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Mediating Presence in Virtual Design Thinking workshops

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Abstract

Design teams have been collaborating virtually due to the increasing demands of the globalized industry. The COVID-19 pandemic made virtual collaboration a necessity due to social restrictions imposed globally in 2020 and 2021. Design teams use virtual Design Thinking to collaborate remotely in real-time. The outcomes of Virtual Design Thinking rely on team composition, planning, the structure of activities, time management, and the choice of space and tools. While these factors have been researched in the context of traditional Design Thinking workshops, research on the selection of tools in virtual workshops is scarce due to the sudden increase in popularity and demand.

This thesis investigates the experience of participants in virtual Design Thinking workshops with a focus on the collaborative environment and the tools used within. Existing literature and participatory observations revealed that remote teams collaborate primarily in two-dimensional (2D) virtual environments using a combination of virtual whiteboards and video conferencing software. Participants face challenges due to the lack of 'presence.' Presence is an emerging topic in recent literature, especially in the context of immersive virtual environments such as three-dimensional (3D) and Virtual Reality (VR). However, these virtual environments are still in their infancy and require further development for conducting virtual Design Thinking.

Qualitative research in the form of participatory observations of four virtual design thinking workshops and in-depth interviews of seven participants revealed the challenges participants face due to the lack of presence. Approaches to mediate presence were explored with the design of a 2D experimental virtual collaborative environment designed to support virtual Design Thinking methods based on the findings. The environment was tested with seven participants.

Results indicated an improvement in participants' experience compared to existing virtual collaboration environments and reported the overall experience to be on par with traditional Design Thinking workshops. The outcome of this thesis has vital implications on the choice and future development of virtual collaboration tools in the post-pandemic world.

Keywords Virtual Design Thinking, Virtual Collaborative Environment, Information and Communications Technology, Presence

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Ameya Chikramane

1 Introduction

Virtual collaboration has become a characteristic of current workplace and innovation practices in the increasingly globalized world and a necessity due to social distancing restrictions placed in workplaces globally during the COVID-19 pandemic in 2020 and 2021. This trend has necessitated the transformation of collaborative methodologies traditionally designed for team members in physically collocated spaces. One such methodology is Design Thinking (Design Thinking)– a creative problem-solving approach based on interdisciplinary collaboration popular in business and management fields (Hanttu, 2013; Hassi and Laakso, 2011). Design Thinking is implemented in collocated workshops, planned meetings where interdisciplinary teams collaborate in a shared space. Lewrick, Link, and Leifer (2018) state that "Design Thinking flourishes through interaction, radical collaboration, and the space in which the interaction and collaboration of interdisciplinary teams takes place."(Lewrick et al., 2021, p. 11). Therefore, the shared space or collaboration environment in which the workshop is conducted significantly impacts outcomes, presenting a challenge for geographically distributed teams who collaborate virtually using internet communication technology. The restrictions placed by the COVID-19 pandemic have forced people to rethink how Design Thinking workshops work in virtual collaboration environments (Lewrick et al., 2018; Andersen, Nelson, and Ronex, 2021; Bader et al., 2020).

In the past decade, there has been scholarly interest in virtualizing Design Thinking. Several researchers emphasize transforming Design Thinking into virtual scenarios (e.g., Furmanek and Daurer, 2019; Redlich, 2020; Lattemann, Siemon, Dorawa, & Redlich, 2017). Latteman et al. (2017) describe Virtual Design Thinking (VDT) workshop as a viable method that can exploit available information systems to produce valuable outcomes. This shows that VDT workshops can be successfully transformed into virtual environments. In fact, these researchers identify the advantages of

conducting Design Thinking workshops virtually over traditional (physically collocated) formats.

However, scholars and practitioners in the field admit that transforming Design Thinking for virtual environments is not an easy task. Lewrick et al. (2018) state that switching from physically collocated workshop formats to virtual workshop formats results in gaps that affect the experience of participants. They discuss the role of participants' experiences in influencing outcomes and emphasize the importance of establishing "... a new culture of virtual collaboration to be successful in the long term." (Lewrick et al., 2018, p.8).

Emerging information and communications technology (ICT) tools such as virtual whiteboards are central to the VDT process, and combined with video conferencing applications, form the Virtual Collaboration Environment (VCE) which replaces the physical collaboration environment from traditional collocated Design Thinking workshops. These tools are used to communicate verbally, non-verbally, and develop ideas visually, due to their advanced functionalities (Redlich et al., 2018; Lattemann et al., 2017). Virtual whiteboards are used for their ability to facilitate the transferring design artifacts created during the VDT workshops to the digital world (Wenzel, Gericke, Thiele, & Meinel, 2016; Alahuhta, 2015). While there has been substantial research on the use of interactive whiteboards (which consist of physical hardware used in collocated settings), especially in the context of learning and education (e.g., Hockly, 2013; Milanovic, 2006; Forster and Wartig, 2009), little research exists on their use in VCEs. The rise in information technology has resulted in development of powerful collaborative applications with capabilities to access computer hardware such as cameras, microphones, and other connected peripherals easily. According to Metrigy's workplace collaboration study of 476 organizations, about 44% of the organizations are using or planning to use virtual whiteboards, such as Mural and Miro (Lazar, 2021). This presents several opportunities for the development of features and functionality in VCEs with

the aim of improving the experience of participants using them in the context of VDT workshops.

1.1 Research Questions and Approach

This thesis introduces the concept of virtual whiteboards in the context of VDT workshops and investigates the experience of participants. The research questions that present themselves in these circumstances are:

1. What are the challenges faced by participants in Virtual Design Thinking workshops?
2. How can these challenges be overcome?

To answer the first question, qualitative research in the form of in-depth interviews with VDT participants and participatory observations of VDT workshops were used to gather practical insights into the opportunities and challenges presented by collaborating in VCEs.

A literature review is done to establish background theory. The literature review explores the topic from the lens of virtual collaboration, virtual teams, and related media theories to understand the factors that affect participant experiences.

Qualitative research in the form of in-depth interviews and participatory observations are used to understand the experience of participants and gain insights about their behaviors in VDT workshops. The findings are used to answer the first research question. Based on the findings from the qualitative research, a hypothesis is formed to answer the second research question.

To answer the second research question, this study proposes an experiment. The hypothesis derived from the qualitative research is used to design an experimental VCEs. The effectiveness of the proposed VCE is tested with seven participants and data is gathered using a combination of action-based and perceptual approaches to derive results.

1.2 Scope and focus

Initially, this thesis started out exploring the experiences of participants in remotely conducted Design Thinking workshops. The literature review revealed the nature of remote collaboration in VDTs. Hence, this thesis narrows down the scope to experiences of VDT participants in VCEs.

The use of the term 'virtual' implies that all team members may not physically present in the 'real' physical space or environment. Literature does acknowledge that Design Thinking is often implemented in mixed situations (Redlich et al., 2018) where some participants may be physically collocated and some might be geographically dispersed, and addresses this situation with the term 'semi-virtual.' Since this study focuses on remote workshop formats in situations where all team members are geographically dispersed and collaborate remotely, especially when it is not possible to gather team members in a collocated space (e.g., pandemic lockdowns), the use of the term 'virtual' also implies 'participating remotely.'

Due to the sudden increase in remote working behaviors, the demand for collaborating in two-dimensional (2D) VCEs is increasing. Recent research on VCEs increasingly explores three-dimensional (3D) VCEs and their potential for supporting VDT tasks (e.g., Alahuhta, 2015; Qvist et al., 2015). However, these kinds of VCEs are still in their infancy especially in collaborative applications, require cost-intensive interfaces and hardware (Jalo et al., 2020; Holopainen, 2020). Hence, while this study does touch upon research into immersive VCEs, it focuses on the experiences and functionalities afforded by 2D VCEs.

Further, while Design Thinking (whether traditional or virtual) has an asynchronous component– tasks, activities and communication using email, chat applications or project management applications (Lewrick et al., 2018; Andersen et al. 2021), this study focuses only on the synchronous component of VDT (workshops) where participants collaborate in real-time.

1.3 Structure

Chapter 1 introduces the topic of the thesis, the research questions, scope, and thesis structure. Chapter 2 reviews existing literature on the topic of VCEs in the context of virtual collaboration and related media theories. Based on the findings in the literature review, the research questions are modified.

Chapter 3 describes the research activities carried out to answer these research questions. Qualitative research is done to explores the context of use, existing solutions, and challenges that affect the experience and outcomes of remote collaborative virtual workshops. This chapter attempts to answer the research questions modified in Chapter 2.

Chapter 4 ideates an experiment based on the findings from Chapter 3 to test the answers and presents the results of the experiment.

Chapter 5 concludes the thesis with a discussion on the results and limitations of the study, the implications and applications of the findings of this thesis, and discusses potential future study directions.

2 Literature review

This chapter reviews existing literature in the field of VDT, VCE and examines existing research on participants' experiences from a perspective of virtual collaboration and virtual teams. Further, it reviews well-established media theories to understand how VCEs contribute to these experiences.

2.1 Design Thinking

To better understand the processes and behaviors in Virtual Design Thinking (VDT), this study first lays out the background on the concept of Design Thinking. Design Thinking is an innovative approach to solve problems in complex societal structures, business strategies, and today's competitive industrial scenario (Lee, Ostwald, and Gu, 2020).

Hanttu (2013) observes that other domains in the context of business design and innovation, such as 'service design' and 'strategic design,' have similarities to Design Thinking in terms of the process and methods and focus on multidisciplinary work, problem definition, and visualization activities. The difference lies primarily in the expected outcomes– whereas service design has more user-centered outcomes, strategic design links to innovation and business value.

Design Thinking provides a creative framework to achieve these outcomes and hence is a viable method in these domains. Furmanek and Daurer (2019, p.1848) state that "In the last decade, Design Thinking has evolved into a method, not only to support innovation, but also to offer a process to improve and to accelerate the creativity of teams." Thus Design Thinking can be considered an umbrella term to cover creative business, innovation, and service design methods.

2.1.1 Design Thinking Process, Methods, Mindset

Kleinsmann, Valkenburg, and Sluijs (2017) state that "...Design Thinking is a multifaceted concept"(p.26), and its ambiguous nature has led to varying

approaches in implementation. Practitioners and scholars in the field have come up with different models(processes) of implementing Design Thinking based on the context of its discourse, its application, and the desired outcome (Hanttu, 2013; Hassi and Laakso, 2011). Popular models include Stanford Design Schools's Design Thinking model and Ideo's model by Tim Brown.

Despite the postulation of these different models, the following phases are common to the most popular Design Thinking models– 1)Understand/Empathize, 2) Define, 3) Ideate, 4) Prototype, and 5)Test. While these phases may be broken down into smaller steps or combined into bigger ones, essentially, they broadly cover methods used in the Design Thinking process (Dam and Siang, n.d.)

Understand/Empathize: This phase is used to establish a shared understanding of the problem and is characterized by team members' knowledge-sharing activities. Design Thinking benefits from multidisciplinary teams, which can facilitate rich and diverse knowledge transfer (Furmanek and Daurer, 2019). This phase may also involve researching the various nuances and complexities of the problem or behaviors and feelings of end-users. Methods include interviews, surveys, and questionnaires or observation-based research to understand the problem statement better.

Define: This phase redefines the problem in light of the new knowledge obtained from the previous phase. Often the problem statement is narrowed down to a specific scope by constraining its use cases or target audience. Activities include grouping, voting, and selecting relevant insights or information that may aid in forming solutions.

Ideate: The ideation phase is where solutions are generated. Furmanek and Daurer(2019) state that it is " ...the core of Design Thinking, in this phase most of the creativity and innovation takes place." (Furmanek and Daurer, 2019, p.1849) and involves creativity-based activities such as brainstorming, grouping similar ideas, and selecting the best ones by voting.

Prototype: The ideas generated in the ideate phase are narrowed down and concretized to their effectiveness and applicability. Activities such as rapid sketching are used, and the outcomes are often low-fidelity representations of the intended solutions.

Test: The concretized ideas from the previous step are tested with end-users or applied in simulated or real-life problem scenarios to gather feedback and decide the solution's applicability to the problem statement. Activities involve user testing and observation-based research to verify the effectiveness and applicability of solutions.

While the Design Thinking process can be characterized by the phases discussed and the activities/methods they cover, literature also points to the importance of a specific Design Thinking mindset (Latteman et al., 2017). Hassi and Laakso(2011), in the context of Design Thinking for management and business discourse, suggest that it requires an experimental and explorative mindset which is tolerant to ambiguity, optimistic and future-oriented. Lewrick et al. (2018) state that "Design Thinking flourishes through interaction, radical collaboration, and the space in which the interaction and collaboration of interdisciplinary teams take place.' (Lewrick et al., 2018, p.11) Thus, implementing Design Thinking is not just about following a process and certain steps or methods but also about adopting a specific mindset that enables its implementation.

