Shared Control Approaches for Hybrid Multidisciplinary Team Meetings

Yuri Manuel Krauland Cabrita
yuri.cabrita@tecnico.ulisboa.pt

Instituto Superior Técnico, Lisboa, Portugal

July 2021

Abstract

Successful cancer treatment depends on individual and group contributions of numerous healthcare professionals who discuss the best course of treatment over Multidisciplinary Team Meetings (MDTMs), aided by 2D medical imagery. Recently, MDTMs held over video conference platforms have become a regular feature in many hospital settings, offering high standard services to geographically distributed locations and favouring a more efficient and economical hybrid setup. In addition, the recent pandemic has further incentivized the need for smaller groups to collaborate remotely to curb in-person limitations. Still, communication issues exist between peers of different medical specialties when analysing imagery, which hampers the MDTMs workflow and limits decision-making processes. To address this, we developed an interactive system to visualize and manipulate visual content for hybrid MDTM settings. We aim to investigate how collaborative interactive displays, including individual and shared workspaces, impact collaboration and potentially enhance peer communication.

Keywords: Medical Imagery, Multidisciplinary Team Meetings, Collaboration, Cancer Treatment

1. Introduction

Over the last years, cancer survival rates have significantly increased, especially due to the early detection and multimodal treatment of the disease [1]. Oncologic pathologies are patient-specific, their treatment is lengthy and requires coordination of multiple medical specialties following a pipeline that allows them to handle great numbers of patients effectively. Cancer treatment workflow follows the ideology of initial diagnosis, followed by a discussion of the best treatment options over a meeting, in an effort to streamline the decision-making process and discuss as many patients as possible.

Multidisciplinary Team Meetings (MDTMs) gather a group of professionals from several clinical disciplines, such as surgeons, radiologists, oncologists, pathologists, psychologists, and nurses, who together make decisions regarding the recommended treatment of individual patients. These meetings usually occur weekly, and 10-15 patients are discussed in 1 to 2-hour meetings relying on the visualization of medical images, namely Magnetic Resonance Imaging (MRI). Even though images are the backbone of this deliberation, enabling effective discussions of multiple patients, these meetings have revealed a pattern of decision-making issues linked to suboptimal imaging quality, hardware, teamwork, and communication habits which point to the importance of successful collaboration [2-4].

Figure 1. Example of a face-to-face MDTM with video conference on upper-left screen. Adapted from [5].

Reliable communication and interaction between the meeting members are essential to enhance the quality of this collaboration aspect. Attendees argue that a high presence of team members, readily available data and adequate time for case discussion are critical for a successful meeting. Furthermore, remote participants require access to the same level of image detail presented locally to avoid misinterpretation and perceptual difficulties. Additionally, recognizing the complex and informal dynamics between members and organizational processes that impact workflow are valuable factors to consider when developing systems to improve these meetings. Finally, they also identified the clear interest for policymakers to pursue an ever-growing teleconferencing approach to the MDTM. It enables concentrating specialist groups in small centres and providing medical services to large geographical areas at a reduced cost. Nonetheless, they considered that the technology at the time of this study suggested that the extensive practice of teleconference MDTMs is unsustainable [6].

Traditionally in the MDTM setting, a single specialist is responsible for controlling the images, performing actions such as zooming, changing image slices, or rotating in the case of a 3D model [7]. There is little work that provides feedback on giving such controls to multiple entities during an MDTM and if it would be beneficial.

Considering the increased workload, future groupware systems must take into account the ever-reducing time per case discussion, the group communication hindering introduced by turn-take-like interaction of a remote setting, and the coordination of patient and meeting related records.

We consider that information technology, with the appropriate considerations of social interactions and interface design guidelines, can lead to the development of systems that facilitate and positively impact MDTMs, either in face-to-face or remote settings.

This work aims to respond to a set of research questions regarding collaboration in a medium-sized group where people shift between individual and shared spaces during a session. We aim to understand how added image control for all users can affect an MDTM's workflow and provide valuable insights on how to enhance group awareness in a hybrid setting. To this end, we intend to design and evaluate a cost-effective, portable, and tendentiously wearable-free prototype.

2. Background

Collaboration is the act of working together to achieve a joint goal and can have multiple variables which impact success. Developing Computer Supported Cooperative Work (CSCW) workspaces which assist aspects such as communication and data sharing, requires understanding what aspects condition it in the first place, such as coordination. Coordination relies heavily on the ability of individuals to harmonize in their activities, enabling them to operate together efficiently. Studies such as [8] have shown that aspects such as social and hierarchical status in a group, diverging work goals or motivations, communication issues, and extensive formal regulation of procedures greatly influence this capability and hinder collaboration. The quality of coordination varies on the type of activity and its perceived value. For instance, in a medical setting, standard discussion procedures which require little to no specialist intel are more likely to include failures in examination than high-status examinations, which require more expertise and administrational processing, thus given more importance.

