Bonding Over Distances: Building Social Presence Using Mixed Reality for Transnational Families

Shuting Zhou

A thesis exhibition presented to OCAD University in partial fulfillment of the requirements for the degree of Master of Design in Digital Futures

205 Richmond Street West, April 2023,
Toronto, Ontario, Canada, 2023

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Abstract

Sparked by the frustrations experienced in transnational family communication and inspired by an interest in exploring the potentials of a mixed reality (MR) future landscape, this study investigates the primary research question: how can we use mixed reality to build social presence for transnational family communication?

This study reviews literature and contextual works from relevant fields, including presence and social presence, mixed reality, transnational relationships (inter-family and human-space relationships), and technology for social presence for transnational families. Then, the researcher situates this study at the intersection of the before mentioned categories.

Utilizing the Research through Design methodology and paired user testing methods, this study describes 4 iterative MR prototypes for building social presence for transnational families, highlighting each prototype's relation to a secondary research question, exploration goals, features, performance evaluation, and takeaways for the next iteration. Then, it documents and analyzes data collected from in-depth user testing sessions with 6 transnational family pairs totaling 12 participants, each with one member living locally (in Toronto), and the other overseas. The quantitative and qualitative data were collected from different components of the user testing, including observation notes from paired-up live connection sessions for collaborative tasks, interviews, and online surveys.

This study contributes to theory at the overlapping fields of social presence, mixed reality research, transnational family relationship, and human-space relationship. The mixed reality prototypes, design frameworks, and evaluation criteria for designing mixed reality spaces to build social presence for transnational families also provide significance to design practice.

Dedication

Thanks to my advisors, Dr. Alexis Morris and Dr. Sara Diamond, for their continuous guidance and feedback.

Thanks to all my participants for generously volunteering their time and sharing their transnational family communication experiences.

Thanks to my peers and instructors for their wisdom and encouragement.

Last but not least, I would like to express gratitude to my own transnational family members, especially Chen, for providing me with inspiration and academic insights.

Table of Contents

List of Figures

List of Tables

Chapter 1. Introduction

This section provides a brief account of the research motivation and research summary, including the problem statement, hypothesis and research questions, significance and contributions, methodology, scope, and limitations of this research. Lastly, it outlines the entire thesis structure by each chapter.

1.1 Research Motivations

First, the motivation behind this study stemmed from the researcher's frustrations experienced in everyday life communicating with transnational family members. Similar challenges in performing transnational "kin-work", or "the conception, maintenance, and ritual celebration of cross-household kin ties" (Di Leonardo, 1987, p. 441), were echoed by many members of the transnational community in surveys this study conducted. Time zone barriers, instability of real-time signals, and asymmetrical technology competency are only some of the common logistical challenges in daily transnational family communication. Furthermore, as some survey respondents noted, these logistical challenges can lead to psychological frustration such as the lack of emotional connection between family members. Over time, such frustrations result in general communication dissatisfaction and stressful familial relationships. As an MDes candidate in the Digital Futures program at OCAD University, the researcher hopes to shed light on some communication struggles unique to transnational families, learn about their needs and wants, and contribute to the transnational community by exploring design solutions utilizing emerging technology.

Second, the researcher has always been interested in mixed reality technologies, having previously completed a placement project designing an AR escape room game, and enjoys playing social VR games on Oculus Quest regularly. The researcher believes mixed reality technologies alter how we perceive and distinguish between the real physical world and the virtual world, which have the affordance to build immersive and memorable experiences.

This study combines the common frustrating pain points experienced in transnational family communication with the researcher's technological interests, in hopes to build social presence for transnational family communication using mixed reality technologies.

1.2 Research Summary

1.2.1 Problem Statement

This study considers the problem of transnational families not being able to build sufficient social presence in their daily communication. Transnational families share frustrating pain points in everyday communication with their family members. Time zone barriers, instability of real-time signals, and asymmetrical technology competency are some of the common logistical challenges the transnational community experience, according to need-finding general surveys and pre-experience surveys the researcher conducted (see more in Chapter 3). These challenges can result in psychological frustrations such as the lack of emotional connection, and over time, result in long-term communication dissatisfaction and stress within the transnational family.

1.2.2 Hypothesis and Research Questions

This study hypothesizes that mixed reality (MR) [1]technology can be used to build social presence for transnational family communication. To test this hypothesis, it proposes the following research questions:

- Primary research question: How can we build social presence with mixed reality for transnational families?
- Secondary research questions:
  - How can we use MR to create a transnational family communication experience that evokes social presence similar to that in real life?
  - What technology qualities, contextual factors, and interaction configurations in mixed reality build social presence in transnational family communication?
  - What is the long-term, future use of the mixed reality transnational family space?

1.2.3 Significance and Contributions

This study contributes to academic theory, industry design practices, and the transnational community.

[1] Note, there is no singular definition of MR, as stated by Speicher et al. (2019), who believed it's more important to speak of the experience MR affords than the specific technology configuration, therefore, they developed a conceptual framework classifying MR experiences along 7 dimensions: number of environments, number of users, level of immersion, level of virtuality, degree of interaction, input, and output. This study's use of the term "mixed reality" or "MR" adheres to Speicher et al.'s framework, according to which, the MR experiences in this study fall into these categories: single environment, multiple users, partly and fully immersive, partly and fully virtual, and with explicit interaction.

First, this study provides an overview of and contribution to relevant academic fields: presence and social presence, mixed reality, transnational relationships (inter-family and human-space relationships), and technology for social presence for transnational families. Specifically speaking, this work contributes the field of social presence research by incorporating theories regarding “kin-work” , or “the conception, maintenance, and ritual celebration of cross-household kin ties” (Di Leonardo, 1987, p. 441) and its effect and focusing on social presence among transnational family members; this work contributes to transnational family communication by researching the unique features and potentials MR technologies can afford when compared to existing, common communication mediums; this work expands the field of MR by envisioning its application in home-making through the democratized digital replica production of domestic materials.

Second, through the production of iterative MR prototypes, design frameworks, and evaluation criteria, this study explores the real-life opportunities and challenges of using MR to build social presence for transnational families, paving the way for future industry research and design.

Third, this study sheds light on and provides an innovative solution to some of the challenges and frustrations transnational families face in daily communication. The importance of presence and social presence has been well explored in prior research: Lee et al. (2006) indicated the importance of social presence in improving social influence and the quality of communication; Baldassar (2008) stated that the presence of the body is an important avenue for “kin-work” (Di Leonardo, 1987, p. 441), through which transnational families maintain relationships. However, with unavoidable geographic distance, social presence is difficult to achieve for transnational families without innovative communication technologies. Therefore, this study empathetically responds to the affective needs of the transnational community at large by investigating pain points experienced in transnational family communication and proposes new technologies and ways of interaction to improve user experience.

1.2.4 Methodology

As the topic suggests, this study is interdisciplinary in nature and focuses on the intersection of these fields of study: presence and social presence, mixed reality, transnational relationships (inter-family and human-space relationships), and technology for social presence for transnational families.

To begin, an extensive literature review identifies an abundance of research conducted in these separate fields and a gap in their overlapping area. By positioning the study at

this intersection, the researcher then focused on iterative prototyping and evaluation of using MR technology for “kin-work” and improving transnational family communication experiences.

In prototyping, this study implements a Research Through Design (RtD) methodology where 4 MR prototypes—each responding to a secondary research question—for building social presence for transnational family communication were designed. Additionally, for each prototype, this study details the exploration goals, features, performance evaluation following unified criteria, and takeaways for the next iteration.

User testing is a key method to evaluate the usability and usefulness of prototypes in this study. A series of in-depth user testing sessions were conducted. User testing featured 6 transnational family pairs, each with one member living locally (in Toronto), and the other overseas, totaling 12 participants. Qualitative and quantitative data were collected from different components of the user testing, including observation notes from paired-up live connection sessions, interviews, and online surveys.

1.2.5 Scope

The focus of this study does not involve developing new technology platforms or applications for transnational family communication, but rather connecting existing technology platforms and applications and reconfiguring the ways they are being used.

This study also does not attempt to rebuild or fix broken transnational family relationships. While it acknowledges the toll communication challenges take on transnational family relationships, the background research and user testing of this study will be limited to transnational families that already maintain regular communication.

1.2.6 Research Limitations

Since this is a graduate thesis project, resource limitations exist, including a short research period (10 months), a solo researcher, and limited research funding. Such constraints impeded advanced prototype developments, long-term and large-group user testings, and diverse participant sample recruitments. Future researchers wishing to further research in this area are encouraged to consider these limitations.

1.3 Thesis Structure Outline

Following the introduction chapter, Chapter 2 provides a background review of the literature and contextual sources from relevant academic fields, including presence and social presence, mixed reality, transnational relationships (inter-family and human-

space relationships), and technology for social presence for transnational families. Then, it identifies gaps and positions the focus of this study accordingly.

Chapter 3 describes and justifies the selection of the methodology and methods implemented in this study, including the Research through Design (RtD) methodology, user testing methods, data collection methods, data analysis methods, and sampling methods. Then, it declares the limitations in implementing the above-mentioned methods in this study.

Chapter 4 describes the iterative prototyping process in detail. For each prototype, this study details its relation to a research question, exploration goals, features, performance evaluation following unified criteria, and takeaways for the next iteration. In particular, prototype 3 was user tested and its evaluation includes qualitative and quantitative data collected from user testing sessions, interviews, and surveys.

Chapter 5 provides an overall reflection on the research process, highlighting the objective and subjective evaluations of the 4 prototypes.

Chapter 6 summarizes this research by restating the thesis goals, highlighting its outcomes and contributions, challenges and limitations, future pathways and applications, and final remarks.

Chapter 2. Background: Critical Literature and Contextual Review

2.1 Overview

Figure 1. Mind Map of the Relevant Fields of Study

Due to the interdisciplinary nature of this study, a background review of critical literature and contextual sources from these relevant fields of study is essential to understanding the relevant academic theories and industry landscape. As Figure 1. indicates, these are the relevant fields highlighted in this chapter:

- Presence and social presence in real life
- Transnational relationships
  - Inter-family relationship: performing kin-work from afar
  - Human-space relationship: home-making
- Mixed reality definition
  - Social presence in mixed reality
  - Applications
  - Tools

    - 3D scanning
    - 360° photography
    - Social VR platform
- Technologies for social presence for transnational families
    - Non-Mixed-Reality (MR) information and communication technologies (ICTs) for transnational families
    - Related works: Social Mixed Reality (MR) and/or immersive applications
    - Gaps

After reviewing the above-mentioned academic fields supporting the secondary research, this chapter identifies the unique intersectional position of this proposed study: using mixed reality technology as a communication medium to build social presence for transnational families, filling in the existing gap.

2.2 Presence and Social Presence

2.2.1 Presence

According to Lombard & Jones (2015), Film theorist Bazin (1951) first applied the word presence, defining it as a sense of “coming within the actual range of our senses” (p. 96). Similarly, sociologist Goffman (1959) defined it as being able to “sense that [people] are close enough to be perceived in whatever they are doing, including their experiencing of others, and close enough to be perceived in this sensing of being perceived” (p. 17).

As communication technologies developed, more definitions of presence arose. Slater and Wilbur (1997) defined presence as “the subjective experience of actually being *in* the mediated virtual environment” (p. 603). Similarly, Lombard and Ditton (1997) defined it as “the perceptual illusion of nonmediation” (section 6), which “occurs when a person fails to perceive or acknowledge the existence of a medium in his/her communication environment and responds as he/she would if the medium were not there” (section 6). More holistically, Waterworth et al. (2015) defined it as the “feeling of being located in a perceptible external world around the self” (p. 35).

As described above, presence, although generally considered as perception, sensation, feeling, or action of engagement, has “divergent and overlapping definitions” (Lombard & Jones, 2015, p. 13) developed by many researchers over the years in different

contexts. To promote standardization and precision, Lombard & Jones (2015, p. 14) developed a framework describing presence with 4 key distinctions:

1. The distinction “presence and telepresence” distinguishes between the existence of face-to-face encounters and the lack thereof. This study mainly focuses on telepresence.
2. The distinction “objective and subjective” distinguishes between the focus on “modes and technologies of communication” and the focus on “experiences of the individuals” (Lombard & Jones, 2015, p. 14). This study mainly focuses on subjective presence.
3. The distinction “spatial and social” distinguishes between involvement with a space and “with entities that are or seem to be alive” (Lombard & Jones, 2015, p. 14). This study mainly focuses on social presence.
4. The distinction “remote, virtual, and medium telepresence” examines the other interacting entity — whether it's “people over distance”, “simulations generated by technology itself”, or “technologies themselves” (Lombard & Jones, 2015, p. 14). This study mainly focuses on remote and virtual telepresence.

2.2.2 Social Presence

Academic research concerning social presence, otherwise known as SPT (Social Presence Theory) traces its roots back to 1976, in the book *The Social Psychology of Telecommunications* where communications scholars Short et al. used social presence to evaluate the affordances of telecommunication mediums. More specifically, it is the degree to which each medium “can communicate verbal and nonverbal cues conveying socio-emotional information in such a way that the other persons involved in the communication are perceived as physical ‘real’ and present” (Kreijns et al., 2021, p. 139). Short et al. (1976) defined social presence as the “degree of salience of the other person in the interaction and the consequent salience of the interpersonal relationships” (Short et al., 1976, p. 65). To develop the concept of social presence, Short et al. extended and built upon previous social psychological research in face-to-face contexts, such as Wiener and Mehrabian’s (1968) concept of immediacy, which suggests that nonverbal behaviors can communicate “warmth, availability, closeness, and interest” (p. 66). Social presence is also based on the concept of intimacy, as Argyle and Dean noted as “a combination of eye contact, physical proximity, and smiling” (Cui et al., 2012, p. 663).

Further research on social presence emphasized the interpersonal interaction and mutual recognition it accompanies. Biocca et al. (2001) defined it as the “moment-by-moment awareness of the co-presence of another sentient being accompanied by a sense of engagement with the other (i.e., human, animate, or artificial being)” (p. 2). On the other hand, Walther (1995) emphasized the “cognitive and emotional involvement in the same social space” (p. 186).

Most recently, Kreijns et al. (2021) conducted a review, *Social Presence: Conceptualization and Measurement*, tracing the development of social presence and its various definitions from research with different focuses. Building on previous notions, they positioned social presence as “a psychological phenomenon in which, to a certain extent, the others are perceived as physical ‘real’ persons in technology-mediated communication enabled by CMC (Computer-Mediated Communication) tools and electronic platforms” (Kreijns et al., 2021, p. 140), which is linked but inequivalent to “sociability”, which is a medium attribute, or “social space”, which is a group attribute.

In this study, the researcher focuses on the psychological aspect of social presence, inquiring into the participants’ cognitive and emotional engagement with one another during transnational family communication moments.

2.3 Transnational Relationships

2.3.1 Inter-Family Relations: Performing Kin-Work From Afar

Transnational family refers to “families whose members are separated between two or more nations but maintain close relationships” (Schmalzbauer, 2004, p. 1317).

According to *Missing Kin and Longing to be Together* by Baldassar, transnational families engage in “kin-work”, or the “conception, maintenance, and ritual celebration of cross-household kin ties” (Di Leonardo, 1987, p. 441), as an outward affect to the inward emotions of missing and longing (Baldassar, 2008, p. 247).

“Kin-work” manifests in 4 ways, “discursively (through words), physically (through the body), through actions (practice) and [through] imagination (ideas), which construct 4 types of social presence “virtual, proxy, by practice, and by imagination”, maintaining family bonds (Baldassar, 2008, p. 247).

In the situation of transnational families, social presence “by body” could not be frequently obtained due to physical distances, and families resort to relying on the three other ways in a negotiated communication pattern to sustain their imagined social presence. As Baldassar (2008) noted in their ethnographic interviews with a sample group of Italian immigrants in Australia and their parents in Italy, during periods of

separation, family members write and call each other (social presence by words), schedule regular remote family gatherings (social presence by practice), and send each other photos and meaningful objects that represent themselves (social presence by proxy of body).

In the process of performing “kin-work” (Di Leonardo, 1987, p. 441) and reminiscing about it later on, transnational families construct a social presence by imagination, which is what this study aims to explore and achieve.

2.3.2 Human-Space Relations: Home-Making and Homeness

This study is situated within the broader social context of the affective space of home and home-making in the transnational community.

The Meaning of Home

According to *Connected Communities: Diaspora and Transnationality* by Bonnerjee et al., (2012) the idea of home is uniquely meaningful to members of the transnational community for 3 reasons.

First, home is a “material connection between ‘here’ and ‘there’ ” (Levin & Fincher, 2010, p. 401). The domestic interiors, where the “rituals of living” take place, the domestic materials, and home-making practices all contribute to a visceral and imagined sense of home (Bonnerjee et al., 2012, p. 22). In his book *Space and Place: The Perspective of Experience*, anthropogeographer Tuan described the intimate experiences of a place as “a pause in movement, and a center of felt value and dependability” (Tuan, 2001, p. 138). People establish intimacy with “home” as they “pause their movements” (Tuan, 2001, p. 138) in this space. This sense of intimacy is based on the emotional attachment to the various material elements a home contains. As Tuan elegantly described, this attachment is deeply subconscious and “comes with familiarity and ease, with the assurance of nurture and security, with the memory of sounds and smells, of communal activities and homely pleasures accumulated over time” (Tuan, 2001, p. 159).

Second, home is an anchor for one’s memories and connects them with the larger transnational community. “Productive nostalgia” is a term coined by Blunt (2005) to denote “the material aspects of connections alongside imaginative ones” (Bonnerjee et al., 2012, p. 26). Material elements such as music, food, and religion bond communities with spaces of home.

Third, home contains aspirations of a new pursuit of identity and belonging, as Blunt and Dowling (2022) contended “… international movements are processes of

establishing home, as senses of belonging and identity move over space, and are created in new places" (p. 2). To the transnational community, home is a place that reflects the past and the future.

Homeness in Everyday Objects

Bonnerjee et al., (2012) stated, "domestic material culture creates a sense of home" (p. 23). Indeed, such a notion was echoed by Tolia-Kelly (2004) in her study of visual and material cultures in British South-Asian homes, as she proposed the concept of "re-memory", which is "an alternative social narrative to memory" and "a conceptualization of encounters with memories, stimulated through scents, sounds, and textures in the everyday. 'Home possessions' constitute precipitates of re-memories and narrated histories" (Tolia-Kelly, 2004, p. 676).

Furthermore, The Geffrye Museum of Home curated a photo exhibition and short interview documentary, *Shelf Life*, asking many members of the transnational community in London to speak about special objects they put on shelves in their homes. Many objects these community members spoke about were small but meaningful embodiments of their cultural identity and symbolizes a tie between them and the larger transnational communities which make up the modern urban culture of London (*A Film Showing in the Home Galleries | Museum of the Home*, n.d.).

This study therefore aims to build a sense of social presence through sharing and experiencing everyday objects, or domestic materials.

2.4 Mixed Reality Definitions

Mixed Reality (MR), as defined by Milgram and Kishino in their 1994 seminal text, *A Taxonomy of Mixed Reality Visual Displays*, is "a subclass of VR-related technologies that involve the merging of real and virtual worlds somewhere along the 'reality-virtuality continuum' (RV) which connects completely real environments to completely virtual ones." Figure 1 (Milgram & Kishino, 1994) Illustrates where MR is positioned on the RV continuum.

Figure 2. Reality-Virtuality (RV) Continuum
Note. Adapted From "Taxonomy of Mixed Reality Visual Displays," by P. Milgram and F. Kishino, 1994, *IEICE Transactions on Information and Systems*, *77(12)*, P. 1321 (Https://Cs.Gmu.Edu/~Zduric/Cs499/Readings/r76JBo-Milgram_IEICE_1994.pdf). CC BY-NC.

In the later *Augmented reality: A class of displays on the reality-virtuality continuum*, Milgram and Takemura (1995) listed seven types of MR displays, including monitor-based (non-immersive) video display and HMD display, which are the types of displays this study focuses on.

As Billinghurst (2018) pointed out, MR displays could be further classified using a three-dimension MR taxonomy, proposed by Milgram and Colquhoun (1999), which includes:

1. Extent of world knowledge (EWK), meaning the "amount of the real world that is modeled and understood by the MR system" (Milgram & Colquhoun, 1999, p. 5);

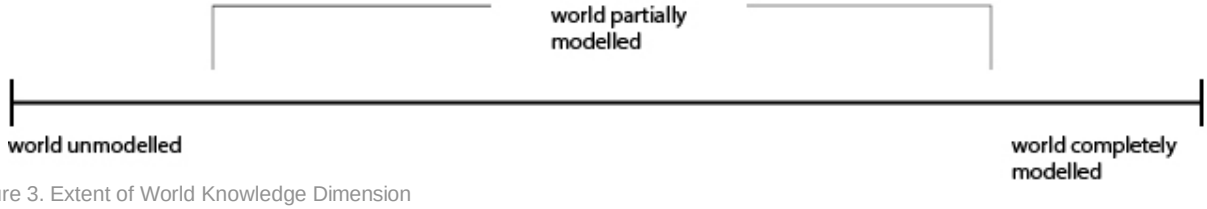

Figure 3. Extent of World Knowledge Dimension
Note. Adapted From "Augmented Reality: a Class of Displays on the Reality-Virtuality Continuum," by P. Milgram and H. Takemura, 1995, *SPIE Proceedings* (10.1117/12.197321). CC BY-NC.

2. Reproduction fidelity (RF), meaning how "realistic the real world is being captured" (Milgram & Colquhoun, 1999, p. 9);

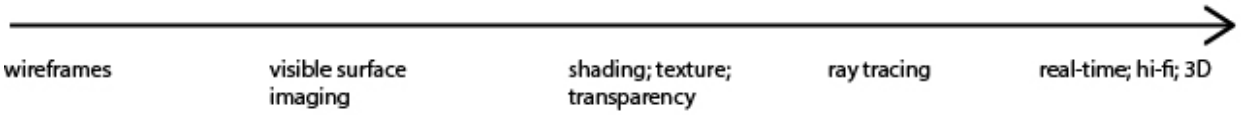

Figure 4. Reproduction Fidelity Dimension
Note. Adapted From "A Taxonomy of Real and Virtual World Display Integration," by P. Milgram and H. Colquhoun, 1999, *Mixed Reality*, P. 5 (10.1007/978-3-642-87512-0_1). CC BY-NC.

3. Extent of presence metaphor (EPM), meaning the "extent that the user feels immersed or present in the displayed scene" (Milgram & Colquhoun, 1999, p. 10).

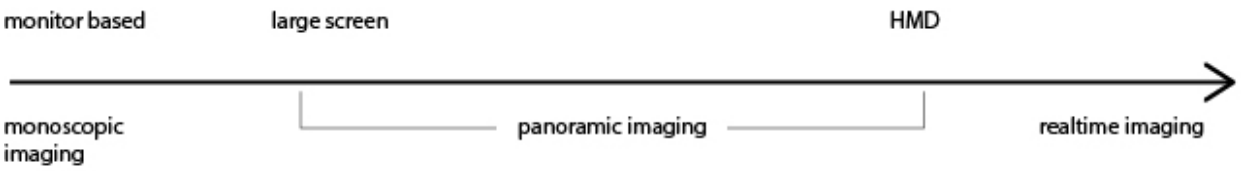

Figure 5. Extent of Presence Metaphor Dimension
Note. Adapted From "A Taxonomy of Real and Virtual World Display Integration," by P. Milgram and H. Colquhoun, 1999, *Mixed Reality*, P. 10 (10.1007/978-3-642-87512-0_1).

Building on the taxonomy above, MR displays can be mapped onto a three-dimensional diagram as Billinghurst (2018) contended. Figure 6. shows a mapping of the 2 MR displays this study would engage with.