2.1.2 Design Thinking Workshops

The characteristics of Design Thinking in terms of phases and mindset reveal that communication and social interaction among participants is necessary take advantage of the interdisciplinary knowledge and effectively disseminate it in a multidisciplinary team. To enable effective communication and social interaction while carrying out the activities, Design Thinking is often planned in the form of workshops. The term workshop implies a planned event where all members of the design team are expected to put away other tasks or activities and focus on the design process for a set amount of time, often with an intention to achieve a pre-determined

goal. A workshop is usually interactive, and expects active inputs from a relatively small number of participants while creating something new or generating ideas (Andersen et al., 2021). Redlich (2020) cites Furmanek and Daurer (2019) on the nature of communication by stating that it is "... a combination of direct group discussions, one-to-one/side-talks, as well as visual communication with the help of whiteboards or similar visualization media." (Redlich, 2020, p.113) Due to nature of the Design Thinking phases that require team members to communicate and interact simultaneously, the workshop activities are often carefully planned, timed and structured.

Alahuhta (2015) highlights the role of artifacts in Design Thinking, which serve as external representations of team member's knowledge and are central to effective team communication. This study describes artifacts as representations of a team's knowledge, and are often representations of objects, processes, and people. Design artifacts such as sticky notes, markers, voting dots or representative objects aid in drawing, sketching, prototyping and presenting ideas. These artifacts serve as a common medium to base the discussion upon, and are therefore simple or versatile enough to accommodate the knowledge in a way that can be easily grouped together, broken apart or re-arranged.

2.1.3 Face to Face communication

In the context of design collaboration, the literature reveals the importance of face-to-face (F2F) communication. Lewrick et al. (2018) state that F2F communication is effective due to clear verbal and non-verbal cues. For example, a person in a face-to-face setting can quickly address a particular team member by just facing them without explicitly calling out their name (Sirkin, Ju and Cutkosky, 2012). Attention can also be directed toward specific design artifacts or team members by facing the speaker, thus contextualizing the conversation richly. Hantula et al. (2011) state seven key elements that characterize F2F communication in organizational settings:

> *First, individuals are co-located and can see and hear one another. Next, there is a high degree of synchronicity that allows individuals to quickly*

interact with each other. Third, individuals have the ability to observe and convey facial expressions. Fourth, individuals are able to observe and convey body language. Fifth, individuals can convey and listen to oral speech. Sixth, individuals are able to engage in mutual gaze; making and holding (or avoiding) eye contact, and seeing where other people are looking. Finally, individuals are able to use and sense subtle olfactory and tactile stimuli, such as pheromones or a light touch. (Hantula et al., 2011, p.343)

F2F communication is considered a precursor to developing trust amongst team members, which is crucial for effectively exchanging information among multidisciplinary and diverse teams. Nandhakumar and Baskerville (2006) state that this trust may dissipate over time with the lack of F2F interactions in any collaborative team due to misinterpretation of information due to lack of non-verbal cues (Lee Kelly et al.,2004, as cited in Nandhakumar and Baskerville, 2006). F2F interactions are instrumental to forming rapid group identities to understand and adjust team members' mental representations. F2F interactions provide cues for time management and help team members renew enthusiasm and energy (Maznevski and Chudoba, 2000, as cited in Jarvenpaa, Shaw and Staples, 2004).

Therefore, it is apparent that establishing clear communication and enabling F2F interactions are essential to support the Design Thinking mindset and successfully effectuate the phases of Design Thinking.

2.1.4 Collaborative space and environment

The previous section reveals the importance of communication and especially F2F interactions in Design Thinking. The physical space in which the team members meet and perform Design Thinking is equally important as it provides the shared collaborative space that enables these interactions. The collaborative environment serves as a platform for Design Thinking and

is necessary to display and interact with design artifacts used and produced during the Design Thinking process. Alahuhta (2015) states that these artifacts are incomplete representations of the knowledge being shared. Instead, they are used to support conversations. Hence, design artifacts depend upon the mechanics of interaction that occur in their context.

In the context of Design Thinking workshops, Lattemann et al. (2017) state that "the design of the space and surroundings, such as moveable furniture, tools and materials, visualization of new ideas foster creativity" (Lattemann et al., 2017, p.36). Vogel et al. (2021) state that according to the theory of organizational creativity, the physical environment can influence a team's creative performance and is essential to effectuate the open, experimental, and empathetic Design Thinking mindset. Therefore, the collaborative space in which Design Thinking teams operate enables effective communication and impacts team creativity.

2.2 Virtual Design Thinking

Virtual Design Thinking (VDT) emerged from attempts at transforming Design Thinking activities to virtual environments due to the shift in the workforce behaviours towards virtual collaboration following digitization and the resulting communication technologies that enable remote work. Further they observe that Design Thinking is originally a method practiced in collocated setups.

The development of ICT technologies presents a solution to overcoming the challenge of location dependence in Design Thinking. Redlich (2020) states that the availability of ICT-based collaboration tools have reduced the need for F2F communication. Lee et al. (2020) reinforce this idea by acknowledging the progressive nature of Design Thinking by stating that it adapts to the globalization of the workforce by adopting new technology.

Thus, the shift in Design Thinking towards VDT is motivated not only by the industry's growing requirements but also by the development of ICT that has enabled remote work and virtualization of team activities Furmanek and

Daurer (2019). The following section presents the opportunities presented by ICT in the virtualization of Design Thinking and the resulting advantages of VDT.

2.2.1 Advantages and Opportunities

Literature on VDTs suggests that collaborating virtually offers several opportunities and advantages over traditional collocated Design Thinking collaboration. The advantages discussed in recent work (e.g., Lewrick et al., 2018; Andersen et al., 2021; Redlich 2020) can be broadly divided into four categories– time and cost efficiency, availability of ICT tools that enable virtual collaboration, and better participation dynamics.

Time and Cost: VDT has precise cost and time advantages from reduced travel and space requirements. Redlich (2020) states that cost advantages serve as the initial motivation for a VDT approach. Latteman et al. (2017) found that team members generated more creative outputs in less time in VDT than in traditional Design Thinking settings. In VDT, time efficiency is increased due to reduced travel, and when planned well, it also reduces the time spent during the process. Combined with the possibility of providing multiple touchpoints, participants can benefit from shorter and more frequent sessions (Andersen et al., 2021).

Communication, visualization and documentation efficiency: According to Redlich (2020), the availability of ICT tools developed in recent years makes VDT a viable approach, as it diverse types of communication such as verbal communication and information visualization. Audio and video communication tools provide a channel for live video-based communication which can effectively transmit facial expressions and even non-verbal gestures to a certain extent. The use of virtual whiteboard tools enables visualization and simultaneous interaction by multiple participants (Lazar, 2021). Further, using these tools has caused new dynamics in virtual communication, such as using emojis for non-verbal reactions (Lewrick et al., 2018). It can bring participants closer to the action of Design Thinking activities.

CMCs afford ready digital results and quick documentation. Lerwick states that this also enables sharing information quickly and easily without media interruption. Redlich (2020) states that digitization of recurring tasks and easier visualization afforded by the use of ICT leads to greater efficiency in VDT.

Personality Expression: Scholars have also discussed how VDT encourages participants to be more open and communicative. Lewrick et al. (2018) state that virtual collaboration makes it easier for some participants to contribute by lowering mental barriers and producing more output. The virtual environment may also encourage equality amongst participants with varying dominance in physical environments. Jarvenpaa et al. (2004) suggests that in virtual, since people do not have individuating information and hence, people assume similarity and tend to reveal factors and cues that reinforce this similarity.

2.2.2 Challenges and Drawbacks

While literature reveals the advantages to the transformation of Design Thinking to VDT, it also acknowledges the challenges that such a transformation presents. These challenges arise primarily from the change in the collaborative environment and the resulting change in communication and interaction dynamics amongst team members.

Physical Space: The lack of shared physical space and the resulting change in communication dynamics make controlling distractions and grasping participants' attention harder (Andersen et al., 2021). It is also harder for team members to judge whether their contributions are acknowledged due to the lack of body language. The lack of natural F2F conversations in a physical space makes simultaneous conversations and cues for participation difficult (Furmanek and Daurer, 2019). Further, it is harder for team members to address other team members or artifacts in the context of their

discussion using familiar gestures such as eye and head movements (Hantula, 2011). The lack of physical space may also affect the establishment of trust and interpersonal interactions amongst participants (Jarvenpaa et al., 2004)

Technological Ambiguity: VDT presents more significant uncertainty and ambiguity in the understanding of tasks and information. Grasping the overview of the workshop can be complex (Lewrick et al., 2018). According to Redlich (2020), a prerequisite to effective VDT is establishing a shared mental model, which is more challenging in virtual environments due to time constraints and virtual interdependence on other team members. The ambiguity may also arise from the introduction of new technology or sudden ICT intervention. Brown, Poole, & Rodgers (2004) found that introducing new technology to participants may affect trust dynamics amongst participants if they are uncomfortable or unfamiliar with it. Redlich (2020) states that applying audio-/videoconferencing may lead to reduced attention due to higher efforts in cognition (Karpova et al., 2009, as cited in Redlich, 2020)

Temporal effects: Time management is also different in VDT, as team members are limited to speaking one at a time, and natural verbal and non-verbal interruptions that occur in physical spaces may prove counter-intuitive in virtual environments. Redlich (2020) states that participants face greater exhaustion in VDTs due to their long and intense nature. Overall, implementing VDT over shorter time frames and with fewer touchpoints can affect the team performance negatively (Redlich 2020; Nandhakumar and Baskerville, 2006)

Emotional Effects: According to Lewrick et al. (2018), it is harder for participants to exhibit their personalities, and there is a lack of interpersonal interactions, which may cause shyness and inhibition. On the other hand, this may cause lengthy discussions or monologues amongst more dominant individual participants, resulting in unpredictable dynamics and unequal participation. The resulting social and cultural distance amongst team

members affects their creative contributions as they cannot build intimacy and trust (Brown et al., 2004). Nandhakumar and Baskerville (2006) found that people behave differently in virtual environments, and the lack of a shared social context eventually leads to lower confidence and motivation. Recent literature acknowledges the emergence of camera shyness, inhibition, and exhaustion caused by participants observing their faces in the videoconferencing software (Ming et al., 2021). Latteman et al. (2017) found that participants prefer collocated F2F collaboration despite the successful performance of VDT.

Thus, while there are advantages to VDT and opportunities that make it a viable option in remote working situations, several obstacles arise from collaborating virtually. The adverse temporal effects can be overcome through careful planning, leadership, and facilitation of the workshops Setting the right expectation for participants and familiarizing them with ICT tools before starting the workshop can help to clear virtual and technological ambiguity (Andersen et al., 2021; Lewrick et al., 2018). Establishing clear communication protocols can help establish positive group dynamics to overcome some obstacles caused by the lack of F2F interactions (Jarvenpaa et al., 2004). However, this may cause adverse emotional effects in ad-hoc groups with varying individual personalities (Nandhakumar and Baskerville, 2006). Choosing the right ICT tools that enable effective virtual collaboration is necessary for performing VDT effectively (Redlich, 2020; Furmanek and Drauer, 2019). The following section dives deeper into the role of VCEs.

2.3 Virtual Collaborative Environments

In virtual collaboration, the lack of physical space and its resulting challenges are overcome using ICT (Redlich, 2020), which in the context of this study is referred to as the virtual collaborative environment. In VDT workshops, synchronous communication is established using audio-/videoconferencing tools, and workshops activities are mediated using shared visualization tools such as virtual whiteboards. These ICT tools make up the VCE that acts as a Design Thinking playground and replaces the physical space from traditional Design Thinking workshops.

2.3.1 Current state of VCEs

Typical ICT tools/applications and their functionality that make up the VCE in have been previously revealed to be virtual whiteboards and audio-/videoconferencing applications. In terms of hardware, the typical requirements for each participant include an internet-enabled device such as a desktop computer, laptop, tablet, or mobile phone equipped with a microphone and webcam. (Andersen et al., 2021) It should be noted that currently, these environments are primarily two-dimensional with a limited spatial agency within their application contexts. Here, spatial agency refers to the ability of the participant to move in the collaborative space. While existing whiteboard applications provide a sense of spatial agency by displaying the collaborators' mouse-pointers (which serve as representations of their presence) in the session, they do not sufficiently embody the essence of the participant (Ming et al., 2021).

Scholars emphasize the importance of selecting the right ICT tools to enable effective virtual collaboration (Redlich, 2020; Furmanek and Daurer, 2019). Redlich (2020) introduces the concept of Shared Mental models as knowledge structures that represent the common understanding of the tasks and activities in Design Thinking. Further, the study states that the choice of technology influences these shared mental models immensely. More specifically, Redlich (2020) states that VCEs need to embody the appropriate

virtual functionalities to enable the advantages of performing VDT. However, scholars agree that these virtual functionalities are constrained by the choice of ICT tools (Vogel et al., 2021; Lattemann et al., 2017; Furmanek and Daurer, 2019). Therefore, the choice and implementation of ICT tools influence the outcomes of the workshops based on the successful establishment of SMMs and the experience of participants performing VDT.

