# Traces of Time through Space: Advantages of Creating Complex Canvases in Collaborative Meetings

Technology have long been a partner of workplace meeting facilitation. The recent outbreak of COVID-19 and the cautionary measures to reduce its spread have made it more prevalent than ever before in the form of online-meetings. In this paper, we recount our experiences during weekly meetings in three modalities: using SAGE2 - a collaborative sharing software designed for large displays - for co-located meetings, using a standard projector for co-located meetings, and using the Zoom video-conferencing tool for distributed meetings. We view these meetings through the lens of effective meeting attributes and share ethnographic observations and attitudinal survey conducted in our research lab. We discuss patterns of content sharing, either sequential, parallel, or semi-parallel, and the potential advantages of creating complex canvases of content. We see how the SAGE2 tool affords parallel content sharing to create complex canvases, which represent queues of ideas and contributions (past, present, and future) using the space on a large display to suggest the progression of time through the meeting.

CCS Concepts: • **Human-centered computing → Collaborative and social computing systems and tools**; *Web-based interaction.*

Additional Key Words and Phrases: Large Displays, SAGE2, Technology mediated meeting, Video-conferencing, Content sharing, Collaboration

**ACM Reference Format:**
. 2018. Traces of Time through Space: Advantages of Creating Complex Canvases in Collaborative Meetings. In *Woodstock '18: ACM Symposium on Neural Gaze Detection, June 03–05, 2018, Woodstock, NY*. ACM, New York, NY, USA, 18 pages. https://doi.org/10.1145/1122445.1122456

## 1 INTRODUCTION

What comes after work-from-home? After more than a year under work-from-home restrictions due to the spread of COVID-19, with the promise of vaccination, researchers, managers, and employees now contemplate this question. For many, the work-from-home mode was advantageous - it allowed more people to participate in the workforce as workers were not limited by lack of transportation, special accommodation, or caring for loved ones. Others are anxiously hoping to return to on-location work - they are suffering from Zoom fatigue [3, 16], feel that they lack boundaries between work and personal life, and miss the socializing and ad-hoc collaboration with colleagues which are intrinsic to on-location work [11]. The real answer must lie in a hybrid solution that allows workers on location and at home to collaborate seamlessly. However, this panacea is not easy to find.

In our research lab, we commonly conduct lab meetings co-located in front of a large display using the SAGE2 software for collaboration. Working in front of large displays is notably beneficial in many tasks given the additional external memory it provides and the ability to encode meaning in larger spatial layouts [1]. The SAGE2 software we use enables any team member to freely share content (images, PDF files, websites, notes, in addition to sharing their screen) from their laptops



*Woodstock '18, June 03–05, 2018, Woodstock, NY*



ACM ISBN 978-1-4503-XXXX-X/18/06…$15.00
https://doi.org/10.1145/1122445.1122456

at any moment. The transition to the more restricting online meeting format has been jarring. Yet, we were briefly introduced to this more sequential form of contribution just before the COVID-19 quarantine took effect. We were in the midst of comparing our co-located meetings with the SAGE2 software with a more classic, projector-based, setup. The shift to online work has broadened the scope of our comparison. At the same time, it became evident that the post-COVID workspace will move in the hybrid location/online format, prompting us to draw from our observations in different meeting modalities design guidelines for the next generation of collaboration software. We notice that sharing content can have a sequential, semi-parallel, and parallel flow, and that permanence of content in space leaves "traces of time" allowing people to queue future ideas as well as remember past ones.

We use the work of Cook [12] as a reference to our understanding of what makes an effective meeting. Key concepts include maintaining focus and active participation. Maintaining focus is tightly linked to active listening, where a person makes an effort to understand the message and content conveyed by others, and correctly interpret them regardless of personal bias. This is usually coupled with attentive non-verbal body language, such as, leaning forward, focusing gaze on the speaker, and making appropriate facial expressions. Likewise, appropriate use of computers to engage with matters discussed by the speaker, as opposed to unrelated matters, is also a sign of maintained focus. Active participation includes contributing content, sharing opinions, giving and receiving feedback. Content contribution should be relevant and well timed to avoid interrupting the flow of a presentation. Sharing information between members of a group is a primary reason to conduct a meeting, but a close secondary reason involves learning and improving your work based on input, and in some cases, debating various options and reaching some kind of consensus. It is therefore integral to active participation to make suggestions that others can act upon, and accept feedback offered to you by others. We complete this set of qualities that compose effective meetings by drawing attention to technical issues, which can be highly detrimental to the effectiveness of a meeting.

The Computer-Supported Cooperative Work (CSCW) matrix divides collaborative work according to space (co-located and distributed) and time (synchronous and asynchronous). In our work, designing the future of collaborative software, we focus on synchronous collaboration that is co-located in front of large displays, but can also support distributed team-mates with minimal deterioration in the quality of experience. We reflect on our personal experiences and use the ethnographic notes of an external researcher visiting the lab to answer research questions regarding: How are the properties of effective meetings supported in three meeting modalities (co-located using SAGE2, co-located using projector, online using Zoom)? What are the observed patterns of content contributions over time? What are the observed patterns of content contributions over space? And what is the role of the abundant space provided by large displays?

In this paper, we present our observations on these questions and synthesize the concept of parallel content contribution. This form of contribution leads to the creation of complex canvases that enjoy the advantages of queuing of ideas, direct referents, and information continuity, and leave a mural-like representation of the meeting.

## 2 BACKGROUND AND RELATED WORKS

### 2.1 SAGE2

The benefits of using large, high-resolution displays for work, collaboration, and sense-making are well researched. Large displays can have positive influence on spatial performance [34], visualization and navigation tasks [4], sense-making [1], data analysis [19], and daily work [6]. However, there are many challenges when it comes to controlling and working from a large display [2]. For

example, when there is only one keyboard and mouse to control a large display, even simple tasks like enlarging a window or starting an app can become troublesome.

To overcome some of the difficulties inherent in using large displays, while still enjoying the benefits of using them, we use the open source SAGE2 software [24, 30]. SAGE2 was implemented using web-based technology, specifically designed to support high-resolution displays and allow users to easily connect and control large displays from their browser. SAGE2 comes with a set of built-in applications, but enables user-created apps, for example, researchers have created apps for sense-making and visualization [29, 33], conference schedule planning [14], and crisis detection [20].

SAGE2 has two components: a display client that runs on the destination large display and a UI accessible from any browser via a url. The UI serves as a proxy for the large display - it demarcates the "wall" (the display area) and shows boxes that represent all the application on the wall for a user to drag around to reposition or resize. The user also uses the UI to start new applications or interact with them.

The abundant space on a large display creates opportunities to share more information at once. SAGE2 is performant when using rich media such as images, videos, and websites. Adding PDF files, videos, or images is as easy as drag and drop from one's computer onto the SAGE2 UI. Adding a note or a webview can be done by pasting content from the computer's pasteboard. SAGE2 provides context menus to preform actions such as downloading a file or editing a note, as well as a SAGE2 pointer mode, which places a user's cursor in a relative position on the large display, where it is visible by all and can interact with a webview as if it were a regular mouse. The SAGE2 PDF viewer allows opening multiple slides of a presentation or multiple pages of a paper side by side. The collaborative nature of SAGE2 means that anyone can share content on the wall at any time.

