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

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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 conventional 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.

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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, 21], 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 [15]. 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 at any moment. The transition to the more restricting online meeting format has been jarring for us. 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 conventional, projector-based, setup. The shift to online work has broadened the scope of our experience with meetings formats. At the same time, it became evident that the post-COVID workspace will move in the hybrid location/online format [41, 42], prompting us to draw from our observations in different, non-hybrid, meeting modalities, design guidelines that may support content contribution in the next generation of collaboration software to support effective meetings, whether they are on location, online, or hybrid. We noticed 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 [16] 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 a 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 a 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 and Large Displays

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 [45], visualization and navigation tasks [4], sense-making [1], data analysis [28], 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 widely available[1], open source, SAGE2 software [33, 39]. SAGE2 was implemented using web-based technology, specifically designed to support high-resolution displays (though the SAGE2 server and display client can be run on any modern computer) 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 [38, 44], conference schedule planning [18], and crisis detection [29].

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. Remote SAGE2 sites can be connected to each other and share content, but this feature is commonly used between two locations with large displays. It is possible for a user in an home environment to create their own SAGE2 server and display, however, this would require a screen dedicated for the display client and a screen for the UI client, which does not show the display content, so this setup is not commonly used.

[1]https://sage2.sagecommons.org/

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. We did not use such a combination in the study presented here.

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[2]). 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. Collaborative work across multiple devices ([10]) in various settings has been explored in many projects such as Shared Substance [22], HydraScope [26], Webstrates [27], and SurfaceFleet [11], to name a few, and is a corner-stone of CSCW research.

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 [20, 34] (but more recently with immersive VR environments in mind [13, 24], or via creating an ad-hoc network of co-located personal devices [9]), assist in moderating the meetings at run-time [48], tools for collaboration, decision making, and expressing ideas (such as electronic or virtual whiteboard tools [17, 27, 30, 36]), and methods to summarize and recall a meeting after its completion [25]. The field explores smart office environments that can help in all of these phases by identifying the context [37].

Collaborative software, like the SAGE2 software we discuss above, is a considerable topic of research on its own. IMPROMPTU [7] and WeSpace [46], 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. Saatçi et al. [41, 42] have observed and analysed hybrid meetings in business settings and comment on ways in which remote participants are excluded or included in meetings. They suggest developing technology that orchestrates turn taking and minimizes socio-technical asymmetries. The MirrorBlender system [23] takes steps to include remote participants in hybrid meetings by providing a spatially consistent frame of reference for both remote and co-located participants, and allows the remote participants to draw attention to themselves by changing the size and position of their camera feed (similar to content control in SAGE2).

2.3 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.

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

For example, Marlow et.al [32] 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. Their 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[3] WebEx[4], and Microsoft Teams[5], are prominent in the research of online meetings, but other tools, such as email and slack[6] are used for organizing groups online, tools like Google docs/spreadsheet[7] and Microsoft 365[8] are used for collaborative file authoring, and tools like Miro[9] 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 [40], detailed how a group of researchers used online tools (Zoom, slack, Miro) to organize a conference [12], designed a group model building workshop using Miro in conjunction with other tools like Zoom, email, Google Drive, and WhatsApp [47], and documented their process of developing a data visualization dashboard during the pandemic using Zoom, Google docs, and Miro [31].

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, at a time when most high education and many workplace meetings are conducted online. For example, Parra and Granda [35] 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 [43] 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 [14] 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. This prevalent multitasking behavior highlights the difficulties of maintaining participants' attention and active listening.

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

3 METHODOLOGY

In this study, we set out to explore how participants contribute content in meetings in three modalities that we have experienced in our lab. We will refer to the three different meeting

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

modalities as **SEM** (Sage Environment Meeting), **CPM** (Conventional Projector based meeting), and **ZM** (Zoom meeting).

The SEM mode includes a large display environment powered by the SAGE2 software, in our lab this includes two SAGE2 servers on two different displays (Makani, size 11.5' by 4', resolution 5.5M Pixels, and Pele, size 16.5' by 5.5', resolution 256M Pixels) that are connected to each other for collaboration. Each individual in the room needs a personal laptop to drive content onto a wall and control it. Content driven to the wall includes: images, PDF files, videos, web pages (fully embedded in the SAGE2 display), and screen shares (can support multiple shares). We consider all the parts of this environment as a holistic communication system. Our lab members have used this environment regularly for lab work (there were no new members at the time of the study). Participants were seated around the tables facing Makani shown in Fig 1. Pele is used for reference material and some participants are not directly facing it during meetings.