2.3.2 Immersive VCEs

In the past year, research on VDT has advanced from conventional two-dimensional (2D) VCEs, which combine audio-/videoconferencing, to three-dimensional (3D) and Virtual Reality(VR) based environments. The primary motivation behind these advances is to take advantage of the increased immersion and the effect of "presence", and the resulting increase in engagement that these environments offer (Vogel et al., 2021, Alahuhta, 2015). Literature identifies presence as an essential factor to enable better virtual collaboration in creative contexts (Alahuhta, 2015; Vogel et al., 2021). Alahuhta(2015) outlines specific affordances provided by immersive environments such as avatars, co-presence, media richness, and simulation capabilities that improve creative performance in virtual collaboration.

Further, the immersive nature in these VCEs and the resulting "presence" are factors that mitigate the challenges presented by the lack of physical space and the resulting emotional effects that make them particularly suited for VDT (Alahuhta, 2015). According to Willans, Rivers, & Prasolova-Førland (2016), there is "...a correlation between emotion and presence" (Willans et al., 2016, p.181), indicating that presence enables the emotional aspects of the Design Thinking mindset. Further, they state that "...the presence experienced in 3D environments also applies to within the context of natural and 2D environments" (Willans et al., 2016, p.182), indicating that the concept of presence (and immersion) is not confined to immersive environments. These statements motivate the application of presence from the context of virtual environments to mitigate the challenges that arise from

the lack of physical space (i.e., immersion) and the resulting emotional effects in 2D VCEs.

2.4 Presence in VCEs

Recent studies explore the concept of presence in the context of virtual environments (e.g., Kirjonen, 2020; Vogel et al., 2021; Alahuhta, 2015). According to Slater and Sanchez-Vives (2016, p.5) presence in virtual environments is a sense of "being there," experienced due to feeling immersed in the virtual environment. The terms immersion and presence are interchangeably used in the context of virtual environments. However, Kirjonen(2020) draws the following distinction between them: while presence is a subjective experience of a person immersed in a virtual environment, immersion is an objective property afforded by the said virtual environment. While presence is a subjective experience of a person immersed in a virtual environment, immersion is an objective property afforded by the said virtual environment. Hindmarsh et al. (2001) classify presence in virtual environments in terms of personal presence (the experience of finding oneself immersed in the virtual environment), social presence (experiencing interactivity with others immersed in the virtual environment), and environmental presence (experiencing interactivity with the elements of the virtual environment). This classification is helpful for this thesis due to its collaborative perspective of user experiences in virtual environments. Alahuhta (2015) states that the experience of feeling co-presence (or social presence) and the subjective experience of being immersed (personal and environmental presence) contribute towards engaging team collaboration. Kirjonen(2020) emphasizes the importance of spatial agency as a contributing factor to the experience of personal presence. The affordance of these three components of presence makes immersive VCEs ideal for virtualizing collaborative methods such as Design Thinking.

Willans et al. (2016), Vogel et al. (2021), Ming et al. (2021), and Alahuhta (2015) mention avatars as representations of team members or participants

in 3D and VR-based collaborative environments. According to Alahuhta, avatars serve as agents to identity and expression amongst participants in VCEs. They can be used, for example, to enrich conversations and provide a sense of co-presence. Further, avatars in immersed VCEs can incorporate rich communication such as gestures or facial expressions, thus serving as agents of embodied interactions. The embodiment of interactions through avatars in immersed VCEs affords a sense of spatial agency through movement in the virtual space, thus contributing to the personal and environmental presence (Kirjonen, 2020; Alahuhta, 2015). Further, avatars enable co-presence by reducing some of the potential biases participants may develop (Alahuhta, 2015) and alleviate shyness or anxiety caused by webcam use (Ming et al. 2021). Thus, avatars with spatial agency can be considered enablers of presence.

However, the phenomenon of presence is also present in 2D conventional collaborative platforms that lack the concept of avatars. For example, Jarvenpaa et al. (2004) state that the communication behavior and dynamics within a virtual team signify the existence of other team members (Jarvenpaa et al., 2004). Willans et al. (2016) state that "Emotion and presence experienced while interacting in three-dimensional (3D) synthetic environments also applies within the context of natural and two-dimensional (2D) environments" (Willans et al., 2016, p.182). In conventional VCEs that support VDTs, participants interact not only with each other in audio/video-conferencing tools but also with design artifacts visualized in virtual whiteboards. However, the experience of presence in 2D VCEs is not integrated nor embodied, and participants need to frequently shift contexts between applications for successful collaboration. The lack of avatars and spatial agency reduces the sense of personal presence. Further, presence in immersive VCEs is enabled by factors such as field of vision and better contextual referencing, limited in 2D VCEs (Steed and Shroeder, 2015). These limitations contribute negatively to the creative performance of virtual teams in such environments.

Therefore, while there is a sense of presence in 2D VCEs, it is insufficient to overcome the challenges of the lack of physical space. While there are several advantages of immersive environments for other applications such as gaming, entertainment, and online education, the mediation of presence is the primary advantage of immersive VCEs over 2D VCEs in the context of VDT.

2.5 Media Theories

Virtual collaborative methods such as VDT are enabled by ICT tools used in the VCE. In the context of VDT, literature discusses the following media theories that support the opportunities and challenges afforded by VCEs: Media Richness Theory (Daft and Lengel, 1986), Media Naturalness Theory (Kock, 2011), and Media Synchronicity Theory (Dennis et al., 2008). These theories reflect the influence of emotional, experiential, and evolutionary aspects of humans on virtual performance (Redlich, 2020). The Media Richness Theory measures the richness of communication media and states that richer media effectively transfers information in collaborative activities (Daft and Lengel, 1986). The relevance of this theory is evident in VDT conducted in 2D VCEs that use virtual whiteboards for visualization and audio/video-conferencing for verbal communication (Redlich 2020). Thus, while the ICT tools used in 2D VCEs may individually be leaner forms of communication media, they can prove to be richer when combined. However, combining different communication mediums (using separate ICT tools) in 2D VCEs is complicated by the Media Naturalness Theory (MNT). According to MNT, the use of communication media such as ICT, which can be unnatural from an evolutionary perspective and suppress key features of F2F communication found in natural, physical environments, can negatively affect cognition, especially in complex collaborative tasks (Kock, 2004). While conventional 2D VCEs may use video conferencing to enable F2F communication, it requires participants to switch their attention from visualized information towards video thumbnails of participants. Often this requires switching ICT tool contexts, which can cause further cognitive load

in participants. In immersive VCEs, the use of avatars may somewhat reduce this effect as they are collocated with visualized information or design artifacts (Alahuhta, 2015; Vogel et al., 2021) and hence provide better synchronicity in communication. However, the effectiveness of using avatars is influenced by their fidelity and the degree to which they can embody participants' facial and body gestures (Ming et al., 2021).

Hantula et al. (2011) explain the concept of media naturalness in the context of VCEs by depicting F2F communication (implying physical environments) in the center of a one-dimensional scale with increasing richness. The naturalness of the medium falls on either side of the center, implying that F2F communication in physical environments affords the highest degree of naturalness. Both immersive VCEs and conventional 2D VCEs fall short of naturalness.

The Media Synchronicity Theory (MST) (Dennis et al., 2008) may provide a possible explanation for this loss in naturalness. The MST states that the synchronicity of a communication medium must sufficiently support the synchronicity that the communication process requires. Dennis et al. (2008) define synchronicity as a "state in which individuals are working together at the same time with a common focus" (Dennis et al. 2008, p.581). Design Thinking is a set of complex communication processes that enable collaboration over shared goals, and hence this theory applies to VDT.

Conventional 2D VCEs use a combination of ICT tools to set up different media channels per MRT. However, the lack of multimodality in media, stemming from using separate ICT tools, affects synchronicity. Redlich (2020) reveals the influence of the Mcgurk Effect (McGurk and MacDonald 1976, as cited in Redlich, 2020) in virtual communication, which states that understanding speech requires not just a sense of hearing but also seeing. Kirjonen(2020) and Vogel et al. (2021) discuss the limitations of using advanced equipment to enable effective collaboration in immersive environments. While these immersive environments enable better synchronicity due to their multimodal nature, a greater effort is required

from the participants due to increased cognitive loads. Distractions from using the hardware can also negatively affect the naturalness of these environments (Kirjonen, 2020). Hantula et al. (2011) warn that immersive VCEs can become "super-rich" (Hantula et al., 2011, p.344) and reduce naturalness of a communication medium when compared to physical F2F meetings. Further, the naturalness of immersive environments can be negatively influenced by:

1. The degree of embodiment of participants in avatars and the resulting sense of presence experienced (Kirjonen, 2020; Alahuhta, 2015)
2. The degree of realism in the immersed environment. (Kirjonen, 2020) Here, realism refers to how similar the immersed environment feels to physical environments.

Despite the advantage of immersive VCEs as explained by the media theories, Vogel et al. (2021) admit that they are still not suitable for widespread use, partly due to the fact that they have not been developed specifically for Design Thinking processes. Other reasons include prohibitive costs– these environments require additional hardware such as head-mounted displays (HMD) that come with their own set of challenges and recent advancements that make them cheaper and more accessible do so at the cost of increased discomfort and ergonomic experience (Kim and Shin, 2021). Vogel et al. (2021) also mention their dependence on pre-existing (Computer Assisted Design) CAD models as a prohibitive factor due to the effort involved in their creation.

2.6 Summary

Design Thinking is a recognized method for problem-solving and is especially relevant in today's globalized information-enabled industry. The rise in advancement of ICT has enabled the transformation of Design Thinking

towards virtual implementation. Existing research indicates that current VDTs use VCEs that comprise of a combination of ICT tools such as audio-/videoconferencing and virtual whiteboards and discusses the advantages they offer and the drawbacks in performance and output when compared to traditional collocated Design Thinking formats. While the challenges that arise from technological ambiguity and temporal effects of virtual collaboration can be overcome with careful planning, structure and leadership of the Design Thinking activities, the challenges that arise from the lack of a shared physical space and emotional effects require further examination– specifically with the choice of ICT tools used. The advantages of virtualizing Design Thinking has motivated research in VCEs that support Design Thinking implementation in remote working scenarios.

Recent research has been fuelled by the COVID-19 pandemic and resulting changes in workplace practices, further necessitating the research of suitable VCEs that support VDTs. The advances in 3D and VR environments has inspired scholars and practitioners to use it as a collaborative environment to implement VDT, but these environments are currently not suitable for widespread use. However, the insights from this research can be used to improve the experience afforded by 2D VCEs– specifically the lack of presence in existing 2D VCEs can be overcome without having to deal with the issues with 3D and VR environments.

To further understand the factors that contribute to presence in VCEs, the term is examined from the perspective of media theories such as MST, MNT, and MRT based on the approaches by previous scholars on VDT platforms.

From a perspective of the media theories discussed in the previous section, comparing 2D VCEs to immersive VCEs and collaboration in physical collocated environments shows that 1) Physical collocated environments with F2F communication provide the most natural experience and, thus, are high on the media naturalness scale. 2) Comparatively, 2D VCEs offer richer communication due to the possibility of combining ICT tools but have lower synchronicity due to increased cognitive loads on users 3) Immersive VCEs

are richer compared to 2D VCEs and physical collaboration environments but less natural, as previously mentioned in this section. Figure 1 is an attempt at visualizing the comparative relationships of VCEs from a media theory perspective.

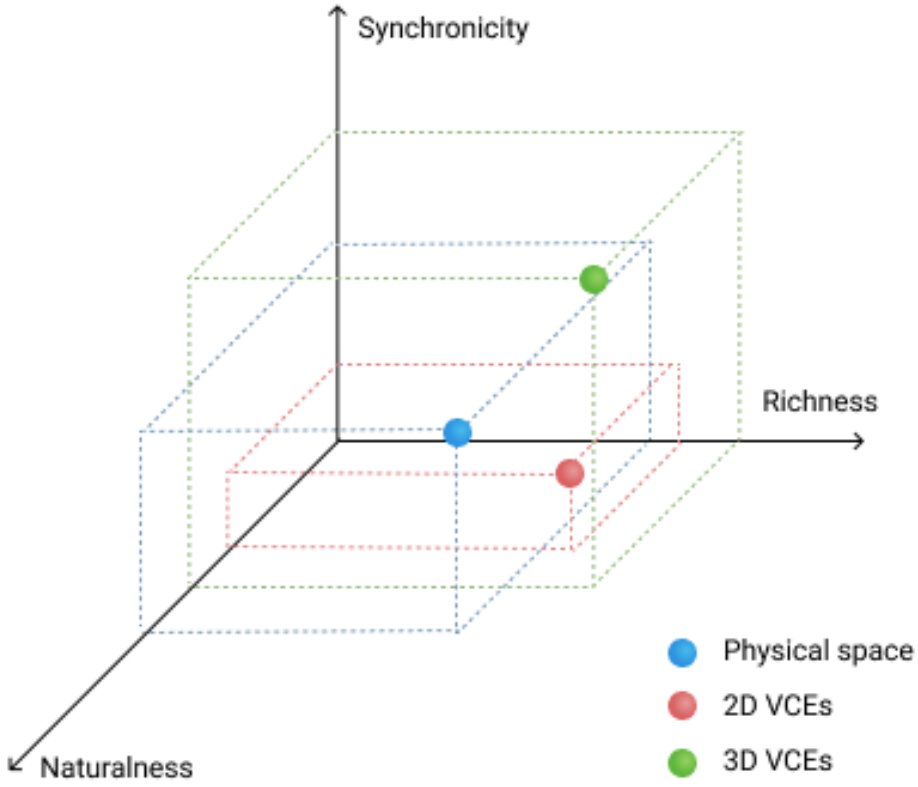

Figure 1 Comparision of VCEs from a the perspective of media synchronicty, media richness and media naturalness

It can be observed from this figure that immersive VCEs provide the most natural experience after physical spaces, which can be attributed to their ability to provide a sense of presence. These findings reveal the relative degree of synchronicity, richness and naturalness in media in physical, 2D and immersive environments.