According to Kane et al. [9], in an MDTM setting, participants perceive their benefit from attendances is proportional to their contribution to the meeting itself, and medical imagery is the most vital asset to assist this. The collaborative work between healthcare professionals is highly dynamic and involves a multitude of practices and mechanisms. This creates the need for flexibility and makes it an ideal object of study for developing systems to help assist these meetings and their final goal, decision-making.

If we intend an effective collaboration over digital displays, the natural interactions and social bonds of the physical world, and workplace, have to be taken into account so that users feel comfortable and motivated to use a remote groupware system [10].

Furthermore, in a medical setting, communication between departments is seen as beneficial, but perceptions of how collaboration is achieved, what defines its success or failure, differ from role to role, and diverging expertise can hinder each other's understanding. Thus, a healthy informal relationship between healthcare specialists is positive to level communication and avoid misunderstandings, and any system that restrains these informal practices would eventually obstruct work activity. Medical collaboration depends heavily on adapting to different perspectives and goals while still offering valuable and distinct inputs on patient care, so too much rigidity is detrimental, and assisting technologies must consider this [8].

Notable work has already been put into the development of interactive systems to help improve collaboration in a group setting, and essential principles have emerged to guide it. Applications like real-time distributed groupware allow multiple users to work in a shared workspace even when these are at different locations. The foundation for high usability in these systems is linked to workspace awareness, which means understanding another individual's interaction at any given time of work. In addition, knowledge about what, how, and why someone is performing an action is helpful in collaboration as it enables better coordination, communication, and assisting opportunities.

Greenberg et al. [11] pointed out the importance of awareness in groupware system design, especially when it comes to a remote setting where attendees heavily depend on the system's tools and mechanics to understand what is going on. Regarding sound and visual on colleagues, remote MDTMs usually use some third-party software to enable the use of microphones and cameras, facilitating synchronization between actions vital to the meeting such as imagery discussion for a given patient.

The interactive systems developed for the MDTM setting have to take into account the "What You See Is What I See"(WYSIWIS) paradigm [11-12]. It is often referred to in the development of multi-user interfaces, and it means that when users interact in a shared workspace, they share the same perception of the work area. For example, when discussing a patient, all medical specialists view the same dataset on their interface.
An important aspect of collaboration is always the environment in which it takes place, as predictable behaviour can be used to guide the development of media spaces to support the interaction [13]. Often the devices and design of groupware software diminish the flow of this perceptual information between colleagues by having poor information collection and display mechanisms. As a result, using such groupware can feel disorganized and cumbersome. Thus, effective gathering and presentation of information on-screen or via sound is a design must in order to promote awareness and workflow, as it helps to stay aware of others and simplifies communication. This way, work tasks and ultimately decision-making can be enhanced, and the recreation of face-to-face interaction can better be achieved or improved upon.

3. Related Work

In medical settings, CSCW systems have shown that it is crucial to aid and support the collaboration and workflow between specialists, rather than provide rigid and immutable programmed solutions lacking the flexibility needed in a hospital ecosystem [14].

According to Berg et al. [15]**,** information technologies enable the effective organization of medical data and coordination of activities. However, an emphasis on their role as support and transparency to the user must be made for them to successfully integrate into healthcare workers' day-to-day. An example of a widely adopted computer system in hospitals is the electronic patient record and the electronic nursing plan. Research on these further corroborates the idea of being helpful additions to workflow, but they do not substitute the complex relations between professionals and traditional work practices as a whole [16].

3.1 Prior Contributions to the MDTM Setting

Some work has been done regarding developing systems and tools for use in MDTMs that rely on interactive technologies.

In a deep-dive research on design and usability, Li et al. [17] present a socio-technical approach to the development process of groupware software when considering MDTMs between two hospitals, performing observational studies to identify relevant challenges to collaboration. Semi-structured interviews with healthcare specialists help identify interaction and behaviour, task distribution, and user needs for what a groupware system should improve for an MDTM. Furthermore, novel technology should be tested in a controlled environment rather than a live setting, so the crucial meetings are not interrupted. Primary elements to keep in mind when developing such software should be that remote users should be able to see and hear each other, the requirement for high image quality, and reduced image delay. Healthcare professionals also referred that they value some form of pointing or laser pointer tool to assist explanations.

Sallnäs et al. [18] provided important insight into the use of laser pointing in MDTMs via a software solution that combines 2D slices and 3D volumes. For this, a field study was conducted where participants used a laser pointer tool to communicate about patient imagery in preoperative meetings. Results showed that the tool clearly benefited discussions, adding valuable awareness cues and supporting verbal referencing. This encourages the inclusion of a laser-type tool into our prototype development.