It should be noted that SAGE2 can be used in conjunction with other meeting facilitation technology, such as those mentioned in the Online Meetings section below.

### 2.2 Technology Mediated Meetings

Computer-Supported Cooperative Work (CSCW) is a large sub-field of Human-Computer Interaction (HCI), garnering its own yearly conferences (such as ACM CSCW[1]). The field deals in the design and evaluation of technology in the workplace settings, such as technology for mediating meetings and collaboration. In the last couple of decades, this flourishing field of research has also spawned many commercial products.

Technology can be used to improve the meeting process in every aspect. These aspects include, but are not limited to, meeting organization and reminders [5], connecting between people, for example, via video-conferencing [15, 25] (but more recently with immersive VR environments in mind [9, 17]), assist in moderating the meetings at run-time [37], tools for collaboration, decision making, and expressing ideas (such as electronic or virtual whiteboard tools [13, 21, 27]), and methods to summarize and recall a meeting after its completion [18]. The field explores smart office environments that can help in all of these phases by identifying the context [28].

Collaborative software, like the SAGE2 software we discuss above, is a considerable topic of research on its own. IMPROMPTU [7] and WeSpace [35], to name but a few, are examples of environments that facilitate collaboration from users' devices to shared large displays, but rely on co-located contributors. A look into co-located and remote hybrid scenarios is naturally on the rise, and this work is an instance of this trend.

[1]https://cscw.acm.org/

### 2.3 Online Meetings

In this section, we draw attention to the specific technology used for online meetings. Since the Internet has become wide spread and networking broadband increased in capacity, various tools were built to help remote workers and distributed teams to meet. The research in this field looks for ways technology can support online meetings by observing the needs of participants in such meetings and driving change in future technology.

For example, Marlow et.al [23] present a study looking at distributed meetings. They interviewed participants that used online meetings for various purposes: status update, information sharing, brainstorming, conversation, and presentation. They interviewees discussed their media sharing habits, sharing anything from websites, text, images, spreadsheets, slides, and videos. However, they noted, it was difficult to share videos well and there was interest in allowing multiple people to share their screen simultaneously.

Indeed, Video-conferencing tools, such as, Zoom[2] WebEx[3], and Microsoft Teams[4], are prominent in the research of online meetings, but other tools, such as email and slack[5] are used for organizing groups online, tools like Google docs/spreadsheet[6] and Microsoft 365[7] are used for collaborative file authoring, and tools like Miro[8] are used as collaborative online whiteboards. An online meeting often necessitates a combination of tools. These tools have become vital in our work lives since COVID-19 sent millions of workers to work from home, and so have become a foci for research and self reflection.

To name but a few of the pandemic inspired papers: since the start of 2020, researchers described using whiteboard (Miro) to support collaboration between students in a science lab [31], detailed how a group of researchers used online tools (Zoom, slack, Miro) to organize a conference [8], designed a group model building workshop using Miro in conjunction with other tools like Zoom, email, Google Drive, and WhatsApp [36], and documented their process of developing a data visualization dashboard during the pandemic using Zoom, Google docs, and Miro [22].

Many other works took a deeper dive into a specific aspect of a tool, taking advantage of the larger number of subjects available for such studies, now that most high education and many workplace meetings are conducted online. For example, Parra and Granda [26] conducted a comparison study between Zoom and Webex in higher education settings, both tools measured equally in user experience but Zoom was considered significantly more attractive. Sarkar et. al [32] looked closely at the parallel chat feature within Microsoft Teams. They saw that parallel chat is helpful for participation without interrupting the primary conversation, is useful for coordinating actions (for example, via sharing links), and promoted social connection despite the online settings. However, parallel chat could also be distracting and divide attention, some users had different expectations for chat use (i.e. for any contribution vs. only ask important question), and it was difficult for presenters to engage with the parallel chat. We observed similar issues in our Zoom/chat experience. Cao et. al [10] present a large scale study on multitasking behavior in Microsoft Team, evaluating how much multitasking is happening during online meetings, what people do while they are multitasking and what are the consequences of this behavior.

In the online meetings phase of our study, we used the Zoom video-conferencing tool, since it was supported by our academic institution.

[2]https://zoom.us/
[3]https://www.webex.com/
[4]https://www.microsoft.com/en-us/microsoft-teams
[5]https://slack.com/
[6]https://docs.google.com/
[7]https://www.office.com/
[8]https://miro.com/

## 3 METHODOLOGY


Fig. 1. Lab Layout

Our lab specializes in the design and research of large scale visualization. As such, the lab and its PI have been staunch proponents of utilizing large, wall-sized, displays throughout our university system. We found that SAGE2 is the best support software to drive such large, high-resolution walls, while allowing easy collaboration from each individual's personal laptop. Our display and software systems have been in use for scientific research and teaching as well as meetings. We have 2 main large displays we frequently use during our meetings: Pele and Makani (see Figure 1). Makani is the main display with people sitting around it, and Pele is a secondary display used mostly for reference.

At the start of this study, our lab engaged 14 student participants: 3 PhD students, 6 master students, 5 undergraduate students, mostly from the computer science department, but also from industrial design, graphic design, and film. In addition, the lab's PI and visiting researcher were present. Several lab members graduated before the final survey was administered.

### 3.1 Preliminary Exploration

The main study presented in this paper is the ethnographic observation described in the next section. However, prior to the start of that study we explored the log files saved by the SAGE2 system to confirm the extent of content contribution from lab members. This data is limited to file creation date, application type, and the user creating the application. We present this data here to inform readers about content sharing behavior that is common in our lab.

### 3.2 Ethnographic Observation

We engaged an ethnographic approach to observing our lab meetings. One of the authors, who was visiting in the lab, would observe the meetings and take notes. When a meeting was done, they would raise questions about technology use and attention during the meeting.

Our study has two distinct phases. In the first phase, we wanted to compare the effectiveness of our meetings with our usual SAGE2 system against a standard setup with a single projector. These meetings were conducted alternating SAGE2 use and projector use over five weeks between

February and March of 2020. This phase ended when our institution mandated employees to work from home after the severity of COVID19 outbreak was evaluated. The second phase, therefore, included lab meetings where all participants use remote video conferencing (i.e. Zoom). Our observer maintained observation for two online meetings (though, they remained as a visitor to our online meetings, they did not find the flow of the meeting change over time).

### 3.3 Survey

Lab members were asked to respond to a short survey summarizing their in-lab meeting experiences in August 2020, and were asked to revisit their reflections regarding Zoom based meetings in March 2021.

The surveys were designed to evaluate participant's attitudes toward contributing content during a meeting, actively participating, receiving feedback, making suggestions (offer feedback to others), reaching a consensus, listening to others, as well as experiencing technical difficulties.