This raises the question whether the insights from the research into immersive environments can be applied to existing 2D VCEs in their existing

hardware setups with the aim of mitigating some of the challenges that the former tries to overcome. Specifically, whether 2D VCEs can attain a higher degree of naturalness in accordance to MNT by mediating presence.

Therefore, the research questions that this study initially set out to answer are modified as:

1. What are the challenges faced by participants in VDT workshops using conventional 2D VCEs?
2. How can these challenges be overcome within 2D VCEs?

The next chapter describes the research activities carried out to answer these questions.

3 Qualitative Research

The main objective of this study is to understand what are the factors that affect the experiences of participants in VDT workshops in conventional 2D VCEs. This chapter provides an overview of the qualitative research done to this end, by justifying the methodology, describing the data collection process and the methods used to derive insights.

3.1 Chosen Methods

VDT workshops are a relatively new phenomenon. While there are several blogs, websites and publications that speculate possibilities and provide for conducting Design Thinking virtually, there are limited academic studies that specifically address participants' experiences in 2D VCEs. This study applies qualitative research methodology to gain an intimate understanding of the experiences of participants in performing Design Thinking in 2D VCEs. Merriam and Tisdale (2015) describe qualitative research as a broader term that covers several methods used to understand subjective experiences, behavior and interactions. Bogdan and Bilken (1997) posit that it employs methods such as in-depth interviews and observations. The authors mentioned above agree that it is usually used to create concepts or hypotheses from the data gathered using these methods. Hence, qualitative research is chosen as the primary research methodology. The qualitative research done in this study is divided into two parts: In-depth interviews with seven participants of VDT workshops are used to understand their experiences and perceptions, and participatory observations from four VDT workshops are used to gain insights about the participant's activities in a natural setting

3.1.1 In-depth Interviews

In-depth interviews were chosen to gain rich insights about the experience and perceptions of participants in VDT workshops. This section describes the interviews conducted in the summer of 2021 with 7 participants from Aalto

University. The main objective of the interviews was to understand the enablers and challenges they faced by reflecting on past or recent experiences. Additionally, the gaps in the experience of VDT workshops when compared to physically collated formats were also explored. Finally, the interviews allowed participants to generate ideas by speculating solutions to their subjective challenges, thus providing useful clues to future conceptualize solutions.

Interviewees were selected based on their past experience in VDT workshops, either as participants or facilitators, and were interviewed face-to-face (FTF) either remotely using video-conferencing applications (Zoom, Microsoft Teams) or in physically collocated space with appropriate precautions as recommended by health authorities at the time. To ensure a holistic view of the topic, the interviews with varied backgrounds were chosen for the study– teachers, students and professionals from the fields of design, business and engineering (Table 1)

Table 1 Backgrounds of interviewees for in-depth interviews

Interviewee	Background	Primary role in VDT workshops
1	Teacher at Aalto Design Factory, Workshop Facilitator	Facilitator
2	Professor in Computer Science, Aalto University. Experienced in online teaching, conducting remote workshops and software development	Participant, Facilitator
3	Facilitating and managing the Design Factory global network, provide training to staff, especially during the COVID-19 pandemic	Facilitator

4	Master's graduate in Visual Communication Design, Teaching Assistant, User Experience and User Interface Designer	Participant
5	Bachelor's Graduate in Computer Science, Research Assistant, web and mobile developer	Participant
6	Teaching assistant at Aalto Design Factory, Course Coordinator	Participant, Facilitator
7	Manages Aalto Design Factory global network, prior experience in communication and content creation, journalism	Facilitator

The interview scheme was designed to allow interviewees to discuss their experiences participating or facilitating remotely conducted design or decision-making workshops, without mentioning terminology such as "Virtual" or "Presence" to get an unbiased and rounded understanding of their experiences, and the interview topic was introduced as "Remote Design Thinking Workshops". The interview questions were divided into four parts and planned to last an hour.

The first part aimed at discovering what stood out memorably as positive experiences during virtual workshops, and the factors that enabled these experiences. Interviewees were probed on the tools that were used, communication, participation, and engagement.

The second part aimed the opposite– to understand what stood out memorably as negative experiences during virtual workshops and the factors that lead to these experiences. Interviewees were further probed on the specific reasons why they felt that it didn't work.

The third part was designed to build upon the insights gathered from the previous two questions and explore the gaps in the experiences of

participating in workshops run virtually when compared to traditional collocated formats. Based on the answers, interviewees were probed about the role of virtuality in the existence of these gaps or challenges discovered.

The final part invited interviewees to speculate what features or functionality may fill the gaps or exploit success factors established in the former questions. Interviewees were prompted about fictional universes to encourage a sense of freedom from physical or technological limitations while speculating.

3.1.2 Participatory Observations

This section describes the participatory observations conducted in four VDT workshops that took place during the COVID-19 pandemic between the years 2020 and 2021. It can be observed that almost all of these workshops were conducted in completely remote settings, due to the restrictions placed on collocated work at the time. Further, the use of Zoom as a video conferencing tool and virtual whiteboards such as Miro and Mural can be noted in all of these workshops. The participatory observations provided first-hand accounts of my experience as a researcher. The author of this study participated in these workshops as part of 1) minor studies in service design 2) a summer job as a research assistant in a research group at the computer science department at Aalto university 3) a student venture at Aaltoes (an entrepreneur students society at Aalto University) 4) a service design course taught at Aalto Design factory. Details of these workshops such as their purpose, collaboration environment, number of participants and tools utilized, are presented in Table 2.

Table 2 Details of workshops in participatory observations

Workshop Context	Purpose/Project	Role of researcher	Number of participants	Collaborative Environment	Synchronous communication tools
Information Technology Program (Minor studies in service design)	To improve upskilling of employees at a multinational accounting firm	Participant, Facilitator	5	2D VCE, completely virtual with remote participation	Zoom videoconferencing, Miro virtual whiteboard
Research group in the Computer Science department at Aalto University	To disseminate research on Developer Experience using a website and gather data from developers to further the research using a mobile app	Participant, Facilitator	5	2D VCE, completely virtual with remote participation	Zoom videoconferencing, Miro virtual whiteboard
A student venture at Aaltoes	To design branding and service for an e-learning platform that teaches e-commerce to students	Participant, Facilitator	6	2D VCE, mostly virtual with remote participation (In some of the workshops, more than 2 participants were collocated)	Zoom videoconferencing, Miro virtual whiteboard
Aalto Design Factory	Service design course where students work on group projects	Technical Assistant	up to 20, but 4-5 in breakout rooms	2D VCE, completely virtual with remote participation	Zoom videoconferencing, Mural virtual whiteboard

3.1.3 Analysis

The responses from the interviews were transcribed into text, abstracted into simpler data that captured the essence of the response, and separated into positive experiences, negative experiences, speculated desirable features,

and general observations. The participatory observations from these workshops were analyzed similar way. This initial grouping presented an overall understanding of the advantages, opportunities, challenges and drawbacks of performing Design Thinking virtually from an experiential lens of the participants. These sticky notes were then mixed and grouped into broad themes to learn how they contributed to the experience in specific focus areas of research as immersion, the use of whiteboards, participation and the use of non-verbal cues.

3.2 Findings

The qualitative research in the form of in-depth interviews provided rich insights based on interviewees' prior experience with VDT workshops. The participatory observations helped confirm and provide further meaning to these insights, besides generating new insights from the researcher's point of view. Several insights were related to best practices in virtual collaboration in general, such as the importance of planning, structuring the session, and familiarizing participants with the process and tools in advance. These findings agree with the studies conducted by Andersen et al. (2021) and Lewrick et al. (2018).

The findings from this study also reveal the importance setting protocols for content and communication, as these contribute to the efficient use of time, which is limited and often falls short in virtual environments. Time is experienced differently, and participants can feel exhausted much quicker, leading to shorter attention spans in virtual environments. These findings agree with Andersen et al. (2021).

The findings also emphasized the importance of establishing trust and empathy in virtual collaboration as it was reported to influence the creativity and outcomes of the team, which is in line with the findings from Jarvenpaa et al. (2004).

Due to the broad nature of questions in the in-depth interview, a large number of insights were generated. However, since this study explores the experience of participants with VCEs used for VDT, these insights were selected based on the following criteria:

1. Relevance to VDT processes and methods
2. Relating VCEs and ICT tools
3. Relating to synchronous activities

The following discussion is based on insights that satisfy these conditions and form the basis for this study.

3.2.1 Communication in the virtual environment

The findings reveal the importance of naturalness, richness and synchronicity of communication in virtual environments. F2F interactions in physical environments feature synchronous communication of visual, auditory and spatial cues.

Quote: The environment acts as a cue of what's expected from a person

Quote: It's easier to spontaneously react in collocated situations: there are more barriers in remote situations

Due to their naturalness, these cues aid in cognition. Team members used actions such as body movements, hand and facial gestures, spatial position and orientation synchronously to enrich their communication.

Quote: gestures, hand and face expressions are lost

Quote: I would like to point to things while talking about them. If I don't have these ability, I cannot be 100% sure if we are talking about the same things

Quote: It was hard to really assess what the participants felt or to effectively communicate the purpose to them

Quote: Non-verbal feedback from team members isn't apparent, so it can feel like you're putting things out into an empty space

The lack of rich, natural channels for communication caused awkward or unpredictable emotions, especially in participants who are weren't familiar with virtual collaboration. Six out of seven interviewees expressed a desire to be able to communicate body movements, spontaneous reactions, and facial gestures. While conventional VCEs can accommodate multiple channels of communication such as chat, audio, video and content visualization synchronously, there is a limit to the number of channels that participants can effectively experience simultaneously. This constrains the use of the ICT tools for effective synchronous communication, and interviewees reported better experiences when fewer ICT tools were used simultaneously.

Quote: Facilitators were discussing the workshop while outside the breakout rooms and using this time to adapt the workshop.

Quote: Organizers weren't able to communicate with each other effectively

Quote: Working in break-out groups was a bit chaotic

Quote: People came in late, it was hard to place them into the right breakout rooms

Quote: Zoom forces participants to conform to its capabilities

At the same time, it was observed that team members often required separate private communication channels in some situations. For example, when organizers or facilitators needed to speak privately to adapt the workshop activities during the session, or when the methods required participants to break into groups. While in physical environments this is as simple as moving closer to group members and away from others, it was complex to accomplish in VCEs. The participatory observations and interviews reveal the use of 'breakout rooms'– a feature of videoconferencing software (eg. Zoom) for this purpose. However, this completely isolated groups from each other, leading to an unnatural experience and difficulties in asking for help or communicating with other groups.

Quote: Enabling camera video gives the appearance like we're listening

Quote: It is important to be able to look at people in their faces

The combination of virtual whiteboards along with a videoconferencing software was observed to be a common VCE setup that all interviewees were familiar with. This combination provided a balance between rich visualization capabilities and natural communication but lacked the synchronicity of F2F communication in physical environments. Communicating in video conferencing allowed synchronous communication through voice and video channels, accommodating facial gestures and even body movements to enrich verbal communication to some extent. Facial gestures especially helped with communication as they were used not only to enrich verbal communication but to also acknowledge the reception and understanding of information.

Q*uote: Whiteboards are important for larger groups of people to communicate and interact effectively*

Quote: Whiteboards solve this to a certain level, as you can see things happen live (Regarding synchronicity of visual cues in virtual environments)

Q*uote: Combining Miro board with live camera feed worked well*

However, in many phases of Design Thinking, visualizing complex information is often the primary activity. Verbal communication is a secondary activity used to support and contextualize this information. Virtual whiteboards serve as a two-dimensional shared space where this information can be visualized. Here, labeled pointer positions of team members provided spatial cues for contextualizing visualized information.

This forces participants to choose between the cues that aid in verbal communication on videoconferencing software and the cues that aid communicating visualized information on virtual whiteboards, leading not only to a loss of richness and naturalness, but also synchronicity of information.

Quote: Remote ones can be exhausting so they need to be more concise

Quote: The workshop sessions felt very long

Quote: Engagement is inversely proportional to the amount of time

The resulting exhaustion from trying to compensate for the loss of cues combined with the effort of processing leaner non-synchronous information resulted in consequences such as loss of time, a dilated sense of time, reduced engagement and reduced attention spans.