The CPM mode includes a 4K projector connected via HDMI cable to presenter's computer and projected on a screen approximately 73" by 55", the screen was positioned in front of the main Makani display and had a similar height to ensure participants were seated at their usual positions. Each individual in the room is equipped with a personal laptop, which they can connect to the projector using an HDMI cable (some laptops require a dongle) and share their screen. Participants were seated in the lab around the tables visible in Fig 1. All lab members had prior experience with this form of meeting in settings outside of our lab. We did not use any additional software in this mode.

In the ZM mode, the lab members participated remotely from their home setup using the Zoom video conferencing software. This modality has the largest variability of displays as some of our lab members used a smaller laptop display to join meetings, while others have multi-display setups at home. Zoom supports video, audio, screen share (from one source at the time of this study), chat messaging (group level, direct messaging), on-screen annotations, and other features (not used in this study). Lab members had some experience with video-conferencing software, mostly, by using the Whereby.com[10] which is web-based and was frequently used in conjunction with SAGE2. However, in this study we did not examine the combination a co-located SAGE2 with remote video-conferencing participants, and the modality of fully distributed online meetings may have been unfamiliar to some lab members.

We note that since these modalities have inherently different experiences due to a variety of reasons, such as, interactions schemes, familiarity with the technology, in addition to displays sizes, this paper does not present an experimental comparison, but rather a broader description of content contribution patterns in three very distinct styles of meetings.

3.1 Facilities and Participants

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. For our lab's needs, 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). We should note that our lab also conducts meetings using only one of the two displays, but for the purpose of this study, we decided to look at the holistic SAGE2 environment available in our lab. Lab members use an integrated workspace approach (shared territory) which is shown to serve better communication [8]. This approach requires some mental adjustment and is likely

[10]https://whereby.com/

Fig. 1. Lab Layout

not relevant for first time users, however, the lab members at the time of the study had experience with the tool and its egalitarian nature.

At the start of this study, our lab engaged 14 student participants aged 20-40: 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.

3.2 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.

3.3 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 regarding the content sharing and observed the behavior of the participants. When a meeting was done, while still seating as a group, the observer would raise questions inspired by their specific observations during the meeting (i.e. participants appearing confused or participants engaging in side discussions) about technology use and member's attention during the meeting. The sessions were not recorded.

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 conventional 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).

3.4 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. The survey forms were distributed online, and were submitted anonymously to limit bias from lab members.

3.5 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. Like most qualitative work, we 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 purpose of this activity was to ascertain to what extent lab members contribute additional content.

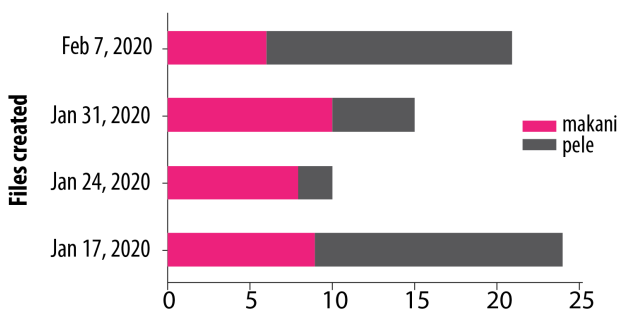

Fig. 2. The number of files shared during lab meeting hours over four weeks on both Pele and Makani displays (not including screen-shares)

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 our study and share it here as a representative showcase of file sharing during meetings on both displays. The resulting chart shown in figure 2 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.

4.2 Observations

To evaluate the data collected in this study, we used the observer's notes and our own reflections on the meetings. We chose to keep Cook's concept of effective meetings [16] in mind. Our coding led to the following categories: contribute content, actively participate, receive feedback, make suggestions, consensus is reached, listening to others, and technology issues. We decided to combine

receive feedback and make suggestions into one category since they represent two sides of the same transaction. Technology issues is not a category directly related to effective meetings, however, we had several occurrences of such problems in the CPM mode that affected the flow of the meeting. 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. We observed that meetings that used SAGE2 (SEM) induced a large number of contributions from participants not in focus. We saw contributions added to the SAGE canvas with supporting news stories, related videos, or related pictures while a different lab member was presenting. These additions were added around the main content shared by the presenter in focus, and appeared to cause minimal to no disturbance, and provided answers to questions raised by the presenter, enhanced something that they said, or brought up a related topic that should be discussed next.