### 3.4 Limitations

The scope of the study we present in this paper is limited as it only involves members of our lab over a span of a few weeks. Our lab members are expert users of SAGE2 and no-doubt this greatly affects the results presented here. We offer this work more as a use-case study and, like most qualitative work, do not claim generalizability.

## 4 RESULTS

### 4.1 Log Excerpts

Before we announced to our lab members that our meetings will be observed, we reviewed the SAGE2 logs of files created on the SAGE2 system. These would include only actual files that were dragged and dropped into the SAGE2 UI and do not include the screen share application. The earliest entry in our log files for Makani was from 30th of November 2017, and the earliest entry in our log files from Pele was from 22nd of August 2019. The data was queried on the 12th of February 2020, and included 3610 records.

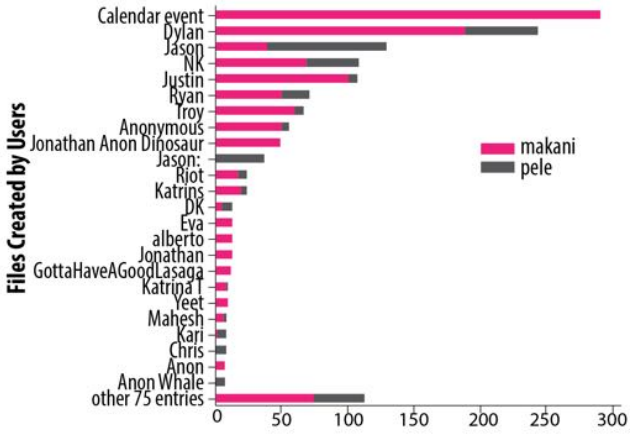


Fig. 2. Number of files created on the Pele and Makani SAGE2 systems over time by unique user names

Figures 2 and 3 show the distribution of the files on the primary display, Makani, and the secondary display, Pele. In Figure 2, we see the contributions by individual unique usernames. We

should note, usernames are self appointed, and a person may have several usernames, and often do, between the two walls, so we cannot ascertain the exact number of unique users and files per user. The calendar event entries are generated by an app and can be ignored, however, we can see several entries that created 50 or more files on SAGE3 and many others with a modest contribution of a dozen files.

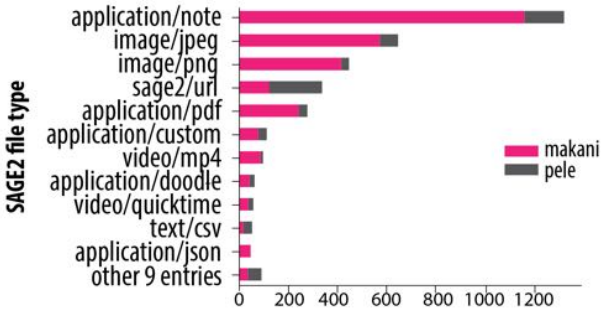


Fig. 3. Number of files created on the Pele and Makani SAGE2 systems over time by media type

In Figure 3, we looked at the distribution of created files by their file type within the SAGE2 system. The most frequently used contribution is a note, this is a short piece of text that can be edited by any SAGE2 user and has the appearance of a sticky note (colorful background, can be made to "stick" the other SAGE2 apps). The second most common contribution includes images, both in jpg and png formats. The third most common contribution is a url link (a webview). It is interesting to note that more instances of links were found on the secondary Pele display where they were used for reference rather than main content. The fourth most common contribution is PDF documents, which reaches nearly 400 instances. This is followed by other file types such as video, csv, and application specific types. Overall, this chart demonstrates the variety of additional content shared on SAGE2.

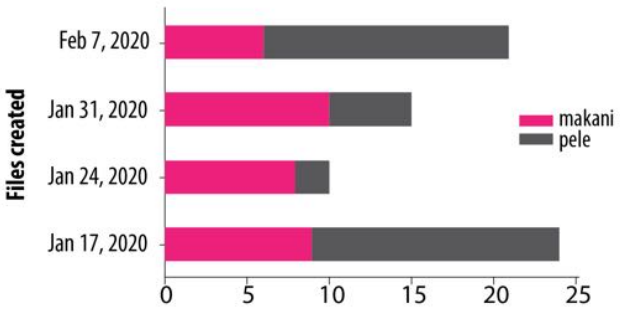


Fig. 4. The number of files created during lab meeting hours over four weeks on both Pele and Makani displays

Finally, we extracted from our logs the data of the files created specifically during the hours of our lab meeting in the month prior to the start of the study presented here. The resulting chart shown in figure 4 shows an average of 7.75 files created on the main, Makani display, and between 2 to 15 files created on the secondary display, Pele. Again, these are additional contributions as the

logs do not include screen shares during meetings. We consider these data to be demonstrative of contributions during meetings that use SAGE2.

### 4.2 Observations

After collecting our observer's notes from our meetings, we arranged observations of participants' behavior during the meetings with and without SAGE2 into categories most pertinent to efficient meetings. We present the observations in this section and reflect on their significance in the discussion section.

*4.2.1 Contribute Content.* It is common to shift the focus of a meeting from one person to another - an employee reports about their work or discusses an issue, and when they are done, the baton is passed to the next employee. This flow is evident in meetings using a single projector or online where only one device can share a screen at a time. However, meetings that used SAGE2 induced more contributions from participants not in focus. We see contributions added to the SAGE canvas with supporting news stories, related videos, or related pictures while a lab member is presenting. These additions are added around the main content shared by the presenter in focus, with minimal to no disturbance, and provide answers to questions raised by the presenter, enhance something that they say, or bring up a related topic that should be discussed next.

> *D has been working on a project to bring large displays to South-East Asia countries. There are several pictures from local news coverage of an event he participated in a couple of weeks prior in Thailand. Realizing that his turn to talk is coming up next, he loads those pictures on the secondary SAGE wall in advance. When his time comes, the pictures have already piqued the curiosity of the group members.*
>
> *E discusses a model she'd designed to prop up a physical artefact that is used in a project. However, when she tried to print it on the 3D printer, she discovered it was not working. After trying to fix it, she declared it beyond repair and suggested that the lab needs a new printer. As E speaks, several people search for plausible printers and post webviews around both primary and secondary displays with suggested printers. The group starts discussion of pros, cons, and cost of the different products presented in the space.*

In the more standard, projector based, meetings it is difficult to share visual content - there is a cable passed around between presenters and other participants have no easy way to contribute visuals, and raising questions aloud may disrupt the presenter's flow. There is no established way for a colleague to help the presenter (i.e. by changing slides, or pointing at items). Some of these issues are ameliorated in online format with tools like Zoom, which allow participants to add comments in the chat box, or annotate the screen shared by another presenter. However, it is still a limited set of contribution formats compared to SAGE2's range.