3.2.2 Personality expression and Engagement

The findings from the interview highlight the importance of empathy and trust in VDT. Two interviewees observed that people's personalities change in virtual environments based on their familiarity with the the team members, with the purpose of the workshop, and with the ICT tools being used. Overall, the findings indicate that conventional 2D VCEs have negative effects on participants' personalities.

Quote: It is easier to stand people up in the virtual world.

Quote: people may not communicate as much remotely

Quote: Participants can feel less or more comfortable speaking up in remote versus collocated workshops

Quote: Participants personalities affect each other and influence group outputs

Quote: it's easier to stay mute if camera is off

Quote: not having a video feed makes it easier to miss jokes and fun

Quote: the workshop should feel accessible and accepting

Quote: It is hard to stay engaged when you cannot see the face of the person talking

The findings draw the connection not only between trust, empathy, and personality expression, but also how they influence engagement and creativity of participants. In conventional 2D VCEs, participants aren't able

to express their personalities effectively and form interpersonal connections synchronously using available communication channels. To circumvent this effect, time is set aside for ice-breaking sessions where participants focus on getting to know each other through fun and entertaining activities that are often unrelated to the purpose of the workshop. However, interviewees reported how these sessions were often perceived as trivial, forced, or time-wasting, proving them to be ineffective.

Q*uote: Trust and psychological safety is important to be creative*

Q*uote: It's very important to empathize with the participants to engage them*

Q*uote: Getting to know a bit about participants made them feel more engaged*

Q*uote: People were engaged because they could talk about themselves*

Q*uote: Participants need to be engaged on several levels: intellectually, analytically, emotionally, physically and spiritually*

Q*uote: The main topic is the tip of the iceberg, all the other stuff that happens, like getting coffee, chit chats, is the 90% of the stuff that contribute to engagement in the environment.*

Q*uote: Icebreakers and small talk are important before jumping into workshops*

Q*uote: In collocated situations, there is an energy that you can feel, a collective learning vibe*

Q*uote: Trust is to empathize with me by looking at my surrounding environment*

Personality expression and engagement is enabled by small talk and environmental cues. While small talk and trivial conversations are easier in physical environments, the ICT tools used in VCEs are optimized for collaborative communication on the shared goals of the workshop. The lack of natural environmental cues, spatial agency, and the resulting spatial dynamics (such as having discreet conversations or sharing jokes) makes personality expression challenging and negatively affects participants' engagement in 2D VCEs.

VCEs need to provide spatial agency and accommodate the transmission of non-verbal communication and environmental cues effectively to enable personality expression for better engagement of participants and creative outcomes.

3.2.3 Presence and Immersion

The insights from this study revealed the importance of immersion and the experience of presence in VDT. Interviewees reported immersive experiences in workshops as positive experiences as they were perceived to be more engaging. Further, the dynamics of collaboration in VDT involve the act of gathering around design artifacts spatially. Several interviewees expressed a desire for spatial agency towards establishing shared context.

Quote:... a feeling of space, with the subject matter we are working on to be in the middle of it all

Quote:...the ability for people to gather around things

Quote:... a way to experience spatial arrangements and people's spatial orientations

Quote:... the ability to look at content, and at the participants looking at content

It was previously discussed that virtual whiteboards provide this ability to some extent by providing a shared 2D environment and spatial cues in the form of labeled mouse pointers of team members. These findings reveal that spatial cues are not only enable richer communication, but also provide a sense of immersion. Further, this sense of immersion not only improves the engagement of participants but enables natural collaborative behaviors that occur in physically collocated Design Thinking workshops.

Quote:...maybe you can hear chuckles without bothering the others

Quote: The physical shared environment is more engaging as more senses are captured

Quote: Participants can smell the vibe and opportunity

Q*uote: If you can feel more dimensions, you feel more immersed in the activity*

Q*uote: It is important to see and hear what other groups are doing and to be able to communicate with them.*

The spatial cues to enable immersion are not necessarily visual, they can also be auditory. The auditory cues set up a collective mood in physical collaborative sessions. In some Design Thinking methods, participants are often placed in groups. Interviewees reported that the experience of breakout rooms in VDT, which attempt to simulate this grouping, is an isolating experience. The participatory observations confirm these findings, and also reveal a loss of engagement and motivation in virtual break-out rooms. To this end, several interviewees expressed a desire to have spatial agency in VDT.

Q*uote: Being on a wagon, being taken through the process*

Q*uote: ability to walk around in immersive experiences*

Q*uote: virtual spaces to move from one place to other*

The findings also reveal the importance of participants feeling a sense of presence– a representation of themselves and of other team members being immersed in the virtual environment. An interviewee suggested the use of avatars as a means to embody presence and serve as a vehicle with spatial agency in the virtual environment.

Q*uote: It is hard to stay engaged when you cannot see the face of the person talking*

Q*uote: Participants don't realize that what they see isn't what others see anymore in the remote situations*

Quote: like to be able to see representations of people and their expressions

Quote: avatars that can mimic facial experiences

Interviewees recounted that the use of webcam video influenced their experience in varying ways. While facilitators often set rules for participants

to keep their cameras on, participants often reported anxiety, shyness and cognitive loads from watching themselves on their screens. Facilitators explained that the c*amera-on rule* not only enables rich communication, but also gives a sense of presence. Avatars were also suggested as a means to embody non-verbal communication and personality expression, and thereby circumvent the discomfort of keeping the camera on.

The findings show that VCEs need to be immersive by providing spatial agency to participants. To experience immersion, participants need to feel a sense of presence not only of themselves in the virtual environment and the design artifacts contained therein but also the presence of other participants to perform VDT effectively. Virtual whiteboards already provide a 2D shared environment for visualizing design artifacts in VDT. Avatars can provide a sense of immersion in this 2D environment as they can embody the presence of participants and serve as vehicles of spatial agency. Further, they can embody non-verbal communication and provide a means for rich communication and personality expression.

3.3 Key findings

VCEs need to accommodate multiple channels of communication synchronously to enable rich communication that feels natural. F2F communication needs to be combined with visualized information, visual and spatial cues synchronously to enable effective communication in VDT. This is in line with the studies conducted by Redlich (2020).

While 2D VCEs can support multiple channels using a combination of ICT tools, there is a loss of richness because it is 1) less natural 2) not experienced synchronously. This is in line with the studies conducted by Hantula (2011).

Spatial cues and spatial agency are necessary for richer, natural communication in VDT. Interview findings and participatory observations reveal that switching ICT tools and trying to work around this can cause mental exhaustion, increased cognitive loads, and a dilated sense of time, leading to a loss of synchronicity. Hence ICT tools need to provide an

integrated experience to enable better synchronicity of communication in 2D VCEs, providing an explanation for the observations made by Kirjonen(2020) and Daft and Lengel (1986).

Further, spatial agency, environmental cues and non-verbal communication enable personality expression. This establishes trust and empathy and helps participants form the interpersonal connections necessary for the Design Thinking mindset, reaffirming the studies by Jarvenpaa et al. (2004) and the suggestions offered by Lewrick et al. (2018) regarding personality expression.

While the findings confirm that spatial agency and environmental cues contribute to a sense of presence in the virtual environment, as suggested by Krijonen(2020), the interviews revealed that a sense of immersion corresponds to more engaging experiences in virtual environments. Engagement contributes towards reduced exhaustion and better motivation by team members, affecting their creativity and output. To experience immersion, participants need to feel a sense of presence not only of themselves (self-presence) in the virtual environment and the design artifacts contained therein (environmental presence) but also the presence of other participants (social presence). Thus, these findings provide an explanation to the findings by Kirjonen (2020) and connect presence to the engagement of participants.

Virtual whiteboards are extensively used in conventional VDT implementation and provide a 2D shared environment for visualizing design artifacts. Avatars can enable immersion in this 2D environment as they can embody the presence of participants, per Kirjonen (2020), and serve as vehicles of spatial agency. Further, interviewees suggested they can embody non-verbal communication and provide a means for rich communication and personality expression, thereby overcoming the challenges of using webcam video, providing a solution to the problem surfaced by (Ming et al., 2021). Thus, while the concept of avatars comes from immersive environments, this study found that it is also applicable to 2D VCEs.

3.4 Discussion

The motivation to carry out this study was based on the two research questions:

1. What is are the challenges faced by participants in VDT workshops using 2D VCEs?
2. How can these challenges be overcome within 2D VCEs?

The findings from the qualitative research answer the first research question and reveal that the lack of rich, synchronous communication, personality expression and immersion are the main challenges faced by participants in VDT workshops using conventional 2D VCEs.

Further, while interviewees did speculate solutions in the immersive VCE space, the structure of the interview questions ensured that interviewees were encouraged to find solutions based on the challenges reported within 2D VCEs. Therefore, the findings from this study also help answer the second research question: How can these challenges be overcome within 2D VCEs? The findings reveal that enabling rich synchronous communication, providing spatial agency and environmental cues, and enabling presence through the application of avatars to provide a sense of immersion can overcome these challenges. The use of avatars in 2D VCEs not only provides an ability to enable rich, synchronous communication by embodying the participant's non-verbal communication but also enables immersion by serving as a vehicle of presence, thereby presenting a convenient solution to both challenges.

To this end, this study explores a more immediate solution to the challenges that require a less radical shift in technological adoption by participants. The next chapter describes an experiment devised to test the hypothesis that participants can feel immersed in 2D VCEs.

4 Experiment

The previous chapter concluded by answering the research questions that set out to discover and overcome the challenges in performing VDT using 2D VCEs. It suggests the use of avatars as a means to mediate presence in 2D VCEs. Qualitative research revealed that 2D VCEs lack spatial agency and efficient communication mediums, thereby affecting participants in terms of cognition, engagement, and the ability to make interpersonal connections that are necessary for Design Thinking methods and mindset. The findings from literature review and qualitative research reveal that these challenges can be overcome by mediating presence. Virtual whiteboards already provide a 2D shared space for the visualization of design artifacts. This space can be enhanced to provide environmental cues and better spatial agency. Avatars can serve as a vehicle of presence by representing participants in this 2D environment and enabling spatial interactions with design artifacts and other participants. Further, avatars can embody non-verbal cues, thereby enabling rich communication and personality expression.

Based on these findings, this study proposes an experiment to design and test an immersive 2D VCE. This chapter describes the design of the experiment, the process of testing it, and the results obtained.

4.1 Design of the experiment

Based on the findings from the qualitative research, this study derives five requirements(**R**) that contribute to the design of the experiment. The requirements are described as follows–The VCE should provide an immersive experience in a 2D environment by supporting avatars with spatial agencies such as locomotion to enable self-presence(**R1**) and interact spatially with other avatars to enable social presence(**R2**). The participants must also be able to interact with design artifacts and visualize information to enable environmental presence and spatial behaviors present in physical Design Thinking (**R3**). Further the avatars should embody non-verbal communication such as facial expressions and body movement (**R4**) without

necessarily requiring participants to view/transmit their faces enable self-presence (**R5**).

These requirements were visualized in the form of mockups to aid in the design of the immersive 2D VCE proposed by this experiment. In Figure 2, the visualized concept attempts to satisfy R1 and R2. Participants are represented as avatars with spatial agency and can move freely in the 2D space provided by the virtual whiteboard.

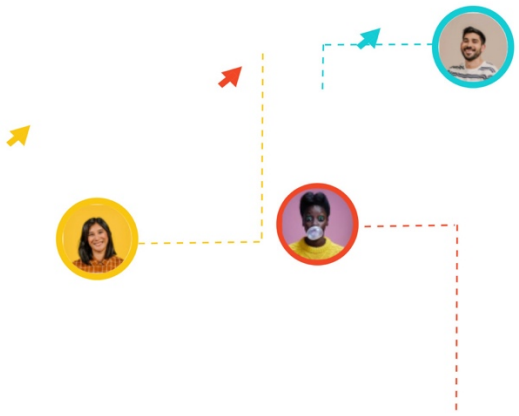

Figure 2. A mockup of 2D avatar with spatial agency and labeled pointers

The mockup shown in Figure 3 introduces design artifacts in the form of sticky notes, which are stationary in the 2D space and provide environmental cues in the form of positional awareness, thereby contributing towards R3. Further, it also shows avatars of participants gathering around the artifacts and separating into groups. Thus, the concept also contributes towards R2.

Figure 3. Mockup showing participants interacting with design artifacts and forming groups

In Figure 4, proximity-based volume levels are applied to verbal communication (their range being depicted in the image by colored circles around the avatars), thereby providing another environmental cue in the form of a dynamic soundscape and contributing towards R3.