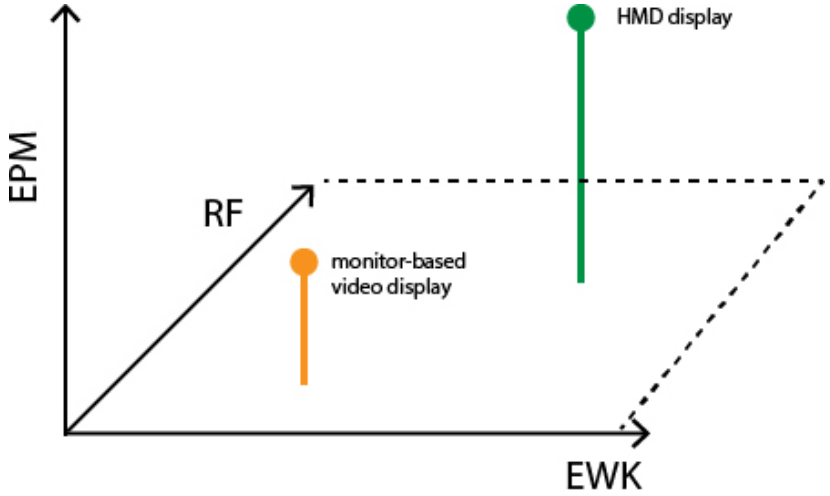

Figure 6. Mapping MR Displays on Three-Dimensional Taxonomy
Note. Adapted From *What Is Mixed Reality* by M. Billinghurst, 2018 (Https://Marknb00.Medium.Com/What-Is-Mixed-Reality-60e5cc284330).

It is important to note, there is no singular definition of MR, as stated by Speicher et al. (2019), who surveyed 68 papers and interviewed 10 AR/VR experts. The above-mentioned “traditional” RV continuum definition is undoubtedly considered to be one of many definitions of MR. However, alternative definitions of MR exist in different research contexts. Speicher et al. (2019) developed a conceptual framework classifying MR experiences along 7 dimensions: number of environments, number of users, level of immersion, level of virtuality, degree of interaction, input, and output. This detailed and all-encompassing framework dissected different aspects of an MR experience, which can be useful for comparisons between experiences based on unified standards.

According to Speicher et al.’s (2019) framework, the MR experiences in this study fall into these categories: single environment, multiple users, partly and fully immersive, partly and fully virtual, and with explicit interaction.

To summarize, mixed reality is a multi-faceted concept, one should always be specific in describing the context this term is used in, by describing the display device, the degree of virtuality in reality or vice versa, and the user experience.

2.4.1 Social Presence in Mixed Reality

Social presence and means to improve it in virtual worlds have been of interest to researchers over the past five decades due to the potential of social presence to

increase social influence and achieve positive communication outcomes (Lee et al., 2006).

Theories on what determines social presence saw an evolution from the seventies to the present, moving from the field of computer science and engineering to a wider range of studies, such as sociology and psychology.

In their 1976 book, *The Social Psychology of Telecommunications*, Short et al. (1976) stated that social presence is a “quality of the medium itself” (p. 62), viewing social presence as driven by technology. This view was echoed by early CMC researchers, exemplified in the media richness theory by Daft and Lengel (1986) in *Organizational Information Requirements, Media Richness, and Structural Design*, stating “richer media content inherently communicates better” (p. 556). Thus, theorists advocating for the medium-first view believe the technological affordances of different mediums are the greatest influencing factor on social presence (Oh et al., 2018).

From the mid-nineties, an alternative view, known as the social information processing theory (SIPT) spearheaded by Walther (1995) started gaining more academic interest. Walther (1995) emphasized the importance of human agency in adapting to different types of communication mediums to achieve a high social presence, although forming such communication strategies may take time (Oh et al., 2018). This view indicates that the level of social presence is a subjective feeling people achieve through a medium. It’s more dependent on the interpersonal communication strategies established over time than the immersiveness of the medium itself.

As Oh et al. (2018) concluded in *A Systematic Review of Social Presence: Definition, Antecedents, and Implications*, social presence in virtual spaces isn’t determined by one factor, but by 3 factors altogether: immersive qualities of the technology, communication strategies established between communicators, and contextual factors. Based on these three factors, studies on social presence diverged into three categories respectively.

Studies focusing on technology’s impact on social presence investigate the technical modality, visual representation, interactivity, haptics, audio, etc. of the MR-enabling devices (Oh et al., 2018), which can be considered as a continuous development of the medium-first view.

Studies on the impact of context on social presence survey the social cues, traits, and agency of the interacting “other”, etc. (Oh et al., 2018). A much-researched area of study focuses on avatar embodiment in virtual spaces, where the user’s mind aligns the avatar body to their physical body, and controls it instinctively (Beaufils & Berland, 2022; Kilteni et al., 2012; Biocca, 2006). A successful avatar embodiment increases

environmental presence and corporeal presence between the user, their avatar, and the virtual environment, “generating a virtuous circle”, as Beaufils and Berland (2022) contended in *Avatar Embodiment: From Cognitive Self-Representation to Digital Body Ownership* (P. 12).

Studies on the impact of individuals on social presence survey demographic variables, psychological traits, etc (Oh et al., 2018). Over time, by engaging in continuous mediated interactions in social environments, individuals learn, become, and stay social in interactions by receiving and granting validity to each other. This includes engaging in joint activities while upholding the obligation to honor each other’s social selves, as the report, *An Interactional View of Social Presence: Making the Virtual Other ‘Real’,* pointed out, after conducting a photo diary study of 35 Second Life players’ interaction experiences of various levels of social presence experienced in online world (Schultze & Brooks, 2018).

In summary, social presence in virtual environments has been long studied, with researchers focusing on its different aspects such as the fidelity of the medium technology, the context in virtual environments (VEs), and individual factors. This study will compare the social presence in MR experienced on different platforms, with altering VEs, and by different users.

2.4.2 Mixed Reality (MR) Applications

The unique qualities of mixed reality MR technology spurred its application to a wide range of industries.

First, in tourism and archeology, MR applications offer compelling historical storytelling experiences by merging the virtual and real environments (Rokhsaritalemi et al., 2020). MR “provide support for expert visual analysis” and “promote [the public’s] social and cultural participation” (Narciso et al., 2015, p. 854). For example, according to research conducted by Narciso et al. (2015), *MixAR* is an AR mobile application that visualizes virtual buildings augmented upon real ruins with realistic renderings while also aligning with real-world surroundings and the user’s location.

Second, in gaming, MR applications allow engaging gameplay experiences by providing “interactions with game objects embedded in real scenes” (Rokhsaritalemi et al., 2020, p. 19). For example, XRoads is a multimodal and multimedia MR spin-off of a traditional tabletop game, *Quest: Zeit der Helden*. By “equipping certain game characters with AI-driven capabilities to become semi-autonomous virtual agents” and allowing the player to give multimodal (speech, touch, and gesture) commands through a digital-physical

hybrid interface (Link et al., 2016, Abstract section), XRoads provides an innovative, smart, and multi-sensorial gaming experience.

Third, in education, MR applications provide embodied learning experiences (Rokhsaritalemi et al., 2020). For example, MEteor is a whole-body interactive projection that teaches students about interplanetary gravitational forces. A comparative user testing conducted between an intervention group (learning with MEteor) and a control group (learning with computer) of middle school students indicated that "enacting concepts and experiencing critical ideas in physics through whole-body activity leads to significant learning gains, higher levels of engagement, and more positive attitudes towards science" (Lindgren et al., 2016, p. 176).

Fourth, MR's capabilities prove to be greatly useful in medical fields by embedding medical data in proper size in real scenes (Rokhsaritalemi et al., 2020). For instance, an MR application for mitral valve repair surgery provides a "seamless integration of pre- and intra-operative imaging, surgical instrument tracking, and display technology into a common framework centered around … the patient" (Linte et al., 2013, p. 83), … "[guiding] surgeons during operation" (Rokhsaritalemi et al., 2020, p. 19).

Fifth, MR applications provide a new creation environment (Rokhsaritalemi et al., 2020, p. 19). A study assessing the advantages of using an MR application to assist product design proved MR improved the participants' geometric analysis abilities, creativity, and model visualization skills (Tang et al., 2020).

Indeed, MR applications, with their unique user experience affordances, are emerging across industries such as tourism, archeology, gaming, education, medical services, design, and much more. Given the immersive, interactive, and multi-sensory characteristics MR applications offer, the researcher believes MR technology has great potential as a tool to support transnational family communication.

2.4.3 Mixed Reality (MR) Tools

Photogrammetry

Photogrammetry, as The American Society for Photogrammetry and Remote Sensing defines it, is the "art, science and technology of obtaining reliable information about physical objects and the environment through processes of recording, measuring, and interpreting images and patterns of electromagnetic radiant energy and other phenomena" (What Is ASPRS? – ASPRS, n.d.). Photogrammetry could be conducted with various image-capture and depth-capture tools, however, this paper will only discuss affordable digital photography as a tool for creating photorealistic 3D models.

To make a photorealistic 3D model, 2 types of information need to be captured by a series of digital photographs taken from different angles—"the position of each surface point on the target object, and the nature (e.g., color, transparency, reflectance) of [each] surface point" (Nebel et al., 2020, p. 2). Being quicker and user-friendlier than 3D modeling and lower cost than laser scanning, digital photography photogrammetry has been adopted by many industries, such as artifact preservation in museums, as it greatly "increases the exhibitions' visibility and accessibility" (Nebel et al., 2020, p. 8). It also encourages generative learning in classrooms, allowing learners to "engage with an object through creating a digitized model of it" (Nebel et al., 2020, p. 8).

Affectively, photogrammetry and photorealistic 3D models evoke unique perceptual and emotional responses. As Nebel et al (2020) stated, photogrammetry increases the environmental fidelity, or "the extent to which virtual representations resemble the real world" (Waller et al., 1998, p. 129), which transfers into an increased interface fidelity, or "the extent which the developed *mental* model is identical to the virtual environment" (Waller et al., 1998, p. 129). Photogrammetry minimizes the deviation between the two fidelities, allowing the perception to be closer to reality, and creating an accurate and compelling digitalization (Nebel et al., 2020). Wormwood et al., (2019) further contended that "perceptions and affective feelings are inherently combined and mutually dependent" (p. 789). Indeed, according to Nebel et al., (2020), a more realistic environment is more immersive, engaging (Walton, 1984; Dede, 2009), and evokes a stronger emotional response (Waltemate et al., 2018) from the viewers.

In this study, photogrammetry is used as a production tool to make photorealistic 3D models of objects that transnational family members find meaningful and share-worthy with other members overseas, as a means to accurately perceive the objects and intimately feel the emotional impact they evoke.

360° Photography

360° photography is a type of "user-controlled omnidirectional photography that allows the viewer to freely explore the entire environment around the viewpoint", thereby creating a "first-person experience of a scenery" (Greussing, 2019, p. 316).

Similar to traditional practices of domestic photography, 360° photography is "a powerful tool for recording and sharing memories" (Jokela et al., 2019, p. 1), especially for indoor and outdoor landscapes and large group gatherings. On an industry level, 360° photography and videography gained much attention in virtual tourism during COVID, as an alternative way to travel when on-site visitations were restricted (Tsai, 2022).

A psychology research studying the relationship between human behavior and the simulated environment examined participants' psychological response to 3 environmental simulation formats in HMD: photographs, 360° panoramas (photographs), and (modeled) virtual reality. It showed that "360° photographs offered the closest to reality results according to the participants' psychological responses" (Higuera-Trujillo et al., 2017, p. 399). This makes 360° a useful tool for viewers to mentally construct a spatial model of the content "in order to replicate the experience of [being in] physical environments" (Higuera-Trujillo et al., 2017, p. 399).

In this study, 360° photography is used to capture holistic images of environments that transnational family members find meaningful and share-worthy with their overseas family, aiming to create a virtual environment of these spaces to simulate similar psychological responses as visiting them in real life.

Social VR Platforms

The researcher noted that far preceding the age of social VR apps, computer-based social games and apps encouraged social interaction between remote users by establishing shared virtual spaces that foster different types of activities, albeit non-immersive in a technology setup sense. The researcher categorized most social games and applications based on how they relate to real life into 2 types:

- Type 1: establishing a virtual space to escape from RL
- Type 2: amplifying RL by facilitating the sharing of RL materials

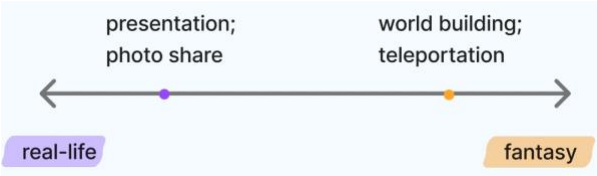

Figure 7. Features Relating to RL-Fantasy Differently as Categorized by Researcher

Features such as world-building and inter-world teleporting in *Altspace, Spatial, Horizon Worlds,* and *Second Life* exemplify the relationship type 1: establishing a virtual space to escape from real life. Users build and customize new worlds with 2D and 3D digital materials, and take on new personas to live in the narrative of each world (Horizon Worlds; Official Site | Second Life). Users have interactions with strangers in shared public spaces.

On the other hand, features such as presenting in *Horizon Workrooms*, and customizing photo walls in *Alcove* and the now discontinued *Facebook Spaces,* are reflective of type 2: amplify real-life by facilitating the sharing of real-life materials. Users acknowledge,

upload and share what's outside of this virtual world with usually a familiar audience (Meta; Homepage | Alcove).

Based on Oh et al.'s (2018) research on social presence in a virtual environment previously discussed, the researcher chose criteria and designed a form for assessing social presence of social VR apps. 8 popular social VR apps (Horizon Worlds, Altspace, Alcove, Half + Half, RecRoom, Bigscreen, Spatial, VR Chat) were selected and evaluated based on the researcher's own experience using each app with an Oculus Quest and engaging in unplanned interactions with the world environment and social others in virtual public spaces.

The 3 large criteria categories: immersion afforded by technology, communication strategies, and contextual factors, are reflective of what Oh et al. (2018) believed to be the major factors influencing social presence. Each large criterion was then divided into several sub-criteria, which were responded to with yes, no, or maybe, mapping to 1, 0, or 0.5 points respectively. The total social presence score for every social VR app was calculated by adding the scores from each sub-category; the social presence score in percentage took the total score and divided it by the highest social presence score achievable in this assessment, which is 9 points.

Social presence assessment of social VR apps

	immersion afforded by technology				Communication strategies		Contextual factors			Researcher's exploration notes	Total social presence score	Social presence percentage (out of 9 max score)
Social VR app name	Audiovisual immersion	Haptics feedback	World interaction freedom	Avatar embodiment	Explicit (speech, text)	Implicit (gesture, emojis)	Environmental cues—is it conductive to the activities it hosts?	Social activities engagement	Social interaction freedom (social agency when interacting with social others)			
Horizon worlds	1	1	1	1	1	1	1	0.5	1	Good balance between avatar fidelity and cartoonification	8.5	94%
Altspace	1	1	0.5	1	1	1	1	0.5	1	Not many social activities allowed by platform	8	89%
alcove	0.5	0	0.5	0	1	0.5	1	1	1	Platform technology out of date—tech issues; VR for family concept is unique	5.5	61%
half+half	1	1	0.5	1	0	1	1	1	0.5	Avatars don't mimic human forms (realism) but doesn't hurt embodiment	7	78%
recRoom	0.5	1	1	0.5	1	1	1	1	1	Audiovisual information overload reduces immersion	8	89%
Bigcreen	1	0	0.5	0.5	1	1	1	1	0.5	Always anchored to seats—limits interactions	6.5	72%
spatial	1	0	1	0.5	1	1	1	1	1	Environmental and avatar realism don't improve immersion much	7.5	83%
VRchat	1	0	0.5	0	1	1	0.5	0.5	1	Social expectations confusing; seeing realistic cosplay avatars reduce immersion	5.5	61%

Note: each criteria allows for 3 responses, yes, no, maybe, which maps to scores of 1, 0, 0.5, respectively. The total social presence score range is [0, 9].

Table 1. Social Presence Assessment of Social VR Apps

The researcher identified a sense of avatar embodiment as not only fundamental to the immersion afforded by technology but also encouraging natural communication strategies, such as gesturing, thereby improving the communication of social cues between users. However, contrary to the researcher's previous assumption, the fidelity,

and realism of the avatar and the environment affected little of the researcher's avatar embodiment and immersion in the space. Avatars too humanlike may backfire and increase lagging and contribute to the uncanny valley effect, a theory first proposed by a robotics professor, Mori et al. (2012), suggesting that "a person's response to a humanlike robot would abruptly shift from empathy to revulsion as it approached, but failed to attain, a lifelike appearance" (p. 98). Social presence is the strongest when the factors from each category work together, allowing frictionless interaction in a space designated for a type of social activity understood by the users, who are represented by avatars that balances fidelity and abstraction.

2.5 Technologies for Social Presence for Transnational Families

2.5.1 Non-Mixed-Reality (MR) Information and Communication Technologies (ICTs) for Transnational Families

An abundance of communication technology tools (ICTs), such as letters, phone calls, video calls, SMS, MMS, and social media platforms, have been used to facilitate the imagined social presence in transnational family communication. According to Cuban's (2017) book, *Transnational Family Communication: Immigrants and ICTs*, these ICTs expand the emotional landscape and the sensory spectrum in communication experiences.

The accessibility and affordance of modern ICTs help transnational families maintain a sense of "ordinary co-presence", where families "kin-work" (Di Leonardo, 1987, p. 441) by sharing life updates spontaneously and ubiquitously, similar to the "exchanges and interactions in the context of physical proximity" (p. 202), as Nedelcu and Wyss (2016) pointed out in *Doing Family' Through ICT-mediated Ordinary Co-presence*, and emphasizes connectivity over content communicated (Licoppe, 2004). Families negotiate consensual communication patterns and digitally perform emotional labor in maintaining family relations to achieve a satisfying communication experience.

Newer, more portable communication devices, cheaper communication fees, and more reliable services "blur the boundaries between online and offline" (Madianou, 2016, p. 185), contributing to a continuously connected and "always on" lifestyle (Boyd, 2012, p. 71). Transnational family members expand their "peripheral awareness" to the virtual world and experience a sense of ambient co-presence with each other, despite the physical distance (Madianou, 2016, p. 183). Furthermore, as Cabalquinto (2019) pointed out, transnational families build and embody a sense of home through a technological "transnational space" (Paragas, 2005, p. 241).

However, according to Cabalquinto (2019), “asymmetrical mobile communication” causing family conflicts can also arise due to “the structural and infrastructural forces in enabling differential mobilities” (p. 52), as exemplified by their research conducted on sustaining transnational relationships through mobile device use of 21 Filipino migrant workers and their left-behind family members at home. Building upon the mediated mobilities frame purposed by Keightley & Reading (2014), which contends mobile device use is affected by the socioeconomic power and political process of the users, Cabalquinto (2019) summarizes 6 categories of differential communicative mobilities: access, social-technical competency, quality of connectivity, rhythms, affective experience, and communicative space (Cabalquinto, 2019). These differential communicative mobilities contribute to communication asymmetries among different members of a transnational family, as well as between different transnational families, allowing some transnational family members to “enjoy a multimedia-rich, connected, and mobile family life, while others grapple with a mediated environment shaped by structural and infrastructural forces” (Cabalquinto, 2019, p. 49). It is therefore important to establish a “critical lens in examining mediated communication in transnational family life”, acknowledge the barriers faced by stratified demographics in the transnational family community, and pursue an “equitable, accessible, and emancipatory connectivity” (Cabalquinto, 2019, p. 58).

In summary, transnational family communication is central to maintaining transnational family relationships. Such communication relies on and benefits from a multitude of ICTs and carefully negotiated family communication patterns. In this study, the researcher set the existing ICT-mediated communication as a baseline transnational family communication experience and compared it to the future-oriented MR-mediated communication platform to understand the change, or the lack thereof, in transnational families’ communication behaviors. Although the day has not come for many transnational households to own devices that allow multimedia sharing, the researcher attempted to anticipate a future use case when the barrier to gaining access to such hardware is flattened.

2.5.2 Related Works on Social Mixed Reality (MR) Applications and Immersive Applications

MR and/or immersive applications designed specifically for building social presence for transnational families are few, however, other social MR and/or immersive applications are highly relevant and comparative.

First, MR applications support remote collaboration and telecommunication. In a paper by Teo et al. (2019), a proposed MR system that integrates a switchable 360 panorama

mode and 3D reconstructed scene mode, received positive feedback from user testing participants, as it allowed users to solve collaborative tasks by "providing variation in controls and features from different perspectives". For future research, the paper suggests recruiting collaborating participants in pairs, as it will "help further investigating social presence and communication behaviors" (Teo et al., 2019, p. 1).

Second, social media, with its geo-tagging practices, finds benefits in incorporating MR. *Geollery,* "an interactive MR social media platform … [featuring real-time renderings of] an interactive mirrored world with three-dimensional (3D) buildings, internal user-generated content, and external geotagged social media … [allowing] users to see, chat, and collaborate with remote participants with the same spatial context in an immersive virtual environment" (Du et al., 2019, p. 1). Results from a 20-participant user study indicated that *Geollery* is "interactive", "creative", and ideal for "travel planning and family gathering" (Du et al., 2019, p. 1).

Third, MR improves gaming experiences. Age Invaders is an "interactive, intergenerational, social-physical game, [allowing] the elderly to play with [their] [grand]children in a physical space, while parents participate … remotely [online]" (Khoo et al., 2008). Its MR system combines a floor digital display game board, networked wearables worn by players, remote online devices for remote players, and a game server that connects all components. Age Invader's user testing suggested that MR has great potential for remote, intergenerational family entertainment, particularly in "improving social interaction, sharing, and support" (Khoo et al., 2008, p. 3).

The related works mentioned above highlighted the unique affordabilities of MR technologies in a variety of social and material domains that improve collaboration, storytelling, sharing, and social interaction. Building on these valuable insights from prior works, this study focuses on MR's application in building social presence in transnational family communication.

2.5.3 Gaps

This section provides a review of the ICT-facilitated transnational family communication behavioral patterns, indicating the potential acceptance of MR technologies that facilitates social presence building for transnational families. Meanwhile, a variety of MR's use cases in different industries further suggested the unique social benefits MR affords remote users.

However, as mentioned before, MR and/or immersive applications designed specifically for building social presence for transnational families are few, likely as a result of the rarity of MR devices in average households, and the technology restraints they impose

on some of the transnational population. This presents an opportunity for this study to focus on building social presence for the transnational family with MR.

2.6 Summary

This background chapter provides a holistic review of the relevant fields: presence and social presence, transnational relationships (including inter-family and human-space relationships), mixed reality, and technologies for social presence for transnational families. Additionally, a wealth of applications, related works, and tools are also described to supplement the fundamental theories.

However, the existing literature and contextual sources indicated a gap in using MR as a technology tool to build social presence for transnational family communication, likely because of the rarity of MR devices in average households, and the technology restraints they impose on some members of the transnational community. Therefore, the researcher situates the focus of this study at the overlap of the socio-technological fields mentioned above, aiming to design and evaluate an MR system that helps to build social presence for transnational family communication. Moving forward, the design direction and the evaluation criteria of the MR system would reflect key ideas regarding mixed reality, social presence, mediated communication, and transnational relationships highlighted in this chapter.

Chapter 3. Methodology and Methods

This chapter details the methodology and methods implemented at different stages of the research and design process to address the research question: How can we build social presence with mixed reality for transnational families?

