Exploring the Use of Telepresence Robots in Long Distance Relationships

by

Lillian Yang

M.Sc., University of British Columbia, 2016

B.A., University of British Columbia, 2010

Thesis Submitted in Partial Fulfillment of the
Requirements for the Degree of
Doctor of Philosophy

in the
School of Interactive Arts and Technology
Faculty of Communication, Art, and Technology

SIMON FRASER UNIVERSITY

Summer 2020

Approval

Name:	**Lillian Yang**
Degree:	**Doctor of Philosophy**
Title:	**Exploring the Use of Telepresence Robots in Long Distance Relationships**
Examining Committee:	**Chair:** Wolfgang Stuerzlinger Professor
	Carman Neustaedter Senior Supervisor Professor
	Bernhard Riecke Supervisor Associate Professor
	Lyn Bartram Examiner Professor
	Leila Takayama External Examiner Associate Professor Computational Media University of California, Santa Cruz
Date Defended/Approved:	June 22, 2020

Ethics Statement

The author, whose name appears on the title page of this work, has obtained, for the research described in this work, either:

a. human research ethics approval from the Simon Fraser University Office of Research Ethics

or

b. advance approval of the animal care protocol from the University Animal Care Committee of Simon Fraser University

or has conducted the research

c. as a co-investigator, collaborator, or research assistant in a research project approved in advance.

A copy of the approval letter has been filed with the Theses Office of the University Library at the time of submission of this thesis or project.

The original application for approval and letter of approval are filed with the relevant offices. Inquiries may be directed to those authorities.

Simon Fraser University Library
Burnaby, British Columbia, Canada

Update Spring 2016

Abstract

This thesis explores the use of telepresence robots as a communication tool for long distance relationships. While communication between partners can be nuanced and varied, current remote communication tools are limited in the aspects of communication that are supported. The lack of an embodiment creates challenges for maintaining relationships over distance because communication becomes limited to audiovisual interactions. The telepresence robot provides an embodiment through which long distance partners can interact, opening up unique opportunities for engagement. This work explores how real world couples utilize telepresence robots to interact over distance and considers how the findings translate to design implications and considerations.

This thesis presents the following three studies in a cumulative format. The first study looks at how telepresence robots are used by long distance couples in the home space. This exploratory field study utilized interviews to collect data while minimizing intrusiveness in the home space. The second study compares the use of telepresence robots versus tablets for the joint activity of shopping as long distance couples. This between-groups study used data from observations and interviews. The third study explores the use of a telepresence robot when paired with voice-controlled devices in a home shared over distance. This autobiographical study collected daily diaries, interviews, and photo/video materials for data.

This collection of studies contributes early insights on the use of telepresence robots by long distance couples to support their uniquely demanding communication needs. My findings show that couples use telepresence robots during evening and weekends to spend time together, with the freedom to move around independently. The telepresence robot supports the sense of a shared home and lets partners participate in everyday life. Movement supports not only independence, but also displays of personality and playfulness. This work also underscores the limitations of an appendage-free design, which constrains helpful acts and joint activities. I include a chapter on design considerations before the conclusion chapter. There I discuss the importance of supporting a sense of belonging and ownership in the shared home home space, and a sense of joint participation and variety in activities.

Keywords: Computer-Mediated Communication; Human Computer Interaction; Telepresence Robots; Long Distance Relationships

Dedication

I dedicate this thesis to my dad. For you, I will always keep trying my best.

Acknowledgements

Thank you to Dr. Carman Neustaedter for setting a shining example. I've been grateful every day of this entire program that you are my supervisor.

Thank you to Dr. Bernhard Riecke for so kindly joining my supervisory committee and always offering thoughtful insights.

Research Acknowledgments

Each of my papers were collaborations with one or more researchers. Here I detail the roles of each researcher.

Lillian Yang and Carman Neustaedter. 2018. Our House: Living Long Distance with a Telepresence Robot. Proc. ACM Hum.-Comput. Interact. 2, CSCW, Article 190 (November 2018), 18 pages.

For this paper, I designed the study methods, conducted the data collection, analyzed the data, and wrote the paper. Dr. Neustaedter contributed insights into the methods chosen for the study, provided feedback regarding the analysis of the data, and worked with me to edit the final paper.

Lillian Yang, Brennan Jones, Carman Neustaedter, and Samarth Singhal. 2018. Shopping Over Distance through a Telepresence Robot. Proc. ACM Hum.-Comput. Interact. 2, CSCW, Article 191 (November 2018), 18 pages.

For this paper, I designed the study methods with input from Dr. Neustaedter. I ran the participants alongside my fellow researcher, Brennan Jones, who also collaborated with me to transcribe and review the data, as well as to edit the paper. Dr. Neustaedter further contributed by providing feedback regarding the analysis of the data, and was also a collaborator in writing the paper. Fellow researcher, Samarth Singhal, was also involved in running early participants.

Lillian Yang & Carman Neustaedter. 2020. An Autobiographical Design Study of a Long Distance Relationship: When Telepresence Robots Meet Smart Home Tools. Conditionally accepted to Proceedings of the 2020 Designing Interactive Systems Conference (DIS '20). Association for Computing Machinery, New York, NY, USA.

For this paper, I designed the study methods, conducted the data collection, analyzed the data, and wrote the paper. Dr. Neustaedter contributed insights into the methods chosen for the study, provided feedback regarding the analysis of the data, and worked with me to edit the final paper.

Table of Contents

List of Tables

List of Figures

Chapter 1.

Introduction

Long distance relationships are a common experience (Stafford, 2005) for many people as a result of situations in life, such as work relocations, family obligations, moving to attend a specific school, etc. The distance makes it difficult to maintain relationships as partners become limited in how they can interact with and support one another when they are physically apart (Dainton & Aylor, 2001). Computer-mediated communication tools are essential to today's long distance couples, making the distance acceptable by supporting communication (Aguila, 2011). However, traditional communication tools are limited to audiovisual channels of communication and therefore lack elements of embodied communication, such as shared spatial context and physical contact.

Figure 1: Telepresence Robot.

With the recent commercialization of telepresence robots, we gain the benefits of greater immersiveness and the potential for more interactivity. Telepresence robots (Figure 1) are a multi-channel communication tool that provides a rich experience of

communication for both the remote user (ie. the partner controlling the telepresence robot) and the local interactant (ie. the partner interacting with the telepresence robot controlled by their partner). The robotic physical embodiment allows the user to move in the remote location and projects the user's voice and face into the remote location. This allows the user to experience and interact in the remote location in an embodied manner.

The mobile and physical form of the telepresence robot presents opportunities for extending the range of interactions that partners can have with one another over distance. However, the potential of telepresence robots to support the communication needs of long distance partners is underexplored in research. Rather, the focus of telepresence robot research has been in organizational settings, such as workplace (Lee & Takayama, 2011; Venolia et al., 2010), and healthcare use (Ellison et al., 2004; Nestel et al., 2007; Vespa et al., 2007) where interactions differ significantly from the personal domain. In response to the potential for telepresence robots to support long distance relationship communication and the lack of research in this area, this work explores the use of telepresence robots by long distance couples in their daily lives and discusses the design implications that arise from the challenges and benefits that are revealed in a series of three studies.

To begin, I will provide the context around my research area. Following this, I will cover my research questions, along with the motivation, rationale, and methods for tackling the questions. Then I will include an organizational overview of the chapters to come.

1.1. Research Context

This dissertation is focused on understanding long distance relationship communication through telepresence robots and generating design implications for such usage. This work falls within the broad field of human-computer interaction. This field is broad because understanding the interaction between humans and computers involves understanding of both the human side (including psychology, cognitive science, and sociology), and the computer side (including computer science, engineering) (Dix, 1998), as well as understanding of the interaction. Within the field of human-computer interaction, there are more specific areas of research.

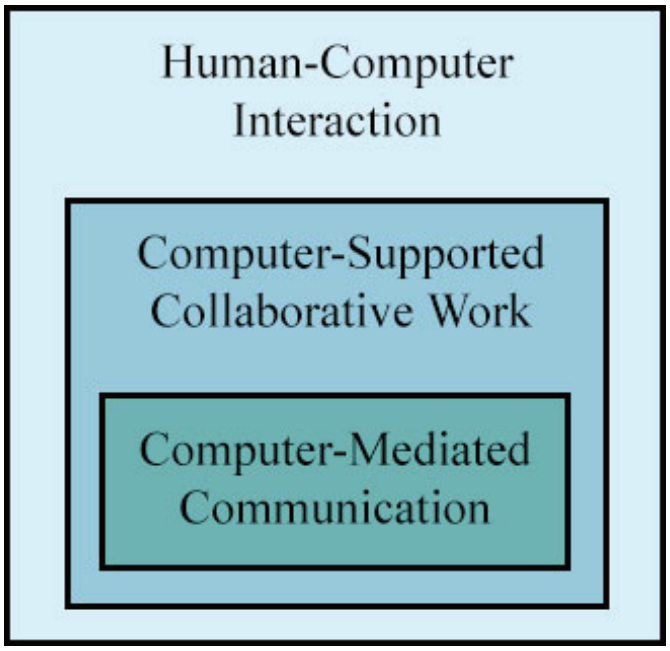

Figure 2: Research context within human-computer interaction.

