reach consensus by visualizing information quickly and easily [27].

Additionally, new integrated communication tools like Slack and Basecamp provide teams with an activity

stream and historical record of both interpersonal communications and file changes/sharing. However, it is unclear to what extent these are currently utilized in remote teams.

Continuing challenges for remote collaboration

Although the progress of video conferencing tools has made distributed, real-time communication easier, both technical and social barriers to sharing information remain. Some of these were highlighted in work from over a decade ago [26] but persist today, including audio problems (poor audio quality, people not being heard, too much extraneous noise), behavior problems (speakers not checking each other for understanding, inadequate advance planning), and technical problems (difficult to identify who was speaking, not everyone could view visual materials, necessary documents not available during meeting).

Apart from these issues, video conferencing seems to work best for one single conversation among a group of people. Supporting more complex interactions like sketching remains difficult [12], and communication in videoconference meetings between distributed actors is curbed by the lack of technology support for the sort of sidebar conversations that are often useful [5].

Finally, resources may be limited in smaller organizations, meaning that teams could be more likely to use free or cheap technological solutions rather than the most advanced state-of-the-art tools. Since working across sites often presents compatibility challenges [17], tool choices have implications for how easily sharing can take place. The overhead incurred by sharing different types of information also varies with the work at hand, location of participants, and other factors.

METHOD

To obtain a more complete picture of media usage in meetings, it is critical to understand characteristics of the meetings themselves, in particular the type and purpose of the meeting as well as the distribution of participants. It is equally important to understand any institutional or other factors that influence participants' tool choices. We focused on small to medium sized companies and startups because workers in these settings are less likely to have access to heavyweight video conferencing technology.

To assess the context in which users choose to share and use media, we utilized a multi-method approach including surveys, interviews, and observations.

Survey

We disseminated a survey to individuals working for startups and small to medium sized companies to get a broad sample of remote collaboration experiences. We began with known contacts and used snowball sampling, enlisting our contacts to both refer others and post the survey to external mailing lists to expand our reach and range. We recruited people across a variety of industries and job roles.

The survey was designed to obtain background information about the types, structure, and general purpose of respondents' distributed meetings. To understand the most common configurations of meeting participants, we asked questions about what types of meetings respondents had with remote others, how often these occurred, and where participants were located. We also asked about the frequency and prevalence of sharing different types of information and files, and how the information was shared (using what types of technology). Finally, we asked participants to describe aspects they liked and disliked about the tools they used.

Interviews

We also asked survey respondents if they would participate in a follow-up interview. Of those who responded affirmatively, we contacted and followed up with 15 participants. The interview sample reflected some of the diversity present in our survey sample: Participants worked in software development (n=5), UX design and research (n=5), and film/entertainment related jobs (n=5).

Interviews lasted between 45 minutes and one hour. The majority of them (13 out of 15) were carried out over video conferencing tools such as Skype or Google Hangouts, and the other two were conducted in person. Participants received a $25 gift card as compensation. The interviews followed a semi-structured format in which we followed up in more detail about responses they gave to our survey. We explored issues pertaining to meeting structure, layout, etc. by asking interviewees to relate examples from their most recent meetings with remote team members. Two members of the research team were involved in each interview, with one leading the interview and another taking notes.

All interviews were transcribed and then coded by two members of the research team. We followed an open coding scheme, using qualitative data analysis software (Atlas.ti) to first cluster comments related to tool use and sharing information around broad themes, and then iterated around these themes to develop a set of sub-themes and cross-cutting trends.

Meeting observations

Finally, we recruited three teams who agreed to let us observe a remote meeting in action. These meetings each lasted around one hour. In one case, we observed from the same room as one of the meeting members, and in two others where this was not possible, we joined in the videoconference from a separate location. Two observers watched the work occurring and took detailed notes about who participated, what was shared and how, and any difficulties encountered in this process.

SURVEY RESULTS

Who is participating: Location and configuration of meetings

We received 53 responses to the survey. Respondents were primarily distributed throughout the United States (90%) and Europe (10%). 93% of respondents reported working with at least one distributed team in the context of their jobs. Most of these teams were small to medium sized, made up of less than 15 people [3]. Around 46% of respondents were in different technical fields; other industries represented included finance (16%), manufacturing (11%), as well as healthcare, scientific research, and entertainment.

For each remote group they worked with, participants provided the locations of group members and the number of people in each location, providing both the distribution and the configuration of groups. There were a total of 91 team meetings provided (given that most survey respondents worked on multiple remote teams). We coded the group makeups using the configurations mentioned by [13]: *Hub and spoke* (e.g., 3:1), *Hub to hub* (e.g., 2:2) and *Fully distributed* (e.g., 1:1:1:1).

Somewhat surprisingly, a fourth configuration not included in this typology emerged as the most frequent configuration. In this arrangement, there are three or more locations, with unequal numbers of participants in each location (for example, 3:2:1). We refer to this configuration here as a "*mixed*" setup.