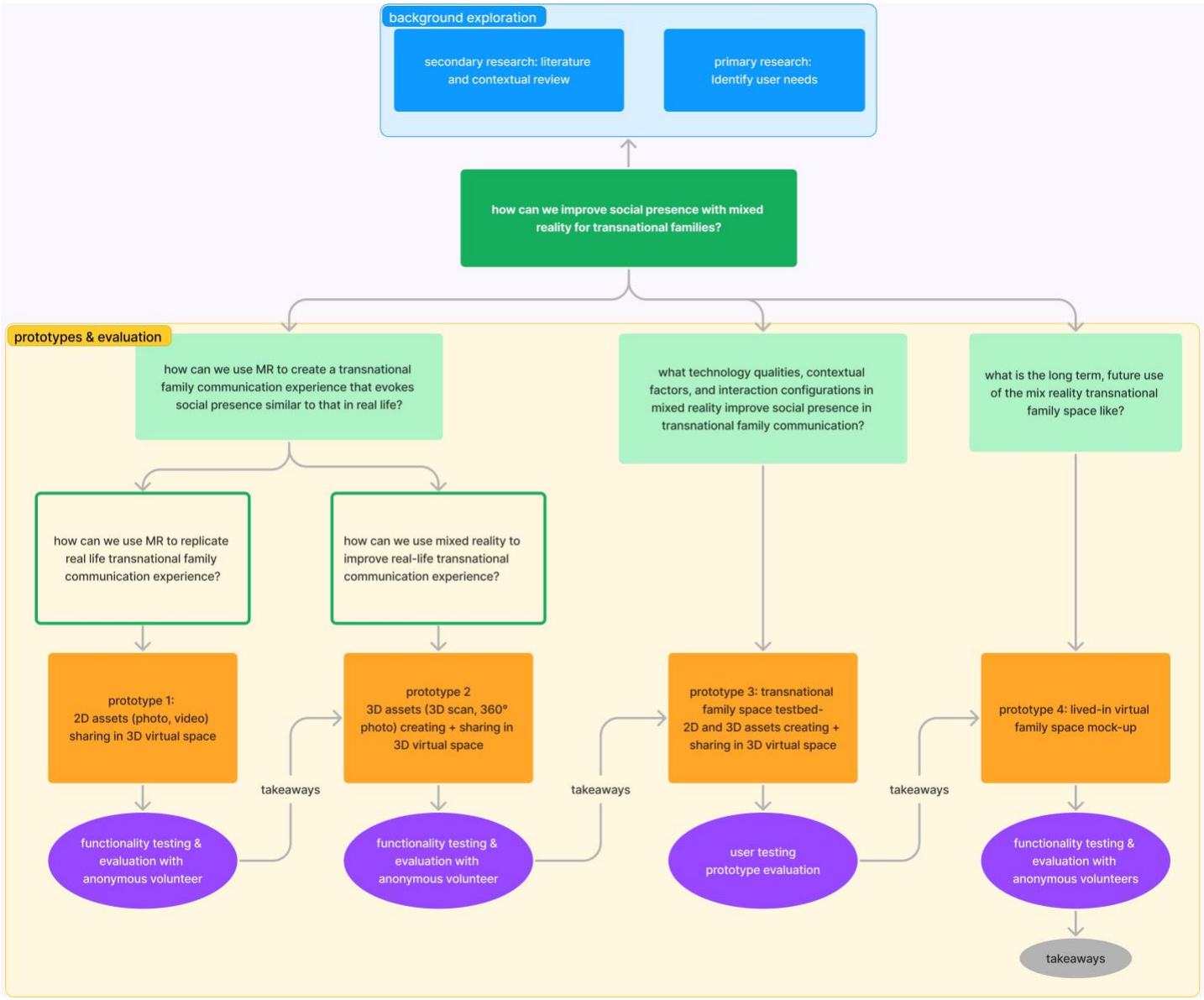

Figure 8. Overview of Chapter 3. Methodology and Methods

As shown in figure 8, the organization of this chapter traces the Research through Design (RtD) implementation in this study chronologically. First, it starts with defining and describing the attributes (including flow, outcomes, and benefits) of RtD, according to relevant literature sources. Second, the background exploration section talks about

the secondary research and primary research methods, which are literature review and online surveying, respectively. Then, the research design section describes the methodology and methods implemented, including RtD and user testing. Lastly, it describes the data collection, analysis, and sample selection methods.

This chapter ends with an overview of the limitations in methodology and method implementation and a summary.

3.1 Research Through Design (RtD) Methodology

3.1.1 RtD Definitions and Attributes

This study is informed by the overarching methodology known as the Research through Design (RtD) methodology, which has its roots in the field of art and design, and gradually gained acknowledgment and popularity in other fields, including Human-Computer Interaction (HCI) research.

Building on the design process, RtD values iterative prototyping, documentation, and reflection.

RtD Definitions

Many literature sources attribute the cultural historian and former rector of the Royal College of Art, Christopher Fraying, for first framing RtD as a research methodology. In the research paper, *Research in Art and Design*, Frayling categorized 3 types of interactions between research and art/design: “research *for* art/design, research *into* art/design, and research *through* art/design” (Frayling, 1993, p. 5). He then contended that RtD is conducted through developing new art and design works by “customizing a piece of technology to do something no one had considered before, and communicating the results” (Frayling, 1993, p. 5).

However, it’s important to note, there isn’t a unified definition of RtD, rather, researchers describe RtD with slightly different focuses based on the research they’re concerned with. According to Godin and Zahedi’s (2014) literature review on RtD, Findeli (2004) further refined Frayling’s definition, stating, “RtD is [resembling] the actual design practice, recasting the design aspect of creation as research. Designers/researchers who use RtD actually create new products, experimenting with new materials, processes, etc” (p. 8). In the field of Human-Computer Interaction (HCI), prominent researchers such as Zimmerman et al. described RtD as a “process of iteratively designing artifacts as a creative way of investigating what a potential future might be” (Zimmerman et al., 2010, p. 313). Despite the diverse definitions of RtD from various literature, there’s no “vital contradiction between the authors’ claims” (Godin & Zahedi,

2014, The Many Faces of Research through Design section) as Godin and Zahedi (2014) contended, these definitions share a “common underlying goal [of] establishing aspects of research done through the design process and its resulting product” (Godin & Zahedi, 2014, The Many Faces of Research through Design section).

As the research and design interests of this study share many similarities to the field of HCI, where Zimmerman et al.’s research is focused on, the interpretation of the RtD methodology in this study is predominately informed by Zimmerman et al.’s definition and descriptions, while occasionally referencing literature from other researchers for supplementary context.

RtD Flow

Most researchers compare the flow of RtD with the design process, as Zimmerman et al. (2010) stated, RtD "employs methods and processes from design practice as a legitimate method of inquiry” (p. 310).

This comparison was further elaborated in Basballe and Halskov's (2012) research, where they described the flow of RtD as a sequence of 3 steps:

1. Coupling: Here, the “research and design interests unite” (Basballe & Halskov, 2012, p. 65), and the project is framed to “serve both levels of interest” (Godin & Zahedi, 2014, Flow of Research through Design section). In this study, this step is exemplified through background exploration in this chapter.
2. Interweaving: Here, the “research interests and design interests influence each other” (Godin & Zahedi, 2014, Flow of Research through Design section), establishing methods. This is exemplified by this methodology and methods chapter.
3. Decoupling: Here, the designer/researcher focuses on the point of interest set to carrying out prototyping and evaluation (Godin & Zahedi, 2014). This is exemplified through the iterative prototyping and evaluation in this study, which is described in detail in Chapter 4.

RtD Outcomes

In general, according to Biggs and Buchler (2007), RtD produces working artifacts and knowledge through the design process. This is further refined by Zimmerman et al. (2010), categorizing the types of outcomes of RtD into these categories: “design artifacts”, “design methods”, “conceptual frameworks on preferred states”, and “nascent theories”, also known as theories that “emerge from exploratory work (generally qualitative)” and “work as a proposition about important relationships between phenomena in a new area” (Zimmerman et al., 2010, p. 311).

In the field of HCI, Zimmerman et al,. (2007) highlighted 4 aspects to evaluate the contribution of RtD:

1. Process, as demonstrated by the “rigor applied to the methods” (Zimmerman et al., 2007, p. 7);
2. Invention, as demonstrated by the “significant advancement” upon the current state of knowledge (Zimmerman et al., 2007, p. 7);
3. Relevance, as demonstrated by the research contributions that support a “preferred state” or a “potential future” (Zimmerman et al., 2007, p. 5);
4. Extensibility, or the thoroughness of the documentation and evolution of the project in a way that future researchers could build upon (Zimmerman et al., 2007).

This study attempts to speculate the preferred state in transnational family communication when mixed reality technology becomes more commonplace by producing design artifacts (MR prototypes), and knowledge (design framework and evaluation criteria).

RtD Benefits

To design for a preferred state, RtD is beneficial for exploring and solving real-life wicked problems (Zimmerman et al., 2007).

This notion of developing research with strong connections to real life is also echoed by Gaver’s (2012) article, *What Should We Expect From Research Through Design?*, in which he stated that RtD is implemented to “bear on situations chosen for their topical and theoretical potential”, and to produce design results seen as “embodiments of the designers’ judgments about valid ways to address the problems and possibilities in those situations” (Gaver, 2012, Introduction section). Similarly, as Ghaoui (2006) framed it, RtD allows the designer to encounter and navigate “real-world obstacles in the way of building the best bridge between the product idea and its usership” (p. 542).

In addition to the design artifacts that demonstrate a design solution to the wicked problems, RtD also transfers knowledge produced in research to practice, providing new engineering and research opportunities for the industry and academia (Zimmerman et al., 2007).

This study identified real-life wicked problems in transnational family communication, designed and tested MR prototypes to improve social presence for transnational family communication, thereby connecting the “product idea and its usership” (Ghaoui, 2006, p. 542).

3.1.2 Design Background

Literature and Contextual Review

To investigate the research question: How can we build social presence with mixed reality for transnational families? this interdisciplinary study identified these fields of study: presence and social presence, mixed reality, transnational relationships (inter-family and human-space relationships), and technology for social presence for transnational families. In addition to fundamental theories, an abundance of applications, related works, and tools was described to enrich the background review.

This review of existing literature and contextual sources indicated a gap in the overlap of the above-mentioned fields, which is using MR as a technology tool to build social presence for transnational family communication, presenting this study with an opportunity for further development.

Finally, the researcher situates the focus of this study at the overlap of the socio-technological fields mentioned above, aiming to design and evaluate an MR system that builds social presence for transnational family communication.

Identifying User Needs: Surveying Current Transnational Family Communication Experiences

As an extension of the background exploration, this study then conducted primary research through online surveys, which were completed by 18 people, to find out about the current transnational family communication experience, highlighting transnational families' communication patterns, moments of high/low social presence, pain points, and wants (see Appendix A, B). These surveys were conducted with the Research Ethics Board's approval (REB number: 2022-90).

As reflected by the survey, most transnational families communicate by texting, voice calling, and video calling daily with their immediate family. The top reasons for selecting an ICT include speediness, portability, and a sense of intimacy.

Furthermore, people responded that they tend to feel the highest social presence when there is a visual element in their communication (sending images, video calling) at moments when they update each other on their everyday lives. Some also mentioned the benefit of having an environment context during a video call, whether it's of a familiar place once shared by both sides or a new place one family member recently visited. Situating real-time communication within the space each family member occupies at the moment feels like "a zoomed-out version where we are doing our own

activities in the background … [but are still] present for each other" (a respondent in the pre-experience survey).

On the other hand, people feel the lowest social presence when communicating through text or when the quality of their ICT connection is bad, suggesting a non-audiovisual, non-live, or delayed connection is detrimental to social presence.

All respondents spoke of the time zone difference as the major pain point experienced in current transnational family communication. A few expressed the limited information carried by words, photos, and videos hurts their communication. Further, the majority of respondents expressed their wants for improved transnational family communication, including deliberately setting time aside for planned activities, and having larger family events, instead of siloed one-on-ones. One responder also acknowledged their want for a better ICT to accommodate such large family events.

This aspect of the background exploration further indicated the existence of user frustration in current transnational family communication experiences, and the user need for a more immersive, more sensorial, and smoother means of transnational family communication.

3.1.3 Prototypes and Evaluation

During design artifact production, RtD emphasizes iterative prototyping, or "a cyclic process of prototyping, testing, analyzing, and refining a product or process . . . [where] the results of testing the most recent iteration of a design, changes, and refinements are made" (WDO | Iterative Design, n.d.).

Referring back to Figure 7. at the beginning of this chapter, the primary research question is supported by 4 secondary research questions, each explored through a prototype. Each prototype was designed, evaluated, documented, and reflected upon for takeaways informing the next. Iteration is indicated by the back-and-forth between producing design artifacts and conducting evaluation activities.

As the figure indicates, the main research question (middle green box) is "how can we build social presence with mixed reality for transnational families?" Which can be supported by these secondary research questions (light green box):

1. "How can we use MR to create a transnational family communication experience that evokes social presence similar to that in real life?" Which is divided further into 2 parts:

1.1. “How can we use MR to replicate real-life transnational family communication experience?” as explored through *Prototype 1: 2D Assets Sharing in 3D Virtual Space*.

1.2. “How can we use mixed reality to improve real-life transnational communication experience?” as explored through *Prototype 2: 3D Assets Creating and Sharing in 3D Virtual Space*.

2. “What technology qualities, contextual factors, and interaction configurations in mixed reality build social presence in transnational family communication?” As explored through *Prototype 3: Transnational Family Space Testbed*.

3. “What is the long-term, future use of the mixed reality transnational family space?” As explored through *Prototype 4: Long-Term, Lived-in Virtual Family Space*.

After each prototype was produced, it was evaluated based on a unified set of evaluation criteria. Each criterion category was scored numerically or with a Likert-chart-based descriptor and documented in a standard table. For prototypes 1, 2, and 4, the evaluation data was derived from functionality testing the researcher conducted with an anonymous volunteer; for prototype 3, the evaluation data was derived from 12 sets of user testing data.

The section *Measuring Social Presence Through User Testing* below provides a detailed account of the criteria.

Usability Testing Method (Prototype 3)

This study conducted user testing by pairs, with each pair consisting of a local participant and one of their transnational family members overseas. Quantitative and qualitative data were collected through online surveys (see Appendix C), observational notes, and interviews (see Appendix D). A detailed description of the user testing sessions is documented in the following chapter.

According to *Usability Testing: a Review of Some Methodological and Technical Aspects of the Method*, user testing is a user-centered method to ensure that “interactive systems are adapted to the users and their needs” (Bastien, 2010, p. 19). Further, Bastien (2010) contended, user testing evaluates 3 aspects of the designed product: how much effort is required to use the product (usability), how effective is the product in achieving its design goals (usefulness), and how well the target users favor it (attitude).

Thus, the user testing activities in this study were centered around semi-structured tasks to test the prototype’s usability. Post-experience interviews and surveys were

conducted to gauge the prototype's usefulness in improving social presence and to understand users' attitudes toward it.

Additionally, this study went to great lengths to ensure user testing was conducted in pairs of transnational family members. Paired-up user testing is essential to this study as it mimics the intended use case, promotes a "natural interaction style [with] more comments than think-aloud sessions", and makes the testing "easier for the researcher and more fun for both participants" (Bastien, 2010, p. 20).

Measuring Social Presence Through User Testing

Social presence is ultimately a subjective feeling, therefore, measuring social presence can take on different approaches. Indeed, researchers in the past have employed a range of measurement techniques, including subjective, behavioral, physiological, neurological, and task-based measures (Van Baren & Ijsselsteijn, 2004). Among these techniques, subjective measures are used most commonly by researchers to measure social presence (Insko, 2002).

Subjective measures of virtual social presence rely on self-reflection from the user, usually in the form of post-immersion questionnaires and ratings (Van Baren & Ijsselsteijn, 2004). In *Presence and Performance Within Virtual Environments*, Barfield and Zeltzer (1995) provided a list of example questions, including "to what extent did you experience a sense of being 'really there' inside the VE", and "how 'real' were your interactions with objects and other people" (p. 473). To answer these questions, users were asked to give numeric scores, which were then analyzed quantitatively. Similarly, these questions could also guide workshop conversations and semi-structured interviews to uncover qualitative insights.

This study evaluated the usability, usefulness, and social presence of each prototype following the set of criteria below:

- access device — computer or VR headset
- usability evaluation
    - navigation — the ease of controlling the position, orientation, and movement in the virtual space (1 to 10 scale)
    - interaction with the other — the ease of interacting with the other user in the virtual space (1 to 10 scale)
    - interaction with UI — the ease of interacting with the UI (user interface) elements in virtual space (1 to 10 scale)

- usefulness evaluation
    - sense of being really there — the extent of feeling “present/really there” in the virtual space (1 to 10 scale)
    - sense of being as one with the avatar — the extent of feeling embodied in your avatar in the virtual space(1 to 10 scale)
    - sense of social engagement when directly interacting with the other — the extent of feeling socially engaged when having face-to-face conversations and interactions with the other user in the virtual space(1 to 10 scale)
    - sense of co-present when in the vicinity of the other — the extent of feeling like being in the same space when being near the other user in the virtual space (1 to 10 scale)
    - sense of social agency — the extent of feeling capable of using resources to fulfill potential in the virtual space (1 to 10 scale)
    - customization freedom — the level of customization available in the virtual space (1 to 10 scale)
    - level of interactivity in comparison to regular communication mediums — compared to how you usually share media content with transnational families, the level of interactivity that changed in the virtual space (decreased a lot; decreased a bit; didn’t change much; increased a bit; increased a lot)
- social presence evaluation
    - virtual space’s effect on social presence — the level of social presence that changed as a result of the virtual space (decreased a lot; decreased a bit; didn’t change much; increased a bit; increased a lot)
    - avatar’s effect on social presence — the level of social presence changed as a result of the avatars (decreased a lot; decreased a bit; didn’t change much; increased a bit; increased a lot)
    - overall social presence score — the extent of the subjective feeling of really being in a mediated virtual space with social other(s) and having access to their thoughts and emotions (1 to 10 scale)

prototype evaluation form									
Evaluation criteria		prototype 1: 2D assets (photo, video) sharing in 3D virtual space		prototype 2 3D assets (3D scan, 360° photo) creating + sharing in 3D virtual space		prototype 3: transnational family space testbed—2D and 3D assets creating + sharing in 3D virtual space [USER TESTED]		prototype 4: speculative long-term, lived-in transnational family virtual space	
Theme	Sub-theme	Computer	VR headset	Computer	VR headset	Computer	VR headset	Computer	VR headset
Usability evaluation	Navigation								
	Interaction with other user								
	Interaction with UI								
Usefulness evaluation	Sense of really there								
	Sense of being as one with avatar								
	Social engagement when directly interacting with other								
	Co-presence when in vicinity of other								
	Social agency								
	Customization								
	Level of interactivity compared to everyday ICT								
Social presence evaluation	Virtual space's effect on social presence								
	Avatar's effect on social presence								
	Overall social presence score								

Table 2. Sample Prototype Evaluation Form

Other measurement techniques, including behavioral, physiological, neurological, and task-based measures, can all be summarized as objective measurement techniques. Instead of relying on direct user responses, these techniques observe how users interact with each other, and physically respond to their environment or specific tasks (Felton & Jackson, 2021). On the other hand, measurement techniques that measure users' physiological and neurological reactions gauge users' bodily reactions by comparing certain sets of biophysical data with pre-established baseline values (Billinghurst, 2019).

In summary, since social presence cannot be directly measured, measurement techniques are either subjective, direct inquiries where users reflect upon their experiences, or objective, indirect observations where the researcher observes and measures the users' activities and biophysical reactions. The latter then helps researchers deduct users' experience of social presence based on perceived correlations between reactions and subjective feelings.

This study documented behaviors as observation notes to supplement direct responses from users through surveys and interviews.

3.1.4 Data Collection Methods

This study implemented subjective measurement through 2 data collection methods—automatic data collection using surveys, and researcher-facilitated data collection, which are described in detail below.

Automatic Data Collection With 3 Online Surveys

3 online surveys were distributed at different points during this study. To understand the current user experience in transnational family communication, a (multiple-choice and short-response) *Pre-Experience Survey* was distributed to participants who were participating in user testing sessions (see Appendix B), and an anonymous (multiple choice) *General Survey* was distributed to participants who weren't (see Appendix A). After user testing, a (multiple choice, Likert scale, and short response) *Post-Experience Survey* was distributed to user testing participants (see Appendix C).

The surveys included multiple-choice and Likert-scale questions, which helped the grouping of similar responses, thereby informing the degree/intensity of subjective experiences. Additionally, short-response questions were also included in surveys to capture individualized qualitative data and provide a space for open-ended reflections. All 3 surveys were created, distributed, and filled out on Microsoft Forms. After data collection was completed, survey results were downloaded from Microsoft Forms as spreadsheet files and analyzed locally.

By distributing this survey online and including a *General Survey* for those who didn't wish to participate in user testing, this automatic data collection method ensured a "high participation in parallel, with little or no incremental cost per participant" (Bastien, 2010, p. 20).

Researcher-Facilitated Data Collection During User Testing

The connected user testing sessions were conducted synchronously using prototype 3 (an MR transnational family environment) between a local (Toronto) participant and one of their remote transnational family member. According to Bastien (2010), remote testing reduces research costs and time.

During testing, the researcher non-intrusively stayed in the same physical testing space occupied by the Toronto participant (in VR headset) and documented qualitative observation findings such as body language and verbalized comments. As Bastien (2010) contended, this type of synchronized data collection is valuable as it captures "spontaneous verbalizations"— a part of irreplaceable quantitative data useful in gauging the participants' attitudes (p. 20).

After user testing, the researcher briefly joined the participants in their virtual family space to conduct a follow-up scripted interview (see Appendix D) about their initial thoughts of the prototype experience. All in-VR activities were screen-recorded with the Oculus Quest 2 worn by the Toronto user. After each session, the completed recording was analyzed offline.

3.1.5 Data Analysis Methods

Overall, a mixed method approach combining quantitative and qualitative data analysis was used to understand the generic user opinions as well as individualized thoughts. As Hashizume and Kurosu (2013) stated in their research on human-centered research design, the quantitative method "construct[s] a generic principle that explains a phenomenon in a certain situation", while the qualitative method "grasp[s] how each individual is [subjectively] trying to comprehend the reality of a certain situation and to interact with it" (p. 71). A mixed method approach combining the two "takes advantage of both. . . [and] depicts the study targets more realistically" (Hashizume & Kurosu, 2013, p. 72).

Data collected from this study includes survey data and user testing data, each including quantitative data and qualitative data. In this study, quantitative data reveals how objectively usable the prototype is, while qualitative data reveals users' subjective experiences at different points of interaction.

Survey Data

The surveys included subjective multiple-choice, Likert-scale, and short-response questions about participants' current transnational experiences and their evaluation of the prototype post-experience. The multiple-choice and Likert scale ratings were statistically analyzed to understand the majority opinion. The short responses were textually analyzed using Microsoft Excel, highlighting recurring key terms and ideas.

User Testing Data

User testing data in the form of screen recordings and the researcher's observation notes were taken throughout user testing. This data was qualitatively analyzed for the mood participants express and the moment these expressions occur. The media content (3D scans, 360-degree images, photos, and videos) produced by participants and screen-recorded post-experience interviews in VR were qualitatively analyzed to understand participants' interaction patterns, attitudes toward the prototype, and significant points of friction during the experience.

3.1.6 Sample Selection

People and their transnational family members whom they communicate regularly with were selected in pairs for the user testing of this study, while anyone who communicates with their transnational family could complete the general survey solo. Being a graduate student at OCAD University, the researcher was permitted recruitment

access to a large international student community, at 1109 people in the year 2020-2021, accounting for approximately 26% of the overall student population (*Facts and Figures*, 2021).

Screening Information

All participants were above 13 years of age with basic computer and literacy skills.

To conduct the connected user testing, participants were recruited in pairs of one Toronto-based participant and one overseas participant from the same family. The Toronto participants needed to understand English. The family members needed to have computer and internet access at home for connected testing. The user testing included 8 transnational family pairs as participants. This size allowed the researcher to collect in-depth data on the usability and usefulness of the tested prototype (prototype 3) while also remaining manageable within a month-long time frame.

The general survey required no participation outside of the survey completion nor pairing up with a family member.

Recruitment

A recruitment email was used to reach out to the international student community at OCAD University through the university's international office's mailing list. The recruitment email informed potential participants of the study and participation requirements. It invited them to join either as a general participant by taking the general survey, or as a user testing participant by starting with taking the pre-experience survey. Both survey links were included in the email. Participants bear no personal relationships with the researcher. For the full recruitment email script, please refer to Appendix E.

3.2 Summary

This chapter discusses the methodology and methods implemented in this study that addresses the research question: How can we build social presence with mixed reality for transnational families?

This chapter starts by establishing the definitions and attributes of the Research through Design methodology based on existing literature. Then, in the background exploration section, this chapter describes the secondary research and primary research methods, which are literature review and online surveying, respectively. The following research design section describes the methodology and methods implemented, including RtD and user testing. Lastly, it describes the data collection, analysis, and sample selection methods.

Being a graduate-level thesis, there are limitations to accessible resources. First, due to the time, resource, and funding constraints, the user testing could not capture a completely realistic use case of the tested prototype. In this study, user testing sessions were cross-sectional, where the participants engaged with an unfamiliar prototype for a short testing period, and not longitudinal, where the participants organically engage and live with the prototype for a duration of time. As a result, the testing results fall short of fully representing the organic and spontaneous nature of transnational family communication in some families.

Second, recruitment from the OCAD University international community likely resulted in a homogenous demographic (transnational people who are educated, financially sufficient, and enjoy consciously maintained transitional family relationships), and therefore may not represent the experiences of the larger diaspora community. However, measures were taken to maximize the pool of qualifying potential users, such as widening the participation requirement age range and forgoing any English language requirement for the overseas family member.