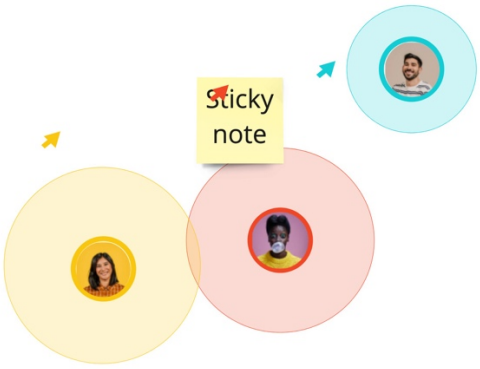

Figure 4. Mockup depicting spatial sound using colored circles

The avatars represented as circular thumbnails in Figure 2 are shown to contain video feeds of participants' webcams to enable non-verbal communication, and thus they satisfy R4. R5 can be satisfied by using live

filters that can embody facial expressions and even body movements to some extent. The mockups shown in these figures informed the choice of ICT tools that were used in the immersive 2D VCE. The chosen tools and the reasons for choosing them are described in the following section.

4.2 Choice of ICT tools

ICT tools were chosen to enable specific functionalities such as spatial movement of participant's avatars, and information visualization functionalities such as being able to view participant's cursors, being able to create and move sticky notes, and being able to type text. The experiment used existing browser-based tools, with the aim of providing a familiar, yet integrated experience to participants. The immersive 2D VCE was built using three applications: Spatial Chat , Snap Camera and Miro.

Spatial Chat provides an immersive experience for virtual meetings in a 2D environment. It provides a 2D space for participants to meet with spatial agency, and hence assumed to satisfy R1. Participants are represented as avatars that take the form of circular thumbnails that can contain a webcam video feed, satisfying R4. The microphone volume varies with distance, growing fainter when the avatars are far apart and louder as they move nearer to each other. This not only replicates the experience of collaborating in a physical space but also establishes a dynamic soundscape, satisfying R2. Besides these specific functionalities, participants have options to mute mic or camera video which are typical to conventional videoconferencing applications.

Snap Camera is an Augmented Reality (AR) based webcam application that applies live effects to a computer's webcam feed before being transmitted over a network. This was used to customize avatars that could express real time facial expressions without revealing the participant's face, thereby satisfying R5.

Miro is a virtual whiteboard that enables the creation of sticky notes, diagrams, tables or other visualizations in an infinite two-dimensional virtual

space. Participants can collaborate on the whiteboard in real time and observe each other's cursors, pull data from external sources, add media and edit the board in real time.

4.3 The experimental VCE

The experimental VCE was designed in a way to provide an integrated ICT experience to participants. In this experiment, Spatial Chat provides a 2D shared space and enables rich communication and spatial interaction using avatars. Spatial chat provides a feature to embed a website frame into this 2D space. An instance of Miro virtual whiteboard is embedded into Spatial chat, thereby introducing it as a virtual artifact and enabling information visualization and interaction capabilities. At the same time, live filters are applied using Snap Camera to enable embodiment of participants' non-verbal communication without revealing their faces. In this way, the immersive 2D environment (Figure 5) combines different ICT tools to satisfy the requirements derived in this study.

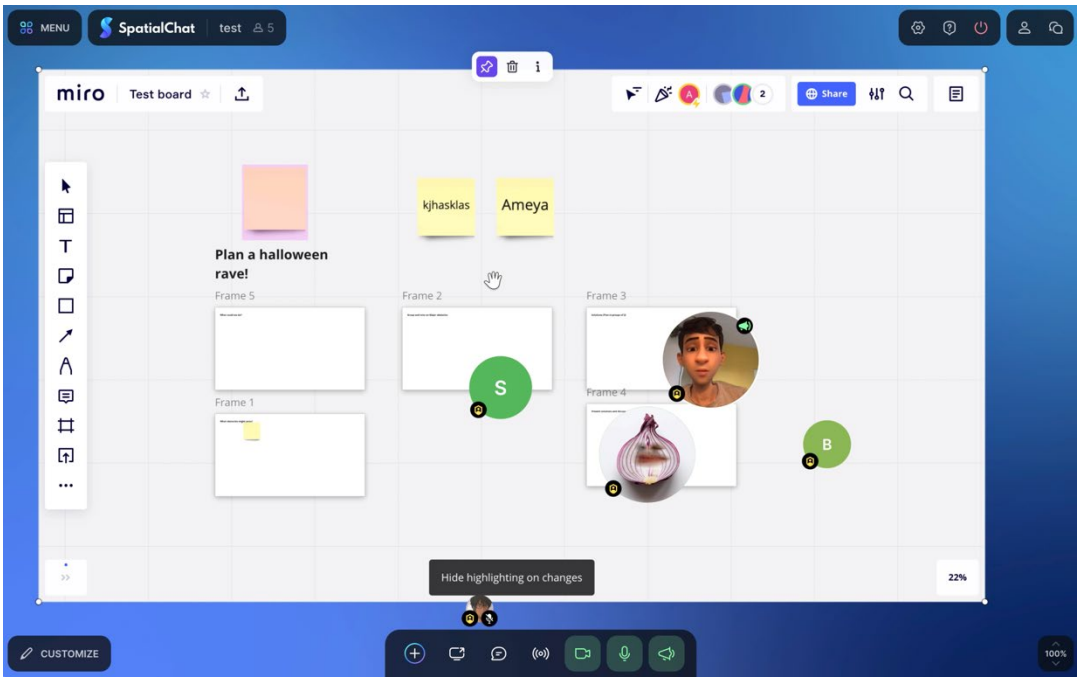

Figure 5. The experimental VCE

4.4 Participation and Procedure

Participants were selected based on varied backgrounds in the fields of arts, visual communication, new media design, game design and industrial design.

The participants were informed about the experiment in advance, served a privacy notice and provided with consent forms via email. This email included an invitation to the workshop, the topic of discussion, instructions to install Snap Camera application and a link to an online survey to be answered after the experiment. Participants were also provided with a list of Snap Camera effects that could be used as virtual avatars that accommodate facial expressions and head movements.

Two sessions of the workshop were conducted towards this experiment. Each session was planned to last one hour. The first 30 minutes were reserved for onboarding participants to the experimental platform, helping them choose suitable avatars on Snap Camera and troubleshooting any problems that might arise in the process. The rest of the time was dedicated to conducting and recording the experiments. Participants initially joined a Zoom video conferencing session where they were briefed about the experiment, and time was allotted for each participant to troubleshoot their setup and choose an avatar using Snap Camera filters. Since this experimental setup was a combination of multiple platforms, specific instructions were provided to overcome some of the usability issues that resulted from this. A tour of the experimental platform was provided via screen-sharing to familiarise participants with its functionality and use. Finally, they entered the platform using a website link.

The immersive 2D VCE was designed to accommodate four to five participants ideating over a hypothetical problem using sticky notes. The experimental workshop was structured into four tasks– individual ideation using sticky notes, grouping ideas in small teams of two to three participants, voting on the best idea groups, and finally choosing the best ideas to present a solution. The tasks were chosen to cover common methods used in Design

Thinking workshops such as ideation, grouping, forming teams and collaborating with other participants, voting and presenting.

4.5 Data and Findings

The collection of data from this experiment was inspired by the approach proposed by Kohonen Aho (2017), which uses a combination of perceptual and action-based approaches for collecting qualitative data, specifically to research social presence in virtual worlds. According to Kohonen Aho, the perceptual approach consists of methods such as interviews, questionnaires or reflections, which focus on individual experiences of participants. The action-based method, on the other hand, is based on objective observations of the interaction and consists of video recordings of the behaviors and interactions that emerge during the experiment. It has been used previously in researching social presence in virtual worlds using avatars (Sivunen and Nördback, 2015). This dual approach was used by both previously mentioned authors in the context of 3D virtual worlds (i.e., immersive environments) with the goal of exploring their potential for design collaboration. In this thesis, this approach is adapted to researching the experience of participants in two-dimensional (2D) virtual environments.

4.5.1 Action-based insights

As part of the action-based approach, data were collected in the form of screen capture video during the experiment. The screen capture video was used to visually observe participants' interactions in the experimental platform and mark the spatial behaviors that may indicate visual presence. The entire session was recorded on the researcher's screen and frames were selected to represent specific behaviors and affordances of the experimental VCE. Hence, these insights are based on visual information that can be derived from these screenshots.

Figure 6 shows participants sharing the 2D space with design artifacts in the embedded virtual whiteboard. It also shows labeled pointer locations of the participants in the screen. Participants' avatars effectively conveyed facial expressions with live filters without revealing their faces using Snap Camera. In the experiment, participants chose filters that only allowed tracking of facial expressions and head movements.

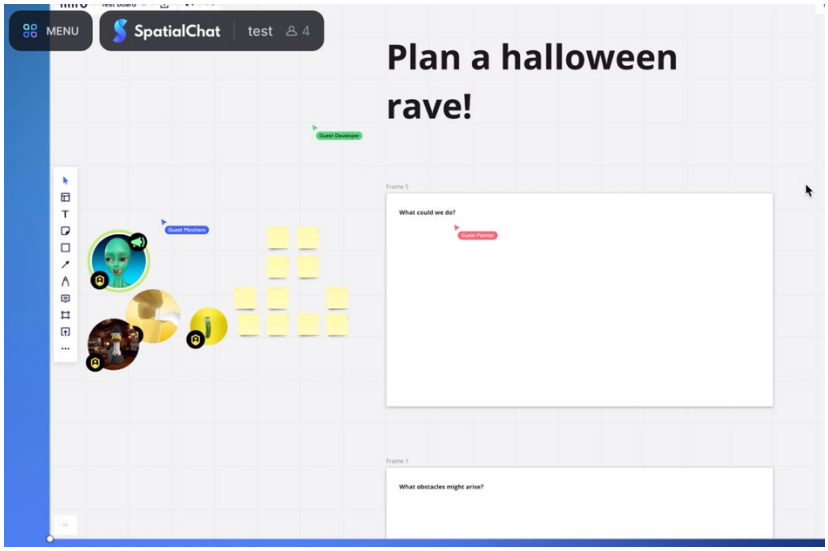

Figure 6. Participants enter the VCE with live filters enabled

Figure 7 shows the ideation phase in which participants interacted with design artifacts in the embedded virtual whiteboard. Participants were observed to use environmental cues and make spatial arrangements of design artifacts, showing that the experiment supports spatial behaviors that exist in physical Design Thinking methods.

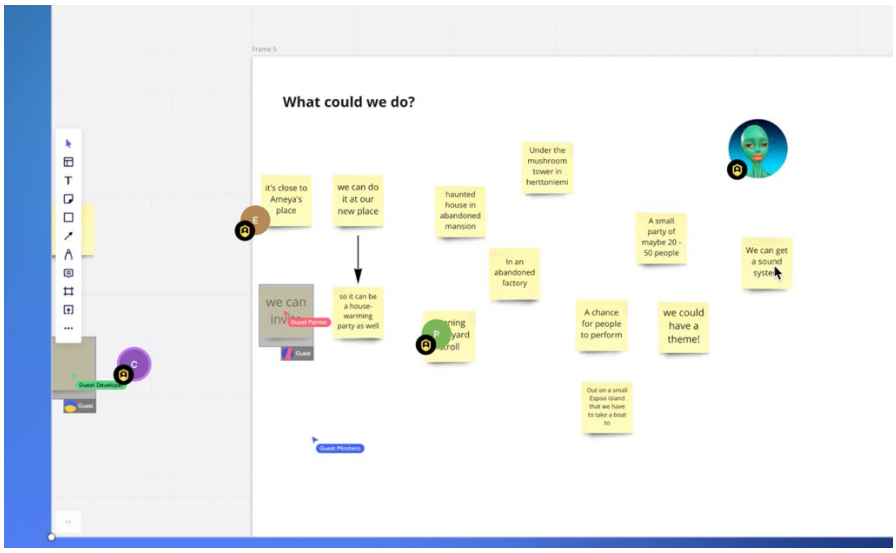

Figure 7. Participants interacting with design artifacts during the ideation phase

Figure 8 shows participants splitting into groups without leaving the shared space and conversing using verbal communication within their groups using proximity of avatars. The avatars can be seen to embody facial expressions and head movements. At the same time, participants could use spatial agency to interact with the design artifacts. The shared space also allowed visibility into the activities of the other group, showing that the experiment supports spatial behaviors typical in physical Design Thinking. Another instance showing the experiment's applicability to Design Thinking methods is shown in Figure 9, which depicts participants casting votes on design artifacts.