> *While K is presenting and showing a powerpoint presentation, one slide is reserved to the work on the project by O. O was working on detecting bodies in Azure Kinect and attaching particles to them. However, it is decided that it is too much of a hassle to switch the projector to his computer, so he quickly verbally recaps his progress without showing the program in action.*
>
> *On Zoom, T is showing the lab a design for a web page she designed for her latest visualizations. R thinks she should center the title of the page and remove the bar behind it. After searching through the Zoom UI he finds the annotation tool and sketches his thoughts on top of T's screen.*

*4.2.2 Active Participation.* The manner in which participants interact with the content presented is much richer in the SAGE2 modality. In SAGE2, when the content shared is a PDF (most of our

presentations) or an image, any participant can download that content from the wall and view in their personal device, making the sharing and reading of PDF files a simple drag and drop. In addition, each participant can modify the layout of applications on the wall, a modification that can sometimes shed a new light on an issue. Often, lab members help each other during presentations by controlling a SAGE app (i.e. changing slides, playing a video, navigating a website) to free the presenter to focus on their verbal delivery without pause.

The projector based meetings, on the other hand, limit possible interaction. Often, participants find themselves "jumping in" to the talk to say something, which can feel more like interrupting the meeting than contributing to it. We saw that many of the "interruptions" in this mode included asking the presenter to scroll up or down to see some content because the passive nature of this meeting format does not support sharing in a real sense. The online meetings have more flexibility as Zoom allows file sharing and adding messages in the chat. However, often, we saw that presenters sharing their screen were not aware that new content has been shared (the chat app is less visible for them) and participants often had to "interrupt" to mention they contributed relevant content in the chat.

> *A shows a webpage with a list of papers he is considering to use in an upcoming study. This is a very long page, and as A scrolls through it, N stops him and asks to scroll back up to something she noticed regarding the dates of the papers. N does not have agency to do this herself without a SAGE webview.*

> *While N is sharing her screen in Zoom she is looking for the link of a conference she wanted to share with the group, but she seems to fumble through her email and not find it. Meanwhile, R found the link and posted it in chat. N doesn't notice the new chat message and continues to search for the link, until D unmutes their mic and tells her that the link is in the chat.*

*4.2.3 Receiving Feedback and Making Suggestions.* When using SAGE2, feedback often takes the form of additional content on the wall (links, documents, notes). With the exception of screen shares, most content is left on the wall and is not removed until the end of the meeting, maintaining a spatial and layered trail of (1) content describing current work and problems, and (2) suggestions and feedback content added by others. Implicitly, when participants add content to the wall while another is presenting, they are indicating they have something to add or suggest, and the presenter is likely to address them accordingly.

> *C has edited several introduction animations for a video produced by the lab. He wanted to get feedback about which direction to pursue. He shared 3 videos and placed them side by side on the display. A discussion ensued. Others could start/stop videos to review them, gesture at a specific video with their SAGE cursor, find videos online showcasing a feature they think C should consider, and place notes to indicate which video they liked.*

Without a SAGE2 wall, it is difficult to keep track of the content. With a standard projection based meeting, feedback and suggestions merely take the shape of verbal interruptions, which are lost from memory and discussion as the meeting progresses. Online, we saw more ways to help a presenter in a way that is referential. In Zoom, the chat offers a way to add comments and share documents while a presenter talks. However, while in screen sharing mode, we have found that presenters often don't notice the chat, so there is a need for the participant to verbally explain when they contribute something. Zoom also supports screen annotations which provide a more direct method of feedback, and the tool allows users to save these annotations as an image for future reference.

*The lab has acquired a new kind of display. R wants to share a link to an application that connects to that display. Without SAGE2, he cannot post the link as a webview on the communal display, so he pastes the link in a document he created for the meeting. R had to email the link of that document to the group at the start of the meeting as some could not find it.*

*O shares his screen on Zoom, showing the particle effects he's been using in Unity. Other lab members want to share particle assets they have used in the past, and paste relevant links in the chat. Unfortunately, since he is sharing his screen, O doesn't notice the chat and has to be told to check it for links.*

*4.2.4 Reaching Consensus.* Given the persistence of (some of the) content on the SAGE2 wall, we saw that when the meeting approaches its end, and a consensus about our next steps needs to be reached - it was easier to refer to all prior topics when using SAGE2. Participants felt more comfortable with the material and had a sense of common ground, possibly due to the visual aids that were shared.

*As the meeting comes to an end, the PI remembers that he was asked to order a 3D printer and asks which one they decided to buy. Lab members quickly find through the space and layers of windows on the wall the webviews with links they have opened during the discussion, make them smaller and place them side by side. R suggests that according to the discussion only two options seemed good, and enlarges those two. The PI decides to order the cheaper of the two.*

In a projector based meeting, after presenters have relinquished their screen sharing turns, we saw that end-of-meeting discussions took place in front of a blank display, with no content to refer to for the purpose of decision making or reaching consensus. Participants had to rely on their memories of preceding content during this discourse. In online meetings, the end-of-meeting discussions were also held without any specific presenter sharing their display, leaving participants viewing the grid of camera boxes that has become synonymous with online video-conferencing. However, due to the persistence of the chat content, they could refer to past comments, links, and shared files to help reconstruct some of the discussion points without relying on memory.

*4.2.5 Participants' Attentiveness.* When using SAGE2, the meeting flows rapidly between speakers, and other lab members remain attentive, paying attention to topics they may contribute to. Occasionally, we saw the meeting derail off topic, but when that happened, the whole group would segue to the side topic or some unrelated reference together.

*While K talks about the interactive installation she is designing, the discussion brings up another famous installation some lab members have visited. Quickly a video of the exhibition is found and shared and lab members brainstorm ideas that are not related to K's project, but may be interesting to pursue in the future.*

It was evident in the projector based meetings that the participants were less engaged. They did not have any agency to actively contribute material. In some cases, they were occupied by searching for information that the presenter was discussing but could not conveniently share. These searches were an unnecessary distraction - while looking up the content, participants would effectively disconnect from the conversation. Our observer noted that several side conversations broke out in this format, some of which were perhaps related to the presentation but remained unshared. Online meetings offer a mixed bag: people are not likely to form side conversations in this format, however, it is noted that in general participants tend to engage with additional tasks while taking part of an online meeting [10] so attentiveness can fluctuate. To minimize distractions, our lab members maintain their camera turned on (with exceptions) during meetings.

*4.2.6 Technology Issues.* All forms of technology sometimes malfunction. How frequently such malfunctions occur and their severity effect our willingness to use it. We did not encounter significant malfunctions in our SAGE2 or online meetings. While working with the projector we encountered some common problems, missing dongles to connect the projector to a computer, cords not being long enough to reach a presenter's position, and display resolution that needed adjustment upon connection to the projector. Some of these problems are ameliorated in environments that use wi-fi based projection (such as Apple Air). The biggest technical problem with the standard form of meeting is the inability to connect a remote participant so only co-located participants can partake in the meeting. SAGE2, being web based, allowed for the occasional remote participation. Going forward, excluding remote participation is impractical.