Despite the limitations stated above, the RtD methodology is still suitable and valuable for this study.

First, by researching, iteratively designing, and evaluating prototypes, RtD guides this study to explore the opportunities and challenges associated with real-life wicked problems (Zimmerman et al., 2007; Gaver, 2012), “bridging between the product idea and its usership” (Ghaoui, 2006, p. 542), resulting in design artifacts and knowledge of the process.

Second, by thoroughly documenting the research and design process, RtD demonstrates a “preferred state” or a “potential future” (Zimmerman et al., 2007, p. 5), paving the way for future researchers studying the field of using MR to build social presence for transnational families.

Chapter 4. Iterative Prototyping

4.1 Introduction

Guided by the Research through Design (RtD) methodology, this chapter zooms in on the design process by describing a series of 4 iterative prototypes. One by one, this chapter highlights each prototype's relation to a research question, exploration goals, features, evaluation results from testing, and takeaways.

Expanding upon Figure 8. in Chapter 3, Figure 9. on the next page provides a detailed account of the research questions and the 4 prototypes. As shown in Figure 9., the main research question (top green box) is "how can we build social presence with mixed reality for transnational families?" Which can be supported by these secondary research questions (light green box):

1. "How can we use MR to create a transnational family communication experience that evokes social presence similar to that in real life?" Which was furthermore explored in 2 parts:
    1.1. "How can we use MR to **replicate** real-life transnational family communication experience?" as explored through *Prototype 1: 2D Assets Sharing in 3D Virtual Space*.
    1.2. "How can we use mixed reality to **improve** real-life transnational communication experience?" as explored through *Prototype 2: 3D Assets Creating and Sharing in 3D Virtual Space*.
2. "What technology qualities, contextual factors, and interaction configurations in mixed reality build social presence in transnational family communication?" As explored through *Prototype 3: Transnational Family Space Testbed*.
3. "What is the long-term, future use of the mixed reality transnational family space?" As explored through *Prototype 4: Long-Term, Lived-in Virtual Family Space*.

All 4 prototypes were evaluated according to a standard set of evaluation criteria listed in Chapter 3. Each category was evaluated by a numeric score or a Likert-chart-based descriptor and documented in the evaluation table shown in Table 2 in Chapter 3.

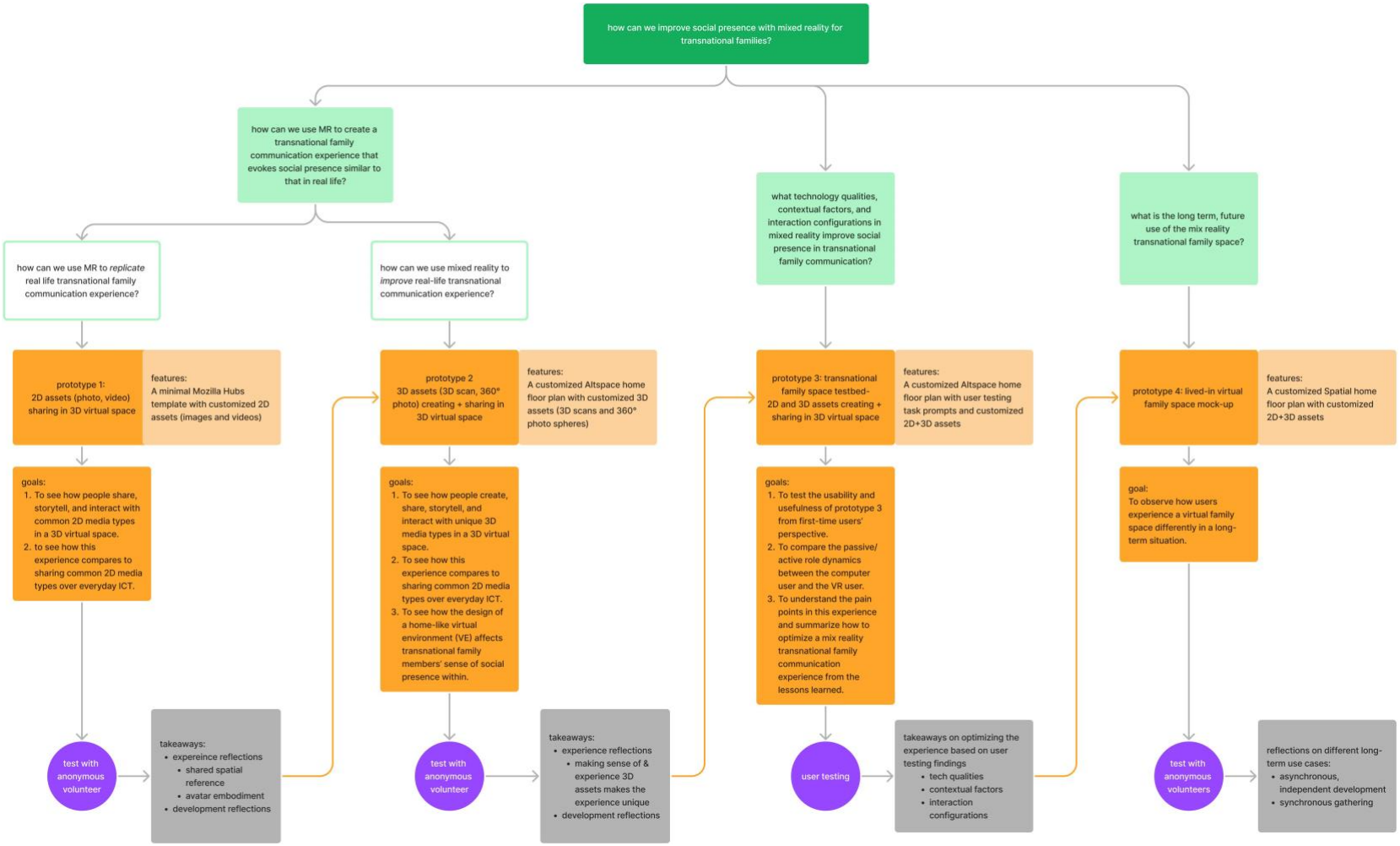

Figure 9. Iterative Prototypes Exploring Research Questions

4.2 Prototype 1: 2D Assets Sharing in 3D Virtual Space

4.2.1 Exploration Goals

To explore the research question “how can we use mixed reality to replicate a real-life transnational communication experience?” two goals were set for this prototype:

1. To see how people share, storytell, and interact with everyday 2D media types in a 3D virtual space.
2. To see how this experience (sharing, storytelling, and interacting with everyday 2D media types in a 3D virtual space) compares to sharing common 2D media types over everyday ICT.

4.2.2 Features

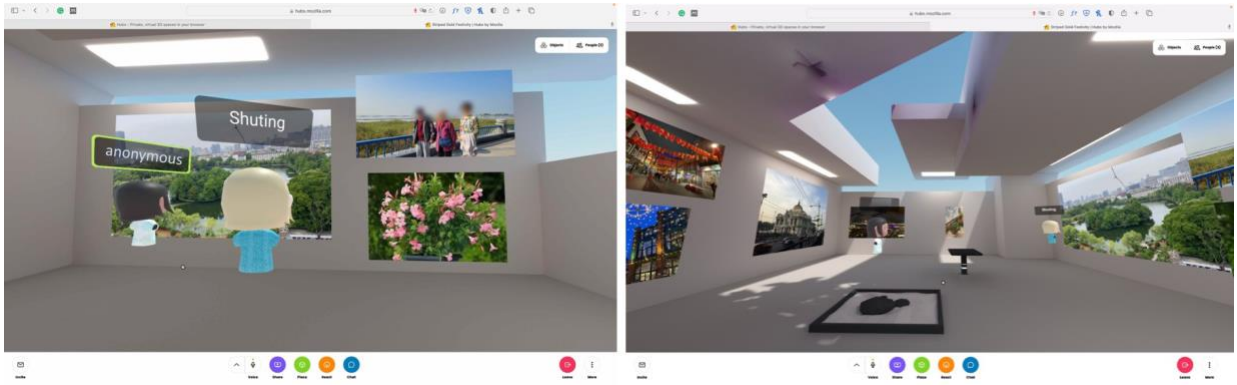

Figure 10. Prototype 1—Testing Activity Screenshots

As the screenshots above (Figure 10.) show, prototype 1 was built on *Mozilla Hubs* with an empty, minimalist 3D space template, allowing interactions to take place without interference from contextual cues.

4.2.3 Activity

The testing activity space was set up with 8 media frames across 3 walls, to which each user uploaded 3 pictures and 1 short (approximately 10 seconds) video. Each user then directed the other user through their 2D assets, sharing the stories behind each captured moment. This 10-minute activity was loosely structured, allowing casual conversations sparked by the stories of the users’ 2D assets to arise naturally.

The testing activity of prototype 1 was conducted between the researcher and an anonymous family volunteer. The activity was conducted twice, allowing the researcher to evaluate the experience of a computer user and a VR headset user.

The technology setups for the repeated activity are as follows:

1. First round: researcher on VR headset; volunteer on computer
2. Second round: researcher on computer; volunteer on computer

4.2.4 Evaluation

After experiencing prototype 1 on a VR headset and a computer, the **researcher** rated the prototype according to the previously introduced criteria, as shown in Table 3. below.

Prototype 1 Evaluation

Evaluation criteria		prototype 1: 2D assets (photo, video) sharing in 3D virtual space			
Theme	Sub-theme	Computer	Computer avg	VR headset	VR headset avg
Usability evaluation	Navigation	7	6.33	9	8.00
	Interaction with other user	7		8	
	Interaction with UI	5		7	
Usefulness evaluation	Sense of really there	6	6.17	9	8.50
	Sense of being as one with avatar	5		10	
	Social engagement when directly interacting with other	7		8	
	Co-presence when in vicinity of other	6		8	
	Social agency	7		8	
	Customization	6		8	
	Level of interactivity compared to everyday ICT	Level of interactivity increased a bit		Level of interactivity increased a bit	
Social presence evaluation	Virtual space's effect on social presence	Improved social presence a bit		Improved social presence a bit	
	Avatar's effect on social presence	no effect on social presence		Improved social presence a bit	
	Overall social presence score	6.5		7	

Table 3. Prototype 1 Evaluation Rating Scores

As detailed in Appendix F., the researcher's evaluation suggests experiencing prototype 1 with a VR headset was more usable and useful than experiencing it with a computer. Compared to everyday ICT such as calling, messaging, or video chatting, prototype 1

improved social presence for both the computer and the VR headset experiences. However, the improvement was more multi-faceted for the VR headset experience.

High-Level Analysis

HOME-MAKING IN VIRTUAL SPACE

Prototype 1 afforded a low level of transnational family home-making. While the material elements of 2D assets (pictures and videos) from both family members situated in a 3D space assisted storytelling, the lack of any homely environmental context made it difficult to experience emotional intimacy and a sense of familiarity deeply rooted in people's notion of home (Tuan, 2001).

PERIPHERAL AWARENESS IN COMMUNICATION

The researcher noticed a medium level of "peripheral awareness" (Madianou, 2016, p. 183) experienced through this prototype. The spatial audio setting allowed the researcher to identify the location of the sound source of the other user without looking at them, and gain a sense of co-presence in the same space. This attribute was more prominent when wearing a headphone.

SPATIAL REFERENCING

According to Klatzky (1998), spatial reference frame, defined as "a system of reference to represent the object's and subject's spatial positions…is involved in spatial memory, perception, performing actions in space, and navigation" (p. 2). Furthermore, there are two types of reference frames: egocentric reference frame where "locations of objects are coded in relation to the observer" (Moraresku & Vlcek, 2020, p. 788), and allocentric reference frame where the locations of objects are coded independent to the observer, but in relation to other objects instead (O'Keefe & Nadel, 1978). Such framing can be adapted to describe the avatar-environment relationship in testing prototype 1, where the (virtual) space is occupied by 2 users; the "observer" can be further categorized into the speaker/reference initiator, and the listener/reference receiver.

During prototype 1's activities, a mix of reference-initiator-centric, reference-receiver-centric, and allocentric reference frames was used by both users, depending on the reference receiver's relative location to the reference initiator, and the existence of significant spatial marks nearby.

4.2.5 Key Takeaways

Experience Reflections

Based on the researcher's testing activities with an anonymous volunteer, the experience of sharing, storytelling, and interacting with common 2D media types in a 3D virtual space felt more precise and intimate than doing so over an everyday ICT due to having a shared spatial reference and avatar embodiment.

A shared spatial reference is apparent at moments when users spoke about a particular media asset or location, descriptors such as "on your left", "where I'm pointing/looking at", and "the wall on the opposite side" were used to precisely and effectively speak about subjects within the virtual space.

Furthermore, as both users were being represented by avatars, the researcher felt a heightened sense of presence; both users used their avatars to express body language and non-verbal expressions. This is known as avatar embodiment, or the sense of being incarnated in a virtual body (Amato & Perény, 2022). The user becomes one with their avatar, viewing it as a "transparent vehicle" (Beaufils & Berland, 2022, p. 1) to conduct cognitive commands in the same way as the physical body (Kilteni et al., 2012). Avatar embodiment "enhance[s] one's sense of presence over the course of the immersive experience and promote[s] the transfer of skills from *in-virtuo* to *in-vivo* experience" (Beaufils & Berland, 2022, p. 6), and also "increase[s] self-recognition and identification through enfacement" (p. 1) according to Peck and Gonzalez-Franco (2021).

Avatar embodiment was especially strong for the VR headset user (researcher), thanks to the unique head and hand tracking features the headset affords, the user not only saw but also had intuitive control over parts of their avatar body, contributing to a much higher sense of "being as one" with the avatar. Reciprocally, seeing the partner user expressing themself through their avatar, the researcher felt more convinced that the avatar was a true embodiment of their partner.

Development Reflections

In this section, the researcher highlights *Mozilla Hubs'* usability pain points revealed during virtual space development and user activity.

The edited *Mozilla Hubs* template, with the addition of media frames, was published and applied to a *Hubs Room* accessible to anyone with an invite URL. During the activity, users uploaded their local 2D assets into the designated media frames. Here, due to the lack of UI visuals signifying the position of the empty media frames when uploading local visuals, and instructional documentation, users struggled with uploading at first.

Additionally, being a browser-based platform, *Mozilla Hubs* clears the *Room* after each webpage refresh, which happened randomly and repeatedly due to connectivity issues during the user activity. To consistently display assets in a *Room* upon every join, developers need to edit the root space template with those assets included. This makes documenting improvised collaborations and edits very difficult.

In summary, despite being easily sharable and accessible to anyone with a *Room* URL, the lack of UI cues, developer documentation, and difficulty in saving impromptu collaboration and customization frustrated the developer and users alike. In hopes to develop on a more robust platform that can handle heavier assets, the researcher experimented with Altspace, an application-based VR platform in prototype 2, detailed in the next section.

4.3 Prototype 2: 3D Assets Creating and Sharing in 3D Virtual Space

4.3.1 Exploration Goals

To explore the research question “how can we use mixed reality to improve real-life transnational communication experience?” three goals are defined for this prototype:

1. To see how people create, share, storytell, and interact with unique 3D media types in a 3D virtual space.
2. To see how this experience compares to sharing common 2D media types over everyday ICT.
3. To see how a home-like virtual environment (VE) design affects transnational family members’ sense of social presence within.

4.3.2 Features

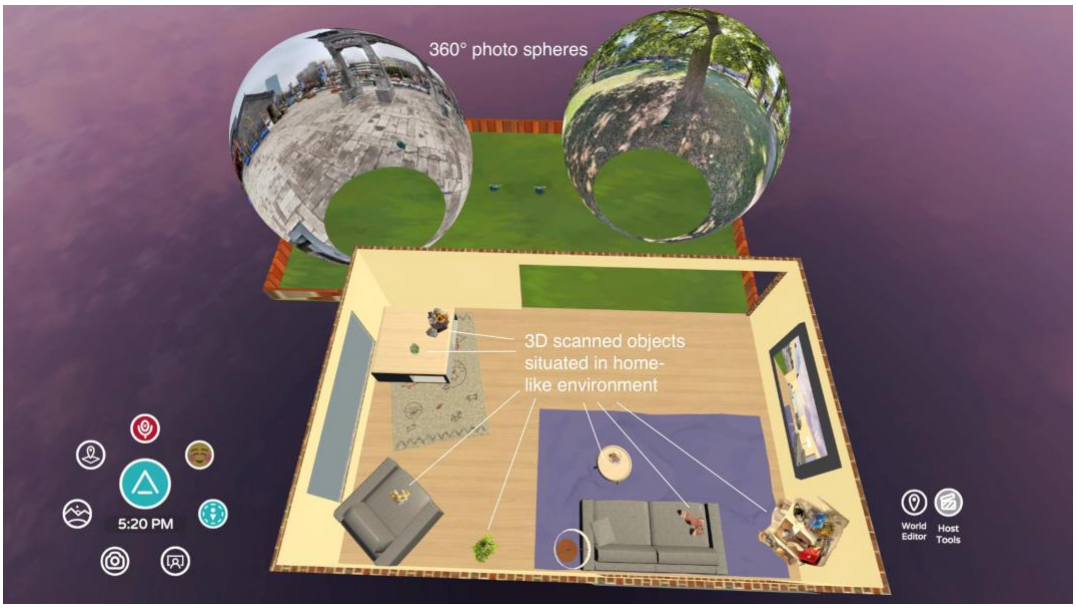

Figure 11. Prototype 2 — Layout and Collection of Assets on Altspace

As shown above in Figure 11., prototype 2 was built on Altspace with a customized floor plan of a home-like environment. Simple living room furniture was placed to further suggest the interactions expected to take place here should resemble family interactions in a living room space.

Prototype 2 focuses on 3D assets creating and sharing in 3D virtual space, for which there were two 360° photo spheres, one from each user, and six 3D scanned objects, three from each user.

4.3.3 Activity

Before the testing activity, both users learned how to 3D scan objects and take 360° photos with lightweight smartphone apps (Polycam and Google Street View), and created 3D assets of locations and objects that they wanted to share with the other user. The researcher gathered and uploaded the 360° photos to Altspace and applied each to a 360° sphere. The researcher also gathered, optimized, and uploaded the 3D scans to Altspace following the process illustrated below. Once the scanned objects were uploaded, both users could manipulate their placement and size in the 3D virtual

space.

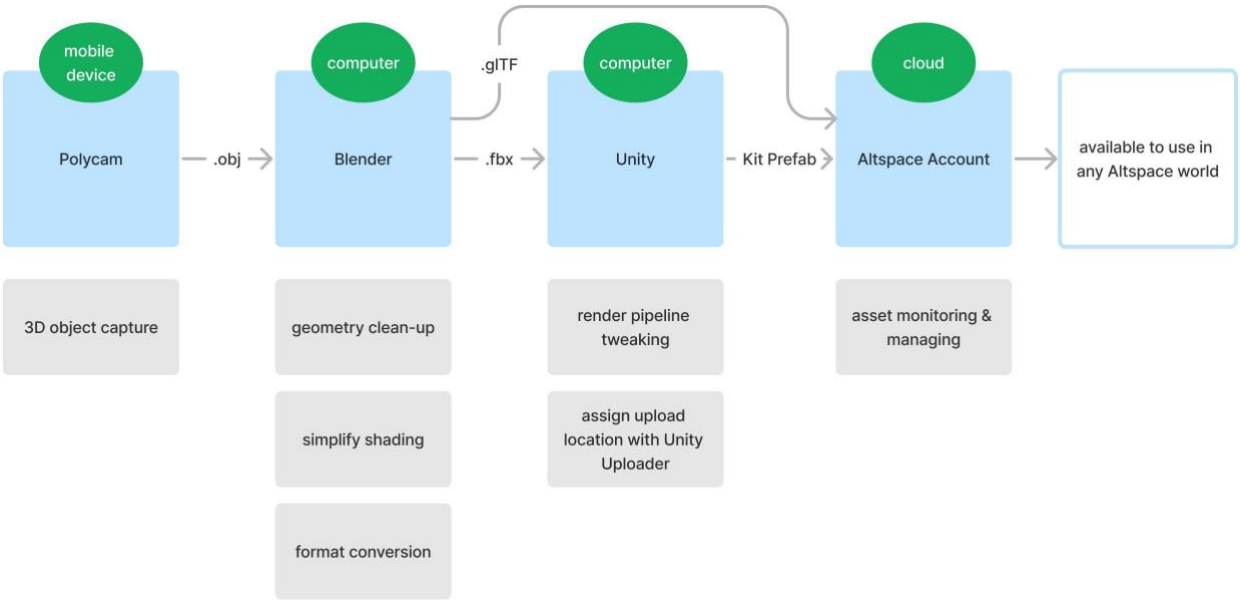

Figure 12. Optimizing 3D Scans Created by Polycam for Use in Altspace

Prototype 2 testing activities included a 5-minute collaborative planning, where two users collaborated in populating the virtual space with their scanned objects. Then, a 15-minute storytelling, where each user spoke to the other about their assets. Both activities were loosely structured, taking about 20 minutes in total, allowing casual conversations about the 3D assets to arise naturally.

Figure 13. Prototype 2 — Testing Activity Screenshots

Figure 13. captures some moments during prototype 2's testing. The top left frame shows the researcher gesturing towards a 3D photogrammetry bookshelf scanned with Polycam to their anonymous family volunteer, who was seeing it for the first time. The contents on the bookshelf, rendered and scaled to look realistic prompted storytelling. The top right frame shows the researcher and their anonymous family volunteer collaboratively reorganizing potted plants 3D scanned by both parties to compliment the interior better. The bottom left frame shows the 360° photo spheres, each displaying a 360° photo contributed by one user. The bottom right frame shows the users being inside a sphere and speaking of the environment, sharing the same "spatial reference frame" (Klatzky, 1998, p. 2).

The testing activity in prototype 2 was conducted between the researcher and an anonymous family volunteer. The activity was conducted twice, allowing the researcher to evaluate the experience of a computer user and a VR headset user.

The technology setups for the repeated activity are as follows:

1. First round: researcher on VR headset; volunteer on computer
2. Second round: researcher on computer; volunteer on computer

4.3.4 Evaluation

After experiencing prototype 2 on a VR headset and a computer, the **researcher** rated the prototype according to the previously introduced criteria, as shown in Table 4. below.

Prototype 2 Evaluation

Evaluation criteria		prototype 2 3D assets (3D scan, 360° photo) creating + sharing in 3D virtual space			
Theme	Sub-theme	Computer	Computer avg	VR headset	VR headset avg
Usability evaluation	Navigation	7	7.33	10	9.33
	Interaction with other user	8		9	
	Interaction with UI	7		9	
Usefulness evaluation	Sense of really there	7	7.67	9	8.83
	Sense of being as one with avatar	7		10	
	Social engagement when directly interacting with other	10		8	
	Co-presence when in vicinity of other	7		10	
	Social agency	7		8	
	Customization	8		8	
	Level of interactivity compared to everyday ICT	Level of interactivity increased a bit		Level of interactivity increased a lot	
Social presence evaluation	Virtual space's effect on social presence	Improved social presence a bit		Improved social presence a lot	
	Avatar's effect on social presence	Improved social presence a lot		Improved social presence a lot	
	Overall social presence score	7		9	

Table 4. Prototype 2 Evaluation Rating Scores

As detailed in Appendix G., the researcher's overall evaluation suggests experiencing prototype 2 with a VR headset was more usable and useful than experiencing it with a computer. Compared to everyday ICT such as sending text and/or images over messages and video chatting, prototype 2 improved social presence for both the computer and the VR headset experiences more than prototype 1, with the improvement also being more significant for the VR headset experience.

High-Level Analysis

PERFORMING TRANSNATIONAL KIN-WORK

As previously discussed, means of performing transnational “kin-work”, or the “conception, maintenance, and ritual celebration of cross-household kin ties” (Di Leonardo, 1987, p. 441) include doing so discursively (through words), physically (through the body), through actions (practice) and [through] imagination (ideas) (Baldassar, 2008).

Prototype 2 allowed the users to perform a high level of transnational kin-work. For instance, manipulating objects and passing them between each other established a “co-presence by proxy”, described by Baldassar (2008) as a sense of co-presence through objects that “embody the spirit of the absent person” (p. 256). On the other hand, freely teleporting between locations represented in 360° photo spheres with a transnational family member created a sense of “co-presence by body” (Baldassar, 2008, p. 251). Although the “bodies” were mediated by avatars with movement constraints, users’ imagination filled in the gap.