Overall, as seen in Table 1, the prevalence of the different kinds of team member distributions were:

Mixed (3+ locations, unequal numbers of participants in each location)	41%
Hub to hub (2 locations, roughly equal numbers in each)	29%
Hub and spoke (1 location with a group, 1 location with a single individual)	23%
Fully distributed (single individuals in each location)	7%

Table 1. Distributions of meeting participant locations

Interestingly, few of the meetings described were "fully distributed". This meant that in the majority of the cases, at least one of the locations had multiple team members interacting with others (also either collocated or distributed). The emergence of the "mixed" category highlights the fact that a large number of meetings were distributed across more than two locations (in fact, the mean number of locations per meeting among all survey responses was 2.62).

A majority (74%) of respondents were involved with multiple distributed teams (53% worked on three or more distributed projects). This predominance of multiple team membership corresponds with other recent findings that 65-90% of knowledge workers are concurrently on more than one work team [23].

What is the purpose of remote meetings?

The survey asked participants an open-ended question about the purpose(s) of their remote meetings. We coded responses based on the typology and descriptions used in [2]: Conversation (short, ad-hoc and informal interaction that happens multiple times a day between two people or among a small group); Status update; Presentations; and Training. Based on the free responses provided, we also added another category of "Information sharing" which is similar to 'conversation' but might be more formal and scheduled than a conversation. The breakdown of types of communications (in Table 2) was:

Status update	33%
Information sharing	18%
Brainstorming	13%
Conversation	12%
Presentations	9%
Other (social, demo, planning, training)	14%

Table 2. Meeting purposes from survey respondents

The purpose of a meeting influences the type of information shared and the importance of saving or referring to it later. The meeting types listed above differ in terms of the degree to which they involve one or multiple people sharing artifacts during a meeting, and their need to access information again later. For example, the goal of a brainstorming meeting or conversation may be to reach a decision (that does not need to be saved or recorded). A status update or information sharing meeting may involve multiple people exchanging information or files that some individuals need to keep and refer back to later, and a presentation meeting may center on one person sharing information that others may wish to revisit afterwards. In turn, users select tools best suited to these needs.

Tools used to enable remote communication

To assess current practices, we asked participants to list the tools they use to communicate remotely. Responses included multiple tools and programs (mean number of tools = 3.26). We grouped responses into broad categories based on the type of tool being used (Table 3).

While free video conferencing tools predominated, these were also either supplemented with or replaced by paid videoconferencing tools, as well as less rich modalities such as IM or phone calls. Some participants reported using multiple free and paid video conferencing tools.

Free/consumer video conferencing (Skype, Google Hangouts, etc.)	64%
Paid/professional video conferencing (GoToMeeting, WebEx, etc.)	34%
Instant messaging	25%
Phone	23%

Table 3. Tools used to communicate remotely

What is being shared? Frequency and type of media sharing

Finally, we asked participants to rank the frequency with which they shared various types of information in different formats with remote team members. Answers were on a 7-point Likert scale ranging from 1=never and 7=every day.

The median ratings of media types being shared appear in Table 4, in order from most frequently shared to least frequently shared. These responses suggest that as the complexity, needed interactivity/explanation or "richness" of the media increases, the frequency with which it is shared decreases. Videos, which can be time consuming to view or transfer due to their relatively large file sizes, were shared least frequently, while links to webpages and text (e.g., documents), which are lightweight to share and view, were shared more often.

Websites (URLs)	6
Text	4
Images	4
Spreadsheets	4
Slides	2
Videos	1.5

Table 4. Median reported frequency of sharing media types

One format that many synchronous meeting tools support is the ability to screen share. Screen sharing was a frequently mentioned means of using video to discuss and create artifacts in a variety of ways, and was something that 80% of respondents did at least occasionally. The main uses of screen sharing were to explain something, co-reference something, give a demo, and interact with material like a prototype.

Summary of survey findings

From the survey, we gained an overall sense of the breadth and diversity of distributed meetings occurring within our sample of professionals in small to medium sized teams. It is clear that a variety of factors, including the nature of work, distribution of participants, and types of meetings all impact what information is shared, when, and how. The goal of our follow-up interviews was to examine more closely the needs for and challenges with sharing multimedia across a variety of meeting scenarios. These examples provided insight into a set of challenges and recommendations for supporting the sharing of artifacts across a range of contexts.

INTERVIEW AND OBSERVATION RESULTS

Analysis

While the survey data provided insight about meeting types and goals, the interviews and observations allowed us to investigate more specifically how participants managed different types of media before, during, and after a meeting.

To examine multimedia sharing, we coded the interview transcripts and observation notes for examples given of instances in which content (primarily documents or other types of media) was sent or shared with others. We sub-coded these examples around what was shared, how it was shared, and comments made about the relative success or challenges in sharing the information. Examples from interviewees are referred to as P1-P15, and examples from observations are labeled Obs1-Obs3.

After an initial round of open coding, we used affinity diagramming to cluster the examples around common themes pertaining to different aspects of the remote sharing process. These themes guided our understanding of the issues that influenced participants' tool choices and, more importantly, how participants used media in meetings. These involved the nature of the meeting, what was being shared, and the rationales for why it was shared in that way.