My work belongs under the category of computer-supported collaborative work (CSCW) in the specific area of computer-mediated communication (CMC) (Figure 2). While CSCW research began in the context of collaborative work, it has expanded to include all manners of distance communication, such as gaming, education, and social networking. Thus, the study of computer-mediated communication for personal communication falls into this multi-disciplinary field.

There are a large number of computer-mediated communication tools that are commonly used, and these can be categorized as asynchronous (e.g. email and text message) and synchronous (e.g. video chat and telepresence robots). Synchronous technologies are used more frequently by long distance partners than by geographically close partners, and are also considered more meaningful (Janning et al., 2018). Synchronous technologies that transmit audio and/or visual information provide a sense of intimacy that is important for long distance partners (Janning et al., 2018). My work is centered on understanding how telepresence robots fit into the array of communication tools that partners have and how this technology may benefit or detract from the mediation of intimacy.

1.2. Research Questions

My body of work focuses on studying how long distance partners communicate through telepresence robots and how to design them to support geographically separated partners in maintaining their relationships and sharing life together. The overarching goal for the following research questions is to learn ***how long distance partners use telepresence robots to maintain their relationships and share life, and how future design work may improve their experience.*** I have broken this down into three subquestions.

The first question is an early exploration of how real-world long distance couples may use telepresence robots to interact in the home space. This early exploration revealed couples' desires for more shared activities and interactivity, thus leading to the second and third questions. The second question considers how usage of the telepresence robot might extend outside of the home space to allow for more variety in potential shared activities. The final question returns to the home space to explore how voice-controlled smart home devices can augment the experience of communicating through a telepresence robot by supporting interactivity through home devices.

Research Question 1

How do long distance couples use telepresence robots in the home and what are the benefits and challenges that come from such usage?

Past work involving long distance couple communication has found that couples have a desire to spend time together when they are home, and sometimes prefer to maintain a connection even when each partner is doing their own activity (Neustaedter & Greenberg, 2011). Many partners are used to spending evenings together at home, whether each person is doing chores, getting extra work done, engaging in hobbies, or simply relaxing, and this remains a desire for partners even when they are separated by distance. However, traditional video chat was not designed for the purpose of casually spending time together. Rather, the independent movement that the telepresence robot allows may be better suited than other communication tools for the times that partners spend at home in the evenings and weekends. Therefore, I chose to study the use of telepresence robots in the home setting. The published work is:

Lillian Yang and Carman Neustaedter. 2018. Our House: Living Long Distance with a Telepresence Robot. Proc. ACM Hum.-Comput. Interact. 2, CSCW, Article 190 (November 2018), 18 pages.

In order to answer my research question regarding how long distance partners use telepresence robots at home, I had seven long distance couples each use a telepresence robot for a month. I conducted semi-structured interviews at the beginning, middle, and end of the one month usage period. The interview at the beginning of the monthlong study gathered information about how the couples communicated prior to the telepresence robot, the interview at the middle of the month allowed me to check in with the participants in case of issues and to collect initial impressions, and the interview at the end of the month provided an understanding of the benefits and challenges that arose from using a telepresence robot to communicate in a long distance relationship.

Through this initial study, we learned that telepresence robot usage allows long distance partners to communicate in a more relaxed and natural manner - offering the remote partner a different perspective, introducing autonomy of movement for both partners in the local space, and evoking moments of surprise. Furthermore, the use of telepresence robots supports a sense of shared space, rather than simply connecting two disparate spaces. Through telepresence robots, remote partners are better able to participate in the local partner's everyday routines, establish a relationship with the local partner's friends and family members, and offer simple forms of help when needed (Yang & Neustaedter, 2018).

The study also brought up questions about interpersonal topics such as asymmetry between the experiences of the partners since only one partner had telepresence robot access to the other partner's home, and issues with privacy and renegotiating boundaries. The challenges that were reported by the users included limitations on interactivity, physical contact, and accessibility (Yang & Neustaedter, 2018). The design of telepresence robots has physical limitations that constrains their versatility – the lack of appendages such as arms and legs stifles interactivity and means that features in homes, such as doors, stairs, and messy floors can limit where telepresence robots can go. Given that long distance partners using telepresence robots value the ability to share a home space and involve the remote partner in everyday

home activities, the limit to interactivity and accessibility are important to address in design improvements.

Research Question 2

How does a telepresence robot support or hinder couples in performing the act of shopping as a relationship maintenance behavior and how do the experiences of using a telepresence robot while shopping compare to using video chat on a tablet?

The previous study I ran showed that couples wanted to be able to go outside of their home with telepresence robots. While telepresence robots gave couples a sense of shared space at home, this feeling was not extended outside of the home as couples were not given a way to easily transport and use the telepresence robots in other areas. As sharing actitivities together is part of relationship maintenance and many common couples' activities happen outside of the home, I felt that this was an important area to explore when considering how telepresence robots could support couples in connecting over distance. Therefore, I decided to do a telepresence robot study with these elements – 1. usage outside of the home and 2. doing a shared activity. My chosen shared activity was shopping as it is a common activity that couples do together that involves moving through a space together, conversing, and joint decision making. The published work is:

> Lillian Yang, Brennan Jones, Carman Neustaedter, and Samarth Singhal. 2018. Shopping Over Distance through a Telepresence Robot. Proc. ACM Hum.-Comput. Interact. 2, CSCW, Article 191 (November 2018), 18 pages.

In order to answer my research question of how couples use telepresence robots to engage in the joint activity of shopping and how this compares to the use of a tablet, I randomly assigned couples to either use a telepresence robot (7 couples) or a tablet (7 couples) in order to complete shopping tasks. The tablet condition gave me a comparison point to understand how the features of movement and physical presence influenced the mediated joint shopping experience. I gathered data through observations, and a semi-structured interview about their experience. The interview included questions on comparing the mediated (telepresence robot or tablet) experience to an in-person shopping experience, how the mediated device supported or hindered

shopping, how purchase decisions were made, and how they felt about their contribution to tasks and their responsibility regarding actions in the mall.

Through this study, I found that doing a shared activity through a telepresence robot supported more partner-focused behavior (e.g. being playful towards one another), as opposed to more task-focused behavior (e.g. finding items to complete the shopping list) that was observed with couples using a tablet. I found that the remote partners' characteristics were better represented through the telepresence robot. Participants could experience their partner's traits, such as independence, playfulness, or clumsiness, whereas these things were not as well represented through the tablet since the remote partner could not independently move around through the tablet.

For couples using the telepresence robot, I also found interesting dynamics regarding the partners' views on responsibility for the actions of the telepresence robot and the level of dependency of the remote partner on the local partner. We asked partners about who they felt would be responsible if the remote partner broke something in a store using the telepresence robot or tablet. Whereas both local and remote partners in the tablet group felt that it would be the local partner's responsibility, in the telepresence robot group, most of the remote partners actually felt it was their responsibility. The discrepancy between how partners felt about whether the remote partner has enough agency to be held responsible for actions in the local space could potentially cause friction in the relationship.

The more interactive nature of the telepresence robot allowed for more expressions of humor. As well, since the remote partner could independently move around to look at items through the telepresence robot, they were better able to provide advice and be more involved in joint decision making for purchasing items. However, there were drawbacks to telepresence robot usage as well. Partners using the telepresence robot missed being able to hold hands and remote partners noted how they wished they could help out with carrying items.

Research Question 3

How does the ability to affect the shared home environment influence the experience of sharing a home through a telepresence robot as part of a long distance relationship?

My earlier studies established how telepresence robot usage provides long distance partners with previously unsupported opportunities for connecting, such as sharing morning routines and other parts of one's everyday life and home, establishing a relationship with friends and family, experiencing new perspectives, opening up space for serious conversations, being physically playful, and offering rudimentary help (Yang et al., 2018, 2017a; Yang & Neustaedter, 2018). However, these studies have also found that the physical limitations of current telepresence robot designs only support these valued interactions in a minimal way. These findings suggest that looking for ways to expand the opportunities for partners to interact with one another and share a home space through telepresence robots is a valuable direction for design work when it comes to designing telepresence robots for long distance partners. Thus, I conducted an autobiographical design study to determine how partners can more richly experience a shared home together over distance through a telepresence robot coupled with voice-controlled smart home devices. The conditionally accepted work is:

> Lillian Yang & Carman Neustaedter. 2020. An Autobiographical Design Study of a Long Distance Relationship: When Telepresence Robots Meet Smart Home Tools. Conditionally accepted to Proceedings of the 2020 Designing Interactive Systems Conference (DIS '20). Association for Computing Machinery, New York, NY, USA.

In order to answer my research question regarding how the ability to affect the shared home environment may influence the experience of sharing a home over distance through a telepresence robot, I used the method of autobiographical design. Autobiographical design is defined as "design research drawing on extensive, genuine usage by those creating or building the system" (Neustaedter & Sengers, 2012, p. 1). This method was chosen as it allows the extensive access that we needed to a couple's home and private life. The study required access to modify the home with smart home devices throughout the study and to monitor day-to-day interactions in the home space.