HOME-MAKING IN VIRTUAL SPACE

The researcher experienced a medium level of transnational family home-making.

The creation and sharing of digitalized 3D domestic materials, interior, and family practices contributed to a visceral and imagined sense of home (Bonnerjee et al., 2012). The design of the homely interior and the addition of living room furniture and decor provided an appropriate context for the domestic materials.

However, prototype 2 presented difficulty for asset co-management and collaborative contribution, making the space more homely to the main creator/owner than the assistant creator/guest.

PERIPHERAL AWARENESS IN COMMUNICATION

The researcher noticed a high level of “peripheral awareness” (Madianou, 2016, p. 183) experienced through this prototype. Aside from the spatial audio feature mentioned in the analysis of the previous prototype, synchronized real-time animation also contributed to a high level of peripheral awareness. In the process of manipulating the position and size of 3D objects, the other user often provided remarks and suggestions, to which the former responds by making adjustments accordingly. Such reciprocal and real-time interaction effectively communicated the physical and mental presence of the other person.

SPATIAL REFERENCING

Similar to prototype 1, prototype 2 is in a third-person perspective. During prototype 2’s activities, a mix of reference-initiator-centric, reference-receiver-centric, and allocentric

reference frames was used by both users, depending on the reference receiver's relative location to the reference initiator, and the existence of significant spatial marks nearby.

4.3.5 Key Takeaways

Experience Reflections

Creating and sharing 3D assets in a 3D virtual space improved social presence more than sharing 2D assets in a 3D virtual space, as explored in prototype 1. The researcher contributed this improvement to the unique ways users make sense of and experience 3D assets in mixed reality.

The researcher interpreted 3D scanning objects as an act of memorabilia preservation with a personal touch. From object selection to 3D scanning, creating a 3D scan of special objects was similar to crafting a hand-made gift for the other family partner, as the objects carried memories, recorded human touch, and encourages reciprocity, as Mauss et al. (2011) believed to be the affective essence of gifting.

Development Reflections

Prototype 2 centered around the creation and sharing of 3D assets, which inevitably required more time and effort from the users and developer in tool mastering and asset optimization.

3D scanning required meticulous attention in selecting objects with appropriate material qualities. Similarly, 360° photography also relied on good environmental lighting.

Optimizing 3D assets was also a heavy task. To optimize the 3D scans, other software such as Blender, Photoshop, and Unity was needed to clean up the geometry, optimize the material image, and adjust the shading and rendering. On the other hand, optimizing 360° images was simple as Google Street View (the application used for 360° photography) automatically fixes obvious misalignments and blurs out faces. Occasionally, more precise edits were still needed afterward with Photoshop.

Finally, the world-building capacity in Altspace was satisfactory. As a software-based platform, Altspace has an advantage over Mozilla Hubs for loading larger and more assets stably. All assets were uploaded and managed on the Altspace website, making organization efforts easy.

4.4 Prototype 3: Transnational Family Space Testbed

4.4.1 Exploration Goals

To explore the research question “what technology qualities, contextual factors, and interaction configurations in mixed reality build social presence in transnational family communication?” three goals were set for this prototype:

1. To test the usability and usefulness of prototype 3 from creation to experience from first-time users’ perspective.
2. To compare the passive/active role dynamics between the computer user and the VR user.
3. To understand the pain points in this experience and summarize how to optimize a mixed reality transnational family communication experience from the lessons learned.

This prototype had been user tested with 6 pairs of 12 participants; each pair included a Toronto participant and their overseas family member participant. Prototype 3’s testing activities split into 2 separate sessions: a one-on-one asset creation session between each Toronto participant and the researcher, and a connected testing session held between each pair of participants and the researcher.

4.4.2 Asset Creation Session

With the researcher’s assistance, each Toronto participant created 3D assets including one 3D scanned item, and two 360° locations photographs; they also submitted common 2D assets including three regular photos and one short video, all of which were used in customizing their user testing virtual family space with their transnational family member. This asset creation session took approximately 30 minutes for each Toronto participant.

Figure 14. shows participants taking 3D scans and 360° photographs.

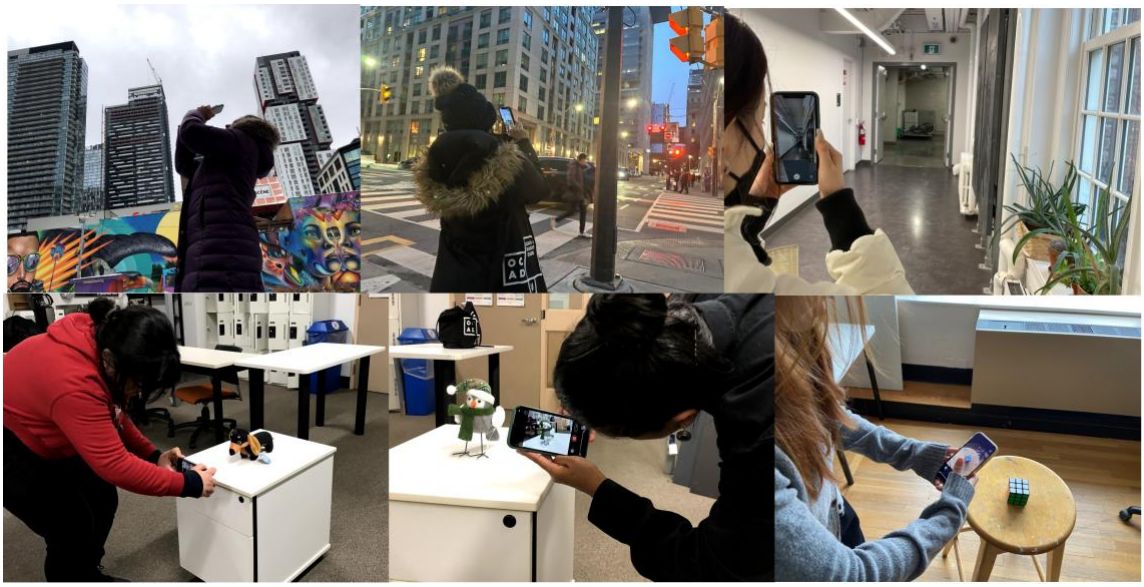

Figure 14. Participants Taking 360° Photos and 3D Scans

4.4.3 Connected User Testing Session

Setup

Prototype 3 was user tested live 6 times, once with each pair of transnational family participants. The Toronto participant experienced the prototype with a provided VR headset, and the overseas participant experienced it with their own computer equipped with the Altspace software. Figure 15. shows a user testing session taking place.

Figure 15. Prototype 3 Connected User Testing in Session

During the connected user testing session, both participants entered the shared virtual family space customized with previously created assets and performed 4 semi-structured tasks (detailed in a later section). After 25 minutes, the researcher entered their virtual family space from another device and conducted a 15-min follow-up interview about the participants' initial thoughts on the prototype experience.

Figure 16. illustrates the technology setup for this phase.

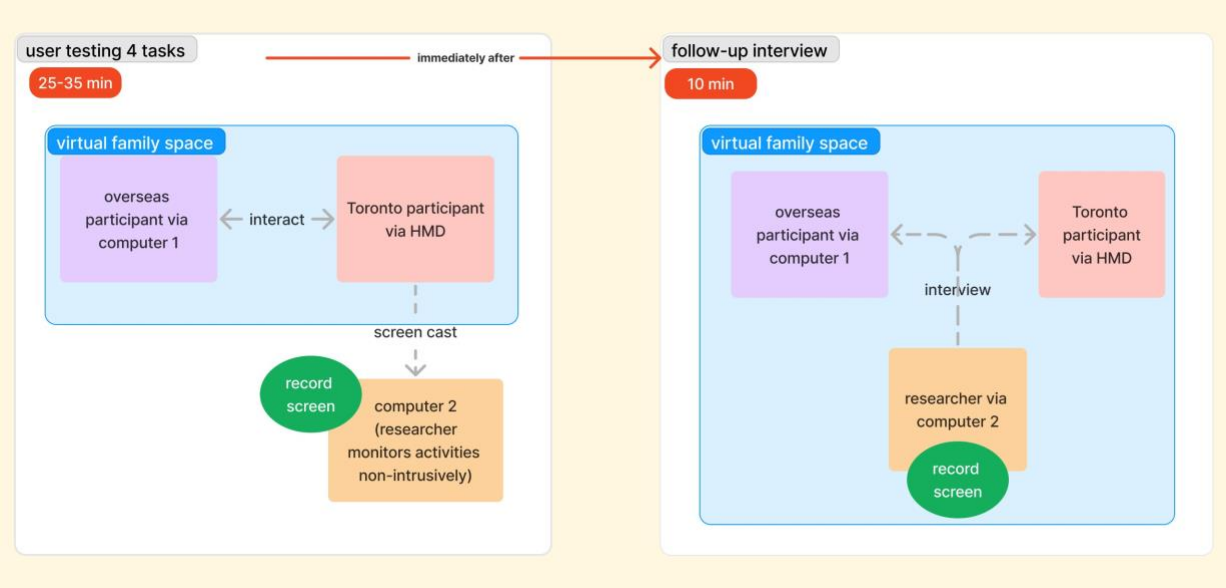

Figure 16. Technology Setup for User Testing and Follow-Up Interview

Lastly, after the entire user testing was completed, both participants responded to an online post-experience survey (Appendix C) on their own time.

Virtual Space Design

Prototype 3 includes 2 interconnected spaces built on Altspace: an initial preparation space and a virtual family space accessible from the preparation space by a portal. Both are described in detail below.

INITIAL PREPARATION SPACE

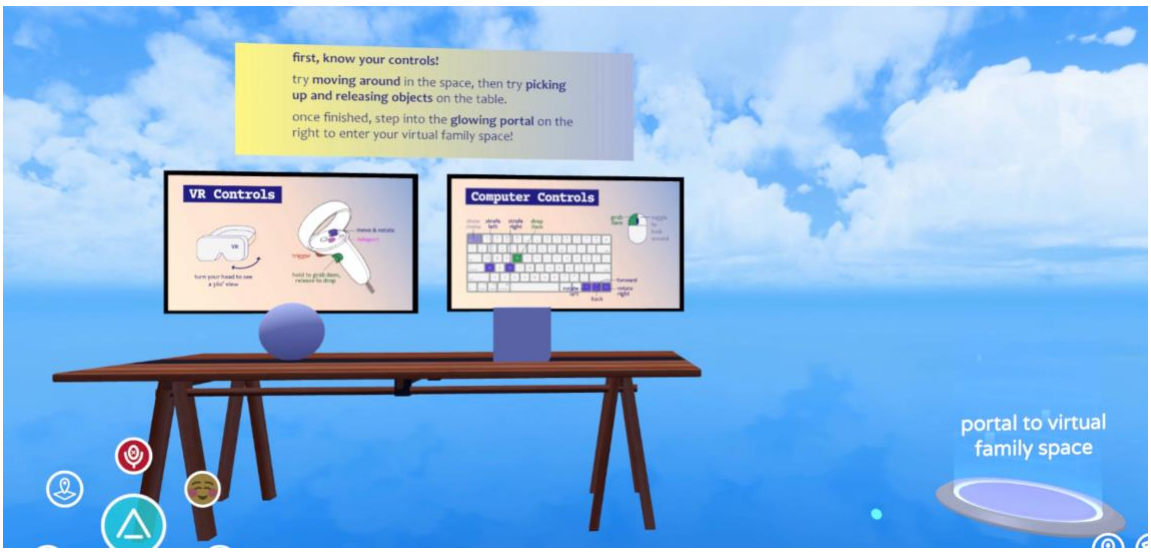

Figure 17. Prototype 3 Initial Preparation Space

As shown in Figure 17, the preparation space featured signage and prompts, which taught computer users and VR users basic controls for navigating in a 3D virtual space and interacting with virtual objects.

This space was built on a minimal default template with only these essential items: 3 instructional signage, a table with two geometric bodies for users to practice object interaction controls with, and a portal leading to the virtual family space.

VIRTUAL FAMILY SPACE WITH TASKS

The virtual family space was where the main user testing activities took place. This space was built on the same living room floor plan as prototype 2, however, the media assets and instructional signage configuration in this prototype served user testing purposes. The researcher prepared the space by uploading the respective media assets created by the Toronto participant of each pair before their connected user testing session.

There were 4 semi-structured “task corners” located in 4 areas of the space, each featuring 1 or 2 instructional signs and a type of media asset to interact with for the task.

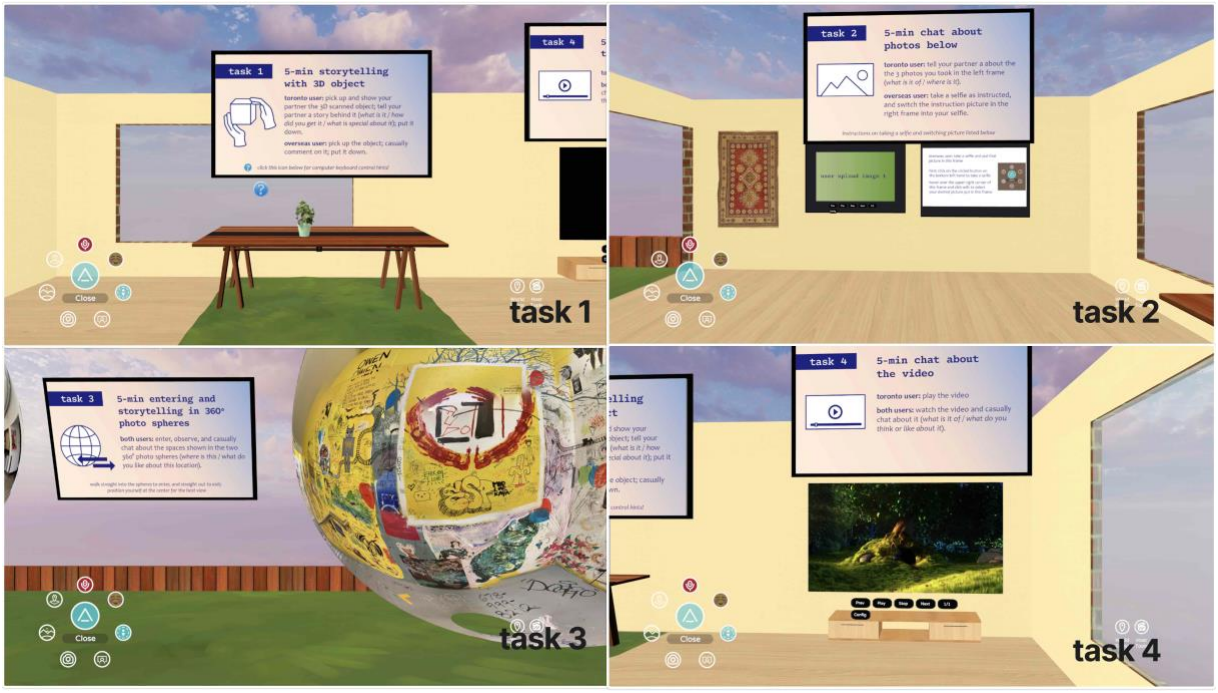

Figure 18. Instructional Signage Displayed at 4 “Task Corners” in the Virtual Family Space

The tasks were as follows:

1. 5-min storytelling with 3D object
2. 5-min chat about photos

3. 5-min entering and storytelling in 360° photo spheres
4. 5-min chat about the video

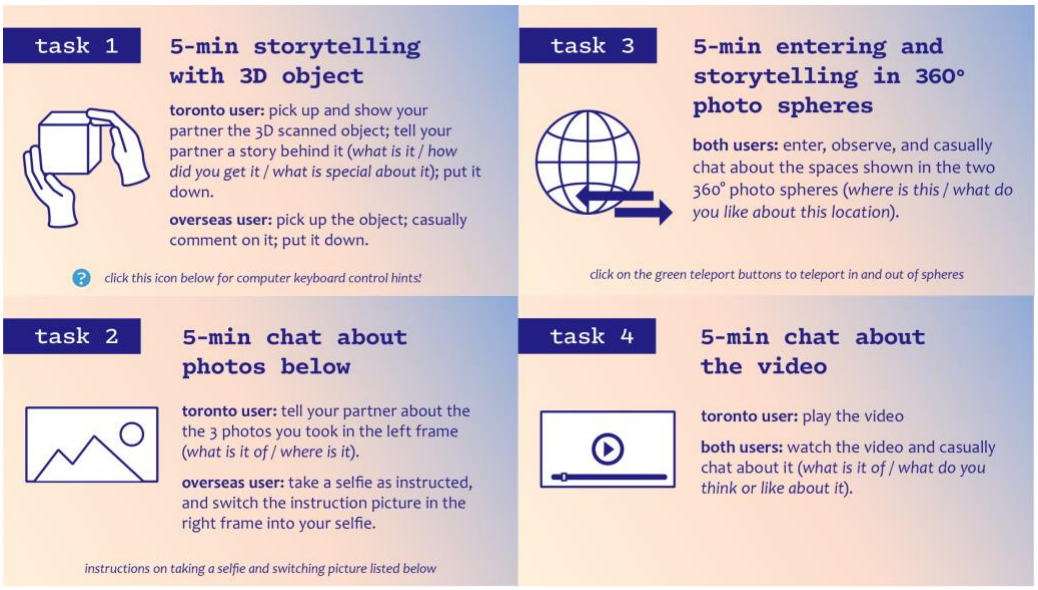

Figure 19. Instructional Signage for 4 Tasks

Using Google Translate, the instructional signage was translated into Mandarin for one overseas participant who is a non-English speaker to ensure their experience of the space wouldn't be unnecessarily affected by language barriers. Since the instructional signage was placed as framed images in Altspace, the researcher could easily switch out the English version for the Mandarin version before conducting the user testing with said group.

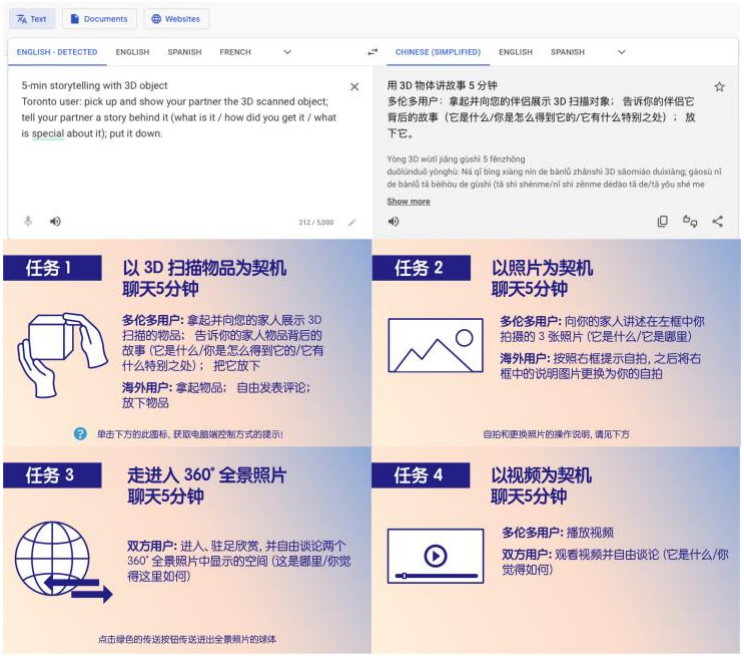

Figure 20. Instructional Signage for 4 Tasks Translated for non-English Speaking Participant

Designing User Testing Tasks

The above-mentioned 4 tasks addressed the research question “what technology qualities, contextual factors, and interaction configurations in mixed reality build social presence in transnational family communication?” by presenting 4 different scenarios shown in Figure 21.

Figure 21. 4 Scenarios Orchestrated by 4 Tasks

In Hudson et al.'s (2019) empirical research on interaction and immersion in VR, they extended Belk's (1988) early notion that experiences are built upon "things, surroundings, and other people" (p. 139) into the realm of virtual experiences.

In the context of this prototype, this study maps "things" to "objects (2D and 3D)"; "surroundings" to "virtual environments"; "other people" to "other avatars", thereby further extending Hudson et al.'s (2019) concept by stating that the social presence experiences in transnational family communication are built on objects, virtual environments, and other avatars. Thus, the 4 tasks can be summarized as such:

1. Task 1: manipulating "object (3D)"; communicating with "the other via avatar"
2. Task 2: manipulating "object (2D, static imagery)"; changing "virtual environment"; communicating and collaborating with "the other via avatar"

3. Task 3: changing “virtual environment (360°)”; communicating with “the other via avatar”
4. Task 4: manipulating “object (2D, motion picture)”; communicating with “the other via avatar”

Figure 22. In-VR User Testing First-Person Screenshots and Selfies

As indicated by Figure 22., frames 1 and 2 show users interacting with 3D scanned objects to conduct storytelling with their transnational family partners; frame 3 shows a user speaking about 2D images with their partner; frame 4 shows a user speaking about the environment represented in a 360° photo sphere with their partner; frame 5 is a selfie of 2 users in the same 360° photo sphere; frame 6 shows a user speaking about a 2D video to their partner.

The variation of objects, virtual environments, and other avatars, as well as the difference in technology setup (Toronto users and overseas users access this space with different devices), allowed this research to test the social presence experienced under different combined conditions and explore the optimal combination in support of the research question investigated through this prototype.

4.4.4 Evaluation

User testing data of prototype 3 included quantitative data and qualitative data.

The quantitative data was collected through the online post-experience survey, which asks Likert-scale questions consistent with the evaluation form used to assess the previous prototypes. The qualitative, observational, and interview data were collected during user testing sessions by notes and screen recordings of in-VR interactions.

Quantitative Data Collected Through Post-Experience Surveys

The post-experience survey distributed securely through Microsoft Forms received 12 responses, one from each participant. After data collection was complete, all survey data was downloaded and reorganized into Table 5.

Prototype 3 Evaluation [User Testing Data]

Evaluation criteria		Prototype 3 Transnational Family Space Testbed					
Theme	Sub-theme	Computer	Computer avg by theme	VR headset	VR headset avg by theme	Overall	Overall avg by theme
Usability evaluation	Navigation	7.33	7.66	8.00	7.89	7.67	7.78
	Interaction with other user	7.83		7.83		7.83	
	Interaction with UI	7.83		7.83		7.83	
Usefulness evaluation	Sense of really there	8.17	7.81	7.83	7.81	8.00	7.81
	Sense of being as one with avatar	7.00		8.00		7.50	
	Social engagement when directly interacting with other	8.00		8.17		8.08	
	Co-presence when in vicinity of other	8.17		8.33		8.25	
	Social agency	7.33		7.67		7.50	
	Customization	8.17		6.83		7.50	
	Level of interactivity compared to everyday ICT	• 50% of computer users: level of interactivity increased a lot • 50% of computer users: level of interactivity increased a bit		• 67% of VR users: level of interactivity increased a lot • 33% of VR users: level of interactivity increased a bit		• 60% of all users: level of interactivity increased a lot • 40% of all users: level of interactivity increased a bit	
Social presence evaluation	Virtual space's effect on social presence	• 50% of computer users: social presence increased a lot • 50% of computer users: social presence increased a bit		• 50% of VR users: social presence increased a lot • 50% of VR users: social presence increased a bit		• 50% of all users: social presence increased a lot • 50% of all users: social presence increased a bit	
	Avatar's effect on social presence	• 83.3% of computer users: social presence increased a bit • 16.7% of computer users: social presence increased a lot		• 50% of VR users: social presence increased a lot • 33% of VR users: social presence increased a bit • 17% of VR users: no effect on social presence		• 50% of all users: social presence increased a bit • 40% of all users: social presence increased a lot • 10% of all users: no effect on social presence	
	Overall social presence score	8		8.17		8.09	

Table 5. Prototype 3 Evaluation Rating Scores

As detailed in Appendix H., prototype 3 was usable, useful, and inductive to social presence improvement for both the computer users and the VR users. Both device groups experienced a similar level of usability, usefulness, and social presence, indicating the active/passive role dynamics between the 2 users did not make the computer users feel less social presence than the VR headset users in a short-term, first-time use case scenario.

Qualitative Data Collected During User Testing Sessions

The researcher conducted semi-structured interviews (for script, see Appendix D.) at the end of connected sessions with each group, during which, the researcher simultaneously took notes of key words and ideas participants mentioned in response to each interview question. Later these notes were organized into qualitative findings in Table 6., highlighting the setups, issues, solutions, user feedback, etc.