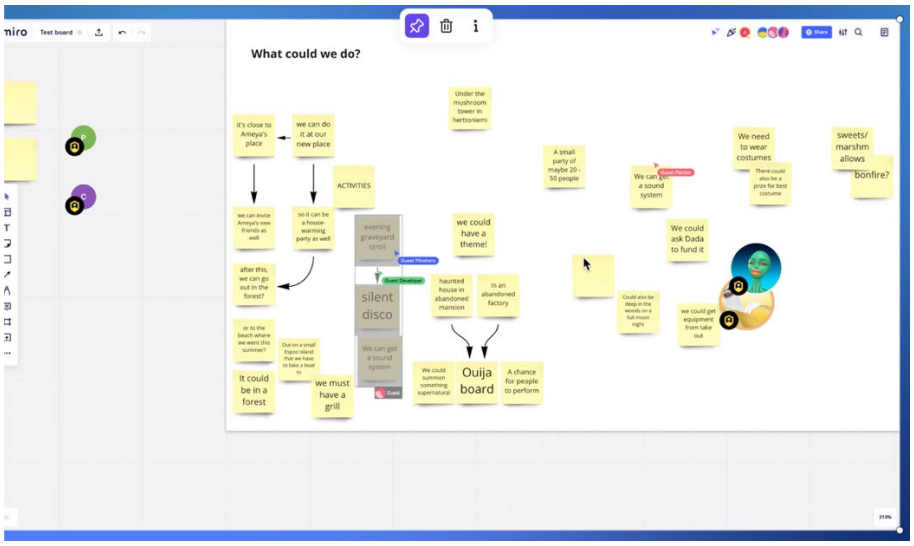

Figure 8. Participants in the right can be seen forming groups

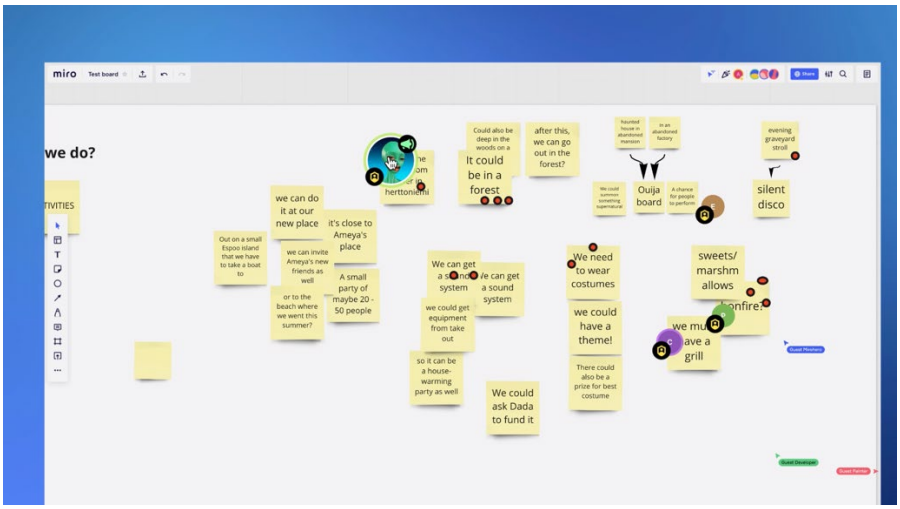

Figure 9. Participants can be seen voting on generated ideas

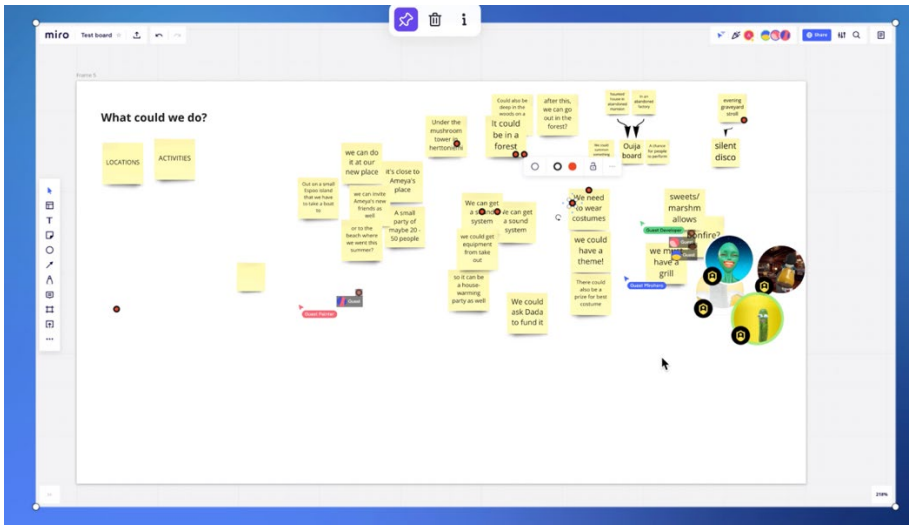

Figure 10. Participants are presenting ideas using proximity to visualized information and rich communication

Figure 10 shows individual participants presenting selected ideas to the rest of the team. Participants were observed to utilize spatial cues in the form of spatial proximity to the artifact being discussed and the position of their mouse pointers. This enabled rich communication around the shared context of all participants, showing that the experiment accommodated the spatial behaviors existing in physical Design Thinking.

4.5.2 Perceptual insights

As part of the perceptual approach, participants answered an online survey after the session, which probed the participants on their experiences during the experiment. The participants were asked to rate their experience and justify their rating for the following situations– overall experience of collaborating in the experimental VCE, comparing the experience to existing 2D VCE environments and also comparing their experience to physically collocated collaboration formats. Further, participants were asked to justify their rating to understand what contributed to their experience. Finally, participants were asked to suggest improvements that would have improved

their experience even further. The questions and their responses are attached in the appendix.

The first question asked participants to rate their experience on a scale of 1 to 5. The average rating was given by the participants was 4.1, indicating that participants had a good experience collaborating in the experiment. Participants reported that the experiment was engaging, and five out of seven participants described it as fun. They found the communication to be more personal to videoconferencing applications. A participant described it as dynamic due to the use of spatial sound. Despite an initial on-boarding and explanation of the platform, participants' unfamiliarity with the tools (especially with spatial chat) negatively affected their experience. Secondly, the specific affordances of Spatial Chat in interacting with embedded content presented initial difficulties, negatively affecting user experience.

When asked to compare their experience to using conventional 2D VCEs, the average rating for their experience was 2.7 on a scale of 1 to 3, indicating that the experimental VCE provided a significantly better experience. Participants reported that the spatial agency and spatial audio made workflows and communication feel structured, natural and intimate. A participant also that this spatial agency aided in visualizing information. The affordance of forming groups easily using proximity, while simultaneously allowing conversation and interaction with other groups were reported to contribute to a better experience. The use of embodied avatars were reported to provide comfortable anonymity.

When asked to compare their experience to physical collaboration settings, the average rating for their experience was 1.9 on a scale of 1 to 3, indicating that the experimental VCE provides a slightly worse experience. While six out of seven participants rated their experience to be at par with collaborating in physical environments, one participant rated it as below par. Participants were of the opinion that collocated physical environments still provide the best collaborative experience due to better communication affordances. However, the anonymity and engagement provided by Snap

Camera's live filters, and the ease of visualization and the subsequent documentation of information and outputs were reported to be factors that contribute to a better experience the experimental VCE when compared to physical environments.

The suggestions to improve the experimental platform fall primarily under two categories. The first deals with better integration of ICT tools. Participants reported the experience of interacting with the whiteboard as being clunky . Spatial chat requires participants to double click on embedded elements to interact with them, and lacking a feature to lock these elements in place; elements can be moved unintentionally by participants. This was because when participants tried to move artifacts within the whiteboard, they often mistakenly moved the entire whiteboard in the 2D space provided by spatial chat. This not only moved their own artifact but all other artifacts contained in the whiteboard, disrupting the environmental cues from the platform. The second category deals with familiarity of tools. Participants reported that the current platform requires better familiarity due to the specific features and nuances of the ICT tools used. To this end, participants suggested that features such as spatial agency and spatial audio should be integrated within existing virtual whiteboard application directly.

4.6 Discussion

The findings reveal that the immersive 2D VCE tested in the experiment provided a better experience as compared to conventional 2D VCEs. The findings also provide evidence that the requirements derived for the design of the experimental VCE are categorically fulfilled.

The experimental VCE provided an immersive experience in a 2D environment by supporting avatars with spatial agencies such as locomotion to enable self-presence, as evidenced in the action-based insights. Participants also reported how this contributed to better experiences, showing that R1 was satisfied. The avatars were observed interact spatially

with other avatars indicating social presence. Further, participants reported that this led to better collaboration, thus satisfying R2. The participants were also observed to interact with design artifacts and visualized information, indicating environmental presence. Participants reported that a better interaction experience and also reported confusion when the environmental cues were disrupted, thereby satisfying R3. Further the avatars embodied non-verbal communication such as facial expressions and body movement, satisfying R4, and the use of live filters were reported to provide a more comfortable experience, satisfying R5.

The experiment was based on requirements derived to overcome specific challenges relating to communication, personality expression and immersion. The results from the preliminary research done in this study revealed the role of presence in overcoming each of these challenges. Further, the literature review revealed that presence is a determining factor in Design Thinking collaboration as it is necessary not only for successfully carrying out Design Thinking methods, but also to enable the Design Thinking mindset. The affordance of presence was discovered to be the primary motivation behind exploring immersive platforms such as 3D and VR environments to perform Design Thinking virtually. In the context of VDT, three components of presence, namely, self-presence, social presence and environment were discovered to contribute to the overall experience of presence and the resulting sense of immersion in immersive environments, in line with the qualitative research findings in this study and the suggestions by Kirjonen(2020). The results from the experiment indicate that presence can also be mediated in 2D VCEs by re-interpreting its components in the 2D context, thereby supporting the answer to the second research question, derived in chapter 4.

5 Conclusion

Initially, this thesis started out exploring the experiences of participants in virtual design thinking workshops. To this end, a literature review was conducted in the areas of Design Thinking, Virtual Design Thinking, Virtual Collaborative Environments and the media theories applicable in these fields.

Previous studies suggest that the synchronous activities in the Design Thinking process are implemented in the form of workshops, where participants collaborate in a shared physical space. Further, it revealed that F2F communication and spatial behaviors in the collaborative space are important factors that influence the methods and mindset required to perform Design Thinking successfully.

Next, this study reviewed literature on Virtual Design Thinking with the aim of understanding the advantages of performing Design Thinking virtually, and the challenges that arise in doing so. Saved time, reduced costs, communication richness, documentation and visualization efficiency, and improved personality dynamics were found to be the motivating factors behind virtual Design Thinking. Lack of physical space, technological ambiguity, temporal effects and emotional effects were found to be challenges that affect participants' performance of Design Thinking in conventional 2D VCEs, thereby answering the first research question.

To understand why these challenges arise, literature was then reviewed from the perspective of virtual environments used for remote collaboration (VCEs). Recent studies in the field suggest that trends in virtual Design Thinking are shifting from conventional two-dimensional VCEs towards immersive VCEs such as 3D and VR environments.

While these findings provided clear reasons for the challenges in VDT and illuminated the importance of presence, they failed to clearly explain the theoretical reasoning behind the ability of presence to overcome these challenges. Specifically, they failed to draw the connection between enabling

presence and how it influences the challenges of communication. Therefore, this study also explored media theories that are applicable to collaborative practices.

The findings from the literature review motivated the focus of this study on 2D VCEs, thereby modifying the research questions to fit the focus. The qualitative research was conducted in the form of in-depth interviews and participatory observations to confirm the findings from the literature review, and reaffirm their applicability to contemporary VDT practices. Qualitative insights from the preliminary study confirmed that the challenges found in the literature review stem from the lack of presence in 2D environments, thereby answering the first research question. The studies also showed that the experience of using ICT tools impacted the sense of presence in 2D environments, in line with findings from the media theories.

While 2D VCEs can support multiple channels using a combination of ICT tools, there is a loss of richness because it's 1) less natural compared to physical environments, and 2) not experienced synchronously, confirming the ideas posited by Dennis et al. (2008) and Daft and Lengel (1986). Further, this study suggests that providing spatial cues and spatial agency can overcome these effects, confirming applicability of the Media Compensation Theory by Hantula (2011). Further, switching ICT tools and trying to work around this can cause mental exhaustion, increased cognitive loads, and a dilated sense of time, leading to a loss of synchronicity. Hence this study also draws the connection between media synchronicity as per Dennis et al. (2008) and synchronicity as per Daft and Lengel (1986).

Further, the studies showed how presence is related to the overall experience of participants, which influences their engagement and sense of time. Using these insights, this thesis concluded that mediating presence in 2D VCEs is an effective way to overcome the challenges in participants' experiences that arise from performing Design Thinking virtually, thereby answering the second research question. This conclusion served as a hypothesis for this thesis, which was realized in the form of an experimental

VCE. The experiment was designed based on five requirements derived from the findings in the literature review and the preliminary research. The five requirements were described in the following way.

R1: The provision of a 2D space that supports spatial agency of avatars

R2: The ability for avatars to interact with other avatars in the space

R3: The ability to interact with design artifacts and visualized information the same space

R4: The ability for avatars to embody non-verbal communication of participants

R5: The ability to emulate F2F conversation without revealing participant's faces

Based on these requirements, appropriate tools were chosen to to construct an experimental 2D immersive VCE. The experimental VCE featured the mediation of presence in the virtual environment using avatars equipped with spatial agency and the ability to convey non-verbal communication. Further, the virtual environment in the experiment provided spatial cues to support the avatars' spatial behaviors. To test the hypothesis, a VDT workshop was performed using the designed experimental VCE with seven participants.