Frykholm et al.[5] proposed a high-fidelity prototype for tablet devices to support collaboration in MDTMs. Their prototype presents an extensive patient overview, and the system allows to add visual cues to medical imagery to aid discussion.

Figure 2. Interface snapshot while using the drawing tool. Adapted from [5].

To enable a streamlined usage experience, the system has two modes, shared or private navigation. Each attendee had his tablet device, and interaction was individually logged in the system for later evaluation. Overall, the groupware was well received, and the evaluation showed great potential for such types of software to make MDTMs more efficient when it comes to case discussion.

Nonetheless, the system's key limitation is that it is not designed to enable remote users to join the MDTM, which we will be including in our work, still it provides valuable insight into design and evaluation methodology.

Olwal et al. [7] proposed a multi-display groupware prototype for the MDTM setting to augment the discussion capability of medical imagery. They developed a multi-user interface that enables different interaction techniques, including touch and pen-based interplays. The heavy reliance on mouse and laser pointer pens to discuss parts of the medical imagery was identified in observational sessions, and lasers are regarded as disadvantageous from a communication flow perspective.

Given that the system is to be used in an in-room setting, a PC server projects medical imagery while mobile tablet devices synchronize over the local network. Users can use pointing and sketching tools, and image navigation is allowed to all users; typically, only the radiologist would control these.

Figure 3. Touch display with interface to the left. Combination of PC screen projection and mobile device on the right. Adapted from [7].

Results showed the pointing tool was considered the most valuable tool as it helped resolve vague verbal references, avoid misinterpretation, and improve communication. On the other hand, the sketching tool seemed less impactful, but numerous specialists expressed positive feedback, as it does not require preciseness to convey ideas.

Regarding image navigation, a discussion about a private and shared mode emerged. Private interaction enabled working in parallel on one's mobile device without disturbing other meeting attendees, and the users could request to share their view when they had something valuable to share. However, some specialists were concerned about users only focusing on their private screen and hindering collaboration.
Furthermore, users were concerned about the disorder that could emerge if multiple people tried to interact simultaneously with the imagery.

Overall, users responded positively to the prototype and its contribution to the meeting, suggesting it could augment communication and help less experienced participants keep better track of the conference. Still, this system considered in-room use only rather than a hybrid setting.

3.2 Remote Collaboration Groupware Solutions

In 1992 Ishii et al. [19] presented "Clearboard", a prototype supporting remote collaboration through shared video drawing. By using a camera to record user's expressions and combining this content with what they draw on a glass board with digitizer pens, a video stream can be sent to a remote user. However, this solution is costly and limited considering an MDTM setting as it can only be used effectively by two users not to clutter the screen, display transparency issues hinder visualization, and the equipment required is expensive. Nonetheless, in their evaluation, the researchers got positive responses regarding the added awareness of others.

Morikawa et al. [12] presented HyperMirror, which enables local and remote participants to appear on a shared video wall via a combination of cameras and sensors, effectively giving them the feeling of being in the same room. Their work reinforces the importance of the "What I See Is What You See" (WISIWYS) design philosophy when developing collaboration software. In this approach, awareness is achieved to a great extent because people have the sensation of physically interacting with each other.

Considering an MDTM setting, these last two works are limited by allowing only two participants at a time, which is not compatible with the medium-sized groups we want to focus our work on.

Wittkämper et al. [20] investigated the use of augmented reality (AR) video streams for remote interaction and, although still in its infancy, AR showed promising possibilities to enhance real-time cooperation. The main drawback of AR systems is their expensiveness. But if one user couples AR with a live stream, various participants could view a real-life artifact-filled environment via a web browser. Nonetheless, this still requires an expensive multiple-camera setup, and image quality is highly dependent on the speed of movement and bandwidth of the streamer. Considering an MDTM setting, where time is crucial to discuss all patients effectively, the fiddly and unreliable state of image quality and difficulty of use for the average user are strong deterrents to try and adapt an AR solution for distributed medical discussions at this stage in time.

In a similar fashion Dai et al. [21] proposed an approach that allows remote participants to see each other from different viewpoints via a combination of cameras. They understood that users require low latency to communicate their ideas in a way that does not deteriorate their activities.

When considering a group meeting, some whiteboard or dashboard is often used in combination with pens and laser tools to explain complex ideas in a digestible manner. Expanding on this Pizarro et al. [22] adapted the dashboard for a remote meeting setting. Information is projected on a board, and a person can interact with it. The user's positioning is recorded by a camera and later on combined with the dashboard content to be streamed to other users. Respondents had an overall pleasant reaction to the silhouette solution and said it brings them closer to a face-to-face encounter like the in-room setup. Nonetheless, considering the traditional exploration of medical imagery and needs for different specialists to provide input in a MDTM setting, the limitation of only one user presenting and manipulating content is not always ideal.