> *While A is presenting, the projector suddenly stops working. R comes over to A's computer and they both fiddle with the cable to see if it got disconnected. Everyone else is waiting.*
>
> *A finished his presentation and it was decided that C should show his work next. A disconnects from the projector as C comes to take the cable. It seems that the cable does not reach the location of C's computer. C awkwardly moves a little forward to barely make it. At this point, C realizes he needs a different dongle from A, and a dongle search ensues.*

### 4.3 Survey Results

The survey we distributed to lab members was inspired by the list of qualities Cook attributes to effective meetings [12]. The first collection of questions (gray in Figure 5) asked participants to reflect on their personal experiences and the second collection of questions (blue in Figure 5) asked them to evaluate the behavior of other participants during meetings. The survey questions were first administered with the SAGE2 and projector-based meetings in mind. At a later date, we revisited these questions as they apply to online Zoom meetings.

The results of the survey show that participants had stronger positive attitudes toward the meetings that included SAGE2, with all 14 questions getting an above neutral response. The co-located projector-based meetings did not promote positive attitudes with only 2 questions yielding an average above neutral ("I maintain focus on the meeting" and "most participants avoided interruption"). The online zoom meetings, which have a more flexible structure than the projector-based meetings, yet still limited in comparison to the SAGE2 system (in addition to some participants not liking the work-from-home model) led to ambivalent attitudes by our lab members, where responses were spread over a wide range of ranks. Still, 8 of the questions scored above neutral, indicating that the zoom experience was somewhat preferable to the standard format of projector-based meetings.

## 5 DISCUSSION

As we could see from logs, lab members use the SAGE2 system to contribute varied content. Our observational study informs us of how the content contribution is enmeshed with the flow of the meeting and how space is used (though, only SAGE2 allows flexible space use). Our survey confirms that our lab members preferred SAGE2 meetings, followed by online Zoom meetings, with standard, projector-based, meetings trailing behind. We show in Figure 6 an illustration of content contribution and meeting flows of the three modalities.

The standard meeting follows sequential content contribution: One person presents, when they are done, another person presents, and so on. This flow does not take any advantage of space of a large display, as each presenter simply maximize their shared screen. Listeners to the presenter do not have an effective way to contribute content - at best, they can interrupt the presenter and verbalize their thoughts, but rarely does the focus switch in the middle of a presentation

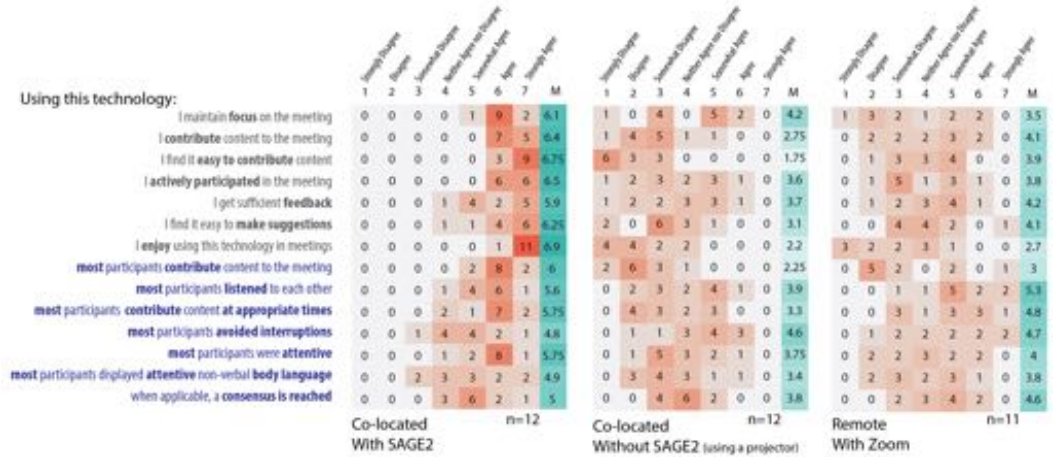


Fig. 5. A tally of the answers to our survey questions about using SAGE2 during a co-located meeting, using a projector during a co-located meeting, and using Zoom remotely.

to show supportive content by another. Often, ideas are lost, as they slip from a ideator's mind. This negatively affects active participation, feedback, and attentiveness. Moreover, the switching between presenters often cause pauses in meetings due to fiddling with technology (which in our observation included looking for dongles, moving to a seat that the cable could reach, changing monitor resolution, etc.).

The online Zoom meetings follow a semi-parallel content contribution scheme, where a main contribution (screen share) is mostly sequential, but there is some agency for minor contributions (chat messages, annotations) during another presenter's time, which crop up in parallel to the main presentation. The annotations allow participants to refer to the same item on the screen (as long as it is shared by the presenter) which showcases a limited use of space, and the chat entries provide an ongoing linear log of shared files, information, and links, that can serve as reference to the events of the meeting. However, there is no way to ensure that all participants are viewing locally loaded content (such as links) in the same way.

SAGE2 meetings promote a fully parallel content contribution scheme, as any member present can share multiple types of content at any given time, and use the abundance of space on the large display to ensure they are not disrupting the speaker. A screen share app can be resized as needed, and often participants start a screen sharing app while another is presenting, and shrink it, to indicate to wish to talk next. While a presenter is speaking, their listeners may come up with **1-** elements the presenter is mentioning, but is not currently showing, **2-** suggestions on how to resolve an issue, **3-** examples that bear relevance for the discussion, and **4-** tangential ideas. They can freely drag images and PDFs onto the SAGE2 wall and open webview windows and notes around the content of the current presenter, and this content can be immediately referred to by the presenter. These contributions create a complex canvas using the space available on the large display.

## 5.1 Advantages of Parallel Content Contribution

*5.1.1 Queuing of Ideas.* In a parallel content contribution scheme it is possible to share content *immediately* when it becomes relevant, and the presence of the content on the large display implicitly creates a queue of ideas. That means that the display serves as an external memory for