> **[SEM]** *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.*
>
> textbf[SEM] *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 conventional, projector based, meetings (CPM) a presenter needs to be explicitly allowed to share content. The permission to share is granted by physically passing a cable to the presenter that they can attach to their computer and mirror its content on the screen via the projector. In some modern systems, users connect to projectors wirelessly, overriding the physical representation of a cable, yet functionally, these system behave the same. If another person wants to share content, they need to express that desire and wait for the projector system to be cleared before the turn is passed to them. Zoom meetings (ZM) have a similar turn-based style for the main screen sharing presentation, but we observed participants finding ways to engage with content while they were not presenting since tools like Zoom, allow participants to add comments in the chat box, or annotate the screen shared by another presenter.

> **[CPM]** *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.*
>
> **[ZM]** *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. While the previous section focuses on content sharing as a main contribution to a meeting, we refer to the interactions of all participants with the content as active

participation. In SAGE2 (SEM), when the content shared was a PDF (such as presentation slides) or an image, meeting participants frequently downloaded that content from the wall to also view it on their personal device, because sharing and reading PDF files was available via drag and drop. In addition, participants occasionally modified the layout of applications on the wall (resize windows or re-position them). Other lab members, instead of the presenter, sometimes interacted with content on the wall during presentations by controlling a SAGE app (i.e. changing slides, playing a video, navigating a website).

We did not observe significant interaction with content by non-presenting participants in the projector based meetings (CPM). They were passive observers of the content. When asked after the meetings, participants described themselves as "jumping in" to the talk to say something, which can feel more like interrupting the meeting than contributing to it. Frequently, participants asked the presenter to scroll or switch back to previous content. The online meetings ZM showed higher levels of active participation as Zoom allowed file sharing and adding messages in the chat as well as annotations. Participants used the chat feature regularly during meetings to share relevant URLs and answer questions on behalf of the presenter. Though, we found that often the presenters themselves, while screen sharing, have difficulty noticing when a new chat message is sent.

> **[CPM]** *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.*
>
> **[ZM]** *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 (SEM), we observed that feedback was often accompanied by additional content on the wall (links, documents, notes). Most content was left on the wall until the end of the meeting, and was often referred to by participants. Specifically, we observed a common pattern that after a participant shared some content, that participant was identified and asked to explain why they contributed this piece of content, which led to a suggestion or feedback. When asked about this pattern, participants said they shared things so they would not forget to talk about them later in the meeting, and while the content persisted on the wall, they assumed they would have the opportunity to elaborate.

> **[SEM]** *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.*

With a conventional projector based meeting (CPM), observed feedback and suggestions took the shape of verbal interjections. Participants commented in the after-meeting discussion that they did not immediately express ideas that they had as feedback/suggestion to other presenters, since they did not want to interrupt the speaker, and subsequently forgot to bring up the ideas later. In Zoom, the chat offered a way to add comments, share documents, and annotate a shared screen while a presenter spoke. We observed that our lab members frequently used the chat feature to respond to answers (in lieu of using their microphone) and share links when offering suggestions

or feedback. In some cases, participants used the on-screen annotation tool to indicate graphical suggestions. There was no document sharing in the observed meetings.

> **[CPM]** *The lab has acquired a new kind of display. R wants to share a link to an application that connects to that display. He cannot pass the link directly to participants, 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.*
>
> **[ZM]** *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. Parts of the meetings had a reporting nature, however, some matters that came up needed to be resolved with an actionable decision. In our meetings, we noticed these discussions were deferred to the end of the session. In our observations, the end-of-meeting discussions took place in front of a blank display in CPM, and in front of the grid of camera boxes that has become synonymous with online video-conferencing in ZM. In the SAGE2 modality (SEM), content remained on the wall for the end-of-meeting discussion. Participants said that having the visual reference gave them a reminder and sense of common ground.