In particular, we found that the process of sharing information and media in a remote meeting often required individuals or groups to make various decisions. First, they had to decide what tool or medium to use to share the content. Second, they had to decide when to share this content (before, during, or after the meeting). These choices then had implications for the persistence and retrievability of the content after the meeting.

Tool selection: Factors influencing program and tool choice for remote collaboration

The specific features and capabilities of the tools used for remote collaboration have the potential to shape and direct both the collaboration as well as how shared media is prepared and disseminated. Interviewees often used a combination of free video conferencing tools, paid video conferencing tools, email, chat, and phone calls for various work scenarios and tasks. This is consistent with Gonzales et al.'s [10] assertion that it is increasingly anachronistic to think of user needs as being supported by a single tool. As a result, groups often cobble together multiple tools and create "media toolboxes" or ecologies to serve their collaboration needs [15, 21, 25].

At the very least, many tools such as Skype, Google Hangouts, Join.me, WebEx, and others offer standard features such as the ability to screen share, send files (photos, videos) and chat in real time. So what caused people to gravitate to one over another? We coded the

interviews around all examples of synchronous meeting communication technologies used and rationales for using these specific tools.

Four interviewees mentioned that they chose the meeting tool (Google Hangouts) because it was "convenient" — namely, because they were already using the suite of collaborative applications such as email, documents, calendar, etc. associated with Google Hangouts and so it was integrated with their workflow and infrastructure.

Five interviewees mentioned having no choice in terms of the specific program or tool they used to meet with others. This took two forms: One form was when the parent company dictated what programs or tools its employees should use. Another form was when security concerns prevented employees from using open cloud-based tools or even webcams on their computers, so as a result all communication had to be audio-only and conducted through an internal version of Microsoft Lync.

A second form of "non-choice" occurred for participants who worked with a variety of external clients. In this case, they were often beholden to the tools their clients used and preferred, even when this was not optimal.

In the third category, seven participants had a choice over the tool they used and mentioned trying out various video conferencing tools over time. In this case, when they had a choice between programs, features that were most important were cost (e.g., number of free functionalities such as allowing multiple parties to share their screen) and overall reliability of the connection.

Thus, teams and groups may be required to use a tool that is non-optimal for their needs due to external or convenience reasons. Since not all tools share the same features, sharing and archiving behaviors are often influenced by the particulars of the tool a team chooses to (or has to) use.

Incorporating media into meetings

Media always plays some role in a remote meeting — at the very least a synchronous medium is used to communicate among the participants during the meeting itself. But there are often many other types of media at play during a meeting, from the preparation of a slide, video, or demo beforehand; photos, files, or screenshots (or even a secondary synchronous medium) shared during the meeting itself; and meeting notes, videos, or other artifacts shared after the meeting.

The meetings described by our participants occurred throughout the process of building or designing an artifact such as software, hardware, graphic design, video, or music. We categorized the examples given by participants and our observations based on the type of meeting they were holding. Overall, there were 13 information sharing meetings, 6 status update meetings, and 6 presentation meetings. Here we analyze the actions taken, decisions made, and implications of these actions at the three stages of a meeting. We focus on both commonalities and variations across all examples.

During: Media interactions during a meeting

As indicated by the survey, sharing and discussing multimedia material during a synchronous meeting is a common activity. Screen sharing is one of the most common and potentially widely used features of most video conferencing tools, and a primary means by which video is used to communicate information about artifacts. It is useful to promote awareness of shared referents, and make sure everyone is on the same page. Twelve interviewees described cases in which someone in their meeting used screen sharing to deliver slide presentations, give demos, and share images. All three of the meetings we observed also included screen sharing. This was often seen as more useful than file sharing because it enabled dynamic co-referencing of parts of an image or web page:

"I figure the screen sharing has the advantage of being able to actually interact with the image that you're sharing, like I can see his mouse when there is screen sharing." (P3)

There were, however, many instances in which information sharing presented obstacles to the collaboration.

Sharing challenge 1: Items could not be screen shared with remote participants

One of the most difficult issues in any remote meeting is making sure all participants are aware and involved in what is happening. Auxiliary media plays an outsized role in this, in some cases making remote participants feel less included but also providing opportunities for local participants to help re-establish common ground with remote attendees.

Sharing physical (non-digital) items with remote participants has been a long-standing problem in remote collaboration. For small items, one solution was simply to hold the object up to the webcam: e.g., comparing two different stylus models (P11, info-sharing) or showing the way an app looked on a mobile phone (P3, info-sharing):

"I deploy the application on my phone. Then we use the videoconferencing so I can put the phone in front of my laptop camera so you can see what it looks like." (P3)

However, sharing large physical objects such as information drawn on whiteboards (P1, P4) or placed on posters and signs (P4) was not feasible with the camera. While some specialized whiteboard capture tools exist to address this problem (e.g., [7]), these were not utilized by any of the teams in our sample. One solution could be to only keep and share information in a digital format; however, there was a tension between having information visible to the rest of the office and visible to the remote participants. For example, posters and flip charts

displayed in the "hub" office could be visible to others in the organization outside the immediate work team.