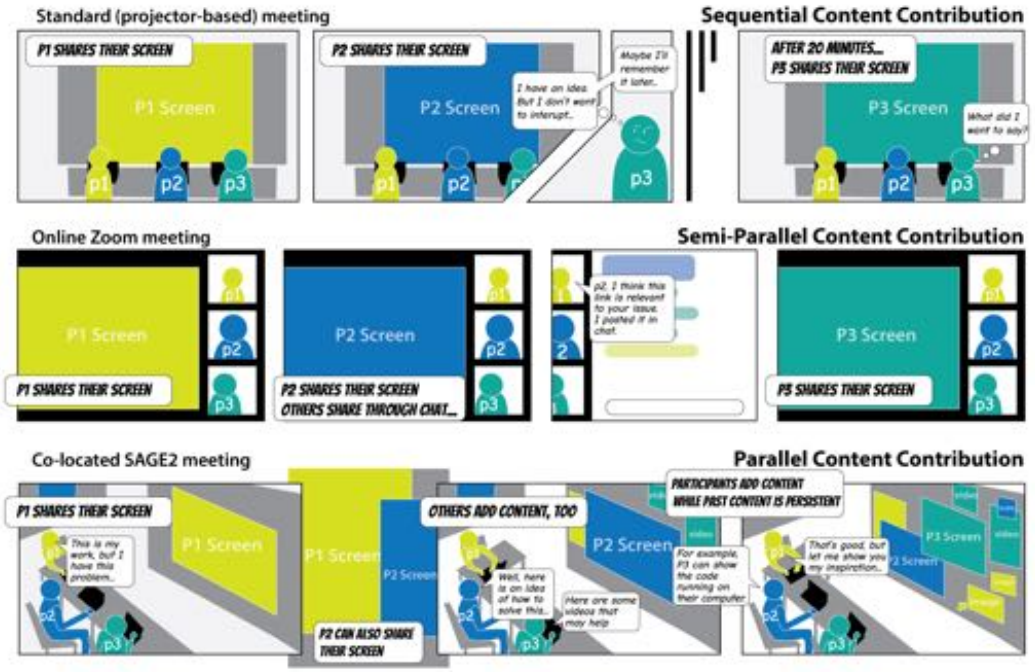


Fig. 6. Three patterns of content contribution: **Sequential** - individuals share their screen one after the other, ideas may be lost along the way, **Semi-Parallel** - individuals share their screen one after the other, but can also contribute (with some limitations) additional content out of turn, **Parallel** - individuals can share screen and any other content as the need arises, triggering many suggestions and ideas

all of the participants, helping them put ideas forward without disruption, but before they forget what their idea was. The new item on the wall clearly declares to the current presenter and all other participants that there is a point that someone wants to discuss. At an appropriate time, the discussion will address that point, and an idea will not fall between the cracks. This virtual queue that is formed on the wall works both to line up future ideas (to be discussed) and remind the team of past ideas (that have been discussed). This is likely to ease the cognitive load during and after the meeting.

*5.1.2 Direct Referents.* Content shared on the wall (with the exception of screen sharing) is both controllable by every user of SAGE2 and attainable to every user (i.e. files can be downloaded, URLs can be copied). Sharing content in this way support referring directly to information and gives all participants agency over the content; people can see an image that was shown several slides ago but maintains important to understanding the discussion; people can scroll up and down a webview to reach a pertinent section on a page instead of asking the presenter to do so; each person can use their pointer on the large display to pinpoint the object of their interest.

*5.1.3 Real-Time Mediation.* It is common that additional content contributions support a presenter rather than bring up a counter point or a follow up idea. While a presenter references some site or image, a different person would search for, and share, that content making it immediately available to the presenter for direct reference. Likewise, meeting participants often act on cues from presenters to scroll through a page, move between pages, or start/stop a video taking some of

the load from the presenter. This spontaneous real-time mediation helps the flow of a presenter as things change on the wall corresponding to their narrative.

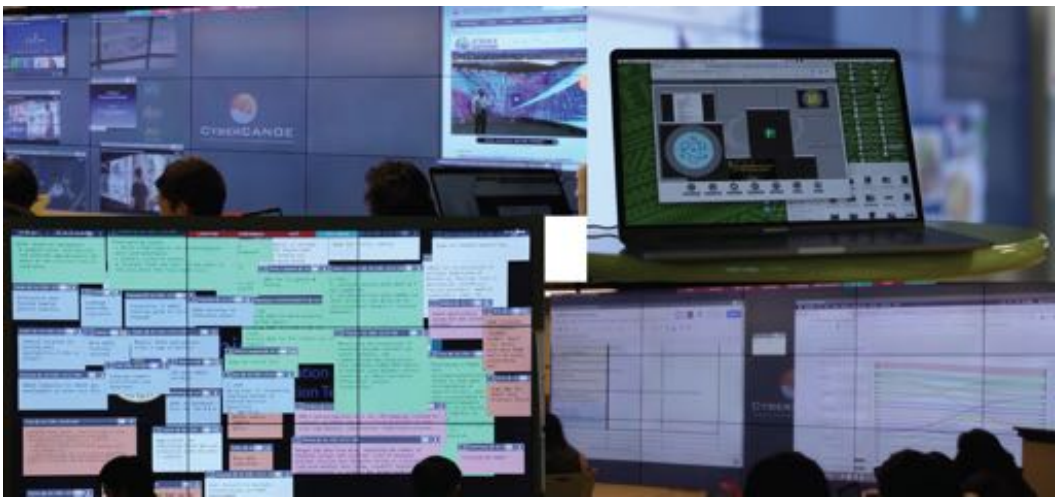

Fig. 7. Examples of complex canvases: *top-left* - a wall is set up for an upcoming presentation, various media files are placed as teaser on the canvas, later to be brought forwards and enlarged at appropriate times; *top-right* - the UI of SAGE2 on a personal laptop, the canvas shows proxies for the content; *bottom-right* - simple canvas, during a meeting, dividing the space between two areas, one showing a reference document from google Docs, the other used for main discussion; *bottom-left* - the result of a complex canvas at the end of a brainstorming session, notes are clustered by content.

### 5.2 Advantages of Complex Canvases

There are advantages that feed into the effectiveness of a meeting that stem from the complex canvases created during meetings that use tools like SAGE2 (for example Figure 7).

*5.2.1 Information Continuity.* When participants are able to contribute content at any point in the meeting - and that content is persistent, remaining on the wall for the duration of the meeting - the queuing of ideas (discussed above) is translated to an information continuity in space. Information for current, past, and future discussions are presented in the same scope. The group can refer to topics that were discussed before with little to no need of memory recall. The layout of content or the z-index of windows (their order in front or behind other windows) represents the time when that content was relevant to the meeting.

*5.2.2 Information Clustering.* As participants freely share content on the wall, a clustering of the information tend to form. They will commonly place relating items adjacent to each other. Proximity is also an indication of importance, while a speaker is presenting, others will place content close to their shared screen if it requires immediate attention or far from the shared screen if it is not pressing. In brainstorming sessions, the canvas of the collaborative space is used almost like a digital whiteboard, and the ability to cluster content in space is inherent to the task. In general, having clusters of topics on a wall make it easier for a meeting participant to quickly glean what kind of content/ideas they may contribute, and where to place that contribution.

*5.2.3 Spatial Orientation.* As content is added to a complex canvas, it is resized and positioned, and its size and location on the wall is registered in the mind of the viewers, making it easier to retrieve that content using spatial mapping. Searching for specific content through the textual linear arrangement of content as seen, for example, in Zoom chat, requires more cognitive load as we use visual cues (the content was 3 lines long, it was a url, it was written in caps etc.) than searching by spatial cues (the content was in a small box on the bottom right). Information is referred to visually rather than by name or URL.

## 6 IMPLICATIONS FOR THE DESIGN OF FUTURE SYSTEMS

We synthesized our observations and outcomes into a list of design considerations that can be incorporated into the design of meeting technologies.