> **[SEM]** *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.*

4.2.5 Participants' Attentiveness. For this category, we looked at participants' body language as an indicator (i.e. sitting forward looking at speaker implied a higher level of attention then a participant sitting back and looking elsewhere). When using SAGE2 (SEM), the meetings flowed rapidly between speakers and other lab members showed attentive body language. When interviewed after the meeting, participants said they were paying attention to topics since they may have something to contribute to them. On several occasions, we saw the meeting derail off topic. When that happened, the whole group seemed to segue to the side topic together.

> **[SEM]** *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.*

In the projector based meetings (CPM) we noticed that the participants' body language appeared to be less engaged. In some cases, as they explained after the meeting, they were occupied by searching for information that the presenter was discussing (i.e. looking for a web page the presenter was showing so that they could explore it. Our observer noted that several side conversations broke out in this format, where two or three participants quietly talked within a small group without sharing with the rest. Attentiveness was harder to evaluate in an online meeting (ZM). Our lab members shared their video camera feed (with exception) as a sign of attention. However, participants noted that in general they tended to engage with additional tasks while taking part in the online meeting (as in [14]) so attentiveness fluctuated.

4.2.6 Technology Issues. All forms of technology sometimes malfunction. How frequently such malfunctions occur and their severity effect willingness to use it. We did not encounter significant

malfunctions in the SAGE2 or online meetings observed in this study (SEM, ZM). While working with the projector (CPM) we encountered some difficulties, such as, 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.

> **[CPM]** *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.*
>
> **[CPM]** *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 reach 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 [16]. The first collection of questions (gray in Figure 3) asked participants to reflect on their personal experiences and the second collection of questions (blue in Figure 3) 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 conventional format of projector-based meetings.

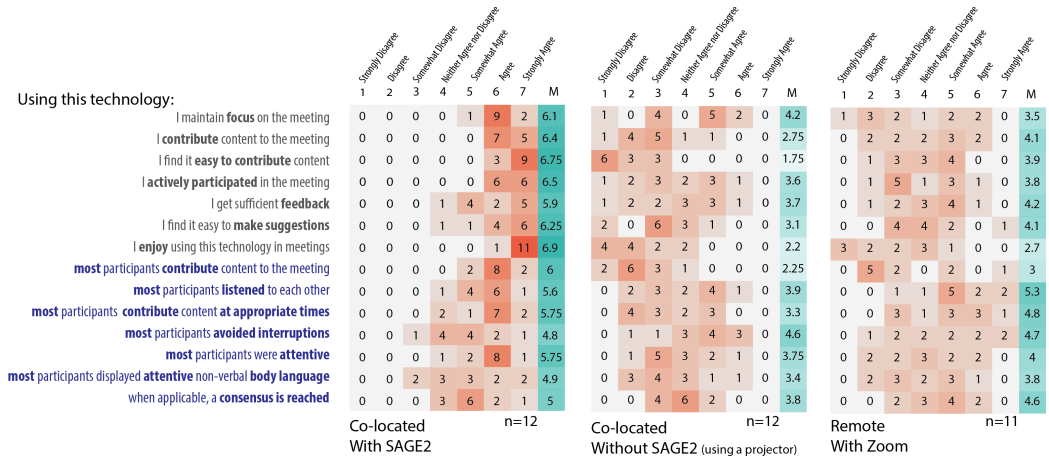

Fig. 3. A tally of the answers to our survey questions about using SAGE2 during a co-located meeting (SEM), using a projector during a co-located meeting (CPM), and using Zoom remotely (ZM).

5 DISCUSSION

Based on our observations, we searched for ways to describe patterns of content contribution, and how they effect the flow of meetings, as well as highlight possible advantages of the use of space in the course of content contribution as it was used in the SAGE2 meetings (SEM). In this discussion, we present a description of these features, and how we rationalize their benefits. In the next section we suggest how to incorporate advanced content contributing in future meeting tools.

The capabilities of users in each mode was vastly different: in CPM users were highly limited, in ZM users had additional ways to interact with each other and the content of the meeting, and in SEM users had additional features, including free-form spatial arrangement of content, and arguably, a more immersive environment. By observing these incremental setups we identified distinct patterns of content contribution. We show in Figure 4 an illustration of content contribution and meeting flows of the three modalities.