"So it works great for the dev team to be able to see this [list of tasks online] and it's good to communicate with management, but the physical paper board for the Sprint team would be better for the office, because people could see it happening." (P4, status update)

In many cases, a local group switched their focus between different artifacts, many of which may not be available to the remote participants. This could be as simple as referring to an object in the local group's meeting room that was not within view of a remote participant's camera. Similarly, screen sharing meant that when the shared artifact was visible on the screen, it replaced the video feed of other meeting participants' faces. This then prevented remote participants from seeing what was happening in the room, such as discussions or social dynamics between participants (P4, P13)

"Also, I suppose it's kind of annoying that [the remote participant] can't easily both see a shared screen and the video camera to people in the room. So, I guess, normally he gets no context of what's actually going on because usually we're sharing the screen." (P4, presentation)

"We don't have the actual Google Hangouts stream on the television, most often it's the Hackpad that stays on the screen." (P13, status update)

Furthermore, the social dynamics of a large group setting often make it difficult for local participants to help the remote user maintain awareness, even when they are aware of the problem.

"We're all talking about this and something comes up which would be useful to share with Ben that he can't see on the board. So if it was just the two of us, yeah, I would take the time to describe it or I'd take a picture and send it and say hang on a second and I'll just send you a picture. It never feels to me that I can do that in the meetings. Say, "hang on" everybody and send a picture to them…." (P4, info-sharing)

This same participant would sometimes use media capture and sharing in a backchannel to help the remote user recover some common ground that would otherwise have been lost:

"…we had a team meeting with a presentation last Thursday, of which I called Ben on my phone. And, of course, the person who was giving the talk doesn't work with remote workers and forgot that we do have remote workers and he could send down the file in advance, and I don't have enough battery on my phone to video it all to ever see it. So, I had to actually take photos of this projected output during the meeting and [send it via] WhatsApp." (P4, presentation)

Sharing challenge 2: Video files could not be screen shared well

One of the most difficult types of media to share during meetings was video or other dynamic materials (such as demos). This was an issue in multiple cases. For example, many of our interviewees across different industries (P5, P7, P9, P10, P12, P14, P15) worked with videos and needed to co-reference a video with remote others to discuss specific points within the video. However, viewing video via screen sharing was not ideal:

"Videos don't work very well. With the refresh rate, it just doesn't translate. If we wanted to share a video, we just send out the link and then people would watch it." (P9, info-sharing)

P12 was a user experience researcher who often wanted to show videos of usability testing, but experienced difficulty doing that over web conferencing.

"So how do you get whatever's playing to be transmitted over in the web conferencing system in the fidelity you're experiencing on?

I think the difficulty can come because you're then relying on the video to work across an audio to pickup and that just never seems to happen. Typically, that will be something that I'm unaware of. It's kind of a flag, right? Do I need to show something? If I do, how am I going to set it up? And I don't do it too frequently because of the challenge, especially with this." (P12, presentation)

In many cases, participants shared video with others via third-party file sharing mechanisms, but this approach was still considered cumbersome and participants struggled to find alternatives.

Sharing challenge 3: Multiple people in a single location wishing to share screens

Tools allow multiple people connecting to a meeting from different locations to take turns sharing their screen by allowing them to "pass the ball" or "switch presenter." However, this assumes that all participants in a meeting are connected via their own laptops. This was often not the case. Particularly when one location had multiple people participating in the meeting (P3, P5, P9, P11, P12, P13), the video conferencing system was hosted on only one computer and the content could only be shared through that computer. It was difficult for other people on their laptops in the room to contribute or share information from their personal devices.

"I think we would might do a little bit more screen sharing if it was simple, like Julie wants to throw her screen into the conversation… say we were in video and [she] wanted to show it quickly, it's probably not her computer that we're actually connected to so and because it just wouldn't be a quick simple thing to do, we probably wouldn't do it." (P3, info-sharing)

Combining the problem of synchronously co-referencing videos with a desire to allow multiple people to contribute videos into a conversation, one participant expressed the desire to seamlessly allow people to share videos from their phones directly into the meeting.

"If I could do that phone to phone, and be like, "Dude, watch this video," and I could sling the phone and I could sling a video but they are actually watching it. They are not trying to look at a pixelated [video] via Skype. I think that would be a huge, huge thing. Because then you are talking about really being able to be like "Hey, can you watch this cut right now?" Because right now, things are slowed down with the fact that there is no instantaneous way to do video." (P5, info-sharing)

The above challenges highlight both the technical and social factors that made sharing certain kinds of material difficult. Because the tool used to support the meeting did not easily address some of the above scenarios, people made decisions about how to integrate other content into the meeting and what adjunct tools to use to do this.

File transfer was one way of dealing with Challenge 1 (items could not be screen shared) and Challenge 2 (digital items could not be screen shared well). That is, people would send a hard copy of the artifact to be discussed to the participants either through email, a file sharing service like Dropbox, or hosting it on another web service like Vimeo (in the case of movies).

However, P14 mentioned that this required "*all kinds of negotiation*" to figure out how to access files, from uploading a file, to sharing its location, and figuring out permissions of who could access it. Even if information was uploaded ahead of time, most people didn't look at it prior to the meeting.