In a similar design philosophy Greenberg et al. [23] presented a transparent display where two users can work in tandem on each side of a glass screen fitted with sensors and cameras so they can see each other. The researchers also identified issues with the transparency of the screens due to lighting problems and graphical nuances, which deeply hindered awareness. While they considered transparent displays as a suitable option for collaborative work, they acknowledged the technical difficulties related to them. They further recognized that newer and upcoming technology could help diminish this issue in the future.

In another solution Greenberg et al. [24] approach a remote solution that embraces a large group collaboration setting. The researchers developed a software prototype that expands on the ideology of an instant messenger. The framework can share media items, display Web items to all users or share the host's screen while maintaining a simple, straightforward design. Although early evaluation with Human-computer Interaction (HCI) experts was optimistic when going over use-cases scenarios, no further field testing was deployed due to bugginess and limitations of no voice communication. Nonetheless, the prototype was seen as promising if made more robust.

In conclusion, many works have explored and enhanced collaboration using groupware. Early remote approaches, such as [19] and [12] provide valuable insight into awareness and collaboration needs, even if limited to two users. Additionally, other works like [20-22], provide relevant information regarding remote interaction and the use of diversified novel technologies. Still, we must consider the time-constrained and dynamic setting of an MDTM and provide a solution that is not only economically viable but easy to adopt and flexible in use. Greenberg et al. [24] provide a solution that upholds these requirements but lacks critical communication channels and visual tools to manipulate medical imagery, which we want to provide. Finally, the distinguished contributions to MDTMs we reviewed, [17][5][18][7], lack the support for remote meetings which is increasingly important in recent times, given the global pandemic, and do not explore how different approaches of image control can impact the workflow of the meetings themselves.

4. Design & Implementation

This section describes the different development stages for the design of our prototype, details our implemented system's infrastructure, and how our interface works.

4.1 Requirements Analysis

In order to make the design and requirement choices for our prototype, observed 4 hybrid MDTM meetings and took relevant notes for development, which we will discuss below.

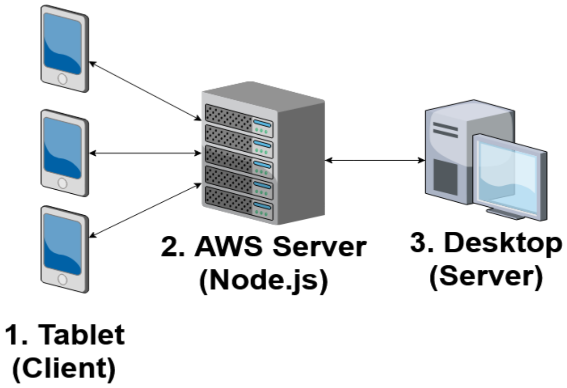

Figure 4. System Infrastructure.

In our observational sessions, the hybrid MDTM meetings were held over Microsoft Teams and had between 13 to 20 participants. The average meeting time was 55.3 minutes (std=23.96). The meeting format follows: a coordinator would introduce each of the patients and briefly introduce their case, followed by the responsible doctor asking image specialists for their input. After this, the specialists would discuss the matter in collaboration. Notable issues fall upon communication, regarding persons interrupting each other, difficulties knowing who is talking, and screen-sharing delays.

4.2 Implementation

To further expand on the concept of collaboration in these meetings, we decided to adopt a multi-device set up to stimulate the individual participation of the MDTM attendees. The imaging specialist controls a desktop device which loads, controls, and enables adding visual cues to the datasets to be discussed, while other attendees can view and make such visual contributions on tablet devices.

Moreover, we adopted a clean and simplistic interface design inspired by the works discussed in the related work section—an uncramped and user-friendly approach with image visualization as the primary focus.

For the interface development, we used Unity (v.2019.3.1f1), and to enable a multi-device setup, we use the FMETP Stream Unity asset to enable effective screen streaming.

The implementation requires a remote-friendly infrastructure as the majority of the MDTM's attendees are not in the same room and connect via the internet.
As a central piece, we have a backend server deployed on the Amazon Web Services using the Node.js runtime environment(2), which handles all

connections and data transfers between the tablet clients(1) and the desktop computer(3) controlled by the specialist responsible for the imaging.
The primary data transferred between the meeting attendees is by streaming. Inspired by the work of Frykholm et al. [5] the application has two modes available to each user: **Solo** and **Collab**. In Solo mode, users are in a private session where they can study and prepare visual cues on the loaded dataset. When in Collab mode, users can see the screen of whoever is streaming at the moment, we will further explain this below. This way, the act of viewing is centralized. To emphasise what mode a user is currently in we use a coloured text and application border. For Solo we use blue, and for Collab we use green.