Group number	Computer setup of overseas user	VR comfort level of Toronto user	Issues and workarounds	Key feedback from interview	Notes
1	• Personal desktop • Mouse • No microphone	Motion sickness when turning especially in 360° degree sphere	• 360° spheres didn't load for overseas user—Researcher screen-shared the live VR cast over Teams	• Getting used to the controls for the computer user was challenging and undermined the sense of presence in the virtual space • Being side by side with each other's avatar was most "real" • Would like to experience it with a larger family group	• Altspace's UI was set to English and doesn't allow alternatives, which made the experience more challenging for the non-English speaking overseas participant • VR Motion sickness became a burden to the experience for VR
2	• Personal laptop • Trackpad	Comfortable	• Overseas user couldn't load virtual worlds, perhaps due to work computer restrictions—researcher screen-shared the live VR cast over Teams; participants used Teams audio to speak to each other	• Computer user couldn't enter virtual spaces so the experience felt lonely for the VR user, who was the only avatar in the space • Would like to see more "live" things from real life instead of a previously documented artifact • Would like to "visit" more locations through the 360° spheres • Would like to experience it in a larger family group	Teams screen-share and audio is the most efficient workaround when the overseas user can't load the prototype
3	• Personal laptop • Trackpad	• Comfortable • Familiar	• Account login—accidentally created a new account instead of logging in with default account • Didn't account for trackpad-only setup—instructions not sufficient	• Computer user needs more tech assistance from signage or their Toronto partner, who's more agile with a VR device • Strong sense of embodiment which strengthened mutual recognization of the avatar as their partner • 3D object storytelling was most immersive • Would like to co-contribute to asset creation	Went 1 hour overtime as both participants enjoyed the experience and maintained engaged
4	• personal laptop • trackpad	Slight motion sickness	NA	• Computer user feels not "really there" as the experience is contained within a computer screen and not immersive • Would like to experience other sensorial stimuli such as smell, touch, etc	No technology issues but overseas user experienced control difficulty due to unfamiliarity with 3D space navigation in general
5	• Personal laptop • mouse	Slight motion sickness	Video lagged for both users	• 360° sphere was the most immersive for both users • 3D scan object—uncertain what to do with it/what the point is • Would like to see more interaction such as games or collaborative DIY • Would like to experience other sensorial stimuli such as smell, touch, etc	VR Motion sickness became a burden for VR user
6	Personal desktop Mic mouse	Slight motion sickness	Overseas user had OS issues and couldn't download Altspace—Researcher entered Altspace on computer and screen-shared the researcher's avatar's POV over Teams	• Good for once-in-a while organized event, but too straining and troublesome for daily communications with current technology • Computer user feels not "really there" as the experience is contained within a computer screen and not immersive • Embodiment and presence were strong for VR user • Both users enjoyed having the same frame of reference when looking at assets in the space • Would like to relax and chat and not do tasks in this space • Would like to co-create a virtual environment either resembling their home IRL or something completely extraordinary and not like RL	If the overseas user can't log in to Altspace, screen-share the POV of the researcher's avatar is better than a live cast of the VR user's POV as it resembles what the overseas user would see.

Table 6. User Testing Qualitative Data

Overall, the user testing was successful. All participants were new to Altspace and enjoyed this mixed reality transnational family communication experience. Some of their favorite features included 360° spheres accompanied by avatar head movement and face-to-face avatar interaction. Some of the recurring pain points included technology unfamiliarity and motion sickness (mainly the VR users).

Some features participants would like to see in a future prototype include:

- Arranging larger transnational family gatherings
- More interactive exchanges and collaborative making/customization of the interior
- Everyone gets to experience through a VR headset
- More sensorial stimuli incorporated into the experience

High-Level Analysis

PERFORMING TRANSNATIONAL KIN-WORK

Due to individual factors and technical issues present in each participant group, the level of transnational kin-work each group performed differs. However, based on user feedback detailed above, prototype 3 allowed users to perform a mid-to-high level of transnational kin-work in general.

In particular, visiting the 360° photo spheres together, taking, and framing a 2-person, in-VR selfie, in particular, contributed to a sense of “co-presence by body” (Baldassar, 2008, p. 251). Although the “bodies” were mediated by avatars with movement constraints, users’ imagination filled in the gap. Furthermore, the selfie-taking activity also contributed to building “co-presence by practice” (Baldassar, 2008, p. 251), as participants decide on the selfie background and avatar poses as if they were physically touring a location and documenting it with a group photo.

HOME-MAKING IN VIRTUAL SPACE

Based on the researcher’s observation and participants’ feedback, a medium level of transnational family home-making was experienced by user testing participants.

The creation and sharing of 2D and 3D domestic materials, interior, and family practices contributed to a visceral and imagined sense of home (Bonnerjee et al., 2012). The design of the homely interior and the addition of living room furniture and decor provided an appropriate context for the domestic materials.

However, due to the limited scope of the user testing activities, prototype 3 presented a few objects created by only one of the pair of participants in each group, causing participants to experience different levels of home-making within each group. Additionally, due to the cross-sectional nature of user testing, participants were unable to build a sense of “familiarity, ease, assurance and security” (Tuan, 2001, p. 159) with the space over time, which is essential to how people make a space into home.

PERIPHERAL AWARENESS IN COMMUNICATION

The researcher noticed a high level of “peripheral awareness” (Madianou, 2016, p. 183) experienced by participants through this prototype as a result of spatial audio. However, the sense of peripheral awareness was more prominent for the VR headset users than the computer users, as their device projects spatial audio more effectively than a computer unequipped with headphones.

SPATIAL REFERENCING

During prototype 3’s activities, a mix of reference-initiator-centric, reference-receiver-centric, and allocentric reference frames was used by both users. Although, according to the researcher’s observation, the VR headset user, benefiting from more intuitive device controls and direct assistance from the researcher whenever needed, often took on the role of the reference-initiator, guiding the computer user from one task to the next. In these cases, reference-receiver-centric and allocentric reference frames were used more frequently.

4.4.5 Key Takeaways

Referring back to the secondary research question “what technology qualities, contextual factors, and interaction configurations in mixed reality build social presence in transnational family communication?” prototype 3 revealed the following insights through user testing:

- Technology qualities
    - For users using computers to experience transnational family communication in virtual spaces, it’s essential to use a non-work computer equipped with a microphone and speakers.
    - For many users who are prone to motion sickness in VR, allowing the mixed reality family communication experience to be dual-modal and easily inter-device-transferable is ideal. Then, users can choose when to use which access device and transfer fluidly from one to another.
- Contextual factors
    - Building a virtual environment that looks like a living room feels natural for transnational family gatherings. For larger family gatherings, a larger space with different areas catering to different interactions is desired, as it resembles how such gatherings occur in real life.
    - Avatars are important in improving social presence for the user themselves and their family members who perceive and interact with them.

- Interaction configurations
    - For such mixed reality technology to become part of long-term communication tools for transnational families, participating family members should co-create assets and interactively collaborate on customizing the space equally, leaving their own “marks”.
    - The “realness” of the experience may be enriched by incorporating designs that appeal to other senses beyond the visuals only.

Moving forward, the design of prototype 4 incorporates some of these key takeaways gathered from user testing prototype 3.

After building prototypes 2 and 3 on Altspace, and exploring its interactive capabilities and limitations, on January 20, 2023, Microsoft announced Altspace’s impending shutdown on March 10, 2023. Due to this unforeseen limitation, the researcher switched to another platform for the next prototype, prototype 4.

In the period before Altspace’s shutdown, many Altspace world builders hurriedly explored alternative virtual social platforms to port their Altspace worlds to, among which, Spatial emerged as a popular choice. With the Spatial Team hosting live AMA sessions (Spatial, 2023) and producing step-by-step guides to help with a smooth migration (*How to Migrate Your AltspaceVR Worlds & Communities to Spatial — Spatial, 2023)*, the process of migrating to Spatial from Altspace is well documented. After considering Spatial’s competency in affording all the main features (uploading and sharing regular photos, videos, 360° photos, and 3D scans) explored in previous prototypes, the researcher moved on to Spatial for prototype 4.

4.5 Prototype 4: Envisioning a Long-Term, Lived-in Virtual Family Space

4.5.1 Exploration Goals

To respond to user feedback from prototype 3 and to explore the research question “what is the long-term, future use case of an MR transnational family space?” Prototype 4 aims to observe how users experience a virtual family space differently in a long-term situation, as opposed to cross-sectional situations reflected in the previous 3 prototypes.

Further, since a long-term use case resembles the intended use case more closely, prototype 4 also provides insight into possible future user experiences where MR becomes one of many communication tools in transnational family communication.

4.5.2 Features

MR Space Design

Figure 23. Prototype 4—Testing Activity Screenshots

As previously mentioned, prototype 4 was built on *Spatial* with a customized floor plan with similarities to prototype 3's floor plan, which includes a 2-room building and a surrounding open area, shown in Figure 23.

Responding to prototype 3's user feedback on the want for collaborative experiences and space separation, a wall separates the building into 2 rooms, where one room (room 1, upper-left frame) was designed for collaborative interactions, and the other (room 2, upper-right frame) for family meetings and conversations; meanwhile, the open area (lower 2 frames) provides space for 360° photo spheres and watch parties through screen sharing.

Systematically Envisioning a Simplified User Journey

To simplify the user journey and to build a system that encompasses the usual array of tools and procedures, this study ends with proposing an all-in-one-app user journey, moving away from the inconvenient 8-app user journey. This simplified user journey is visualized through a proposed user interface of a proposed all-encompassing system designed on Figma, *FamilyMR*, with synced mobile and web touchpoints shown below:

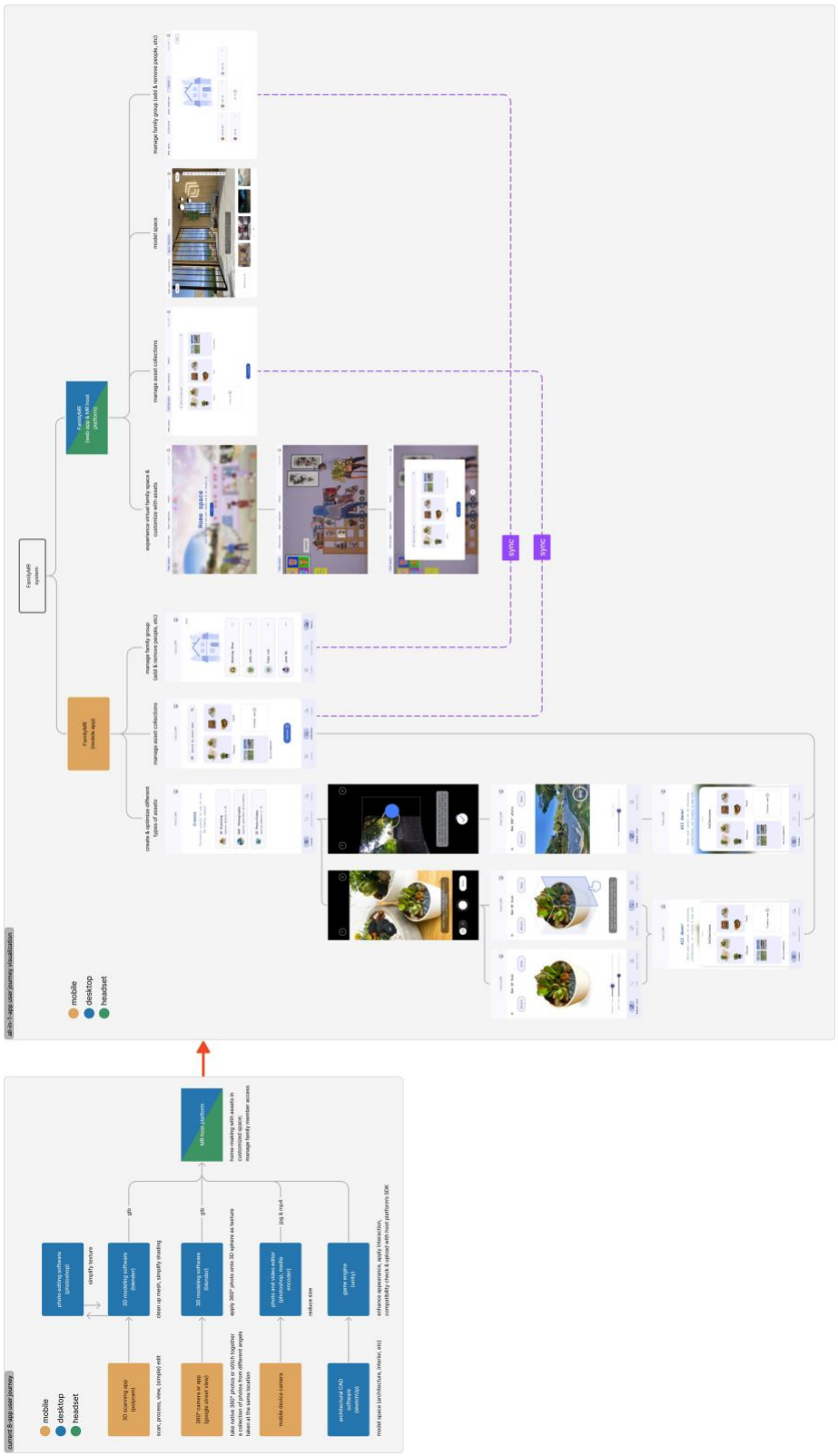

Figure 24. Proposed all-in-One-App User Journey

As shown in Figure 25., the mobile touchpoint allows users to create different types of assets (3D scanning, 360 photography, photos and videos), optimize assets, manage asset collections, and manage family groups.

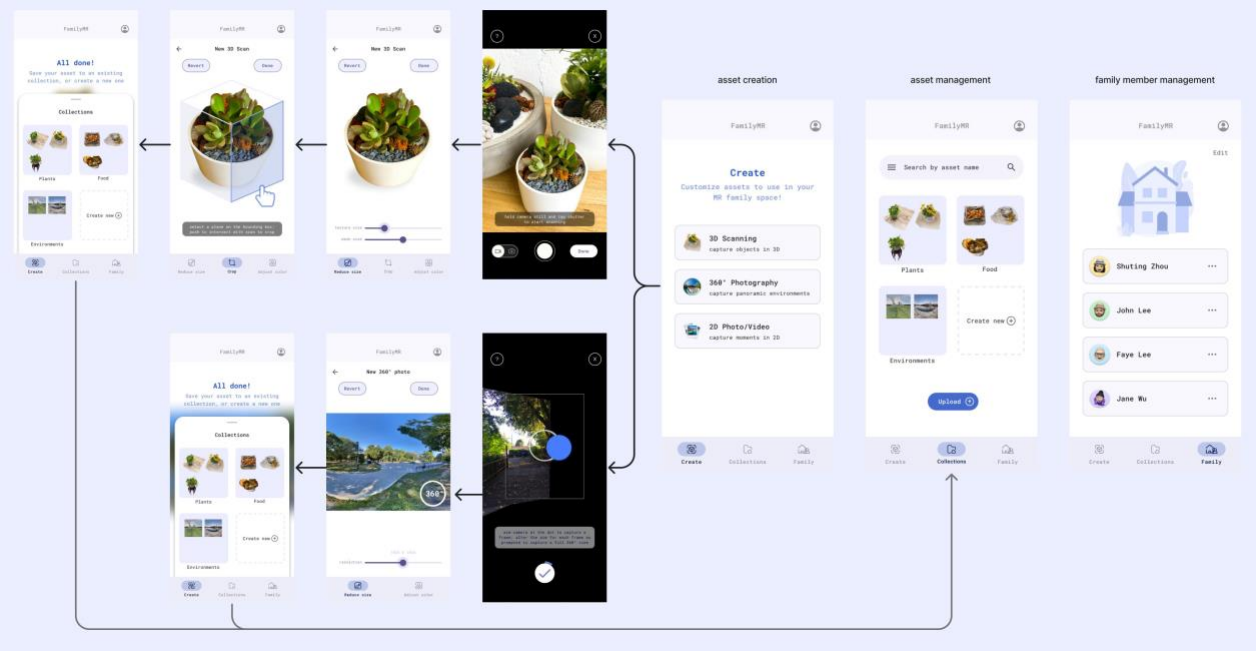

Figure 25. The Mobile Touchpoint in the Proposed User Journey

As Figure 26. shows, the web touchpoint allows users to experience the virtual family space, customize the floor plan and objects in the space using assets synced from the mobile touchpoint. Similarly, it also allows asset management and family group management.

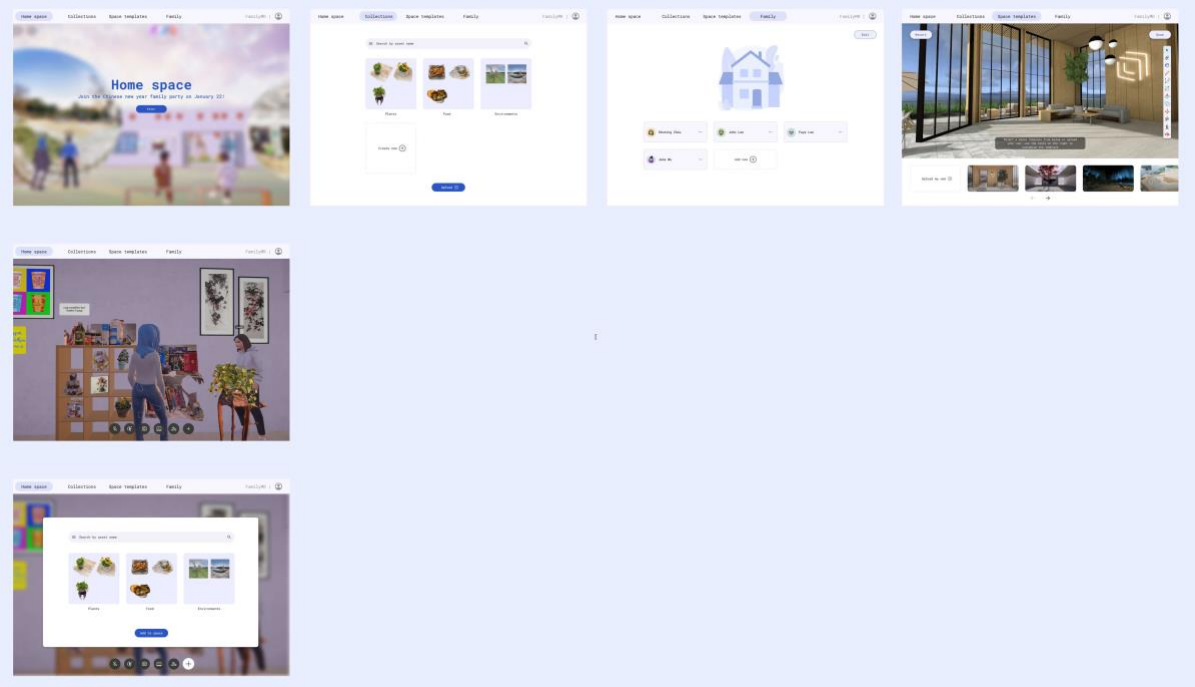

Figure 26. The Web Touchpoint in the Proposed User Journey

4.5.3 Activity

To resemble the intended use case, the activities held on prototype 4 were semi-structured, leaving much customization freedom to users.

Overall, prototype 4 was centered around preparing for and/or participating in a virtual transnational family Chinese new year party. 2 users, including the researcher and an anonymous volunteer, were assigned the role of “hosts”, who were in charge of preparing the space with 2D and 3D assets that are meaningful and festive, similar to such preparations in real life. Over the course of 2 days, the hosts first collaborated synchronously, establishing a consensus on asset selection and placement; they then worked asynchronously, each logging into the space on their own time, adding and adjusting new 2D (images and sticky notes) and 3D content (3D models, 3D scans, and 360° photo spheres). Specifically, inside the building, the hosts uploaded 2D assets including a set of customized Chinese new year calligraphies and illustrations, hand-written and typed sticky notes with new year’s messages, and photos they’ve taken; they uploaded 3D assets of photogrammetry household objects scanned by both of them, including pantry staples, an ukulele, a backpack, a tray bake meal from the

researcher (also a host), and a plate of traditional snacks from the other host; they also uploaded online 3D models of festive decorations. In the open area outside, each host added a 360° photo sphere, each showing a 360° photo they took, representing places that carry emotional significance within the family.

On the third day, a 30-min virtual transnational family party was held between a group of 5, including 2 hosts and 3 anonymous volunteer attendees. Users were first introduced to the space by the host, then scattered into different areas where they chatted and collaborated in further customization. During the virtual party, all users were encouraged to further contribute to the space with their own content. All users responded by adding images (including photos and illustrations) to walls, substituting existing images in frames, and putting up sticky notes with personalized content in celebration of the new year or for a good laugh. No 3D asset was uploaded by the 3 attendees, however, they did interact with existing 3D assets by altering their placement, rotation, and size.

The researcher used a browser and a VR headset interchangeably in party preparation and attendance, while all the other 4 users accessed the space on their own computers. Of the other 4 users, 2 had some prior experience with navigating in 3D virtual worlds, while the other 2 had none.

4.5.4 Evaluation

After experiencing prototype 4 on a VR headset and a computer with a larger transnational family group (5 users in total) over the course of a week, the **researcher** rated the prototype according to previously introduced criteria, as shown in Table 7. below.

Prototype 4 Evaluation

Evaluation criteria		Prototype 4 long-term, lived-in virtual family space			
Theme	Sub-theme	Computer	Computer avg	VR headset	VR headset avg
Usability evaluation	Navigation	6	7.00	10	9.33
	Interaction with other user	7		8	
	Interaction with UI	8		10	
Usefulness evaluation	Sense of really there	6	7.58	9	8.33
	Sense of being as one with avatar	5.5		5	
	Social engagement when directly interacting with other	10		8	
	Co-presence when in vicinity of other	7		10	
	Social agency	8		9	
	Customization	9		9	
	Level of interactivity compared to everyday ICT	Level of interactivity increased a bit		Level of interactivity increased a lot	
Social presence evaluation	Virtual space's effect on social presence	Improved social presence a lot		Improved social presence a lot	
	Avatar's effect on social presence	Improved social presence a bit		Improved social presence a bit	
	Overall social presence score	7		8.5	

Table 7. Prototype 4 Evaluation Rating Scores

According to the researcher's evaluation detailed in Appendix I., prototype 4 was usable, useful, and inductive to social presence improvement for both the computer experience and the VR experience, with the improvement being more significant for the latter. However, as the researcher noticed, due to the movement-avatar mismatch (see Appendix I.), the sense of being "as one" with the avatar was low, and the avatar's improvement to social presence was minimal for both experiences.

High-Level Analysis

PERFORMING TRANSNATIONAL KIN-WORK

A high level of transnational family kin-work was performed using prototype 4 by directly conversing with each other in real-time through virtual avatars (social presence by words), organizing and participating in a traditional festival family event (social presence by practice), sharing and decorating the space with photos, notes, 3D scans, and 360° photos (social presence by proxy to virtual body). When preparing for and participating

in this virtual family event and reminiscing about it afterward, family members also constructed a social presence by imagination.

HOME-MAKING IN VIRTUAL SPACE

A high level of transnational family home-making manifested in 2 ways in prototype 4's virtual space. First, it served as a "material connection between 'here' and 'there' " (Levin & Fincher, 2010, p. 401) through the accumulation of assets contributed collectively by family members. By putting together digital replicas or representations of objects or environments that are physically distant in real life, the family built many separate "here"s into a single, shared, and homely "there".

Second, it appealed to people's emotional attachment to homely material elements. True to Tuan's (2001) notion of intimacy associated with home rooted in the subconscious, and Blunt's (2005) notion of "productive nostalgia", domestic materials, interior, and family practices contributed to a visceral and imagined sense of home (Bonnerjee et al., 2012). As the researcher witnessed the gradual multiplication of Chinese new year objects in the virtual space, dormant memories deep in the subconscious, such as the smell of snacks in an ornamental lacquer box prepared only for the new year, the clinking of mahjong tiles, the constant noise of fireworks and firecrackers, etc, gradually woke up. These specific memories evoked sensorial experiences of home during a ritualistic event, despite only being exposed to audiovisual content in the virtual space.