For this study, a telepresence robot and smart home devices were brought to my partner's and my shared home prior to me moving to another country for a three month internship during which we were in a long distance relationship. We used this setup to communicate during long distance and were not restricted against using other communication devices. To choose the smart home devices to be used alongside the

telepresence robot, I kept a diary of our daily interactions and interviewed my partner to gain perspective on what devices were important to our daily interactions. The devices and their placement in the home were open to iteration throughout the study and two devices were added during the study in response to relationship needs that emerged. The list of devices controlled over distance were the TV, lights, vacuum, printer, and sous vide machine for cooking. Data was collected in the form of a daily log of interactions, weekly interviews, and photo/video capture.

Through this study, I found that the ability to control one's remote surroundings when present through a telepresence robot supports feelings of ownership and belonging. For example, voice controlled lights allowed me to brighten up the home if I was there at night, rather than moving around in the dark like an intruder. The ability to control typical home devices such as the TV and vacuum created a sense of normalcy after transitioning to being long distance, since I could continue to engage in typical routines involving these devices. This work also revealed the importance of having diverse ways to interact and the value of giving control over to the users rather than using automation as this presents opportunities for partners to perform mutual care. Design challenges to consider include how to design devices that support interaction with groups, such as how to allow a remote partner to better host and interact with guests, as well as continuing limitations with the appendage-free form of the telepresence robot.

1.3. Methodological Approach

The motivation for my thesis is to gain deeper insights into how technology can be designed to support couples in connecting over distance. Communication between couples is nuanced and varied, shaped by intimate knowledge between partners and an interconnectedness from sharing life together. My use of qualitative research is suitable for understanding the intricacies of the multifaceted communication between long distance partners for reasons that I dedicate this section to explaining. Qualitative research is characterized by the following traits which are outlined by Creswell (Creswell, 2013, Chapter 3). I will discuss these traits and how they guide my work.

The first trait of qualitative research is that it is often conducted in natural settings. Doing so allows researchers to see behaviors occuring within the contexts of

time and place. In many cases, the research can be unobstrusive and allow participants to behave normally without consideration of being observed. My three studies in this thesis all occur in a natural setting and my analysis of the findings consider the features of the settings. In fact, the context of my research differentiates this work from other telepresence robot research, which focuses on organizational settings, such as the workplace.

The second trait of qualitative research is that the researcher is a key tool for collecting data. For example, the researcher can collect data by interviewing and observing participants. Repeated interaction with a researcher can build a rapport with participants, which can make them more comfortable with sharing information (Judge & Neustaedter, 2015, Chapter 10). The three studies in this thesis all utilize the researcher as a key tool for data collection. This was beneficial to my studies, because they involve the participants talking about their personal relationships and the repeated interactions with the researcher may have helped participants become more open to sharing.

The third trait of qualitative research is the use of multiple forms of data. For example, in my third study I collected interview, observation, diary, and photo/video data. Finding corroborating results across various data sources provides some evidence for validity, which is concerned with credibility, authenticity, and self reflection in qualitative research (Creswell, 2013, Chapter 10).

The fourth trait of qualitative research is that it begins with inductive logic. This involves coming to findings through the organization of data to reveal insights, rather than using the data to answer a specific question. Qualitative research is useful in exploratory phases where researchers are asking broad questions rather than specific ones. This is the case with my work because the study of telepresence robots in the context of long distance relationships is still nascent.

The fifth trait of qualitative research is the value of participants' perspectives. Researchers accept that there can be multiple perspectives and acknowledge the different opinions that participants may hold. In my work, I note the differing perspectives that emerge to present a complete picture of the findings.

The sixth trait of qualitative research is emergent design, which means that the study design can be refined as the researcher gains more knowledge about a topic. In

my third study, I added new devices to be studied as the need arose. This flexibility is helpful when conducting research in the real-world setting where the unpredictability requires adaptability.

The seventh trait of qualitative research is reflexivity. Researchers should reflect on biases and be transparent. In my research, I focus on understanding both the benefits and challenges of the devices I study and value the importance of reporting on both.

The eighth trait of qualitative research is providing a holistic account. This involves trying to identify the various factors that influence a situation and considering different perspectives. In my research, I invite the complexity of a natural setting and include multiple perspectives and methods to foster a rich understanding.

The qualitative approach is suitable for the exploratory nature of my work. The combination of interviews, observations, diary logs, and photo/video collection has led to a detailed picture of telepresence robot usage in long distance relationships. The qualitative research portrays the perspectives of different couples, taking into consideration their unique relationship dynamics and how these influence their usage of telepresence robots to communicate.

1.4. Organizational Overview

This thesis discusses the use of telepresence robots as a communication tool for long distance couples. Three studies are described, followed by design considerations that have emerged from these studies, then a conclusion chapter.

The first chapter was an introduction to the topic of the thesis, including the context and motivation for this work.

The second chapter describes related work to help the reader become acquainted to the research area. This chapter covers long distance relationships and their communication needs, the evolution of computer-mediated communication and how these do and do not address long distance relationship communication needs, strategies for mediating intimacy over distance, and the current state of telepresence robot research.

The third chapter presents a field study exploring the use of telepresence robots by real-world couples in their daily home interactions (Yang & Neustaedter, 2018).

The fourth chapter presents a between-groups study of shopping as a shared activity for long distance couples, comparing the use of telepresence robots and tablets (Yang et al., 2018).

The fifth chapter presents an autobiographical design study of a telepresence home setup, which is constituted of a telepresence robot alongside voice-controlled home devices (Yang & Neustaedter, 2020).

The sixth chapter offers design considerations that have emerged from the set of three studies described in this thesis.

The seventh chapter is the conclusion of the thesis and will establish the contributions of this body of work.

Chapter 2.

Related Works

In this chapter, I present related work to give the reader a solid understanding of how computer-mediated communication has evolved to support long distance relationships. I begin with describing the prevalence and definition of long distance relationships. Next, I explain the concept of relationship maintenance behaviors, which represent the array of needs that couples have to sustain their relationships. I follow this by discussing the advances in the field of computer-mediated communication, and how these advances do or do not support relationship maintenance. I then describe a shift in the field towards designing for personal and intimate communication. Finally, I introduce telepresence robots as a promising technology for personal communication by discussing the existing research in the organizational setting.

2.1. Long Distance Relationships

Long distance relationships (LDRs) are common in today's society (Knox et al., 2002; Maguire & Kinney, 2010; Skinner, 2005). People maintain or begin relationships in separate parts of the world for a variety of reasons, such as moving for work opportunities, family obligations, or to attend a specific school (Neustaedter & Greenberg, 2011; Stafford, 2005). We can get a sense of how common long distance relationships are by looking at a segment of the population that is often part of research studies – college students. The reported prevalence of LDRs amongst college couples ranges from 20-50% (Knox et al., 2002; Maguire & Kinney, 2010; Skinner, 2005). The number goes as high as 80% when including college students who were not in LDRs at the time, but had at one point been in one (Neustaedter & Greenberg, 2011; Skinner, 2005). In the general population, the percentage of couples in long distance arrangements can be found in US Census Bureau reports. In a report released on 2002 data, 1.3% of married females and 1.6% of married males in the American population were described as "married (spouse absent)" (Spraggins, 2003), which according to the U.S. Census's Subject Definitions page "includes married people living apart because either the husband or wife was employed and living at a considerable distance from home, was serving away from home in the Armed Forces, had moved to another area,

or had a different place of residence for any other reason except separation" (Bureau, n.d.).

According to Stafford (a prominent researcher in the area of long distance relationships), LDRs can be defined as relationships between partners who are committed to maintaining a relationship, even though geographical distance limits communication (Stafford, 2005). This definition acknowledges that issues with communication are a key problem in maintaining relationships over distance. However, with an increasing variety of computer-mediated communication tools, couples are able to meet more of their communication needs (Aguila, 2011).

2.1.1. Relationship Maintenance Behaviors

While each partnership is different and partners can require unique things from one another, the broader relationship needs remain the same. Relationships require ongoing maintenance and this is accomplished through maintenance behaviors (Canary et al., 1993; Stafford, 2005)(Canary et al., 1993; Stafford, 2005)(Canary et al., 1993; Stafford, 2005). These behaviors serve to cultivate one's relationship to a desired level, whether that is to progress to a more committed relationship, to diminish an undesirable relationship, or to maintain a relationship at its current state (Guerrero et al., 1993). Often in the literature, the effects of relationship maintenance behaviors are measured by commitment, liking, satisfaction, control mutuality (i.e. the mutual agreement on the power distribution in the relationship), and development – these factors are considered to be important relational outcomes (Ogolsky & Bowers, 2013; Stafford & Canary, 1991). The original five maintenance behaviours include:

1. Positivity (the expression of positivity)
2. Openness (providing support for confiding in one another)
3. Assurances (confirming commitment)
4. Social Network (dedication to a shared social network)
5. Sharing Tasks (taking on an equal share of responsibilities) (Canary et al., 1993; Stafford, 2005).