- The system should support video-conferencing as well as rich media sharing (i.e. screen-share, images, PDF documents, videos, notes, but also fully functioning web pages).
- Web pages should be interact-able and synchronized between clients to support direct referents in this tricky form of media.
- The system should work in devices of different sizes, optimized to take advantage of the device's size (i.e. operations on large displays and personal computer have different needs and affordances).
- In co-located meetings, large displays should be controllable by any user from their remote device (no fighting over the single keyboard and mouse for the display's computer).
- Content sharing should be immediate, this imposes a system model that allows multiple screen-shares and democratic access to the "wall".
- Resizable or infinite canvases may provide an approach to enhance the spatial advantages of complex canvases, allowing for content that does not overlap to improve information continuity and spatial orientation.
- When users are remote and cannot enjoy the benefit of the large display, we need to devise other methods to inform them of new content that was shared (i.e. animated cues, follow up on other users and their cursors, use of highlights on a mini-map of the canvas).
- Consider delegating some of the patterns we identified - such as information clustering, and real-time mediation - to artificial intelligence.

Some of these considerations are already available on existing tools, for example, SAGE2 supports interact-able and synchronized web pages, a technically difficult feature in modern browsers that results in the use of an electron client, and Miro uses infinite canvases that can support most of the media forms discussed here, but we are not familiar with a tool that complies with all of these considerations.

These considerations also map out a research agenda into interface and interaction design of future hybrid meeting tools: how should interfaces differ on a large display or a small one, what are the most effective methods to draw users attention to new content, how should one interact with a canvas that automatically organizes their content in space, and so on.

## 7 CONCLUSION

Effective meetings are important to productive collaboration in the workforce. Our comparative exploration of meetings with the standard projector format, the SAGE2 format, and online meetings with Zoom has elucidated several advantages of the latter two formats over the former. This is due to the ability to contribute content in parallel to a presenter and to use well the space provided by complex canvases.

Parallel content contribution enables the queuing of ideas for discussion, direct referents of shared content, and real-time mediation to assist presenters without interrupting them. While Zoom provides some degree of parallel content contribution, mainly through its chat feature, our exploration clearly shows that complex canvases like those provided by SAGE2 empower collaboration in meetings much more effectively through the use of space to externalize memory and encode meaning.

Complex Canvases like SAGE2 also have further advantages: the large amount of space provided by them enables information continuity through the persistence of content, information clustering both to group items and to direct the focus of a discussion, and spatial orientation for efficient retrieval of earlier items. Through thoughtful use of complex canvas space, SAGE2 meetings empower employees to better engage in collaborative discussion, making the most of both audio and visuals.

In addition to this exploration of meeting technologies, we also contribute a synthesis of our results that serves as design guidelines for future meeting technology systems; these include the ability to work on devices of varying sizes, additional cues for remote employees, and the use of artificial intelligence to aid with patterns like real-time mediation, among others.

With the impact of COVID-19 on the future of work [11], meeting technologies must be developed and refined with the goal of empowering all employees towards productive collaboration, regardless of location. SAGE2 is especially effective for co-located collaboration; still, more work remains to be done to empower remote employees. While some workers will choose to return to the office, others may decide to work from home or remotely, which makes research towards effective hybrid solutions that empower seamless collaboration between these two groups critical for organizations to successfully adapt to the changing times.

## ACKNOWLEDGMENTS

## REFERENCES


[1] Christopher Andrews, Alex Endert, and Chris North. 2010. Space to Think: Large High-resolution Displays for Sensemaking. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (Atlanta, Georgia, USA) *(CHI '10)*. ACM, New York, NY, USA, 55–64. https://doi.org/10.1145/1753326.1753336

[2] Christopher Andrews, Alex Endert, Beth Yost, and Chris North. 2011. Information visualization on large, high-resolution displays: Issues, challenges, and opportunities. *Information Visualization* 10, 4 (2011), 341–355.

[3] Jeremy N Bailenson. 2021. Nonverbal overload: A theoretical argument for the causes of Zoom fatigue. *Technology, Mind, and Behavior* 2, 1 (2021).

[4] Robert Ball and Chris North. 2005. Effects of tiled high-resolution display on basic visualization and navigation tasks. In *CHI'05 extended abstracts on Human factors in computing systems*. ACM, 1196–1199.

[5] Pauline M Berry, Melinda Gervasio, Bart Peintner, and Neil Yorke-Smith. 2011. PTIME: Personalized assistance for calendaring. *ACM Transactions on Intelligent Systems and Technology (TIST)* 2, 4 (2011), 1–22.

[6] Xiaojun Bi and Ravin Balakrishnan. 2009. Comparing Usage of a Large High-resolution Display to Single or Dual Desktop Displays for Daily Work. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (Boston, MA, USA) *(CHI '09)*. ACM, New York, NY, USA, 1005–1014. https://doi.org/10.1145/1518701.1518855

[7] Jacob T Biehl, William T Baker, Brian P Bailey, Desney S Tan, Kori M Inkpen, and Mary Czerwinski. 2008. Impromptu: a new interaction framework for supporting collaboration in multiple display environments and its field evaluation for co-located software development. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. ACM, 939–948.

[8] Beatrix Busse and Ingo Kleiber. 2020. Realizing an online conference: Organization, management, tools, communication, and co-creation. *International Journal of Corpus Linguistics* 25, 3 (2020), 322–346.

[9] Abraham G Campbell, Thomas Holz, Jonny Cosgrove, Mike Harlick, and Tadhg O'Sullivan. 2019. Uses of virtual reality for communication in financial services: A case study on comparing different telepresence interfaces: Virtual reality compared to video conferencing. In *Future of Information and Communication Conference*. Springer, 463–481.

[10] Hancheng Cao, Chia-Jung Lee, Shamsi Iqbal, Mary Czerwinski, Priscilla NY Wong, Sean Rintel, Brent Hecht, Jaime Teevan, and Longqi Yang. 2021. Large scale analysis of multitasking behavior during remote meetings. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*. 1–13.

[11] Heejung Chung, Hyojin Seo, Sarah Forbes, and Holly Birkett. 2020. Working from home during the COVID-19 lockdown: Changing preferences and the future of work. (2020).

[12] SARAH COOK. 2009. *EFFECTIVE TEAM MEETINGS*. IT Governance Publishing, 57–72. http://www.jstor.org/stable/j.ctt5hh47q.12

[13] Ross Cutler, Yong Rui, Anoop Gupta, Jonathan J Cadiz, Ivan Tashev, Li-wei He, Alex Colburn, Zhengyou Zhang, Zicheng Liu, and Steve Silverberg. 2002. Distributed meetings: A meeting capture and broadcasting system. In *Proceedings of the tenth ACM international conference on Multimedia*. 503–512.