For Challenge 1 (items could not be screen shared) and Challenge 3 (multiple people in same room could not share information via the video conferencing system), another way of sharing information with others was to use an alternate tool (often a mobile phone) to take photographs of physical or digital information and send them to remote participants. Examples of photographs shared in real-time included notebook pages, a screen of statistics in the office, slides being presented, mockups, and screen shots.

As these examples indicate, it was common for people to take an extra action and use a supplementary tool to effectively share multimedia content during a meeting. However, this meant that they had to make decisions about *what tool* to use for sharing. These tools ranged from mobile chat applications (e.g., WhatsApp) to email to sending photos through the Skype chat window.

One factor influencing decisions about supplementary tool use was where the artifact would end up:

"I think the only case where file sharing is OK is if you send a snapshot that is easily displayed inside the tool. For example, you send a file on Skype, it needs to be easily visible. If you send a photo, that works. I'm glad that it's not cluttering my inbox. For a document it's not adequate, especially if we have to look at it." (P3)

Interviewees did not necessarily always use the same tool for sharing photographs. Instead, they performed an assessment of whether they would need to access that information again later. The tool used had implications for the persistence and re-discoverability of the material being shared. For example, P4 explained what influenced his decision to send a photo via a mobile SMS program (WhatsApp) or via email.

"Maybe there's a choice between things I e-mail and I [send via] WhatsApp. So [WhatsApp] is kind of a stream, right? It's not made terribly well. I can't search it…In the team meeting when I took the photos of the projected slides and just WhatsApp that, perhaps it was also partly because I know we don't need a record of it…but…I might e-mail that because actually I'll go back to my computer and probably save that on the drive as well." (P4)

Finally, the location of participants also made a difference. P4 noted that when all participants were physically distributed, it was easy to know that everything had to be saved in an online, easy-to-refer-to format. However, in a two-to-one situation, it was less obvious what needed to be preserved and what didn't:

"It gets a bit scattered when there are two people in the office doing stuff and one person is remote. It's almost worse than one or ten and one, because it's like where do you keep the shared to do list? Will you record from these meetings? When it is just me and [remote colleague], I know we have to record stuff remotely because it's going to be seen so we'll make notes in the JIRA [issue tracking program] tasks and manage it all very carefully there. But, when it's easier for me to just talk to [collocated colleague] in the office and say, "how are you getting along with that", then we're like should we both be writing it down in the tasks?" (P4, status update)

After: Archiving, accessing, and distributing media after a meeting

The end of a meeting does not signal the end of meeting-related media creation and sharing. In some instances, teams had a structured way of archiving meeting minutes or to-dos in an easily accessible place via persistent web link, for example in Hackpad or Etherpad (Obs3*,* P4, P11, P13*)*. However, minutes typically only were recorded or updated by one person and emailed to the rest of the group. Slides could be shared afterwards, and often were (Obs3*),* but the off-topic conversations that deviated from the slide content were lost. Thus, two sets of challenges around archiving meeting content emerged.

Archiving challenge 1: Recording not possible or not useful

Recording can be especially useful when the meeting itself constitutes useful data. For example, a user experience researcher (P8) recorded remote usability sessions conducted over video conferencing to refer back to later. For this reason, using a more advanced, paid professional web conferencing tool that allowed recording was advantageous:

"That's one of the benefits of GoToMeeting. It's really easy just to record a session."

However, when the client required that a free tool be used, this functionality was lost, and required her to rely on handwritten notes as a reminder of what had happened:

"I wasn't able to record because it was on Google Hangouts and I was like, "How do you record with this thing?" But I wasn't allowed to use any other [conferencing tool], because the client required that I use Google Hangouts… And then you just rush over and write everything down and whatnot." (P8)

When asked about how information from meetings was typically saved or preserved, a common response was that it was up to individuals to take notes about what was personally important to them. Sometimes these notes or meetings were sent around (P5, P6, P9), but most often individuals just kept them for themselves and did not share them with others. This made it hard for team members to accurately remember what had been discussed previously:

Interviewer: "Do you record what is going on with the screen sharing, to be able to refer to that later"?

P9: "We don't. It probably would be actually very useful to do that, but we don't."

Interviewer: "How do you remember the information then?"

P9:"I just remember it. I don't know".

However, the same interviewee later acknowledged the system of remembering information did not always work:

"Right now, I have a bunch of emails that I go through and write them down and try to remember what I am supposed to do. Then, the next meeting, I say I forgot, and half the other people forgot, so it's okay." (P9, status update)

However, in most cases meeting summaries or to-dos were generated from personal notes taken during a meeting. In many cases this reflected either a complete lack of recording functionality or a poor search interface for recordings. Therefore, recording meetings was either not possible with the tool, or not seen as useful to look at again afterwards (one team had 2 years' worth of recorded meetings that they did not refer to again).

Archiving challenge 2: Re-finding scattered information is difficult

Apart from recording video conversations, some tools had the ability to record conversation history, such as email, instant messenger chat logs, and the like. This did not require meeting participants to do anything extra to preserve what was being discussed. The problem, however, was re-finding a particular piece of information that could be spread across a variety of places. For example, two participants (P3, P4) struggled to remember whether a photo had been shared in the Skype chat, email, or elsewhere.