Additionally, the researcher noticed the sense of attachment and homely familiarity increased over time, as the researcher entered, "paused movements" (Tuan, 2001, p. 138), and developed the virtual space over the course of a week.

PERIPHERAL AWARENESS IN COMMUNICATION

"Peripheral awareness" (Madianou, 2016, p. 183) experienced through this prototype was high. During this large (more than 2 people) family gathering, smaller groups organically formed and shifted in the 3D space, allowing for different activities and conversations to occur simultaneously. Despite not being engaged with every group, every member had a spatial awareness of who was doing what at which location.

SPATIAL REFERENCING

Due to the interchangeable first-person and third-person perspectives in Spatial, and the previously mentioned difficulty in navigation, users often used allocentric referencing to reference objects in relation to other objects (Moraresku & Vlcek, 2020).

4.5.5 Key Takeaways

Experience Reflections

Compared to the previous 2prototypes built on Altspace, the researcher noticed much stylistic and customization differences with prototype 4 on Spatial. Stylistically, the avatar and object rendering leaned toward realism, as opposed to Altspace's cartoonification. Such a shift neither increased usability, usefulness, and social presence nor decreased them. However, the researcher noticed occasionally instances of the uncanny valley effect (Mori et al., 2012), especially when using a VR headset and had their avatar moved too close to another user's avatar, revealing an enlarged realistic human face.

Regarding customization, the user dynamics shifted from a strict admin-visitor model represented in Altspace, to a fluid and democratized main-contributor-collaborator model, lending every member equal potential control over the space.

Additionally, prototype 4 provided a uniquely long-term, lived-in experience of an MR transnational family space, which increased the sense of social presence, home-ness, and peripheral awareness. Although the technological capacities and setup are similar to the previous prototypes, prototype 4 benefits from the enriched contexts including a large family group, a ritualistic family event, and realistic host-guest roles. The researcher observed that the sense of social presence is reciprocal, as the number of family members increased from 2 to 5, conversations and activities became livelier, multiplying the sense of social presence for all members involved.

Development Reflections

Thanks to the experience gained from building previous prototypes, modeling an environment, creating, and optimizing 2D and 3D assets for such space were not difficult. The development challenge of prototype 4, however, stemmed from the transition from the previous development platform (Altspace) to this platform(Spatial). Spatial's limited processing capacities as a browser-based 3D platform, and its version/ feature updates, which outpaces their corresponding documentation, caused instructional confusion. These obstacles were unaccounted for and increased the time needed to build a functional prototype 4, eliminating the original hope to further explore the interactive components through visual scripting for this prototype.

Despite these challenges, the researcher still believes Spatial is a user-friendly platform, as it greatly simplifies virtual space accessing, asset uploading, and asset managing.

Exhibition Observations & Reflections

Prototype 4 was displayed at the graduate exhibition for 3 days in April, 2023 in a setup shown below. The computer, equipped with an extended monitor, was logged into the virtual space of prototype 4 as one user, and the VR headset was logged into the same space as another user. This demonstrated the interaction between 2 users and the different experiences afforded by different access devices. On another screen, an autoplaying slideshow provides an overview of the study. A poster on the table illustrates the simplified user journey.

Figure 27. Exhibition Setup and Visitor Interaction

In general, the exhibition of this prototype was well received, visitors, especially those with overseas families, enjoyed the virtual space and saw the potential use of it in their transnational family communication, commenting that this could be a effective and affordable future alternative when large gatherings in-person are not possible.

Participants who user tested prototype 3 acknowledged the improvement of prototype 4 in comparison. They highlighted the effective representation of the long-term, lived-in and homely quality use conveyed through the variety of accumulated objects from different users in the family. They also appreciated the realistic rendering and avatar style in prototype 4, as well as the ease of collaborative customization that enabled a more symmetrical ownership among family members. However, they also pointed out that avatar and object interactions could be more intuitive by customizing teleporting and physics settings, which can be achieved potentially with visual scripting refinements.

4.6 Summary

This chapter explains how the RtD methodology was implemented to answer the primary research question “how can we build social presence with mixed reality for transnational families?” by describing a series of 4 prototypes, including their goals, features, testing process, evaluation, and takeaways for future development.

In summary, the iterative prototypes suggest that MR can help build social presence for transnational family communication by providing a collaborative, customizable, and interactive platform as a virtual social space.

Furthermore, this virtual social space can become a shared virtual home by improving transnational kin-work, home-making, and ordinary co-presence in communication, as the space gets “lived-in”, or populated and updated with domestic materials of 2D and 3D assets contributed by all members of a larger (more than 2) group of transnational family members over a long-term use case. This sense of developing attachment and familiarity as family members use, and “pausing movements” (Tuan, 2001, p. 138) in the space is similar to how people form emotional connections with a physical place of home.

Chapter 5. Overall Reflection

This chapter provides an overall reflection on the research process, highlighting the goals and subjective evaluations of 4 prototypes.

To answer the primary research question, “how can we use mixed reality to build social presence for transnational family communication?” This study first conducted secondary research reviewing relevant literature, applications, and tools to understand existing research and identify any gaps. It then conducted primary research using surveys to discover the user experience pain points, connecting theory to real-life experiences. Afterward, guided by the RtD methodology, this study produced and evaluated a series of 4 iterative prototypes, each responding to a secondary question, as shown in Table 8.

Prototype	Question	Goals	Features	Activity	Evaluation
Prototype 1	How can we use MR to replicate real-life transnational family communication experience?	To see how people share, storytell, and interact with everyday 2D media types in a 3D virtual space. To see how this experience compares to sharing common 2D media types over everyday ICT.	A minimal Mozilla Hubs template with customized 2D assets (images and videos)	2D asset-sharing, storytelling, and interacting between 2 users, one on a computer and another on a VR headset.	Researcher evaluated (standard evaluation criteria)
Prototype 2	How can we use mixed reality to improve real-life transnational communication experience?	To see how people create, share, storytell, and interact with unique 3D media types in a 3D virtual space. To see how this experience compares to sharing common 2D media types over everyday ICT. To see how a home-like virtual environment (VE) design affects transnational family members’ sense of social presence within.	A customized Altspace home floor plan with customized 3D assets (3D scans and 360° photo spheres)	3D asset-creating, sharing, storytelling, and interacting between 2 users, one on a computer and another on a VR headset.	Researcher evaluated (standard evaluation criteria)

Prototype	Question	Goals	Features	Activity	Evaluation
Prototype 3	What technology qualities, contextual factors, and interaction configurations in mixed reality build social presence in transnational family communication?	To test the usability and usefulness of prototype experience from creation to experience from first- time users' perspective. To compare the passive/ active role dynamics between the computer user and the VR user. To understand the pain points in this experience and summarize how to optimize a mixed reality transnational family communication experience from the lessons learned.	A customized Altspace home floor plan with user testing task prompts and customized 2D+3D assets	2D+3D asset- creating, sharing, storytelling, and interacting between 2 user testing participants, as guided by 4 task prompts. 6 pairs of users participated in the testing, with one of each pair on a computer and another on a VR headset.	User testing data (standard evaluation criteria)
Prototype 4	What is the long-term, future use of the mixed reality transnational family space?	To observe how users experience a virtual family space differently in a long-term situation.	A customized Spatial home floor plan with customized 2D+3D assets	Collaborative 2D+3D asset-creating, sharing, storytelling, and interacting among 5 users over the duration of a week.	Researcher evaluated (standard evaluation criteria)

Table 8. Objective Reflection on Prototypes

A set of standard criteria was used in subjectively evaluating the usefulness, usability, and sense of social presence experienced with each prototype, as shown in Table 9. and Table 10. Table 9 lists the evaluation results from experiencing the 4 prototypes on a computer, while Table 10. lists the evaluation results from experiencing them on a VR headset. In all, this study produced design artifacts and frameworks for design and evaluation.

Evaluation criteria		Prototype 1	Prototype 2	Prototype 3	Prototype 4
Theme	Sub-theme	Computer			
Usability evaluation	Navigation	7.00	7.00	7.33	6.00
	Interaction with other user	7.00	8.00	7.83	7.00
	Interaction with UI	5.00	7.00	7.83	8.00
Usefulness evaluation	Sense of really there	6.00	7.00	8.17	6.00
	Sense of being as one with avatar	5.00	7.00	7.00	5.50
	Social engagement when directly interacting with other	7.00	10.00	8.00	10.00

	Co-presence when in vicinity of other	6.00	7.00	8.17	7.00

Evaluation criteria		Prototype 1	Prototype 2	Prototype 3	Prototype 4
Theme	Sub-theme	Computer			
	Social agency	7.00	7.00	7.33	8.00
	Customization	6.00	8.00	8.17	9.00
	Level of interactivity compared to everyday ICT	Level of interactivity increased a bit	Level of interactivity increased a bit	50% of computer users: level of interactivity increased a lot 50% of computer users: level of interactivity increased a bit	Level of interactivity increased a bit
Social presence evaluation	Virtual space's effect on social presence	Improved social presence a bit	Improved social presence a bit	50% of computer users: social presence increased a lot 50% of computer users: social presence increased a bit	Improved social presence a lot
	Avatar's effect on social presence	no effect on social presence	Improved social presence a lot	83.3% of computer users: social presence increased a bit 16.7% of computer users: social presence increased a lot	Improved social presence a bit
	Overall social presence score	6.50	7.00	8.00	7.00

Table 9. Subjective Evaluation of Prototypes Experienced With a Computer

Evaluation criteria		Prototype 1	Prototype 2	Prototype 3	Prototype 4
Theme	Sub-theme	VR headset			
Usability evaluation	Navigation	9.00	10.00	8.00	10.00
	Interaction with other user	8.00	9.00	7.83	8.00
	Interaction with UI	7.00	9.00	7.83	10.00
Usefulness	Sense of really there	9.00	9.00	7.83	9.00

evaluation	Sense of being as one with avatar	10.00	10.00	8.00	5.00
	Social engagement when directly interacting with other	8.00	8.00	8.17	8.00

Evaluation criteria		Prototype 1	Prototype 2	Prototype 3	Prototype 4
Theme	Sub-theme	VR headset			
	Co-presence when in vicinity of other	8.00	10.00	8.33	10.00
	Social agency	8.00	8.00	7.67	9.00
	Customization	8.00	8.00	6.83	9.00
	Level of interactivity compared to everyday ICT	Level of interactivity increased a bit	Level of interactivity increased a lot	67% of VR users: level of interactivity increased a lot 33% of VR users: level of interactivity increased a bit	Level of interactivity increased a lot
Social presence evaluation	Virtual space's effect on social presence	Improved social presence a bit	Improved social presence a lot	50% of VR users: social presence increased a lot 50% of VR users: social presence increased a bit	Improved social presence a lot
	Avatar's effect on social presence	Improved social presence a bit	Improved social presence a lot	50% of VR users: social presence increased a lot 33% of VR users: social presence increased a bit 17% of VR users: no effect on social presence	Improved social presence a bit
	Overall social presence score	7.00	9.00	8.17	8.50

Table 10. Subjective Evaluation of Prototypes Experienced With a VR Headset

The evaluation results indicate that customizing, maintaining, and interacting with 2D and 3D assets and each other's representations (avatars) in a family-wide mixed reality home virtual space can build social presence in transnational family communication.

Chapter 6. Conclusions

6.1 Thesis Goals

To investigate the research question: how can we use mixed reality to build social presence for transnational family communication? This study reviewed literature and contextual works from relevant fields, including presence and social presence, mixed reality, transnational relationships, and technology for social presence for transnational families. Through literature and contextual review, it identified a gap in using MR as a technology tool to build social presence for transnational family communication.

As a response to the identified gap, this study implemented the Research through Design methodology and paired-up user testing methods to build 4 iterative MR prototypes for building social presence for transnational families, each exploring a secondary research question.

Through the production and documentation of design artifacts, design frameworks, and evaluation frameworks, this study contributes to academic theory, industry design practices, and the transnational community.

6.2 Outcomes and Contributions

First, this study contributes to theory in the fields of social presence, mixed reality research, transnational family relationship, and human-space relationship.

Second, this study contributes to design practice. Implementing the RtD methodology, it explores the real-life opportunities and challenges of using MR to build social presence for transnational families, “building the best bridge between the product idea and its usership” (Ghaoui, 2006, p. 542). More specifically, the contributions include design artifacts of functional prototypes, design and evaluation frameworks, and user testing strategies.

Guided by the RtD methodology and research questions, this study produced 4 prototypes of MR transnational family space:

1. “How can we use MR to create a transnational family communication experience that evokes social presence similar to that in real life?” Which was furthermore explored in 2 parts:

    1.1. “How can we use MR to replicate real-life transnational family communication experience?” as explored through *Prototype 1: 2D Assets Sharing in 3D Virtual Space*.

1.2. “How can we use mixed reality to improve real-life transnational communication experience?” as explored through *Prototype 2: 3D Assets Creating and Sharing in 3D Virtual Space*.

2. “What technology qualities, contextual factors, and interaction configurations in mixed reality build social presence in transnational family communication?” As explored through *Prototype 3: Transnational Family Space Testbed*.

3. “What is the long-term, future use of the mixed reality transnational family space?” As explored through *Prototype 4: Long-Term, Lived-in Virtual Family Space*.

Based on prior literature review, an evaluation framework was designed and implemented to subjectively and quantitatively assess the usefulness, usability, and social presence each prototype afforded. Specifically speaking, this work contributes the field of social presence research by incorporating theories regarding “kin-work” (Di Leonardo, 1987, p. 441) and its effect and focusing on social presence among transnational family members; this work contributes to transnational family communication by researching the unique features and potentials MR technologies can afford when compared to existing, common communication mediums; this work expands the field of MR by envisioning its application in home-making through the democratized digital replica production of domestic materials.

Third, this study analyzes the behavioral, social, and affective impacts of using MR to build social presence for transnational families, empathetically responding to communication, kin-work, and home-making needs of the transnational community.

6.3 Limitations and Challenges

This study encountered both expected limitations and unexpected challenges.

The expected limitations include a short research period, a solo researcher, and a small research funding. These resource constraints impeded advanced prototype developments, long-term and large-group user testings, and a diverse sample participant pool.

Furthermore, unexpected challenges occurred during the period of this study, including a slow recruitment process, cross-time-zone communication and scheduling inconveniences, technology setup, and connection difficulties in conducting connected user testing sessions due to various personal computer configuration of the overseas participants, and the abrupt shutdowns of essential applications including Microsoft Altspace and Google Street View. These unforeseen challenges further increased the time and effort needed to complete this study.

6.4 Future Pathways and Applications

Considering the above-mentioned limitations and challenges in this study, the researcher suggests future researchers advancing research in the field of social virtual experiences for transnational families to consider the following:

1. Establish an international partnership/collaboration to ensure the user testing participants overseas can get direct assistance and guidance.
2. For more in-depth, future user study, consider arranging ethnographic testing and interview sessions to understand user experiences in their own environmental and social contexts; also consider using diary studies for long-term user study.
3. Unify and standardize the device every testing participant uses; if this isn't feasible, inquire about the specifications and setup of the participants' own devices to verify their compatibility. Additionally, depending on the project's reliance on existing external software and applications, strategize alternative plans to prevent project incompletion due to software terminations.
4. Consider the possibility of encountering different regional network censorship and restrictions when conducting international testings.

On the other hand, considering the current ever-shifting MR application landscape and the possibility of sudden application service terminations, the researcher suggests transnational families who are interested in adapting such MR technologies into their communication to briefly research the available virtual platforms, and aim for ones with promising potential for future growth, detailed development documentation, and efficient customer support. During development, it's also recommended to save local files of the customized assets that could be opened and manipulated with third-party applications such as Unity and Blender. This will allow easy reproduction on most other virtual platforms, if the original platform is no longer in operation.

There are many future applications of this research. First and foremost, social virtual experience designers could utilize the design framework as a guide for building advanced transnational virtual spaces. By simplifying and streamlining the process of 2D and 3D asset creation, optimization, and uploading, as illustrated in Figure 24., such systems could democratize world-building. Such virtual spaces could be for small-scale inter-family use as a virtual home, as well as large-scale diaspora use as a community center centering around collaborative "productive nostalgia" (Blunt, 2005, p.2). Furthermore, the connected user testing design and evaluation could also be adapted to assess the usability, usefulness, and social presence afforded by immersive communication mediums as experienced by 2 or more communicating parties.

6.5 Final Remarks

Through conducting this study, the researcher established that MR has great potential in building social presence for transnational family communication. However, the current technology and its associated user experience still impede users from enjoying a smooth, connected user experience. It is hoped that this study will assist future MR researchers and designers in envisioning and developing an MR system for transnational families to enjoy a high sense of social presence in communication.

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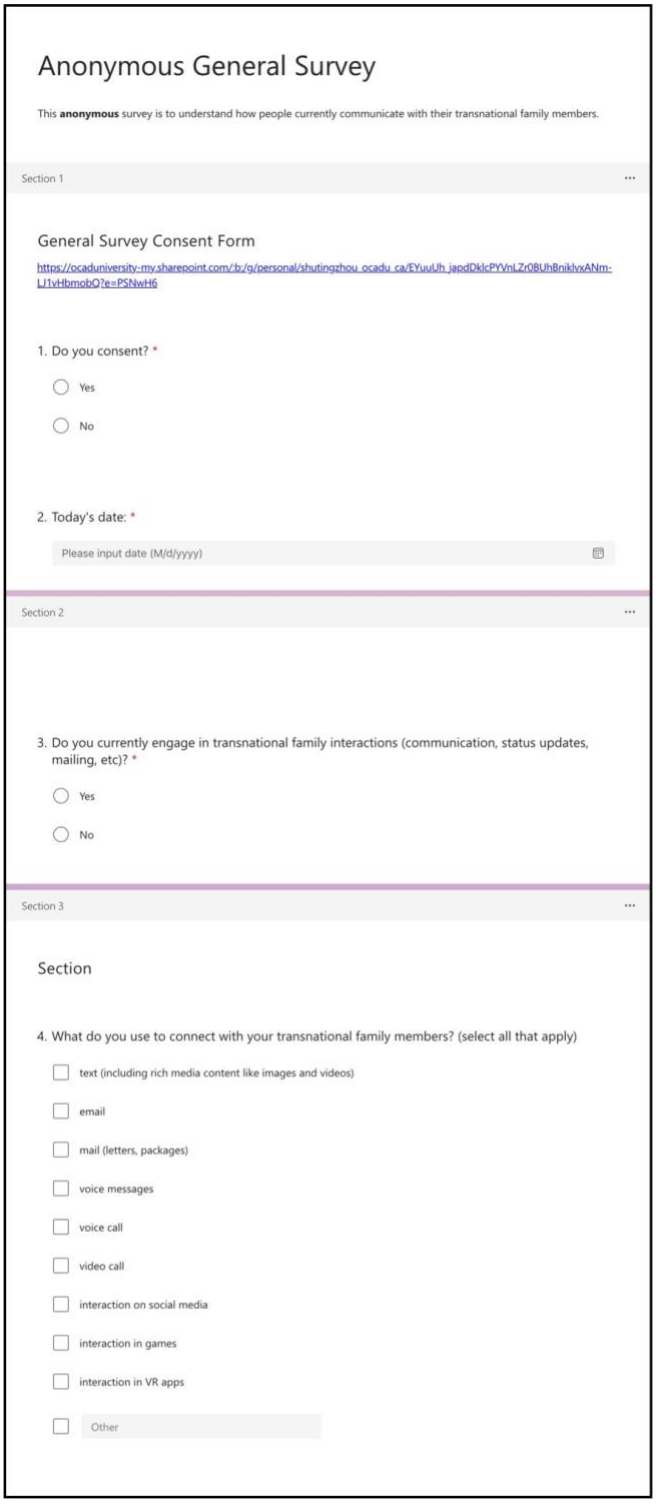
Appendices

Appendix A. Anonymous General Survey



Anonymous General Survey

This **anonymous** survey is to understand how people currently communicate with their transnational family members.

Section 1

General Survey Consent Form

https://ocaduniversity-my.sharepoint.com/:b:/g/personal/shutingzhou_ocadu_ca/EYuuUh_japdDklcPYVnLZr0BUhBniklvxANm-LJ1vHbmobQ?e=PSNwH6

1. Do you consent? *
   - Yes
   - No

2. Today's date: *
   - Please input date (M/d/yyyy)

Section 2

3. Do you currently engage in transnational family interactions (communication, status updates, mailing, etc)? *
   - Yes
   - No

Section 3

Section

4. What do you use to connect with your transnational family members? (select all that apply)
   - text (including rich media content like images and videos)
   - email
   - mail (letters, packages)
   - voice messages
   - voice call
   - video call
   - interaction on social media
   - interaction in games
   - interaction in VR apps
   - Other

5. At what frequency?
   - daily
   - Weekly
   - Monthly
   - Other

6. Social presence is the feeling of being really "there" while also emotionally connected with the other person.
   To what extent do you feel social present when you connect with your family overseas?
   1 being not really; 10 being very much

1	2	3	4	5	6	7	8	9	10

7. Rate the level of social presence you experience with transnational family members through these channels. Select N/A for never experienced.

	1 (lowest)	2 (lower)	3 (medium)	4 (higher)	5 (highest)	N/A
texting	○	○	○	○	○	○
emailing	○	○	○	○	○	○
mailing (letters, packages)	○	○	○	○	○	○
voice message	○	○	○	○	○	○
voice call	○	○	○	○	○	○
video call	○	○	○	○	○	○
interaction on social media	○	○	○	○	○	○
interaction in games	○	○	○	○	○	○
interaction in VR apps	○	○	○	○	○	○

8. Rate the level of social presence you experience with transnational family members through these channels. Select N/A for never experienced.Rate the level of social presence you experience with family in these different modalities.

	1 (lowest)	2 (lower)	3 (medium)	4 (higher)	5 (highest)	N/A
face to face	○	○	○	○	○	○
voice only	○	○	○	○	○	○
text based	○	○	○	○	○	○
voice and audio based	○	○	○	○	○	○

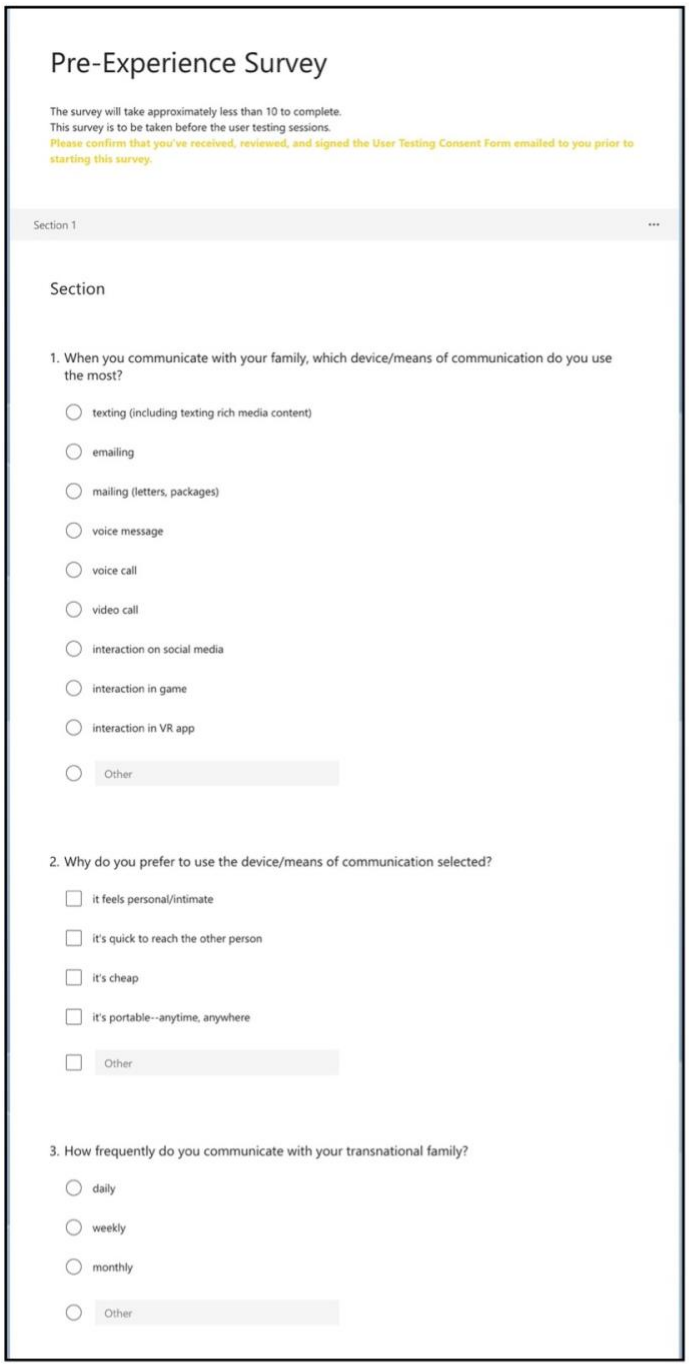
Section 4

Call For Participation in User Testing

Thank you for your input! If you are interested, please consider participating in the user testing part of the study where you connect with your overseas family member in VR! Email shutingzhou@ocadu.ca to for more information!