This list has expanded since its creation and may continue to change. An extended list will be discussed in greater detail and in relation to relationship theories where applicable in the following section.

Positivity: Couples can nourish their relationship through the use of positivity. This involves meeting various situations with a cheerful attitude. Focusing on positivity to make interactions with one's partner enjoyable has been correlated with the positive relational outcomes of achieving relationship stability and even progression (Guerrero et al., 1993). Researchers have also found a high positive correlation between positivity and relationship satisfaction (Ogolsky & Bowers, 2013). Furthermore, self-reported use of positivity also correlates with liking one's partner (Stafford & Canary, 1991). While the directionality of such correlations seems unclear, it seems highly plausible that the effects are cyclical, i.e. liking someone leads to being positive around them, leads to liking them more, and so forth.

Openness: Being open in a relationship involves sharing one's thoughts, feelings, and opinions with one's partner, as well as encouraging one's partner to do the same. In a meta analysis paper, researchers determined that openness is highly correlated with loving one's partner and moderately correlated with feeling satisfied in one's relationship (Ogolsky & Bowers, 2013). The researchers also found that openness was highly correlated with control mutuality, which is the mutual agreement on the power distribution in a relationship, and that the use of openness as a relationship maintenance behavior decreases with longer relationships (Ogolsky & Bowers, 2013). This could be interpreted as there being less to reveal about yourself to a partner that knows you very well after several years of being together.

Assurances: Using assurance as a maintenance behavior involves the reiteration of one's commitment to the partnership. Assurances could involve talking about the future and making plans for relationship progression, such as moving in together, getting married, sharing finances, starting a family, etc. In fact, research has found that the use of assurances is correlated with the continuation and progression of relationships (Guerrero et al., 1993). Similar to positivity, assurances have been found to be highly correlated with relationship satisfaction (Ogolsky & Bowers, 2013; Stafford & Canary, 1991). Amongst college students, assurances are more often used in correspondences between romantic partners than in correspondences between family

members (A. J. Johnson et al., 2008). This finding suggests that assurances are uniquely important in relationships when the relationships are sustained more by choice than by obligation. When there is uncertainty in a relationship, partners benefit from being reassured that the relationship has a future. By that same logic, long distance partners are likely to face more uncertainty in their relationships, and thus might find assurances particularly important as a maintenance behavior.

Social Network: Partners can support their relationship through making an effort to connect with members of their shared social network. This includes maintaining a connection with shared friends, as well as a partner's family members. According to systems theories, each person affects the rest that are part of their system (or network) (Stafford, 2005). Thus, maintaining a healthy, positive relationship with not only one's partner but also those around them has an overall positive effect on a relationship. Incorporating a partnership's social network into maintenance behavior routines is moderately correlated with relationship satisfaction (Ogolsky & Bowers, 2013). Unlike with openness, assurances, and positivity, involving social networks in one's relationship maintenance does not decrease with relationship length and is therefore a steady form of relationship maintenance (Ogolsky & Bowers, 2013).

Sharing Tasks: The sharing of tasks is also a way to maintain relationships. For positive relationship outcomes, partners should take equal ownership of the things that need to be accomplished. For partners that share a home, there are many tasks that can be shared between partners. For example, partners can split up cleaning tasks, so that one partner vacuums, while the other scrubs the bathroom. Or partners can split up kitchen tasks, so that one partner cooks, and then the other partner washes the dishes. However, in a long distance relationship where each partner resides in a different home, there are fewer tasks that can be shared. As one would expect, in a study that looked at which maintenance behaviors correlated with which communication channels that were being used by long distance partners, those couples with some face-to-face communication were able to engage in task sharing whereas the use of other communication channels (i.e. telephone, letters, and internet) did not correlate with task sharing behaviors (Dainton & Aylor, 2002). Sharing tasks is a maintenance behavior that is stable over time (i.e. couples use this maintenance behavior even after being together for many years) (Ogolsky & Bowers, 2013).

Conflict Management: Accepting responsibility during disagreements is a relationship maintenance behavior. Partners should work through disagreements together. This is an issue for long distance partnerships as living apart supports conflict avoidance, rather than management (Aguila, 2011). According to the hyperpersonal model, computer-mediated communication allows one to represent oneself more positively than through face-to-face communication (Hampton et al., 2017). For example, if someone is upset with their partner, they can easily hide this fact by using positive text messages. This has led to issues with idealization in long distance relationships (Stafford & Merolla, 2007).

Support: Being there to support one's partner is a form of relationship maintenance. This can be done to support a partner through the daily stresses of work, and stressful life events such as the onset of an illness or the death of a family member. Support provides protection from stress, thus reducing damaging health effects during difficult times (Cohen, 2004). Research has shown that support provided in person leads to greater improvement in positive affect than when provided through text, suggesting that visual, audial factors are important when providing support (Holtzman et al., 2017).

Advice: Advice is a form of support that is described as "informational" as it involves providing information that may help the receiver (Cohen, 2004). Partners can maintain their relationships by acknowledging what is going on in one another's lives and offering advice to be helpful when needed. In cases where lack of information is causing the stress, informational support (i.e. advice) has been found to be more effective than emotional support in reducing the stress of uncertainty regardless of whether this advice is given in person or through instant messaging (Rains et al., 2017).

Focus on Self: Part of relationship maintenance also involves knowing when to give one's partner the room to work on themselves. For example, one's partner may want to work on personal projects during their spare time, or go back to school to improve future job prospects. Perhaps they need time for self-care, such as grooming practices or therapy. Regardless of the specifics, it is important to support one's partner in their efforts towards self fulfillment. The ability to focus on oneself through diet and exercise is reported as a benefit of long distance relationships (Du Bois et al., 2016).

Joint Activities: Maintaining a relationship also involves doing activities together. For example, going on trips together, taking classes together, watching movies together, etc. A review of relationship communication literature has found significant evidence that healthy relationships incorporate joint activities (Vangelisti, 2012).

Shared Activities: Aside from doing activities together, partners can also benefit from sharing the more mundane parts of daily life, for example, reading in bed together each night. This maintenance behavior broadly includes any activity that holds significance to a couple as something that they share (Stafford, 2005) such as daily routines or yearly traditions.

Small Talk: Couples can maintain their relationships by sharing the small details from their day and listening to one another talk about their day. Researchers have found that long distance relationships can lead to unrealistic idealization between partners and it is suggested that regular small talk may help mitigate this issue (Stafford & Merolla, 2007).

Humor: Partners can bring laughter and fun into the relationship by using humor. Furthermore, using inside jokes can strengthen the sense of bonding between the partners. Partners enjoy being playful with one another (Vetere et al., 2005).

Affection: Expressions of affection can be verbal or physical. It has been found that the most common reason for romantic partners to use communication technology was to express affection (Coyne et al., 2011). Partners can feel emotionally connected through the sense of touch (Singhal et al., 2017).

Long distance partners are faced with the challenge of maintaining their relationships over distance, and they rely on computer-mediated communication to do so. In the following section, I will discuss the situations where computer-mediated communication has been helpful in supporting long distance relationship maintenance and where computer-mediated communication falls short.

2.1.2. Computer-Mediated Communication and Relationship Maintenance

Computer-mediated communication has advanced considerably over the years. Studies of the personal use of mediated communication from the early 2000's regarded computer-mediated communication as a written medium only (Dainton & Aylor, 2002; A. J. Johnson et al., 2008). These studies investigated the use of email, instant messaging, and chat rooms (Stafford, 2005). Now, only a few years later, studies of personal computer-mediated communication include video-based, text-based, and audio-based communication (Hampton et al., 2017). It is evident that computer-mediated communication now has broader capabilities, and thus also broader uses.

Computer-mediated communication has been able to support several types of maintenance behaviors since its adoption into the personal sphere. Positivity, openness, assurances, social networks, conflict management, support, advice, small talk, humor, and affection could all be communicated through text-based communication. People were able to compensate for the lack of richness in the communication channels by offering more richness in the content of their communication (Hampton et al., 2017). For example, people could reveal deep feelings in their email messages, and show concern for one another through long messages. Furthermore, even lacking body language and facial cues, people could get a sense of their interactions through other indicators. For example, if a partner responds very quickly and reliably, it shows their attentiveness and reveals their caring (Stafford, 2005). One can also get a sense of how their partner is reacting to a message through punctuation. In one study, it was found that people perceive messages that end with a period as less sincere (Gunraj et al., 2016). Capitalization of words is equated to shouting, either in anger or excitement, depending on the context, and emoticons can be used to express one's mood (Stafford, 2005).