[14] Vishal Doshi, Sneha Tuteja, Krishna Bharadwaj, Davide Tantillo, Thomas Marrinan, James Patton, and G. Elisabeta Marai. 2017. StickySchedule: An Interactive Multi-user Application for Conference Scheduling on Large-scale Shared Displays. In *Proceedings of the 6th ACM International Symposium on Pervasive Displays* (Lugano, Switzerland) *(PerDis '17)*. ACM, New York, NY, USA, Article 2, 7 pages. https://doi.org/10.1145/3078810.3078817

[15] Robert S Fish, Robert E Kraut, Robert W Root, and Ronald E Rice. 1992. Evaluating video as a technology for informal communication. In *Proceedings of the SIGCHI conference on Human factors in computing systems*. 37–48.

[16] Liz Fosslien and Mollie West Duffy. 2020. How to combat zoom fatigue. *Harvard Business Review* 29 (2020).

[17] Jens Grubert, Eyal Ofek, Michel Pahud, and Per Ola Kristensson. 2018. The office of the future: Virtual, portable, and global. *IEEE computer graphics and applications* 38, 6 (2018), 125–133.

[18] Thomas Hain, Lukáš Burget, John Dines, Philip N Garner, František Grézl, Asmaa El Hannani, Marijn Huijbregts, Martin Karafiat, Mike Lincoln, and Vincent Wan. 2011. Transcribing meetings with the AMIDA systems. *IEEE Transactions on Audio, Speech, and Language Processing* 20, 2 (2011), 486–498.

[19] Søren Knudsen, Mikkel Rønne Jakobsen, and Kasper Hornbæk. 2012. An exploratory study of how abundant display space may support data analysis. In *Proceedings of the 7th Nordic Conference on Human-Computer Interaction: Making Sense Through Design*. ACM, 558–567.

[20] Dylan Kobayashi, Matthew Ready, Alberto Gonzalez Martinez, Nurit Kirshenbaum, Tyson Seto-Mook, Jason Leigh, and Jason Haga. 2018. Sage River Disaster Information (SageRDI): Demonstrating Application Data Sharing In SAGE2. In *Proceedings of the 2018 ACM International Conference on Interactive Surfaces and Spaces* (Tokyo, Japan) *(ISS '18)*. ACM, New York, NY, USA, 33–42. https://doi.org/10.1145/3279778.3279798

[21] Andreas Kunz, Thomas Nescher, and Martin Kuchler. 2010. Collaboard: a novel interactive electronic whiteboard for remote collaboration with people on content. In *2010 International Conference on Cyberworlds*. IEEE, 430–437.

[22] Tatiana Losev, Sarah Storteboom, Sheelagh Carpendale, and Søren Knudsen. 2020. Distributed Synchronous Visualization Design: Challenges and Strategies. In *2020 IEEE Workshop on Evaluation and Beyond-Methodological Approaches to Visualization (BELIV)*. IEEE, 1–10.

[23] Jennifer Marlow, Scott Carter, Nathaniel Good, and Jung-Wei Chen. 2016. Beyond talking heads: multimedia artifact creation, use, and sharing in distributed meetings. In *Proceedings of the 19th ACM conference on computer-supported cooperative work & social computing*. 1703–1715.

[24] Thomas Marrinan, Jillian Aurisano, Arthur Nishimoto, Krishna Bharadwaj, Victor Mateevitsi, Luc Renambot, Lance Long, Andrew Johnson, and Jason Leigh. 2014. SAGE2: A new approach for data intensive collaboration using Scalable Resolution Shared Displays. *Collaborative Computing: Networking, Applications and Worksharing (CollaborateCom), 2014 International Conference on*, 177–186.

[25] Antonios G Nanos and Anne E James. 2013. A virtual meeting system for the new age. In *2013 IEEE 10th International Conference on e-Business Engineering*. IEEE, 98–105.

[26] Otto Parra and Maria Fernanda Granda. 2021. Evaluating the Meeting Solutions Used for Virtual Classes in Higher Education during the COVID-19 Pandemic.. In *VISIGRAPP (2: HUCAPP)*. 190–197.

[27] Elin Rønby Pedersen, Kim McCall, Thomas P Moran, and Frank G Halasz. 1995. Tivoli: An electronic whiteboard for informal workgroup meetings. In *Readings in Human–Computer Interaction*. Elsevier, 509–516.

[28] Carlos Ramos, Goreti Marreiros, Ricardo Santos, and Carlos Filipe Freitas. 2010. Smart offices and intelligent decision rooms. In *Handbook of Ambient Intelligence and Smart Environments*. Springer, 851–880.

[29] Khairi Reda, Andrew E Johnson, Michael E Papka, and Jason Leigh. 2016. Modeling and evaluating user behavior in exploratory visual analysis. *Information Visualization* 15, 4 (2016), 325–339.

[30] Luc Renambot, Thomas Marrinan, Jillian Aurisano, Arthur Nishimoto, Victor Mateevitsi, Krishna Bharadwaj, Lance Long, Andy Johnson, Maxine Brown, and Jason Leigh. 2016. SAGE2: A collaboration portal for scalable resolution displays. *Future Generation Computer Systems* 54 (2016), 296–305.

[31] Theerasak Rojanarata. 2020. How Online Whiteboard Promotes Students' Collaborative Skills in Laboratory Learning. In *Proceedings of the 2020 8th International Conference on Information and Education Technology*. 68–72.

[32] Advait Sarkar, Sean Rintel, Damian Borowiec, Rachel Bergmann, Sharon Gillett, Danielle Bragg, Nancy Baym, and Abigail Sellen. 2021. The promise and peril of parallel chat in video meetings for work. In *Extended Abstracts of the 2021 CHI Conference on Human Factors in Computing Systems*. 1–8.

[33] Simon Su, Vincent Perry, Nicholas Cantner, Dylan Kobayashi, and Jason Leigh. 2016. High-Resolution Interactive and Collaborative Data Visualization Framework for Large-Scale Data Analysis. *Collaboration Technologies and Systems (CTS), 2016 International Conference on*, 275–280.

[34] Desney S Tan, Darren Gergle, Peter Scupelli, and Randy Pausch. 2003. With similar visual angles, larger displays improve spatial performance. In *Proceedings of the SIGCHI conference on Human factors in computing systems*. ACM, 217–224.

[35] Daniel Wigdor, Hao Jiang, Clifton Forlines, Michelle Borkin, and Chia Shen. 2009. WeSpace: the design development and deployment of a walk-up and share multi-surface visual collaboration system. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. ACM, 1237–1246.

[36] Brooke Wilkerson, Anaely Aguiar, Christina Gkini, Igor Czermainski de Oliveira, Lars-Kristian Lunde Trellevik, and Birgit Kopainsky. 2020. Reflections on adapting group model building scripts into online workshops. *System Dynamics Review* 36, 3 (2020), 358–372.

[37] Ying Zhang, Marshall Bern, Juan Liu, Kurt Partridge, Bo Begole, Bob Moore, Jim Reich, and Koji Kishimoto. 2010. Facilitating meetings with playful feedback. In *CHI'10 Extended Abstracts on Human Factors in Computing Systems*. 4033–4038.