The conventional 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 maximize their shared screen. Listeners to the presenter do not 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. Often, ideas are lost, as they slip from the ideator's mind. This negatively affects active participation, feedback, and attentiveness. Moreover, the switching between presenters often cause pauses in meetings. This was observed in the CPM mode, however, this pattern is not technology dependant and can be attributed both to technology limitations and social conventions during meetings (i.e. waiting for a manager to indicate that a participant should speak [42]).

The online Zoom meetings (ZM) follows what we dub as 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. In Zoom, annotations allow participants to refer to the same item on the screen shared by the presenter, 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. This is identified as parallel chat feature in the work of Sarkar et al. [43], however, we wanted to express that this mode is intermediary between fully sequential and fully parallel content sharing, while still acknowledging its parallel nature, resulting in the moniker semi-parallel. A similar effect can be achieved in meetings by using multiple tools in conjunction as described in the related works section [12, 31, 47]. In that case the nature of the parallel contribution may vary (for example, if Google Docs is the secondary tool, it is more likely to involve linear contributions, while tools like Miro support spatial positioning), but the meeting is still led by a presenter sharing their screen.

The SAGE2 meetings (SEM) exhibit a fully **parallel** content contribution scheme, as any member present can share multiple types of content at any given time, including their screens, and use the abundance of space on the large display to ensure they are not disrupting the current speaker and this helps blur the line between main and secondary contributions. A screen share app can be resized as needed, and often participants started a screen sharing app while another is presenting, and shrink it, to indicate their wish to talk next. MirrorBlender [23] uses a similar mechanic of window resizing to indicate turn taking and to draw/dismiss attention. In the parallel content contribution pattern, while a presenter is speaking, their listeners and collaboration partners may share **1-** elements the presenter is mentioning, but is not currently showing, **2-** examples that bear relevance for the discussion, and **3-** tangential ideas. Placing such additional content in proximity to the content the current speaker is looking at, means that they can immediately refer to it. These contributions create a complex canvas using the space available on the large display.

The fully parallel content sharing pattern can be achieved in the other formats of meeting by willing participants and with the use of multiple software tools, for example, the Miro board tool supports some of the spatial positioning capabilities of SAGE2 and has an infinite canvas (in lieu of a large display on a personal computer). On the other hand, inexperienced SAGE2 users may not know (or want) to use its parallel nature and follow a more conventional singly-directed meeting that is sequential or semi-parallel. We will discuss the advantages of the parallel content sharing pattern as it was seen in our SEM mode - co-located participants in front of a large display - however, the pattern itself can be adapted to distributed participation and mixed large/personal computer screens, and should be evaluated in future work.