Then with the widespread adoption of video chatting, even more could be expressed through computer-mediated communication. Video chatting allowed partners to see one another and hear each other at the same time. More could be expressed/interpreted through facial expressions, tone of voice, body language, and the view of one's partner's environment. With an array of computer-mediated communication tools, partners can choose whichever tool is most suited for the desired communication. For example, people tend to use instant messaging when they don't require an

immediate response and simply want to check in or have a chat, while people use email to send detailed messages which might include information that they want a record of (H. Kim et al., 2007) For example, a couple might use an instant messaging channel such as Facebook Messenger to say “Just wanted to let you know I’m thinking about you” or to share some thoughts they have throughout the day, and they might use email to forward a boarding pass so that both partners have their flight information for a trip. The convenience of computer-mediated communication supports extended usage throughout the day, thus encouraging even unimportant musings to be shared (Aguila, 2011). Therefore, relationship maintenance behaviors such as small talk and humor are supported. Furthermore, with both synchronous and asynchronous communication channels, partners have the option of interacting in real-time or reaching out to one another even if one partner is busy.

However, while computer-mediated communication technologies offer many benefits to couples communicating over distance, their functionality remains limited. Physicality is one factor that is limited in computer-mediated communication. This factor is limiting for performing several types of maintenance behaviors. Long distance couples are limited to expressing affection verbally, but physical affection is also an important part of romantic relationships (Field, 2014) and supports greater feelings of intimacy (Singhal et al., 2017). Furthermore, computer-mediated communication does not support the maintenance behaviors that are largely neglected as a result of being physically apart and living in separate homes. Even with the variety of computer-mediated communication tools that are available to long distance couples today, it is not feasible to share tasks such as household chores, or to engage in joint activities. Additionally, long distance partners are limited in their ability to support one another over distance. Whereas in person, one can bring food for a partner who is overwhelmed with work and too busy to cook, one can drive a sick partner to the doctor when they are not feeling well, and one can give their partner a warm embrace to comfort them during difficult times, these acts of support are not possible through mediated commnunication.

Another area where computer-mediated communication does not benefit long distance relationships is in supporting honesty. While couples may share many things about themselves through mediated communication, they may avoid revealing things that are not flattering. This creates unfounded idealization and leads to unstable reunions (Stafford, 2010; Stafford & Merolla, 2007). For example, a partner might hide

their messiness by directing their webcam somewhere clean during video chats. This unexpected messiness can cause tension upon reunion with this person's partner. One can imagine different scenarios where a partner might hide something they are ashamed of and even with video chat tools becoming more mobile, affordable, and high resolution over time, the dynamic of having one's partner control one's view makes it easier for that partner to hide things.

As well, computer-mediated communication supports conflict avoidance, rather than the relationship maintenance behavior of conflict management (Aguila, 2011; Stafford, 2010). When the full gamut of social cues that are present in face-to-face communication are unavailable or reduced, people are more prone to misunderstanding one another (Aguila, 2011). This means that communication channels that are only verbal or written are not suitable for conflict management as arguments can be escalated without real cause because of misunderstandings. Even with video chat, which provides visual and audial cues, the ability to communicate is still restricted. Typically, video chat uses a face-to-face orientation, but this can feel confrontational during an argument. Some partners need physical space when they are upset, and video chat does not support such styles of argumentation (Neustaedter & Greenberg, 2011).

Computer-mediated communication is also poorly equipped for sharing important life events with one's partner when they can not travel to be there. While "sharing life events" is not one of the established relationship maintenance behaviors (perhaps because it is not part of day-to-day life), I feel that it is important to mention as research has found that sharing life events is something people do with video chat technology (Massimi & Neustaedter, 2014). The effort people put into establishing a remote connection shows that they value sharing important events with remote loved ones. However, since one has to keep an eye on the streaming technology to make sure that it is operating smoothly, that the view is framed well, and perhaps that the streaming device is safe from theft or damage, the camera work can take away from the experience of participating in the event (Jones et al., 2015; Massimi & Neustaedter, 2014).

Computer-mediated communcation technologies were largely propelled forward by workplace needs in the early days of their design (Kaye et al., 2005; Vetere et al.,

2005). For this reason, such technologies have been largely geared towards reliable information exchange and even the social cues that are supported revolve mostly around the head area (hence the term “talking heads”) (Kirk et al., 2010). However, an increasing amount of research has been dedicated towards understanding how to support intimacy in mediated communication (Hassenzahl et al., 2012; Kaye et al., 2005).

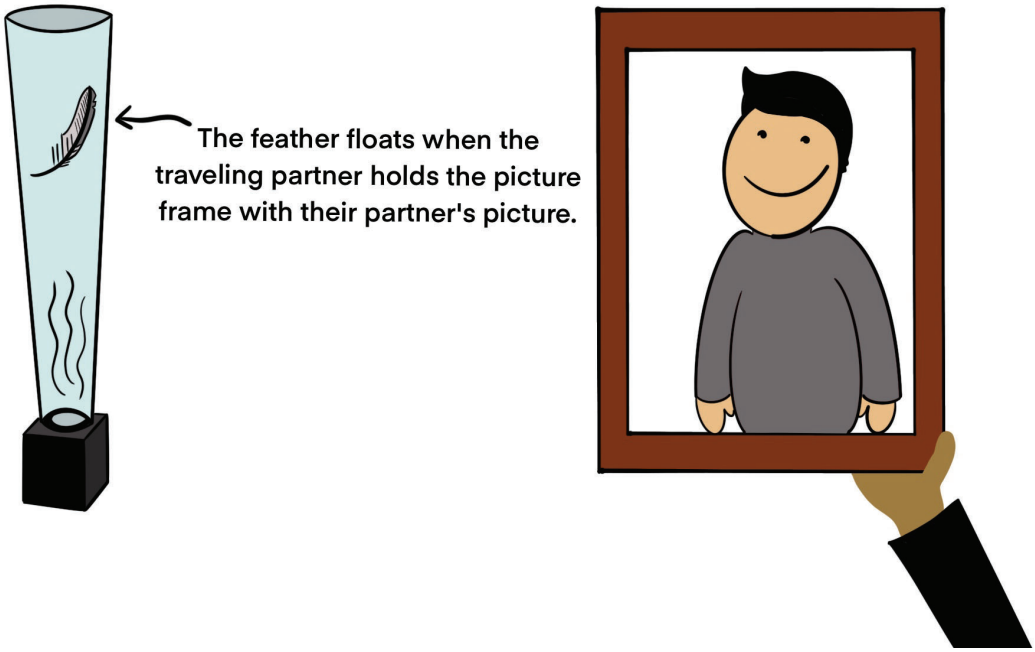

Figure 3: Illustration of Strong and Gaver’s Feather communication system.

2.1.3. Advances in Mediating Intimacy Through Computer-Mediated Communication

Research in mediating intimacy through technology was pioneered by Strong and Gaver whom moved the communication narrative away from explicit to implicit communication (Strong & Gaver, 1996). They explored devices that could convey emotion and awareness between partners without words or even explicit symbolism. In one part of their 1996 study, Strong and Gaver designed a picture frame that could be held by a long distance partner, which, when handled, caused a feather at home to float in a vase (Figure 3) (Strong & Gaver, 1996). The floating feather conveyed to the partner at home that their long distance partner was thinking about them. For the long distance

partner the picture frame device might convey a sense of closeness and physicality from holding the symbolic object. Other designs in this early work by Strong and Gaver explored communication through smell and touch.

Over the past two decades, researchers have designed an assortment of devices for mediating intimacy between loved ones over distance (Bales et al., 2011; Goodman & Misilim, 2003; Grivas, 2006; Joi et al., 2015; Kaye et al., 2005; Kowalski et al., 2013; Lottridge et al., 2009). A review sampling 143 of these devices reveals the main strategies that have emerged for mediating intimacy (Hassenzahl et al., 2012). The six strategies are awareness, expressivity, gift giving, physicalness, joint action, and memories.

When a communication device supports awareness between partners, it can alleviate feelings of loneliness (Hassenzahl et al., 2012; Lottridge et al., 2009). Such devices can promote a range of awareness levels from vague awareness to detailed awareness. For example, Strong and Gaver's feather device (Strong & Gaver, 1996) promotes vague awareness, only conveying to the at-home partner that their traveling partner is thinking of them while giving no information about that partner's mood, activities, surroundings, or other contextual information. MissU and Digital Devices (Grivas, 2006; Lottridge et al., 2009) are both examples of systems that support more detailed awareness, as one's partners activities may be deduced through the auditory and location cues (respectively) that are communicated. More detailed awareness cues can bring up concerns about privacy (Bales et al., 2011), but the transparency can also serve to promote intimacy between partners (Hassenzahl et al., 2012).