The findings from the experiment confirmed the ability of the designed 2D immersive VCE to mediate a sense of presence. Action-based insights confirmed the use of spatial behaviors which were enabled by spatial agency and spatial cues that the VCE supports. Further, the action-based insights provided visual proof that the requirements derived from the hypothesis were satisfied. Perceptual insights from the participant showed that the experimental VCE enabled richer communication as compared to conventional 2D VCEs, and confirmed that these abilities led to better experiences in the workshops, and reported an increase in engagement and comfort.

5.1 Implications

This thesis expands on current literature on presence in virtual environments and its application to VDT. It illuminates the challenges of performing Design Thinking in conventional 2D environments shows that mediation of presence can overcome these challenges and improve the overall experience of participants.

It contributes to existing literature by drawing the connection between presence, communication dynamics, spatial behaviors and personality expression, and their effect on participant experiences. Further it interpreted the individual components of presence as described by Hindmarsh et al. (2001) and Kirjonen (2020) and the factors that influence them in the 2D VCE context.

This study previously mentioned the shift in research on virtual collaboration towards 3D and VR environment, and the challenges presented by these environments. The main challenges were found to be breaks in presence arising from the natural world (Kirjonen, 2020), the increased effort required to build these virtual environments using pre-fabricated CAD models and the prohibitive hardware costs (Kirjonen, 2020; Vogel et al., 2021). Further, the high degree of immersion in these environments can feel unnatural due to an overload of richness (Hantula, 2011) and VR sickness (Kim and Shin, 2021). The findings from this study imply that presence can be mediated in existing 2D environments, thereby saving costs, effort and circumventing challenges arising from super-richness and discomfort associated with immersive environments, have vital implications on the choice and future development of virtual collaboration tools.

5.2 Future Studies

The perceptual insights from the experiment showed the limitations of the experimental VCE. While the requirements derived from the hypothesis

focus on enabling spatial behaviours and richer communication, it did not address the challenges arising from technological ambiguity sufficiently. As part of the experiment, participants were provided information of the ICT tools being used, and the use of these tools were demonstrated before the experiment commenced. Despite these measures, participants found working with the chosen ICT tools initially challenging. Further, participants reported that the simultaneous use of multiple platforms caused their computers to lag and perform poorly. Hence, while participants' experiences were improved due to the mediation of presence, the challenges brought on by technological ambiguity negatively affected their experiences. This shows that while 2D VCEs can be made immersive to support typical VDT methods, integrated ICT tools need to be developed to support this immersion. Further, the usability challenges can be improved by conducting usability studies.

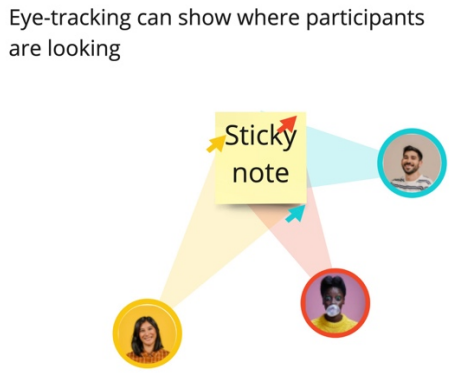

Figure 11. Mockup depicts an eye-tracking concept for shared context

An important finding from the preliminary research was the importance of shared context. Specifically, it revealed that spatial orientations and eye movements of participants indicate what they are looking at (Hantula, 2011). While a concept was explored to enable this interaction in a 2D representation using eye-tracking to depict what participants are looking at (Figure 11), it was difficult to implement in the VCE as it required a deeper

integration of tools and considerable development effort. Hence, the use of emerging technologies such as eye-tracking should be explored in the context of VDT.

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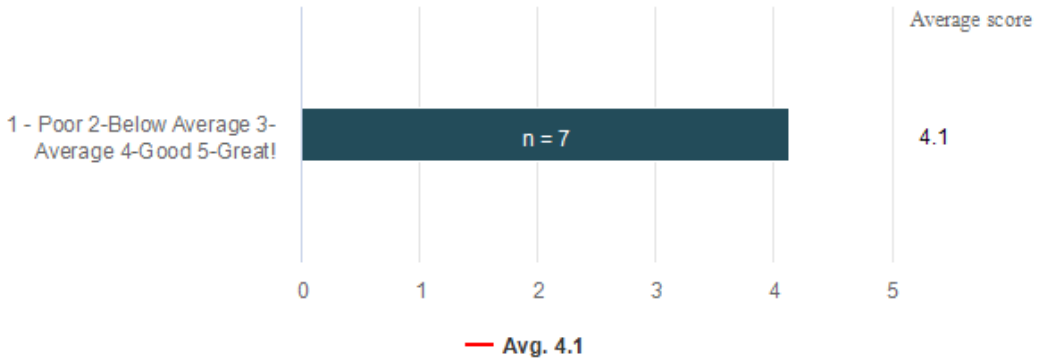
Appendix

Post-experiment Questionnaire

Total number of respondents: 7

1. How would you rate your experience collaborating in the experimental workshop?

Number of respondents: 7



	1	2	3	4	5	Av-er-age	Me-dian
1 - Poor 2-Below Average 3-Average 4-Good 5-Great!	0.0%	0.0%	0.0%	85.7%	14.3%	4.1	4.0

2. What reasons would you use to justify your rating for the above question?

Number of respondents: 7

Responses

It was a fun way to interact with each other, and it felt more personal than a regular zoom call for example. However, I still think in person meetings are the best.
It was fun and easy to understand and follow because the facilitator provided instruction and asked many times if everyone was following or if there were any questions. It was easy to follow the process and what the goal of the experiment was.
I feel like the platform is effective for collaboration and group formation, but the integration of the miro board can be a bit "glitchy". Sometimes I feel like I accidentally moved the whole board and made it much smaller at some point. At some point, I also moved my position on the board somewhere else and it took me a while to find the frames where we added the ideas. I guess a lot of that has to do with me not being very used to Miro in the first place.
It was quite fun experience! Did not feel like the usual online meeting/session. Was more enjoyable and dynamic. It was bit hard to jump between Miro and your camera head
It took some time to learn how to use the tools but overall it was very fun to interact with each other based on how close our avatars are together on the screen.
The audio tracking allowed private conversation without the need to enter a separate meeting room or breakout room.
It was a bit clunky to get started, as we were using multiple platforms together, but once everything was up and running it worked well and was quite fun. I really liked the spatial audio feature where you could pick up your avatar and move it closer to what you wanted to hear.

3. If you have used a virtual collaborative whiteboard tool other than Miro, Mural or Padlet, name the tool here:

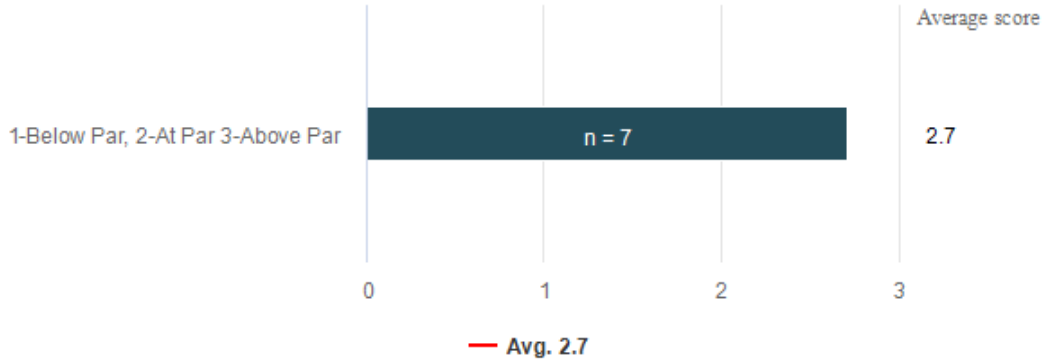
Number of respondents: 4

FigJam(by Figma)
-

N/A
I use a lot of Google products for collaboration (Drive, Docs, etc.). I also use Slack and Zoom regularly, although none of these are technically whiteboard tools

4. How would you rate your experience collaborating in the experimental setup when compared to other virtual collaboration setups such as Miro, Mural, Padlet, Zoom, Google Meets, Microsoft Teams, or any other collaborative environment you might have used?

Number of respondents: 7



	1	2	3	Aver-age	Me-dian
1-Below Par, 2-At Par 3-Above Par	0.0%	28.6%	71.4%	2.7	3.0

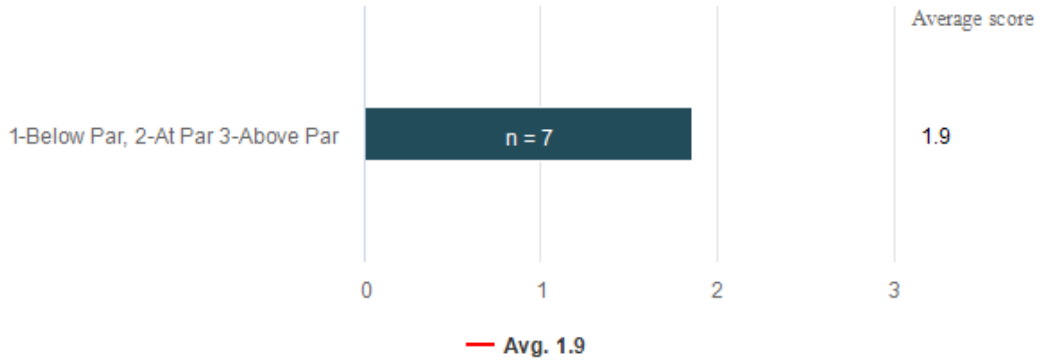
5. What reasons would you use to justify your rating for the above question?

Number of respondents: 7

Responses
The avatars provided a comfortable anonymity, and the sound varying by proximity to others was also a good touch. It felt much more intimate than a zoom call or interactive whiteboard
Probably the platform should still be improved (sometimes it was a bit laggy, at least for me)
It was easier to separate and form the groups with the participants and talk to just the person we wanted to discuss something with, while also having the option to talk to all participants. I feel like that made the work-flow more structured.
The spatial-ness was a good touch, made it feel more like a real space and easier to break into groups(as compared to Zoom breakout rooms). Was more intuitive and fun
It was better in terms of the break out room effect where participants could have relatively private conversations between themselves.
A lot easier to format and edit text as opposed to other setups.
I haven't used Miro or Mural before, so I can't comment on those, but writing and placing post-it notes in the test setup was pretty straightfor-ward, visual, and easy to understand. Comparing to Zoom and Google Meet though, I felt the spatial audio feature in the test setup was much more intuitive and quick to set up than breakout rooms. It was also quite fun to pick up your avatar and move it around and have private discus-sions.

6. How would you rate your experience collaborating in the experimental setup when compared to physically collocated collaborative sessions?

Number of respondents: 7



	1	2	3	Aver-age	Me-dian
1-Below Par, 2-At Par 3-Above Par	14.3%	85.7%	0.0%	1.9	2.0

7. What reasons would you use to justify your rating for the above question?

Number of respondents: 7

Responses
In my opinion in person meetings are always more fruitful than online collaboration, however this method was the best remote method I've been a part of
in this virtual session, talking and exchange ideas was easier than usual.
I feel like the physical presence of people in the same room often sparks more original ideas while enabling the participants to react to them and express their opinion immediately. The conversation also flows nicer, as it's harder for the participants to talk over one another.
It is very hard to compare to real physical setting... having the snap cam gave a more fun effect which we can't do in real life and miro board leads to digital documentation. But still hard to replicate the "magic" of taking to a human in physical setting
Even though physical meetings for collaborations are much more "real", virtual collaborations allow the data to be recorded digitally and this increases efficiency. The same setup that is applied in physical meetings

can be achieved with the experimental setup. I think this experimental setup is at par with physical meetings because a sense of physical space was achieved.
I personally prefer in-person meetings, but I would use the experimental setup a lot more than other setups.
Collaborating in person is still "easier" and more natural for me, and it's hard for a digital product to compete with this. But after getting used to the controls and how things worked, it was about about as smooth and enjoyable as a virtual collaboration tool can be.

8. What are your suggestions for improving the experiences afforded by this experimental setup for virtual collaboration?

Number of respondents: 7

Responses
I can't think of many ways to improve the experience, other than perhaps getting familiar with the platform beforehand so I could participate more readily.
maybe just spend more time explaining the "conversational bubble" function to get the most out of it (it´s a cool feature).
Locking the Miro board so participants can't accidentally move it around. Ability to group/link the two or more participants' bubbles together, so one doesn't randomly drift away and cuts the conversation by doing that (as you can't hear them anymore). Ability to snap the participants' bubbles to different elements on the Miro board (maybe allowing the admin to do that, so nobody is left behind while discussing something next to a certain frame).
Easier switching between Miro board editing and moving your circle around. Have not just whiteboard layout but more fun spaces as well
I think the activities done in the beginning where participants get to learn the experimental setup were great! Maybe additional trouble shooting can be planned to eliminate tech related issues as much as possible. But of course there is always going to be the possibility for internet failures or equipment failures.

N/A
Integrating the spatial audio feature directly into Miro would be a great improvement. My only issue with the test was the initial clunkiness of setting up both tools. Understanding and using both tools was easy, so removing that initial blocker would be great.