+ Add new

Appendix B. Pre-Experience Survey



Pre-Experience Survey

The survey will take approximately less than 10 to complete.
This survey is to be taken before the user testing sessions.
Please confirm that you've received, reviewed, and signed the User Testing Consent Form emailed to you prior to starting this survey.

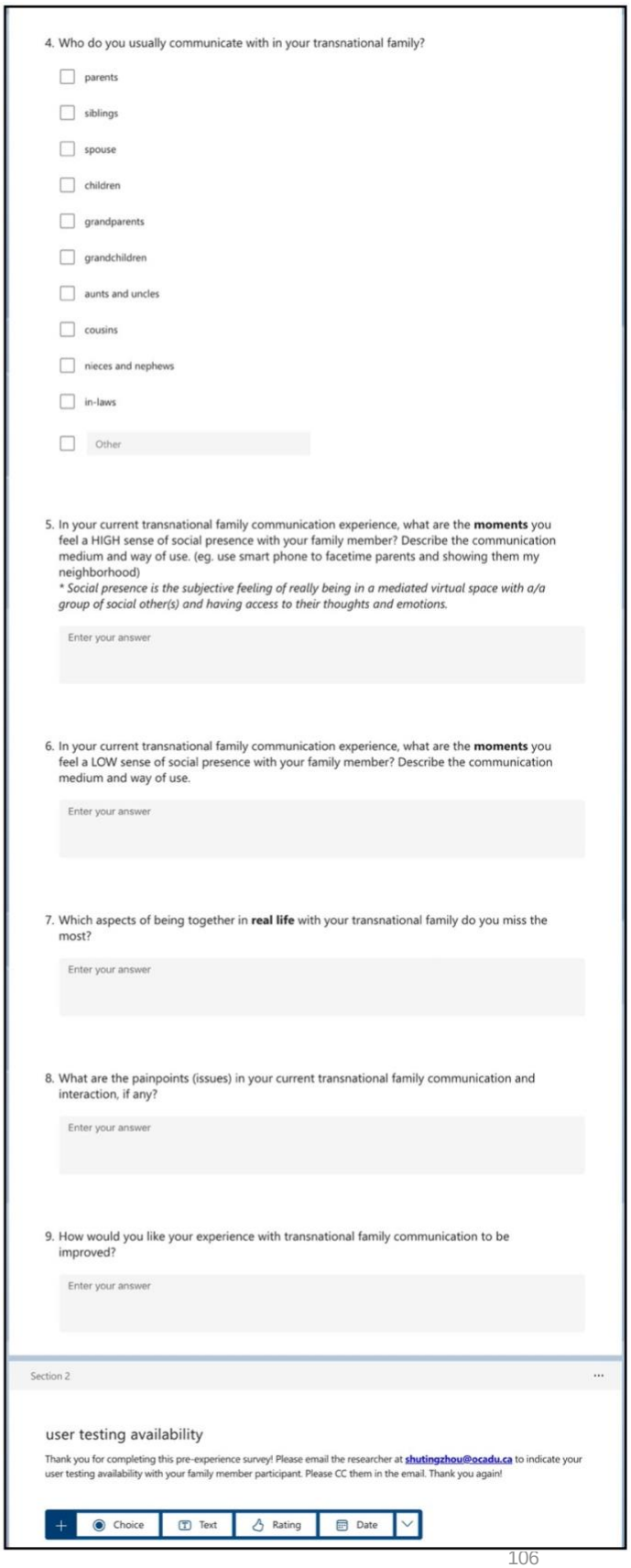
Section 1

Section

1. When you communicate with your family, which device/means of communication do you use the most?
   - texting (including texting rich media content)
   - emailing
   - mailing (letters, packages)
   - voice message
   - voice call
   - video call
   - interaction on social media
   - interaction in game
   - interaction in VR app
   - Other

2. Why do you prefer to use the device/means of communication selected?
   - it feels personal/intimate
   - it's quick to reach the other person
   - it's cheap
   - it's portable--anytime, anywhere
   - Other

3. How frequently do you communicate with your transnational family?
   - daily
   - weekly
   - monthly
   - Other



4. Who do you usually communicate with in your transnational family?
   - parents
   - siblings
   - spouse
   - children
   - grandparents
   - grandchildren
   - aunts and uncles
   - cousins
   - nieces and nephews
   - in-laws
   - Other

5. In your current transnational family communication experience, what are the **moments** you feel a HIGH sense of social presence with your family member? Describe the communication medium and way of use. (eg. use smart phone to facetime parents and showing them my neighborhood)
   ** Social presence is the subjective feeling of really being in a mediated virtual space with a/a group of social other(s) and having access to their thoughts and emotions.*

   Enter your answer

6. In your current transnational family communication experience, what are the **moments** you feel a LOW sense of social presence with your family member? Describe the communication medium and way of use.

   Enter your answer

7. Which aspects of being together in **real life** with your transnational family do you miss the most?

   Enter your answer

8. What are the painpoints (issues) in your current transnational family communication and interaction, if any?

   Enter your answer

9. How would you like your experience with transnational family communication to be improved?

   Enter your answer

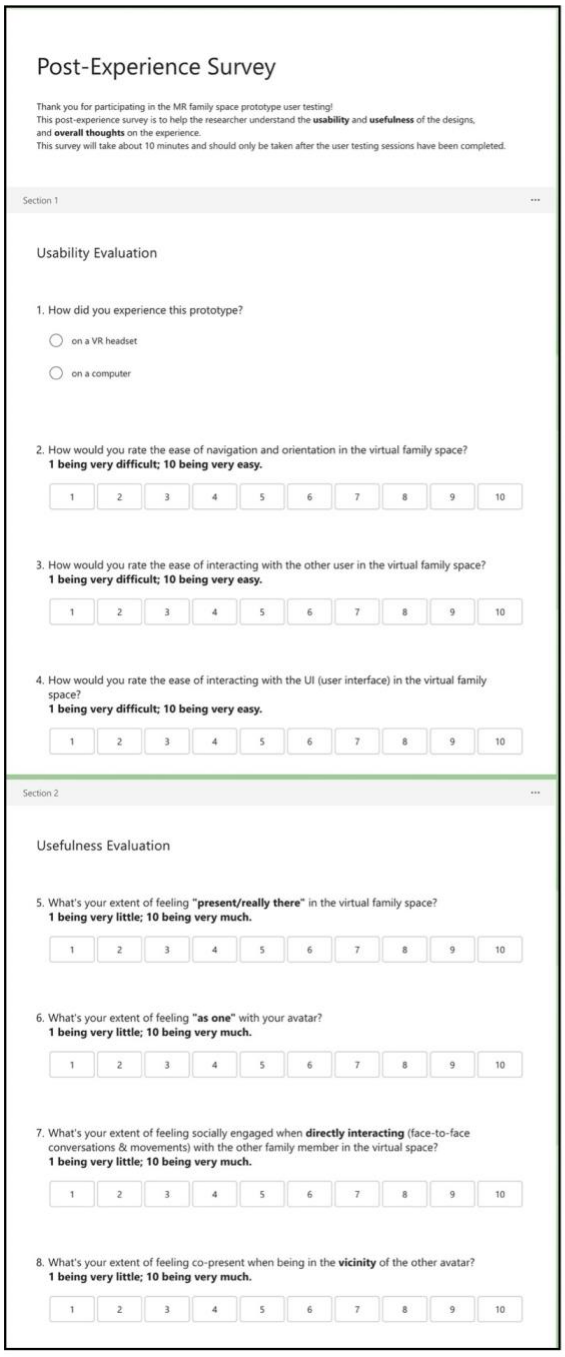
Section 2

user testing availability

Thank you for completing this pre-experience survey! Please email the researcher at **shutingzhou@ocadu.ca** to indicate your user testing availability with your family member participant. Please CC them in the email. Thank you again!

+ Choice | Text | Rating | Date

Appendix C. Post-Experience Survey



Post-Experience Survey

Thank you for participating in the MR family space prototype user testing!
This post-experience survey is to help the researcher understand the **usability** and **usefulness** of the designs, and **overall thoughts** on the experience.
This survey will take about 10 minutes and should only be taken after the user testing sessions have been completed.

Section 1

Usability Evaluation

1. How did you experience this prototype?
   - ◯ on a VR headset
   - ◯ on a computer

2. How would you rate the ease of navigation and orientation in the virtual family space?
   1 being very difficult; 10 being very easy.
   1 2 3 4 5 6 7 8 9 10

3. How would you rate the ease of interacting with the other user in the virtual family space?
   1 being very difficult; 10 being very easy.
   1 2 3 4 5 6 7 8 9 10

4. How would you rate the ease of interacting with the UI (user interface) in the virtual family space?
   1 being very difficult; 10 being very easy.
   1 2 3 4 5 6 7 8 9 10

Section 2

Usefulness Evaluation

5. What's your extent of feeling **"present/really there"** in the virtual family space?
   1 being very little; 10 being very much.
   1 2 3 4 5 6 7 8 9 10

6. What's your extent of feeling **"as one"** with your avatar?
   1 being very little; 10 being very much.
   1 2 3 4 5 6 7 8 9 10

7. What's your extent of feeling socially engaged when **directly interacting** (face-to-face conversations & movements) with the other family member in the virtual space?
   1 being very little; 10 being very much.
   1 2 3 4 5 6 7 8 9 10

8. What's your extent of feeling co-present when being in the **vicinity** of the other avatar?
   1 being very little; 10 being very much.
   1 2 3 4 5 6 7 8 9 10

9. What's the extent of social agency (the capacity of individuals to have the power and resources to fulfill their potential) you experienced in the virtual space?
   1 being very little; 10 being very much.
   1 2 3 4 5 6 7 8 9 10

10. What's the level of customization you experienced in the virtual space?
    1 being very low; 10 being very high.
    1 2 3 4 5 6 7 8 9 10

11. Compared to the ways in which you **normally share media content** transnationally, how has the **level of interactivity** changed in the virtual space?
    - ◯ the level of interactivity **decreased a lot** in the virtual space
    - ◯ the level of interactivity **decreased a bit** in the virtual space
    - ◯ the level of interactivity **didn't change much** in the virtual space
    - ◯ the level of interactivity **increased a bit** in the virtual space
    - ◯ the level of interactivity **increased a lot** in the virtual space

Section 3

Social Presence Evaluation

This section evaluates the effect that the VE, the object, and the avatar Have on social presence, which is the subjective feeling of really being in a mediated virtual space with a/a group of social other(s) and having access to their thoughts and emotions.

12. How has the **virtual space** affected your sense of social presence?
    - ◯ diminished social presence a lot
    - ◯ diminished social presence a bit
    - ◯ no effect on social presence
    - ◯ improved social presence a bit
    - ◯ improved social presence a lot

13. How has the **avatars for you and your family member** affect your sense of social presence?
    - ◯ diminished social presence a lot
    - ◯ diminished social presence a bit
    - ◯ no effect on social presence
    - ◯ improved social presence a bit
    - ◯ improved social presence a lot

14. **Overall**, rate the degree of **social presence** (being in the same place and emotionally connected) with your family member in the virtual family space.
    1 being very low social presence; 10 being high social presence.
    1 2 3 4 5 6 7 8 9 10

Section 4

Final Notes

15. Is there any additional thoughts/feedback regarding the prototype or the user testing? :)
    Enter your answer

Appendix D. Interview Script

Post-Experience Interview Script

After each participating pairs' 25-minute testing session, the researcher will join them in the virtual space to conduct a 15-minute post-experience interview following this script. The online interview will be screen recorded with audio.

- Do you think this prototype is effective in improving social presence for transnational families?
  - Where do you find it effective/ineffective?
- Was there a **moment** when you felt an especially high sense of social presence with your family member during the experience? If so, briefly describe the moment.
- What are the issues you experienced using this prototype, if any?
- What are some features you'd like to see in future prototypes?

Appendix E. Recruitment Email Script

Hello,

My name is Shuting, and I'm a MDes in Digital Futures candidate at OCAD University currently recruiting participants for my graduate thesis research on the topic of improving social presence of transnational families using mixed reality. Virtual reality has the potential of connecting people over long distances, and this work hopes to explore ways to immersively engage transnational families using this new media.This project has received REB (Research Ethics Board) approval.

As a pair, you and a member of your transnational family (overseas member) are invited to participate in an online pre-experience survey, an in-person creation session (only required for the Toronto participant), a connected testing session, and an online post-experience survey for the *Improving Social Presence for Transnational Families Using Mixed Reality* project at OCAD University and online. The purpose of this process is to test and receive feedback on a mixed reality prototype shared between 2 participants.

Interested participants should email the researcher at shutingzhou@ocadu.ca with your transnational family participant CC'ed. The researcher will then respond back with Microsoft Forms links to user testing surveys (pre-experience survey and post-experience survey) and consent forms detailing instructions and details of the user testing for both interested participants to review, sign, and email back.

See participation criteria below and pre-experience survey here.

If you are unable to join the user testing, you're still welcome to complete this anonymous general survey about your current experience of tech-mediated transnational family communication.

If needed, a translated version of all the documents for your family member can be offered.

If you have any questions or would like to find out more about this project, please don't hesitate to reach out to me at shutingzhou@ocadu.ca.

Thank you!

Shuting

Participation Criteria

Participants would be recruited in pairs (you will need to select an overseas family member as your partner, preferably someone you usually engages in transnational family communication with). All participants should be at least 13 years of age with basic computer and literacy skills. The Toronto participant need to understand English. This study aims to recruit 10-12 pairs of participants.

The overseas participants need to have computer and internet access at home for connected testing sessions. They will also be asked to download the Microsoft Altspace VR desktop software, which will be used as the testing platform. A secure download link will be provided and tech support will be provided in the process.

User Testing Session

Participants will be invited to join an approx. 90-min user testing session of my mixed reality design prototype detailed here:

IN-PERSON CREATION SESSION (30-MIN ACTIVITIES + 20-MIN BREAK)

The in-person creation session is for the Toronto participant only. The overseas participant does not need to participate in this session.

The Toronto participant is asked to bring a small (up to a basketball size) and meaningful object that they are willing to openly share for the creation session. It should not be too valuable in case of loss or breakage, or illegal/dangerous such as explosive devices, guns, knives, etc. The object will be 3D scanned and uploaded to the VR space to share with the overseas participant for storytelling.

- 5-min project and prototype brief from researcher
- 20-min content creation where the Toronto participant uses a provided smart phone with specialized apps to capture a 3D scan of a small meaningful object, 2 360-degree images, 3 photos and 1 short video of an on-campus environment of their choice to share with their overseas family participant in VR.
- 5-min avatar customization
- 20-min break

CONNECTED TESTING SESSION (40 MIN)

Both participants will join in a virtual space customized with content from the previous creation session and be prompted to complete a few tasks. The Toronto participant will joining on a provided VR headset, and the overseas participant will be joining remotely with their own computer. This session occurs immediately after the previous session.

This session includes 2 parts: task performing and poset-experience interview.

An in-VR screen-recording featuring avatars and real-person audio of this session will be taken. Data collected is intended for the internal use of the research team only.

- 25-min task performing: participants will be asked to perform a list of 4 semi-structured tasks to test the usability and usefulness of the prototype.
    1. Pick up the scanned 3D object, talk about it, and put it down.
    2. Flip through the photo album and change the photo displayed.
    3. Enter and exit 2 360-degree spheres.
    4. Play a video, watch it together, and talk about it.

- 15-minute post-experience interview: participants will be asked 4 open ended questions regarding the subjective experiences of the prototype. The interview will be conducted in the same mixed reality space where the user testing previously took place.

ONLINE POST-EXPERIENCE SURVEY (15 MIN)

Both participants are expected to answer multiple choice and short response questions evaluating the usability and usefulness of the prototype based on their testing experience.

Appendix F. Prototype 1—Evaluation Data Comparison

Horizontal Comparison

For every “usability”, “usefulness”, and “social presence” sub-theme that was evaluated with a numeric score, there’s a higher rating for the VR headset user than the computer user, with “sense of as one with avatar” being rated with the greatest score difference.

On average, in “usability”, the headset experience scored 1.5 points higher than the computer experience; in “usefulness”, the headset experience scored 2.33 points higher than the computer experience; in “overall social presence score”, the headset experience scored 0.5 higher than the computer experience.

For both the computer experience and the VR headset experience, compared to everyday ICT, prototype 1’s level of interactivity increased the sense of social presence minimally; prototype 1’s virtual environment increased the sense of social presence minimally. Meanwhile, prototype 1’s avatars had no significant effect on social presence in the computer experience, but improved social presence in the VR headset experience.

Overall, this evaluation suggests experiencing prototype 1 with a VR headset was more usable and useful than experiencing it with a computer. Compared to everyday ICT such as calling, messaging, or video chatting, prototype 1 improved social presence for both the computer and the VR headset experiences. The improvement was more multi-faceted for the VR headset experience.

Vertical Comparison

The computer experience scored a higher average score in the theme “usability” than in “usefulness”, with a difference of 0.08.

On the other hand, the VR headset experience scored a higher average score in the theme “usefulness” than in “usability”, with a difference of 0.75.

Appendix G. Prototype 2—Evaluation Data Comparison

Horizontal Comparison

For nearly all “usability”, “usefulness”, and “social presence” sub-themes evaluated with a numeric score, the VR experience received a higher rating than the computer experience. However, in the sub-theme “social engagement when directly interacting with the other”, the researcher gave a 10 for the computer experience and an 8 for the headset experience. The researcher believes this is due to the computer user's fewer avatar body controls, which made their avatar appear less active, resulting in weaker social engagement.

On average, in “usability”, the headset experience scored 2.25 points higher than the computer experience; in “usefulness”, the headset experience scored 1.16 points higher than the computer experience; in “overall social presence score”, the headset experience scored 2 points higher than the computer experience.

For both the computer experience and the VR headset experience as experienced by the researcher, prototype 2’s level of interactivity, virtual space, and avatar all increased the sense of social presence compared to everyday ICT. However, the level of interactivity and virtual space increased social presence more for the headset experience (a lot) than the computer experience (a bit). On the other hand, the avatar’s effect on improving social presence was equally high for both device users.

Overall, the evaluation suggests experiencing prototype 2 with a VR headset was more usable and useful than experiencing it with a computer. Compared to everyday ICT such as sending text and/or images over messages and video chatting, prototype 2 improved social presence for both the computer and the VR headset experiences more than prototype 1, with the improvement also being more significant for the VR headset experience.

Vertical Comparison

The computer experience scored a higher average in theme “usefulness” than in “usability”, with a difference of 0.42.

The VR headset experience scored a higher average in the theme “usability” than in “usefulness”, with a difference of 0.67.

Appendix H. Prototype 3—Evaluation Data Comparison

Horizontal Comparison

On an overall average, computer users and VR headset users rated this prototype as usable, useful, and inductive to social presence. Noticeably, the average ratings differed little based on the access device. In the “usability evaluation”, the computer users rated a score of 7.66 on average, 0.23 points lower than the VR users. In the “usefulness evaluation”, the computer users and the VR users both rated a 7.81. In the “overall social presence score”, the computer users rated a score of 8 on average, 0.17 points lower than the VR users.

To compare the “sub-theme” ratings, the VR users’ ratings on “navigation”, “sense of being as one with avatar”, “social engagement when directly interacting with the other”, “co-presence when in the vicinity of the other”, "social agency”, and “overall social presence score” were higher than that of the computer users, with “sense of being as one with avatar” drawing the greatest difference of 1 point. Both the computer users and the VR users rated “interaction with another user” and “interaction with the UI” the same. The computer users’ ratings on “sense of really being there” and “customization” were higher than that of the VR users.

For both the computer users and the VR headset users, compared to common communication mediums, prototype 3’s level of interactivity, virtual space, and avatar all increased their sense of social presence. However, the level of interactivity increased social presence more for the headset user (67% rated *a lot*; 33% rated *a bit*) than the computer user (50% rated *a lot*; 50% rated *a bit*). On the other hand, the virtual space’s effect on improving social presence is equally high for both computer users and VR users (50% rated *a lot*; 50% rated *a bit*).

The avatars’ effect on social presence ratings was diversified. All computer users expressed that the avatars increased social presence, with the majority (83.3%) of them expressing that the increase was by *a bit*, and the minority (16.7% of all computer users) expressing that the increase was by *a lot*. The majority (83.3%) of VR users expressed that the avatars increased social presence, with more (50% of all VR users) expressing that the increase was by *a lot*, and fewer (33% of all VR users) expressing that the increase was by *a bit*. Additionally, a minority of VR users (1 person, 17% of all VR users), expressed that the avatar has no effect on social presence.

In summary, prototype 3 was usable, useful, and inductive to social presence improvement for both the computer users and the VR users. Both device groups experienced a similar level of usability, usefulness, and social presence, indicating the

active/passive role dynamics between the 2 users did not make the computer users feel less social presence than the VR headset users in a short-term, first-time use case scenario.

Vertical Comparison

The computer experience scored a higher average in theme “usefulness” than in “usability”, with a difference of 0.15.

The VR headset experience scored a higher average in the theme “usability” than in “usefulness”, with a difference of 0.08.

Appendix I. Prototype 4—Evaluation Data Comparison

Horizontal Comparison

For nearly all “usability”, “usefulness”, and “social presence” sub-themes evaluated with a numeric score, the VR experience received a higher rating than the computer experience, with the sub-theme “navigation” revealing the greatest score difference — 6 for the computer experience and 10 for the VR experience. The researcher believes the significant challenge in navigation using a computer is due to the easy mix-up of the many viewport and movement control settings Spatial provides, which are all controlled by the same few keyboard and mouse buttons, making accidental commands and navigation errors commonplace. This issue is reduced to a minimum in the VR experience as the control mechanisms simplify.

However, in the sub-themes “sense of being as one with avatar”, the researcher gave low scores to both experiences, with the VR experience scoring lower than the computer experience, at 5 and 5.5 respectively. The researcher believes this is due to the unique design of Spatial that does not portray the avatar's body when the user attempts to look that their virtual self in first person, and shows an empty space instead. This lack of connection with the avatar was more noticeable when the researcher experienced this prototype using a VR headset, which functionally affords more agile and natural movement control over the avatar compared to a computer, but visually displays a void, causing a mismatch. Similar to prototype 2, in the sub-theme “social engagement when directly interacting with the other”, the researcher gave a 10 for the computer experience and an 8 for the headset experience. The researcher attributes this to the fewer avatar body controls the computer user has, which made their avatar appear less active, consequently resulting in a feeling of weaker social engagement.

Additionally, although the sub-theme “customization” was rated 9 for both the computer experience and the VR headset experience for an easy customization experience, the types of customization a user can perform are different depending on the device they are experiencing this prototype with. While customizing on the computer gives the user access to many local files and default system assets, customizing on a VR headset allows the user to scribble in the air or on notes, and have more control over object placement.

On average, in “usability”, the headset experience scored 2.33 points higher than the computer experience; in “usefulness”, the headset experience scored 0.75 points higher than the computer experience; in “overall social presence score”, the headset experience scored 1.5 points higher than the computer experience.

For both the computer experience and the VR headset experience as experienced by the researcher, prototype 4's level of interactivity, virtual space, and avatar all increased the sense of social presence compared to everyday ICT. The virtual space's effect on improving social presence was equally significant to computer users and VR headset users. On the other hand, the avatar's effect on improving social presence was equally minimal for users of both devices, which the researcher attributes to the above-mentioned movement-avatar mismatch. However, the level of interactivity and virtual space increased social presence more for the headset experience (significantly) than the computer experience (minimally).

Vertical Comparison

The computer experience scored a higher average in theme "usefulness" than in "usability", with a difference of 0.58.

The VR headset experience scored a higher average in the theme "usability" than in "usefulness", with a difference of 1.