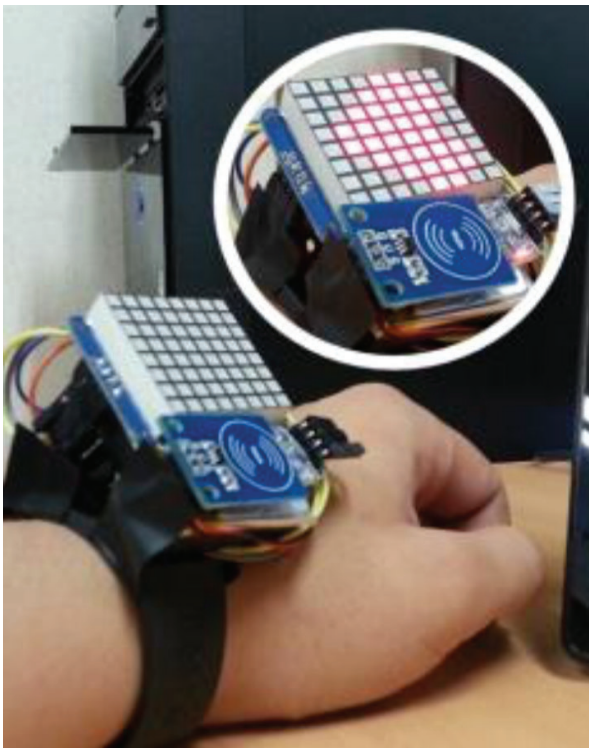

Figure 4: Joi et al.'s WearLove device for communicating affection.

It is also important for communication devices to support expressivity. Expression of affection, positivity, assurances, and humor are all aspects of relationship maintenance (Stafford, 2005). For example, WearLove is a wearable device (Figure 4) that lets partners send heart symbols to one another's devices as a show of affection (Joi et al., 2015). Cubble is another more expressive device that lets partners communicate with a choice of colors and taps, as well as light and heat when both partners are touching their devices (Kowalski et al., 2013).

Partners may also communicate their affection through gift giving. For example, the Magic Sock Drawer is a system which lets partners draw or write messages that are then printed out in an intimate location for the other partner to find (Gooch & Watts, 2011). This work brings up the issue of expected reciprocity which can make subsequent gifting interactions feel obligatory (Gooch & Watts, 2011; Kaye et al., 2005).

Figure 5: Singhal et al.'s Flex-N-Feel gloves for communicating touch.

Physical sensations such as touch and heat are valued and missed by long distance partners. Efforts to mediate physical interactions has led to devices such as Flex-N-Feel (Figure 5), which transmits touch through a vibratory glove (Singhal et al., 2017). Other examples are Kissenger, which uses linear actuators to simulate the pressure from lips during a kiss (Zhang et al., 2016), and Sensing Beds, which emit warmth to represent one's partner being in their bed over distance (Goodman & Misilim, 2003).

Besides wanting to feel physical closeness, partners also want to be physically together to share activities. With the availability of 360 degree camera technology, Singhal and Neustaedter conceptualized a system that would allow partners to share 360 degree streaming views of their environments, imagining that couples would share experiences together such as hiking or visiting museums (Singhal & Neustaedter, 2016). This conceptualization led to a head-mounted prototype device called MyEyes which could stream partners' views to one another so that both partners could see one another's perspectives. The two perspectives could be presented in different orientations within their visual fields, including overlapping, side-by-side, and stacking of the two views (Pan et al., 2017). This system supported creative playfulness between partners, including games like rock paper scissors, high fiving, and collaboratively forming shapes using one hand from each partner.

Of the mediating intimacy strategies mentioned above, the two most challenging to implement over distance are what Hassenzahl termed as “physicalness” and “joint action” (Hassenzahl et al., 2012). These largely require a remote physical presence so that partners can share the same space and contextual information. Telepresence robots are an emerging technology that grants the user a physical presence in a remote space. In the next section, I will discuss this technology and what role it may play for the future of mediating personal communication.

2.2. Telepresence Robots

The telepresence robot is a communication tool that is unique because it provides a mobile physical presence. Since the early days of telepresence robot design, the system’s potential for supporting remote social interactions has been acknowledged (Eric Paulos & Canny, 1998). The mobile embodiment of the telepresence robot allows users to feel more present in a remote space, compared to stationary alternatives (Rae et al., 2014). The use of telepresence robots is currently being explored, largely in the public domain. This includes use in workplaces (Desai et al., 2011; Lee & Takayama, 2011), nursing homes (Koceski & Koceska, 2016), schools (Bloss, 2011), and conferences (Neustaedter et al., 2016). Such studies have found that communicating through telepresence robots allows for more natural social interactions than through traditional video chat systems (Lee & Takayama, 2011; Venolia et al., 2010).

Figure 6: Depiction of a casual conversation between co-workers supported by a telepresence robot.

Studies of telepresence robots in the workplace setting have focused on interpersonal factors such as trust and collaboration (Rae et al., 2012, 2013b) while studies in the healthcare setting typically focus on measures of perceived usefulness and ease of use (Cesta et al., 2016; Ellison et al., 2004; Koceski & Koceska, 2016). In the workplace, telepresence robots allow remote workers to have a more normalized working experience, including spontaneous meetings and conversations with co-workers (Figure 6) (Lee & Takayama, 2011). For example, through a telepresence robot, one can indicate where one's attention is through body positioning, and engage in casual interactions when passing by people in the remote space (Lee & Takayama, 2011). Telepresence robots are also used in the medical field to facilitate doctor-patient interactions such as post-operative checkups (Ellison et al., 2004). Doctor-patient dialogue is important for recovery and telepresence robots allow this interaction to happen remotely without a loss in patient satisfaction (Ellison et al., 2004). Telepresence robots are also being used for elderly care and socialization, and it has been found that the use of telepresence robots can help to decrease loneliness (Cesta et al., 2016). Telepresence robots have also been studied as a tool for homebound children to attend school. Researchers have found that the embodiment promotes autonomy as well as inclusion by the other students (Bloss, 2011; Newhart & Olson, 2017). The socialization contributes to the homebound child's wellbeing (Newhart & Olson, 2017).

2.2.1. Interpersonal Interaction Through Telepresence Robots

As mentioned previously, telepresence robot research in the context of the workplace has looked at what influences interpersonal factors, such as trust and collaboration, when people use or interact with telepresence robots (Rae et al., 2012, 2013b). This area of telepresence robot research has found that between a local interactant and a remote user, people in both roles trust the other person more when the other person is in control of the robot embodiment (Rae et al., 2013a). The authors reflected that this can be understood through research on trust and risk-taking. Having the other person control the robot was analogous to taking a risk and being vulnerable, and when this was rewarded with dependable behavior, trust was built. Workplace research has also surfaced knowledge on supporting collaboration through telepresence robots. Rae's research in this area has emphasized the influence of verbal framing on attitudes and behaviors, finding that simply saying that the participants' results in a task were interdependent with the telepresence robot user's results led to greater cooperation, liking, and self-disclosure (Rae et al., 2012).

The form of a telepresence robot can influence interpersonal factors. For example, the height of a telepresence robot relative to an interactant influences the interactant's sense of dominance, self image, and persuadability (Rae et al., 2013b). A user using a shorter telepresence robot is perceived as less persuasive and interactants respond with more dominance and a more positive self image (Rae et al., 2013b). Since current telepresence robots do not look like their users, there are conflicts of identity. In a study where people attended a conference through telepresence robots, remote users were not aware of how they looked which was important to them in the social setting (Neustaedter et al., 2016). With multiple telepresence robots in the conference space, local interactants also struggled with the identities of the remote attendants, many of whom only had a small name badge for identification. Furthermore, participants reported finding it difficult to monitor their speaking voices, sometimes being unaware that they were speaking too loudly or softly (Guth & Vander Meer, 2017; Neustaedter et al., 2016).

Even with issues of self-representation, remote users can feel strong ties to the specific telepresence robot they are using although the robot looks and functions the same as other robots (Neustaedter et al., 2016). Remote users have reported feeling embarrassed when there are issues with the robot, as if taking on the robot's failings as

their own (Lee & Takayama, 2011). The representation of the robot as the remote user may be less quickly established with interactants. In an office telepresence robot study, researchers found that the local co-workers held different views regarding the telepresence robot embodiment of their remote co-workers (Lee & Takayama, 2011). Some co-workers regarded the robot as a machine while others treated the robot with the same courtesy as they would treat a person. There may be factors, such as how one is introduced while using a telepresence robot or whether a telepresence robot is used by multiple different people, that affect how interactants view the telepresence robot but further research is necessary to understand the discrepancies in how people view telepresence robots.

2.2.2. Telepresence Robot Design

In the various settings that telepresence robots are used, some of the same challenges exist across contexts. These include the limited field of view (Heshmat et al., 2018), speed limitations (Heshmat et al., 2018; Lee & Takayama, 2011), as well as the cognitive effort of controlling the telepresence robot while socially interacting (Heshmat et al., 2018; Lee & Takayama, 2011; Rae et al., 2014). However, different contexts for telepresence robot usage also present unique design requirements. For example, when used to attend a conference, self-representation was an issue because there were several people attending through telepresence robots and others had difficulty recognizing them (Neustaedter et al., 2016). Used in another setting by an elderly couple, users wanted the robot to be able to assist them in case of emergencies (Cesta et al., 2016). Thus, design requirements should specify the context they apply in and be tailored to suit the typical conditions of the specified context.