"When I go back to history to look for something, I know I stored some information but I don't remember what it is, I know it's by Skype so I can go in there and look for it. If I'm not sure it was on Skype, it would be one of the places I'd be looking into." (P3, info-sharing)

IMPLICATIONS FOR TOOL DESIGN

As both our survey and interviews suggest, participants in remote meetings have to balance an array of considerations. Their institution or client may have specific requirements, they may have their own needs for different types of meetings, and they may have their own preferences based on past experiences. These issues, combined with the growing number of videoconferencing, file sharing, IM, and workflow applications being used can make it necessary to cobble together and integrate information across a set of tools. Table 4 summarizes the main findings and challenges found in our work across different types of meetings.

Some challenges, such as organizational policy issues, are independent of tool functionality or usability. However, the capability of sharing and saving information that arises in the course of video calls is something that can be added to currently existing tools. Popular video conferencing tools are designed to support synchronous conversations between people. While they offer some ability to screen share or send files in the moment, often times, once the call ends, this information is lost. Here we suggest improvements in video-conferencing tools to support the issues of dispersed information and archiving.

Aggregation of disparate information

One common theme noted across the different examples of meetings in our work is that participants had to make decisions about what to share with others and how, and weigh the tradeoffs between the options they had for doing so. It is clear from our study that using a variety of tools and programs to share different kinds of information is not the desired approach for users, but as described above, a result of attempting to navigate the myriad shortcomings of current tools in the course of getting work done. While they were able to deal with managing this multiplicity of tools, it often led to increased cognitive load of deciding what to share and where to find it later. This also implies the need to anticipate upfront

Meeting type	Who shares and what do they share?	Sharing and archiving needs and challenges	Design implications
Status update	Multiple people; Minimal multimedia sharing	Sharing: Mostly verbal reports; Demos of phone apps may not be easily screen-shared (*Sharing Challenge 1: Not all items could be screen-shared*) Archiving: Information such as to-dos kept in a shared file with a persistent online link to another application (e.g., notes in Smartsheet, Hackpad, etc.)	Tool should support members' ability to synchronously contribute information from different, dispersed devices
Information sharing	Multiple people; Sharing of many different types of artifacts, both digital and/or physical	Not all types of information can be shared well (*Sharing Challenge 1: Not all items could be screen-shared; Sharing Challenge 2: Video files could not be shared well)* Multiple people may wish to show information over the video feed (*Sharing Challenge 3: Multiple people wishing to share information)* Archiving: Screenshared information or backchannel is lost unless saved as a file elsewhere (*Archiving Challenge 1: Recording not possible or not useful)* Non-screenshared information is scattered about and out of context (*Archiving Challenge 2: Re-finding scattered information is difficult)*	Tool should support members' ability to synchronously contribute information from different, dispersed devices Tool should support persistent storage and access of shared information linked to the video conferencing tool Personalized archiving of information
Presentation	One person typically screensharing digital artifact (presentation)	Remote parties can't see presentation if presenter neglects to share slides online. Slideshows with embedded video face quality issues. Not all types of information can be shared well (*Sharing Challenge 1: Not all items could be screen-shared, Sharing Challenge 2: Video files could not be shared well*) Accessing: Screenshared information or backchannel is lost unless saved as a file elsewhere (*Archiving Challenge 1: Recording not possible or not useful)*	Tool should support members' ability to synchronously contribute information from different, dispersed devices Personalized archiving of information

Table 4. Sharing and archiving needs and challenges across meeting types

the extent to which meeting content will be referred to in the future.

In particular, one design change that may be relevant given the discussion of the users in our study is decoupling video sharing practices from file sharing practices, which users find confusing and burdensome. For example, most popular photo sharing applications today do not require users to move photos into a separate folder for sharing, but rather allow users to easily and quickly insert photos into an ongoing narrative or conversation, of which the other user can instantly view through their application. Similarly for video, designers may want to look into tools for easily selecting and sharing relevant portions of video/screenshots through synchronous communications.

To support members' ability to synchronously contribute information from different, dispersed devices the video conferencing tool could provide a better means of integrating relevant information within the tool itself. On the sharing side, this might involve improving mobile phone apps so that they can connect directly to collocated meetings and allow seamless sending of information (e.g., pictures) from a participant's mobile device directly into the video conference tool interface. Such integration of additional devices would address Sharing Challenge 3, where multiple meeting participants wished to contribute material (such as a photo from their mobile phone) or into the video conference without using a laptop.

To address the design challenge of how to support persistent storage and access of shared information linked to the video conferencing tool, conferencing programs could better integrate content sharing from a variety of sources, applications, and devices alongside the video meeting. This could help reduce users' cognitive burden and need to decide how to share something and then remember where it was later. Tools like Slack offer automatic archiving and search of text-based

conversations, as well as the ability to share files such as images. It could be possible to share all information in such a place and refer to it while on a video call. However, as we have seen, this introduces a tradeoff between focusing on the meeting participants (observing faces, social dynamics, etc.) and focusing on a shared document.