Figure 5 highlights the server-side interface of the desktop computer.

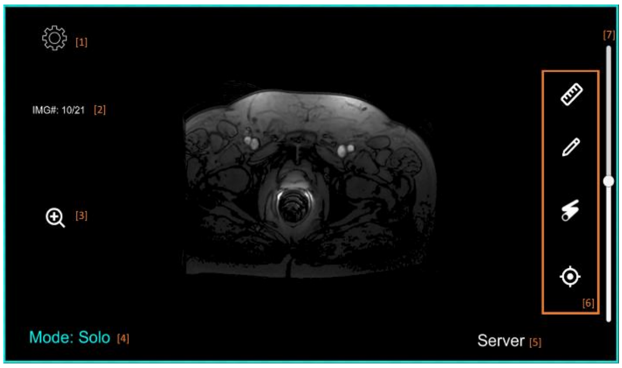

Figure 5. Interface Overview. [1] Settings, [2] image slice, [3] zoom, [4] mode indicator, [5] username, [6] toolbar, [7] slider.

The settings interface enables the user to load a dataset (Figure 6). When the Solo/collab toggle button is pressed we switch to Collab Mode and can wait for a client to stream their view.

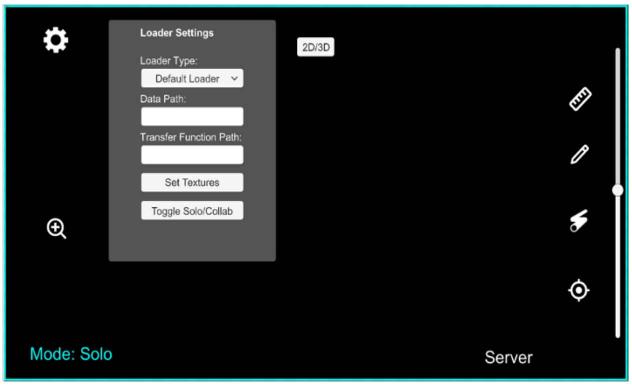

Figure 6. Settings interface.

The tools are the same for both the server and clients and help produce visual cues which support communication and ultimately improve collaboration (Figure 7).

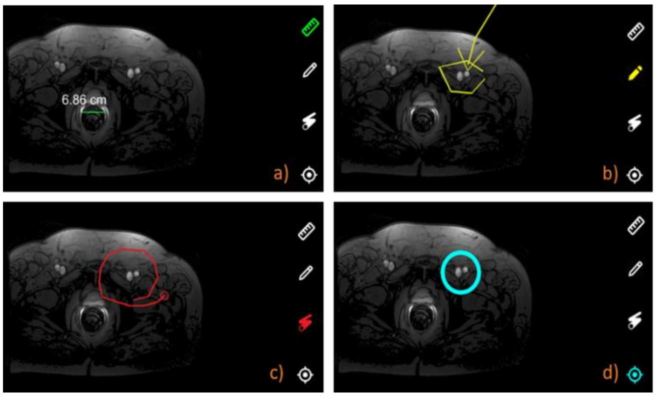

Figure 7. Visual tools. a) ruler. b) sketch. c) laser. d) pointer.

At Figure 7(a) we have a ruler tool to allow the measuring of distance in centimetres. In Figure 7(b) we have a sketching tool that enables the user to draw any combination of lines to appear, Figure 7(c) displays a laser tool which, similarly to sketching, permits the creation of lines, but these disappear after a couple of seconds. We consider this could be useful to go through a detailed demonstration without cluttering the screen with too many visual cues over time. Finally, in Figure 7(d) we have a Pointing tool that works like a zoomable circle to hover over target areas.

Instead of a mouse, the handheld user uses their fingers for drawing and a pinch-to-zoom gesture for sizing the pointing tool.

There are two versions of this prototype, version A and B. The reason being that we want to evaluate feedback on giving multiple users the ability to control imagery versus the traditional MDTM, where only one user has this capacity. In Version A, the desktop computer has complete and only control over the imaging and how long a tablet client can stream their screen. The client can only make visual annotations and start streaming their view via a button. Stream stopping is controlled by the desktop server, by switching to solo mode. In Version B, each tablet client has their separate instance of images that they can manipulate. Streaming can not only be started but also toggled by users. The main interface changes between the versions are exclusive to the client-side application.

5. Evaluation & Methodology

In this chapter, we will discuss the methodology used to evaluate our prototype.
We underwent a qualitative and quantitative user study with groups of laypeople as participants. We consider our participants as laypeople because they do not have any in-depth knowledge about medical image visualization or cancer treatment.