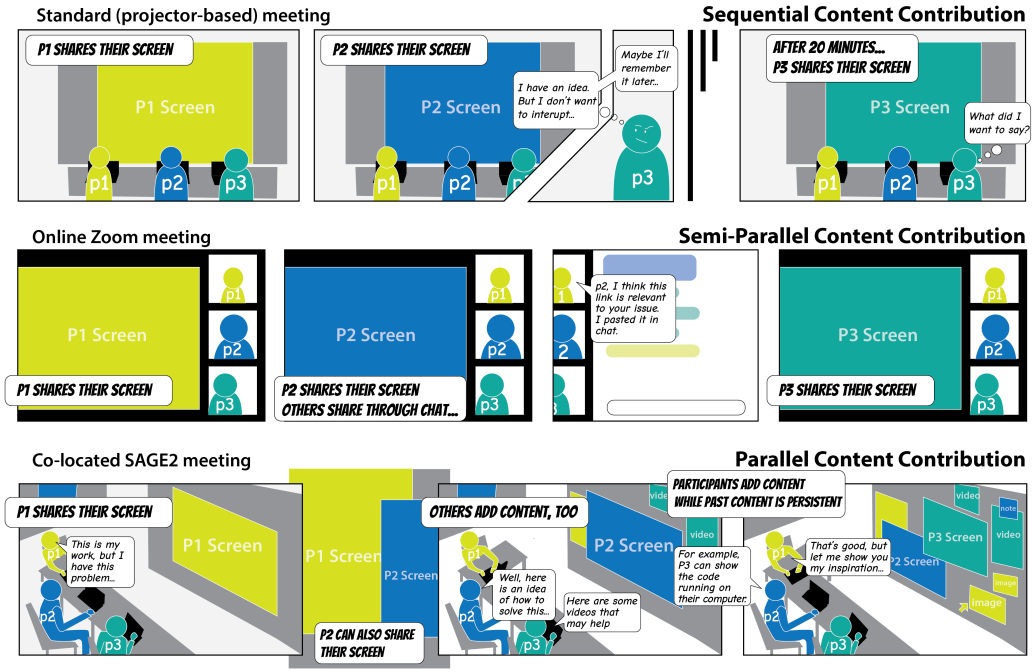

Fig. 4. Three patterns of content contribution: **Sequential** - individuals share their screen one after the other, ideas may be lost along the way, **Semi-Parallel** - individuals share their screen one after the other, but can also contribute (with some limitations) additional content out of turn, **Parallel** - individuals can share screen and any other content as the need arises, triggering many suggestions and ideas

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 a large display implicitly creates a queue of ideas. That means that the display serves as an external memory [1] for 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 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. When content is shared on a collaborative space (with the exception of screen sharing) is both controllable and attainable (i.e. files can be downloaded, URLs can be copied) to every participant. Sharing content in this way supports referring directly to information and gives all participants agency over the content; people can independently choose to see an image that was shown in a previous slide; 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 to pinpoint the object of their interest.

5.1.3 Real-Time Mediation. With parallel content sharing additional content contributions can be made that support a presenter. While a presenter references some site or image, a different person can search for, and share, that content making it immediately available to the presenter and audience for direct reference. Likewise, meeting participants can act on cues from presenters to scroll through a page, move between pages, or start/stop a video, taking some of the technology intervention 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.

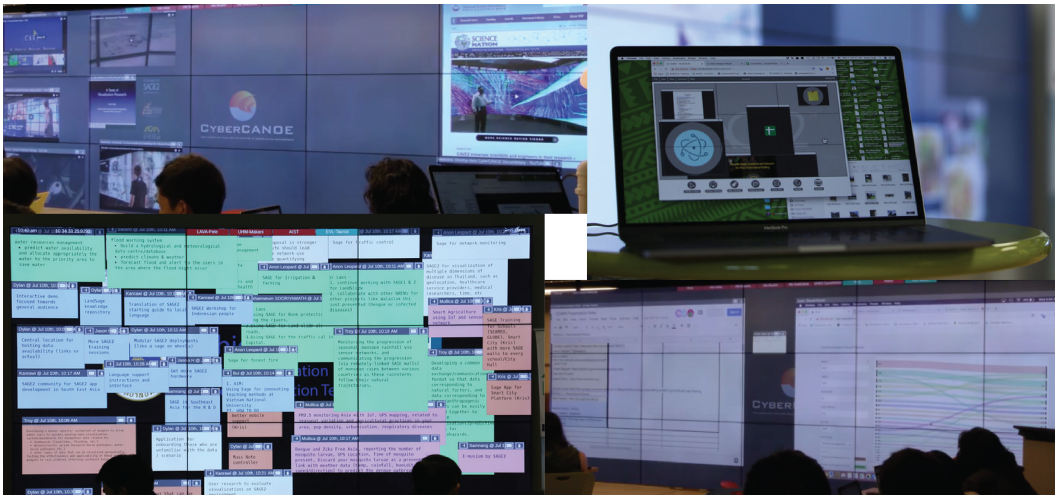

Fig. 5. Examples of complex canvases: *top-left* - a wall is set up for an upcoming presentation, various media files are placed as teaser on the canvas, later to be brought forwards and enlarged at appropriate times; *top-right* - the UI of SAGE2 on a personal laptop, the canvas shows proxies for the 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 5).

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, a kind of space to think [1]. 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 in what is arguably a simpler way to recollect meetings than transcription tools [25]. 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 can form. People 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. MirrorBlender [23] showed a similar interplay between position of content and its relevance. 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 Memory. 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.

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 [19], and real-time mediation - to artificial intelligence.

Some of these considerations are already available in existing tools, for example, SAGE2 and Webstrates [27] support interact-able web pages. We specifically mention the importance of shared web pages, since they are often relevant during meetings and can benefit from being direct referents that can also be real-time mediated.

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, personal 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 qualitative exploration of vastly different technological meeting setups using the conventional 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 attendees 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 participants, 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 [15], 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 workers. 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.

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