Guidelines currently exist for designing telepresence robots for use in a few specific contexts. I will discuss the design guidelines for two common uses of telepresence robots to illustrate how their design needs change across contexts. In the context of elderly care, the telepresence robot may be used by different people, such as caretakers, family members, or the elderly patient (Beer & Takayama, 2011; Orlandini et al., 2016). The variety of users will vary in their experience with telepresence robot controls, as well as their familiarity with the patient's home space, and their appropriate level of access. These remote users are likely to encounter poorly lit and cluttered spaces, but be expected to respond to emergencies. With such considerations in mind,

Orlandini et al. determined thirteen recommendations for designing telepresence robots for elderly care (Orlandini et al., 2016). To accommodate the different users, the authors recommend a choice of control interfaces so that different users can control the telepresence robot using the method most effective for them. For example, the Beam telepresence robot by Suitable Technologies allows for control via keyboard, game controller, mouse, or touch interface, providing users with many choices. It is also recommended that these different users should have different levels of access, and the elderly interactants should be able to identify who is trying to connect and accept or reject calls in order to protect their privacy (Orlandini et al., 2016). Navigational aids such as a map of the elderly person's home, obstacle detection, and automatic orientation towards the patient would be helpful for remote caregivers to more efficiently reach their patient. In the elderly care context, camera and screen performance become vitally important due to the need to discern things like pill color (to locate correct medication) and skin color (to assess health) (Orlandini et al., 2016). While issues such as accessibility and privacy are of concern in all contexts of telepresence robot usage, it is apparent that unique specifications and different levels of criticality exist when designing features for each context.

Next, consider the design implications for the context of the workplace. In contrast with the context of elderly care, workplaces are likely to be better lit and less cluttered. Rather than the telepresence robot being in the home space, it is in the work space. Socially, the interactions are between colleagues, rather than between the elderly and their family or caregivers. As well, conversations may come from a spontaneous meeting with a co-worker walking by, rather than from planned sessions (Lee & Takayama, 2011). Desai and Uhlik reported what they considered essential features of telepresence robots upon studying users completing common workplace activities including navigating to meeting rooms, attending meetings, as well as walking and talking (Desai et al., 2011). They suggest dynamic video profiles which would switch between low latency video when moving and high quality video when still, so that users could read office signage, such as wall maps and office numbers. Unlike with guidelines for telepresence robot design for elderly care, color accuracy was not a consideration. The authors recommend that telepresence robots be adjustable to standing and sitting heights so that the remote user remains at eye level for both standing and sitting scenarios. They also note that telepresence robots should be able to reach human

walking speed (~3 miles/hours), have a wide field of view, enable autonomous navigation when encountering latency, allow head panning and tilting for orienting perspective and indicating focus of attention, and support volume control (Desai et al., 2011). A workplace field study by Lee and Takayama provides design implications from studying months of telepresence robot usage across three companies that reflect more on the interpersonal aspects of design in this space (Lee & Takayama, 2011). The authors suggested strategic placement of recharging stations in high-traffic areas in order to stimulate spontaneous workplace meetings. As well, they report the need for implementing feedback that would help users monitor their self presentation (Lee & Takayama, 2011). Their work highlights the importance of establishing social norms for telepresence robot interactions in the workplace where appropriate behavior is held to high standards.

Telepresence robot usage for the contexts of elderly care and remote work have clear contrasts to using this communication tool to support long distance relationships. For couples, a telepresence robot is meant to represent one person, and therefore access is more limited and easier to manage than if the telepresence robot accomodated multiple users. Furthermore, unlike in the the workplace, users of telepresence robots in the relationship context are more likely to interact with one person, rather than multiple. That interaction will be highly personal and private in nature, rather than professional. These differences inform unique design considerations for the context of long distance relationships. I will discuss the design implications in Chapter 6.

2.3. Summary

This chapter presented a literature review to familiarize the reader with the needs of long distance partners and the evolving role of computer-mediated communication in supporting these needs. To establish the impact of my work, I explained the prevalence of long distance relationships and their reliance on computer-mediated communication, as well as the limits to current communication technologies in supporting relationship maintenance. I then introduced telepresence robots as a promising tool for supporting personal communication and discussed the existing research in the area. Lastly, I noted that unique design requirements exist for different contexts of usage. This is to establish that original design insights come from studying telepresence robot usage in different

contexts, such as with my work which has revealed design insights specific to designing for intimate communication. In the following three chapters, I present three papers (two published and one conditionally accepted) that explore the use of telepresence robots for long distance relationship communication. The design considerations for telepresence robots in this context will then be discussed in Chapter 6.

Chapter 3.

Long Distance Partners with Telepresence Robots at Home

3.1. Overview

Long distance partners rely on computer-mediated communication for maintaining their relationships (Aguila, 2011). New technologies are increasingly supporting long distance connectivity, allowing long distance partners to share more areas of life. Telepresence robots have a form factor which uniquely provides a presence and mobility in the remote space and thus has the potential for further expanding how partners can share life over distance.

The first research question of my thesis is: *How do long distance couples use telepresence robots in the home and what are the benefits and challenges that come from such usage?*

The objective is to explore how long distance couples use telepresence robots to communicate in the real-world home setting, and to uncover the benefits and challenges that arise.

The paper included in this chapter (in section 3.2) addresses this topic and is published as:

> Lillian Yang and Carman Neustaedter. 2018. Our House: Living Long Distance with a Telepresence Robot. Proc. ACM Hum.-Comput. Interact. 2, CSCW, Article 190 (November 2018), 18 pages.

3.2. Our House: Living Long Distance with a Telepresence Robot

Abstract

Many couples are in long distance relationships due to a variety of reasons ranging from work opportunities to family obligations. However, current computer-

mediated communication tools are not designed to support the entire range of communication behaviors that long distance couples engage in during daily life. Our research explored how telepresence robots might fit into the array of tools that long distance couples use to communicate, given the factors of mobility and physicality that could support acts of interactivity and autonomy between partners. We found that telepresence robot communication facilitated interactions in five areas: participation in mundane everyday routines, feelings of sharing a home, connection with one's partner's family and friends, increased helpfulness, and the enjoyment of quiet companionship. However, telepresence robots also presented challenges related to privacy and asymmetry, as well as continued deficiencies in the level of interactivity. In response to these findings, we discuss design opportunities for telepresence robots.

Introduction

Given the importance of communication in maintaining relationships, and the prevalence of long distance couples (Knox et al., 2002; Maguire & Kinney, 2010; Skinner, 2005), the continued exploration and improvement of communicative tools holds great value for improving the quality of life for those living far apart from their partners. Couples typically use computer-mediated communication (CMC) tools, such as email, text messaging, mobile phone calls, video chat, and social networking sites to stay connected (Neustaedter & Greenberg, 2011). While often considered necessary for maintaining relationships over distance (Aguila, 2011), commonly used CMC tools do not support the full spectrum of communication needs that long distance partners have (Neustaedter & Greenberg, 2011). For example, mainstream CMC tools, such as text messaging and email, are not designed to support partners in "hanging out" during leisure hours at home (Neustaedter & Greenberg, 2011) or in sharing activities (Hassenzahl et al., 2012). They are typically unable to provide feelings like one is actually physically present in the remote location (Neustaedter & Greenberg, 2011). There is also little understanding of how emerging technologies map to the communication needs of long distance partners, and what design directions would be best-suited for supporting the at-home life of long distance couples.

In this paper, we utilize an in-home field study to investigate how telepresence robot technology may be used as a method for connecting long distance partners. Telepresence robots are a multi-channel communication tool that includes a video

conferencing display attached to a base with wheels. Remote users can see into the remote space and move the telepresence robot as desired. The embodied and mobile design of telepresence robots allows them to better replicate certain qualities of in-person interactions compared to traditional communication tools (e.g., email, text messaging, video chat) (Neustaedter et al., 2016), making them a potentially beneficial tool for long distance couples. To date, telepresence robot research has primarily focused on workplace and other organizational entities (e.g., (Lee & Takayama, 2011; Neustaedter et al., 2016; Newhart & Olson, 2017)), and yet the movement capabilities as well as the embodiment of telepresence robots make them a compelling tool for personal communication. Our work aims to answer the following research questions to address the research gap: How do long distance couples use telepresence robots in the home? How does communication between long distance partners change using telepresence robots, if at all? What design factors are important in telepresence robots to support long distance relationships in the home context? Our overarching goal was to identify both positive and negative experiences of using telepresence robots to support in-home activities in long distance relationships, and inform design opportunities.

To answer the research questions, we conducted one month long field trials in the homes of seven long distance couples who used a Beam+ telepresence robot. Together, our work contributes the first field study of telepresence robots in a domestic setting for connecting loved ones over distance, as most telepresence robot research focuses on organizational settings such as the workplace, schools, or health-care settings (e.g., (Lee & Takayama, 2011; Newhart & Olson, 2017; Rae, 2015)). Our work brings forward the unique needs of long distance couples for telepresence robots not seen in the prior literature, which includes using telepresence robots to connect to see the mundane everyday activities of one's partner and the need to just 'be present' without necessarily talking to support 'quiet companionship.' We also present both the benefits and challenges from asymmetry and the fact that the telepresence robots are only in one location and not both. Together, our results present a series of design opportunities for telepresence robots if they are to be designed to adequately support the needs of long distance partners in domestic contexts.