5.1 Setup & Apparatus

Participants used their own portable android devices in the setup, with a minimum of Android version 11 installed, and connect to a zoom call with their pc. The person acting as the server used the same computer to run the prototype and enter the zoom call. Zoom was used as the communication medium for people to exchange ideas and enhance group awareness, seeing and communicating with each other while using the application on their handheld device.

5.2 Participants

A total of 16 participants (12 male, 4 female) with ages between 16-66 years old ($\overline{x}$ = 26, std = 10.93) and receiving no compensation, participated in their own will. 5 participants were students, 6 worked in IT industries, 4 were entrepreneurs and 1 was a social educator. Pre-test questionnaires assessed their familiarity with other types of collaborative software, established a demographic profile, and acquired their consent for participating and being recorded. When asked about their experience in collaborative work in a mixed remote setting, 37.5% of the participants expressed average and 43.8% above average experience level. 46.7% of participants stated they usually worked in groups of 4, while 53.4% reportedly work in larger groups. Visual cue tools such as drawing or pointing tools were used regularly by 56.4% of them.

Regarding the profiling questionnaire, 56.3% of participants acknowledged they had an above-average degree of familiarity with collaborative work, with 37.5% expressing very high experience levels with this setting. However, regarding a mixed setting with both co-located and remote users, only 25% expressed an excellent experience level. Concerning the number of people participants usually interact with in such a mixed setting, 46.7% worked in groups of 4 as they did during our evaluation. About two-thirds of the respondents expressed an average or above-average use of visual cue tools for drawing or pointing. From a set of collaborative systems, 81.6% of respondents answered they are most familiar with Zoom for collaborative work.

5.3 Methodology & Procedure

The user study aimed to evaluate our interface and explore how four groups of four users interacted when asked to complete tasks in collaboration. For this, the participants explored a selection of images prepared in advance, using the visual cue tools, and share the screen function explained in the implementation section of this paper. The choice of which version to start with was chosen via the Latin square method.

Participants were introduced to both versions of the prototype and allowed to explore the interface while using the think-aloud method. After completing the given test tasks, post-test questionnaires in the form of a System Usability Scale (SUS) and individual preferences were filled out. Finally, individual semi-structured interviews were held with the respondents.

All sessions and interviews were recorded and transcribed for further analysis.

5.4 Tasks

After a brief habituation period, the participants were asked to complete three tasks per prototype version. The tasks were simple and equal for each version, completed on different sections of the images used, and required collaboration for best accomplishment. Task one was to measure a given distance between two objects. Task two was to identify a mistake in the drawing present in a given image, and task three was to identify an object somewhere in the dataset.

6. Results & Discussion

The logging of interface usage has shown that, in both versions, users were using their private workplace in solo mode for most of the tasks. Moreover, participants averaged 95 seconds for both versions using the collaboration mode to view other participant's screens. Users made more use of the screen-sharing tool when using Version B, as in Version A they all shared the same imagery instance and would instead cooperate directly with the user controlling the imagery rather than stream each other's screens.

In the post-test individual interview, respondents expressed no significant issues when using the application, stating the interface was natural and familiar, tools were easily understood after using them once. Some delays related to network bandwidth and individual internet speeds occurred specifically in Version B, but users said it did not majorly impact them. Two respondents felt some variations between the collaboration of co-located and remote participants. Participant ID006 was in a co-located setting and felt it was somewhat easier to collaborate with the user in the same room as they could show them their screen in person, but felt no significant differences to using the screen-sharing with remote users. Respondent ID009 felt that local users had more facilities than remote users due to occasional system delays.

Respondents agreed that the simultaneous use of the application facilitated the collaboration process, rather than each person working alone and sharing their findings at a later stage. The screen-sharing capability was seen as positive by all 16 respondents.

Most said that seeing another person's screen and what they were doing helped them better understand their explanations rather than only hearing and watching their faces. If a user draws something and all others can see it, it accelerates the collaboration process. All respondents also reacted positively to the visual tools, claiming they supported communication even further when coupled with screen-sharing. The most valued tool among users was the drawing tool, as it was considered the most versatile. It could function as both a pointer or a more complex highlighting tool. Some respondents found the laser tool more valuable if someone already had a pre-rehearsed explanation, as the disappearing line could confuse others if the explanation were sloppy. Nonetheless, 87.5% of respondents found that all tools were average or above average in their usefulness in the post-test preferences questionnaire.

Regarding the dual application setup, with zoom for communication and the prototype for image manipulation, users expressed a mixed reaction. 9 of the respondents liked the current setup, with some expressing how they enjoyed being conscious about verbal communication on one application and dominating the image manipulation on the other, as there is no cluttering of a single screen. Respondent ID003 expressed that looking ahead onto the pc screen to see others and down at the phone to manipulate images simulated a round table type environment as if all were in the same room. The other 7 respondents felt they would prefer a single application setup as that is how they usually work. Communication and webcams should be integrated into our prototype, but a larger device like a tablet would be preferred in this case. More testing would be needed to allow a statistically significant decision on this matter.