Persistent archived information tied to the video tool

On the archiving side, better information integration would involve keeping shared information easily accessible and address Archiving Challenge 2 (Re-finding scattered information is difficult). For example, if a team had a recurring video conferencing meeting, the tool could provide access to notes and snippets of previously shared information/slides/presentations in the same interface used to hold the video conferencing meeting. This could help in situations where material was shared in various formats, inaccessible to remote participants, or when multiple people wish to share content from their own devices. It could also assist in the case where individuals have several recurring meetings and want to have a record of key information from each. One participant described the potential utility of having persistent, archived information:

"One thing that would be nice to be able to keep up those minutes I write in hand, to actually embed them into the meeting, itself, so people can see what I am typing while they are watching, so maybe a split screen feature. Or, if we come back the next week, if I said I expect you to do this by next week, if it could just be there in the meeting, itself, that would nice." (P9)

Archiving and saving information was also a theme that came up often. In some meetings, information being shared was transient and there was no need to keep a record of it for later. In fact, individuals sometimes appreciated that a photo shared over chat wasn't "*cluttering my inbox*" (P3). If old information needed to be accessed, it had to be made new again, for example by resending the old email to the group. However, different meeting participants might have different attitudes towards the same information.

We saw that often individuals took notes to record meeting items that were pertinent to them. An artifact such as information on a slide or a photo may be relevant and archivable to one person but not to another. Therefore, easily allowing meeting participants to have a "sandbox" where they can extract or refer to relevant bits of the meeting and its artifacts for either personal or group use could provide useful functionality. This would address Archiving Challenge 1, where recording an entire meeting was either not possible or not seen as useful (due to information overload). It may be that only small bits of useful information need to be extracted and preserved before the call ends and all data is lost, and these needs may be different from individual to individual.

Modular options to adapt to diverse meeting types and needs

As highlighted in Table 4, we also discovered diverse meeting types and needs. A single team may, over time, participate in many different types of meetings, as our survey and interviews suggest. A presentation meeting may not require much information sharing beyond walking through a slide deck together. A brainstorming session may not need to be archived; the end result of the discussion during the meeting is a decision that is reached and the process to get there is irrelevant. A mixed-configuration meeting has different social dynamics than a hub-and-spoke layout. These differences make it challenging to design a one-size-fits-all tool, and contribute to the multiplicity of tools being used in parallel.

To better support different meeting types, it could be feasible to design a single video conferencing tool with a variety of modules that could be mixed and matched depending on the meeting type and attendees. For example, the default layout for a status update meeting could include a large area for persistent note-taking, while the default (recommended) layout for an information sharing meeting could provide a space for external, non-screen shared content to be sent from participants' mobile devices and aggregated in one place. The tool could also allow individuals to choose themselves what parts of the meeting would be useful to them to record and keep later, perhaps even allowing them to capture important keyframes or screenshots from the conversation and shared references.

As described above, significant friction still exists in accessing past video, and in using archived video information. Tools that would facilitate an easier, simpler way of accessing this information would allow collaborators to spend more time building upon, rather than merely recovering, work from previous meetings.

The main focus of this paper is on factors and challenges that influence sharing multimedia material during and after video meetings in the context of creating artifacts. The insights in this paper apply to office-based knowledge workers who have a variety of choices for their communication tools. However, our work also highlights other challenges, both technical and social, that arose from different configurations of participants and varied across different job roles. In future work, we will examine more of these factors in more depth through collecting additional examples from various industries.

CONCLUSION

Videoconferencing, file sharing, and workflow applications are flooding app stores. These tools are well suited for facilitating conversations between "talking heads", but struggle to facilitate richer collaboration and multimedia sharing. Our interviews and observations with members of distributed teams using those tools reveal

some insights into this phenomenon: different users have peculiar institutional, social, and personal needs, and no one tool readily satisfies all of these. Thus, users sample from many different apps to cover a variety of different contextual issues, needs, and backup scenarios.

This abundance of collaboration tools has in turn inspired a rise of other tools, such as Slack, Glip, and others, that have as their main selling point the ability to integrate other tools together in a single interface. However, while those tools might make it easier to use a combination of collaboration apps, they do not provide users with enough guidance for choosing among them in different circumstances, or for adapting the interface functionalities and presentations based on their goals and tasks. Similarly, they do not close the gap between video content and what is preserved from other asynchronous communication.

Remote collaboration is prevalent for information workers in companies, and small teams of workers need technologies to help them converse and coordinate around shared artifacts. Finding ways to bring more material from outside the meeting into the meeting, and to capture relevant material and retain access to it for future reference has the potential to help streamline distance work for people in a variety of settings.

ACKNOWLEDGMENTS

We thank our interviewees for taking the time to contribute to this research. We also thank Matthew Cooper for his feedback and suggestions on the paper.