The post-test SUS questionnaire provided us with positive feedback. Our mean SUS score was of 88.44 (std=9.83) which is in the excellent range.

Concerning tools participants gave scores ranging from 0 to 5 on usefulness, usability and memorability of use which we present in the following table (Figure 8).

	Usefulness	Usability	Memorability
Ruler	4.50 (1.00)	5.00 (1.00)	5.00 (0.00)
Draw Pen	5.00 (1.00)	5.00 (0.00)	5.00 (0.00)
Laser	5.00 (1.25)	5.00 (0.00)	5.00 (0.00)
Pointer	5.00 (1.25)	5.00 (0.25)	5.00 (0.00)
Zoom	5.00 (0.00)	5.00 (1.00)	5.00 (0.00)

Figure 8. Results of the questionnaire regarding the visual tools. Values are Median followed by Interquartile Range in parenthesis.

Regarding preferences and personal experiences between version A or B, the majority of respondents found controlling the images themselves was more natural to them (Median=4.5 IQR=1). Moreover, most users found this accelerated the speed of finishing the tasks at hand(Median=4 IQR=2). All users felt like they were part of the group and participated in the collaborative process of completing the tasks (Median=5 IQR=1).

Concerning users' preference for version B given the added control of images by each individual, we must consider that in an MDTM setting, users might prefer to have the image specialist in control and prefer version A, so further research is required to reach conclusions in this case.

Improvement suggestions of users regarded minor design changes and system performance enhancement. For example, some users suggested changing the image slider into two arrows which instantly change to the following or previous image, or add more visual guides to annotate where the images are situated on the slider to simplify finding a specific image but considering an MDTM setting where large datasets are used this might not be practical. Finally, the visual tools and screen-sharing were seen as sufficient features for group collaboration.

While these sessions cannot simulate the interaction of an MDTM, they allowed us to gather relevant feedback on the system's functionality, ease of use, and applicability to a group setting, without hindering the actual setting of a time-constrained medical meeting.

7. Conclusions & Further Work

We have developed and evaluated a prototype technology for supporting collaboration in MDTMs. Prototype evaluation and semi-structured interviews with groups of lay people provided us with insights into how our system improves collaboration and what further improvements can be made when considering an MDTM setting. Based on the results of this work and further building upon our solution, we can introduce updated versions of our prototype into a medical setting to potentially improve communication and collaboration, leading to safer and faster medical decisions with a positive impact on patient outcomes.

8. References

[1] P. S. Houts, R. E. Lenhard, and C. Varricchio, “ACS cancer facts and figures,” *Cancer Pract.*, vol. 8, no. 3, pp. 105–108, 2000, doi: 10.1046/j.1523-5394.2000.83001.x.

[2] B. Kane and K. Groth, “Multidisciplinary work practices: A comparison of three major European Hospitals,” *Proc. - IEEE Symp. Comput. Med. Syst.*, no. August 2015, pp. 369–375, 2014, doi: 10.1109/CBMS.2014.14.

[3] B. Kane, S. Luz, D. S. Sean, and R. McDermott, “Multidisciplinary team meetings and their impact on workflow in radiology and pathology departments,” *BMC Med.*, vol. 5, pp. 1–10, 2007, doi: 10.1186/1741-7015-5-15.

[4] S. Rowlands and J. Callen, “A qualitative analysis of communication between members of a hospital-based multidisciplinary lung cancer team,” *Eur. J. Cancer Care (Engl).*, vol. 22, no. 1, pp. 20–31, 2013, doi: 10.1111/ecc.12004.

[5] O. Frykholm, M. Nilsson, K. Groth, and A. Yngling, “Interaction design in a complex context: Medical multi-disciplinary team meetings,” *Nord. 2012 Mak. Sense Through Des. - Proc. 7th Nord. Conf. Human-Computer Interact.*, pp. 341–350, 2012, doi: 10.1145/2399016.2399070.

[6] B. Kane, S. Luz, and P. Toussaint, “Developing a framework for evaluation of technology use at multidisciplinary meetings in healthcare,” *Proc. - IEEE Symp. Comput. Med. Syst.*, pp. 355–360, 2013.

[7] A. Olwal, O. Frykholm, K. Groth, and J. Moll, “Design and evaluation of interaction technology for medical team meetings,” *Lect. Notes Comput. Sci. (including Subser. Lect. Notes Artif. Intell. Lect. Notes Bioinformatics)*, vol. 6946 LNCS, no. PART 1, pp. 505–522, 2011, doi: 10.1007/978-3-642-23774-4_42.

[8] G. Symon, K. Long, and J. Ellis, “The coordination of work activities: Cooperation and conflict in a hospital context,” *Comput. Support. Coop. Work*, vol. 5, no. 1, pp. 1–31, 1996, doi: 10.1007/BF00141934.

[9] B. Kane and S. Luz, “Information Sharing at Multidisciplinary Medical Team Meetings,” *Gr. Decis. Negot.*, vol. 20, no. 4, pp. 437–464, 2011, doi: 10.1007/s10726-009-9175-9.

[10] E. Tse, S. Greenberg, and C. Shen, “Multi User Multimodal Tabletop Interaction over Existing Single User Applications,” *Hum. Factors*, no. May 2014, pp. 5–7, 2006.

[11] S. Greenberg and C. Gutwin, “Implications of We-Awareness to the Design of Distributed Groupware Tools,” *Comput. Support. Coop. Work CSCW An Int. J.*, vol. 25, no. 4–5, pp. 279–293, 2016, doi: 10.1007/s10606-016-9244-y.

[12] O. Morikawa and Y. See, “HyperMirror : Wdeo Mediated Communication System,” *Proc. 1998 ACM Conf. Comput. Support. Coop. Work*, pp. 149–158, 1998.

[13] W. W. Gaver, “Affordances of media spaces for collaboration,” *Proc. Conf. Comput. Coop. Work*, no. November, pp. 17–24, 1992, doi: 10.1145/143457.371596.

[14] G. C. Van Der Veer, B. F. Lenting, and B. A. J. Bergevoet, “GTA: Groupware task analysis - Modeling complexity,” *Acta Psychol. (Amst).*, vol. 91, no. 3 SPEC. ISS., pp. 297–322, 1996, doi: 10.1016/0001-6918(95)00065-8.

[15] M. Berg, “Accumulating and Coordinating: Occasions for Information Technologies in Medical Work,” *Comput. Support. Coop. Work*, vol. 8, no. 4, pp. 373–401, 1999, doi: 10.1023/A:1008757115404.

[16] G. Munkvold, G. Ellingsen, and E. Monteiro, “From plans to planning: The case of nursing plans,” *GROUP’07 - Proc. 2007 Int. ACM Conf. Support. Gr. Work*, pp. 21–30, 2007, doi: 10.1145/1316624.1316628.

[17] J. Li, T. Mansfield, and S. Hansen, “Supporting enhanced collaboration in distributed multidisciplinary care team meetings,” *Proc. - IEEE Symp. Comput. Med. Syst.*, pp. 482–487, 2008, doi: 10.1109/CBMS.2008.85.

[18] E. L. Sallnäs, J. Moll, O. Frykholm, K. Groth, and J. Forsslund, “Pointing in multi-disciplinary medical meetings,” *Proc. - IEEE Symp. Comput. Med. Syst.*, no. June, 2011, doi: 10.1109/CBMS.2011.5999133.

[19] H. Ishii, M. Kobayashi, and J. Grudin, “Integration of Interpersonal Space and Shared Workspace: ClearBoard Design and Experiments,” *ACM Trans. Inf. Syst.*, vol. 11, no. 4, pp. 349–375, 1993, doi: 10.1145/159764.159762.

[20] M. Wittkämper, I. Lindt, W. Broll, J. Ohlenburg, J. Herling, and S. Ghellal, “Exploring augmented live video streams for remote participation,” *Conf. Hum. Factors Comput. Syst. - Proc.*, pp. 1881–1886, 2007, doi: 10.1145/1240866.1240915.

[21] B. Dai and X. Yang, “A low-latency 3D teleconferencing system with image based approach,” *Proc. - VRCAI 2013 12th ACM SIGGRAPH Int. Conf. Virtual-Reality Contin. Its Appl. Ind.*, pp. 243–247, 2013, doi: 10.1145/2534329.2534359.

[22] R. Pizarro, M. Hall, P. Bermell-Garcia, and M. Gonzalez-Franco, “Augmenting remote presence for interactive dashboard collaborations,” *Proc. 2015 ACM Int. Conf. Interact. Tabletops Surfaces, ITS 2015*, no. February, pp. 235–240, 2015, doi: 10.1145/2817721.2823486.

[23] J. Li, S. Greenberg, and E. Sharlin, “A two-sided collaborative transparent display supporting workspace awareness,” *Int. J. Hum. Comput. Stud.*, vol. 101, no. April 2016, pp. 23–44, 2017, doi: 10.1016/j.ijhcs.2017.01.003.

[24] Y. Sun and S. Greenberg, “Places for lightweight group meetings: The design of come together,” *Proc. 16th ACM Int. Conf. Support. Gr. Work. GROUP’10*, no. December 2010, pp. 235–244, 2010, doi: 10.1145/1880071.1880111.