REFERENCES

1. Pernille Bjørn, Morten Esbensen, Rasmus Eskild Jensen, and Stina Matthiesen. 2014. Does distance still matter? Revisiting the CSCW fundamentals on distributed collaboration. *ACM Transactions on Computer-Human Interaction (TOCHI)* 21, 5, 27.
2. Matthias Böhmer, T. Scott Saponas, and Jaime Teevan. 2013. Smartphone use does not have to be rude: making phones a collaborative presence in meetings. *Proc. MobileHCI*, 342–351.
3. Erin Bradner, Gloria Mark, and Tammie D. Hertel. 2005. Team size and technology fit: Participation, awareness, and rapport in distributed teams. *IEEE Trans. On Professional Communication*, 68–77.
4. Jed R. Brubaker, Gina Venolia, and John C. Tang. 2012. Focusing on shared experiences: moving beyond the camera in video communication. *Proc. DIS*, 96–105.
5. Lars Rune Christensen, Rasmus Eskild Jensen, and Pernille Bjørn. 2014. Relation Work in Collocated and Distributed Collaboration. *Proc. COOP,* 87–101.
6. Azadeh Forghani, Gina Venolia, and Kori Inkpen. 2014. Media2gether: Sharing Media during a Call. *Proc. GROUP*, 142-151.
7. Lutz Gericke, Raja Gumienny, and Christoph Meinel. 2012. Tele-board: Follow the traces of your design process history. In *Design thinking research*. Springer, 15–29.
8. Jennifer L. Gibbs, J. L., & Malgorzata Boyraz. 2015. International HRM's role in managing global teams. In Collings, D. G., Wood, G., & Caligiuri, P. (Eds.), *The Routledge companion to international human resource management,* 532-551.
9. Jennifer L. Gibbs, Nik Ahmad Rozaidi, and Julia Eisenberg. 2013. Overcoming the "ideology of openness": Probing the affordances of social media for organizational knowledge sharing. *Journal of Computer-Mediated Communication* 19, 1, 102–120.
10. Joseph A. Gonzales, Casey Fiesler, and Amy Bruckman. 2015. Towards an Appropriable CSCW Tool Ecology: Lessons from the Greatest International Scavenger Hunt the World Has Ever Seen. *Proc. CSCW*, 946–957.
11. Raja Gumienny, Lutz Gericke, Matthias Wenzel, and Christoph Meinel. 2013. Supporting creative collaboration in globally distributed companies. *Proc. CSCW*, 995–1007.
12. Demetrios Karis, Daniel Wildman, and Amir Mané. 2014. Improving Remote Collaboration with Video Conferencing and Video Portals. *Human–Computer Interaction*, 1–98.
13. Benjamin Koehne, Patrick C. Shih, and Judith S. Olson. 2012. Remote and alone: coping with being the remote member on the team. *Proc. CSCW*, 1257–1266.
14. Charlotte Massey, Thomas Lennig, and Steve Whittaker. 2014. Cloudy forecast: an exploration of the factors underlying shared repository use. *Proc. CHI*, 2461–2470.
15. Tara Matthews, Steve Whittaker, Thomas Moran, and Sandra Yuen. 2011. Collaboration personas: A new approach to designing workplace collaboration tools. *Proc. CHI*, 2247–2256.
16. Lora Oehlberg, Kyu Simm, Jasmine Jones, Alice Agogino, and Björn Hartmann. 2012. Showing is sharing: building shared understanding in human-centered design teams with dazzle. *Proc. DIS*, 669–678.
17. Judith S. Olson and Gary M. Olson. 2014. How to make distance work work. *interactions* 21, 2, 28–35.
18. Polycom. 2014. http://www.polycom.com/content/dam/polycom/common/documents/guides/polycom-guide-to-collaborating-across-borders-enus.pdf
19. Polycom. http://www.polycom.com/defydistance/top-10-challenges-with-remote-collaboration.html

20. Jeffrey Treem and Paul Leonardi. 2012. Social media use in organizations: Exploring the affordances of visibility, editability, persistence, and association. *Communication Yearbook* 36, 143–189.
21. Thea Turner, Pernilla Qvarfordt, Jacob T. Biehl, Gene Golovchinsky, and Maribeth Back. 2010. Exploring the workplace communication ecology. *Proc. CHI*, 841–850.
22. Himanshu Verma, Flaviu Roman, Silvia Magrelli, Patrick Jermann, and Pierre Dillenbourg. 2013. Complementarity of input devices to achieve knowledge sharing in meetings. *Proc. CSCW*, 701–714.
23. Ruth Wageman, Heidi Gardner, and Mark Mortensen. 2012. The changing ecology of teams: New directions for teams research. *Journal of Organizational Behavior* 33, 3, 301–315.
24. Wainhouse Research. 2015. The collaborative enterprise: How enterprises are adapting to support the modern meeting. White paper. http://cp.wainhouse.com/content/the-collaborative-enterprise-paper
25. Stephanie L. Woerner, Wanda J. Orlikowski, and J. Yates. 2004. The media toolbox: Combining media in organizational communication. *Proc. Academy of Management,* 1-36.
26. Nicole Yankelovich, William Walker, Patricia Roberts, Mike Wessler, Jonathan Kaplan, and Joe Provino. 2004. Meeting central: making distributed meetings more effective. *Proc. CSCW*, 419–428.
27. Roshanak Zilouchian Moghaddam, Zane Nicholson, and Brian P. Bailey. 2015. Procid: Bridging Consensus Building Theory with the Practice of Distributed Design Discussions. *Proc. CSCW*, 686–699.