Related Work

The role of computer-mediated communication (CMC) for maintaining relationships is becoming increasingly prominent. However, given the lengthy physical absence that long distance couples experience from one another, there are further forms of connectivity that are unavailable to them, such as touch, shared contexts, and the ability to participate in joint activities (Hassenzahl et al., 2012). Current mediated communication tools do not support the same range of relationship maintenance behaviors that partners can engage in when together in person. Behaviours such as having open communication, managing conflicts, sharing tasks and chores, being positive, and expressing one's love physically are well-established in relationship literature as being important for the continued maintenance and development of relationships (Stafford, 2005). Yet CMC systems can constrain conversations to focus on topics that are easy to discuss over certain mediums (e.g., short conversations for text messaging) (Neustaedter & Greenberg, 2011). They also make it difficult and/or awkward to do activities together (Neustaedter & Greenberg, 2011). Thus, previous work has considered the implications of communicating through mediated channels versus in person (Dainton & Aylor, 2002). It has been found that couples who are long distance full-time perform less maintenance behaviors than long distance partners who are only long-distance part-time (Dainton & Aylor, 2002). Such findings are significant because engaging in relationship behaviors is positively correlated with desirable relationship outcomes such as relationship satisfaction (Stafford & Canary, 1991) and development (Guerrero et al., 1993). While long distance couples are using many of the same CMC tools as geographically close couples (Stafford & Merolla, 2007), research has shown that some long distance couples use video chat tools in a unique manner, that has been described as "always-on" video (Neustaedter & Greenberg, 2011). By leaving video chat systems on for extended periods of time, often in the background of other activities, partners simulated hanging out with one another while at home. Together, this research provides strong motivations for continued explorations of CMC systems for long distance couples, especially with expanded abilities to better support a wider range of relationship maintenance behaviors.

Design work on connecting couples over distance has often focused on expressive communication systems involving interconnected tangible objects (Hassenzahl et al., 2012; Strong & Gaver, 1996). For example, WearLove is a device

worn on the wrist and used to send heart symbols to the wearer's partner's device (Joi et al., 2015). Cubble lets partners express their emotional connection through colors, vibration, and warmth sent to one another's devices (Kowalski et al., 2013). MissU transmits shared music and background sounds between partners so they can share an audio space (Lottridge et al., 2009). Flex-N-Feel transmits touch over distance through vibrotactile gloves, and has been found to support both feelings and acts of intimacy between partners (Singhal et al., 2017). MyEyes streams first person views between partners and includes viewing modes, such as overlapping or split views to 'see through a partner's eyes' (Pan et al., 2017). The Sensing Beds simulates the warmth of each partner's body on the other partner's bed (Goodman & Misilim, 2003). CoupleVIBE automatically sends location updates to one's partner through coded vibrational signals to increase partners' sense of connectedness (Bales et al., 2011). A study found that it was able to help keep couples in 'sync' (Bales et al., 2011). Naturally, there are a whole host of other systems of a similar genre where awareness information or interactions can be shared between partners using a specific object or device. In contrast, our work explores what it might be like to have long distance partners use a telepresence robot to connect across homes with a much larger range of possible interactions than these systems.

In 1996, Paulos and Canny introduced the concept of socially oriented telerobotics and described a Personal Roving Presence (PRoP) (E. Paulos & Canny, 1996). Presently, it is more widely called a telepresence robot. Telepresence robots are video chat systems with added mobility and physicality. Research on telepresence robot usage for social purposes is consistent across various settings. Both remote pilots and local interactants view telepresence robots as useful communication tools for people who cannot physically be somewhere they need to be (Lee & Takayama, 2011; Neustaedter et al., 2016). For example, companies have explored the use of telepresence robots to better integrate remote workers into the workplace experience and have found them to be useful for supporting a sense of presence in the remote location, largely because of the remote user's ability to be mobile (Lee & Takayama, 2011). Local interactants also became more aware of the remote user's presence as the remote user moved around autonomously through the space (Lee & Takayama, 2011). Furthermore, the remote pilots benefitted from greater impromptu availability, which led to inclusion in spontaneous conversations, such as hallway discussions, and unplanned

meetings (Lee & Takayama, 2011). Use in schools granted similar benefits as seen in the workplace, such as access to hallway conversations and joining peers for lunch (Bloss, 2011). Telepresence robot usage at academic conferences has found them beneficial for small-scale social interactions (Neustaedter et al., 2016).

Issues with telepresence robot use include the effort of driving, the lack of self-awareness (ie. what do I look like? how loud am I to the people around me?), lack of self-presentation (ie. the ability to dress the robot or represent other facets of one's appearance) (Lee & Takayama, 2011; Neustaedter et al., 2016; Newhart & Olson, 2017), and privacy challenges due to use across mixed contexts (Neustaedter et al., 2016; Newhart & Olson, 2017). Due to the absence of appendages, telepresence robots are limited in expressiveness when it comes to body language (Neustaedter et al., 2016; Newhart & Olson, 2017). Furthermore, the lack of a head-turning function leads to a limited field of view leaving remote users with less peripheral awareness (S. Johnson et al., 2015). Given these challenges, researchers have suggested various improvements to telepresence robots including wide or panoramic views (S. Johnson et al., 2015; Jouppi, 2002; Kimura et al., 2007), robots with adjustable heights (Rae et al., 2013b), adjustable audio levels based on ambient noise (Jouppi, 2002), and features to mask video details to better preserve privacy (Neustaedter et al., 2016). While many findings are generalizable across settings, there has been little research into telepresence robot usage in the home as a communication tool between loved ones (Yang et al., 2017b). An initial study of telepresence robots in long distance partners' homes shows preliminary results from two couples and illustrates the value of the robot's mobility (Yang et al., 2017b). We provide a larger scale study in the current paper with a more nuanced exploration of couples' behaviors with telepresence robots and their effect on relationship maintenance behaviors.

Overall, our work extends the literature on telepresence robot usage for social purposes in considering the use of this technology in the home setting. The relaxed nature of at-home interactions is counter to the high-efficiency communication that CMC tools are typically designed for in workplace and educational contexts, and yet the home is also an important space for our daily interactions. Thus, there is a need for better understanding of how to design for communication in this private space. The embodied and mobile traits of the telepresence robot represent a potentially beneficial tool for supporting natural in-person interactions, making it potentially suitable for scenarios that

are currently poorly supported by CMC tools, such as sharing activities and hanging out. On the other hand, telepresence robots may also reveal new challenges. This is the focus of our research where we explore how telepresence robots might be used by long distance partners to support everyday activities and interactions in the home.

User Study

The goal of our research was to understand how long distance couples would use telepresence robots in the home; how communication between long distance partners might change when using telepresence robots, if at all; and, what design factors are important in telepresence robots to support long distance relationships. The study was approved by our university research ethics board.

Participants

We recruited seven couples through snowball sampling across our social networks. We created email and social media posts and shared them within our social networks via email lists at our university, Facebook, and Twitter. Of the couples who participated, two couples had direct ties to the researchers. The remaining couples were not known to the researchers prior to the study. When responding to our study call, some participants were hesitant to the idea of using a telepresence robot to mediate their relationship. In some cases, one of the two partners had to convince the other to try out the technology. Overall, what this means is that some participants were excited about trying out a new technology, while others were hesitant and skeptical. Thus, in our convenience sample, we have a diversity of perspectives coming into the study, which we believe helped us draw out both positives and negatives about the technology.

	Couple #1	Couple #2	Couple #3	Couple #4	Couple #5	Couple #6	Couple #7
Name Aliases	Ron & Kelly	Stan & Tara	Gary & Laetitia	Beth & Carl	Arnie & Mirna	Ellie & Alan	Sarah & Ken
Length of Relationship (years)	4	1.5	5	5	2.5	2	0.4
Relationship Type	Married	Dating	Dating	Dating	Dating	Dating	Dating
Time Difference (hours)	15	3	0	3	13	3	0
People in the Household	2	2	1	5	4	4	1
Local Gender	m	m	m	f	m	f	f
Local Age	23	25	32	20	27	24	35
Local Occupation	Master's student	Master's student	researcher	student	student	Master's student	teacher
Remote Gender	f	f	f	m	f	m	m
Remote Age	23	23	31	23	22	30	40
Remote Occupation	software engineer	Master's student	Master's student	store clerk	student	senior analyst	pharmacist
Remote Location	Southeast Asia	East Coast USA	Western Canada	East Coast USA	South Asia	Eastern Canada	Western Canada
Main CMC used before study	WeChat	FaceTime iMessage	text, phone, email	Skype	Facebook Messenger	WhatsApp	WhatsApp
Activities shared during CMC before study	playing video games	local cooking during call	none - the focus is on the call	watching shows/ playing games at the same time	playing built-in games and sharing links in Messenger	local partner cooking or showing remote partner the birds	none - the focus is on the call
Most important long distance challenge	timezone differences	scheduling calls	missing non-verbal communication	timezone differences	time zone differences	not being able to do activities together	scheduling calls

Table 1: Summary of participants (names anonymized).

Table 1 describes details about each couple who participated in the study. 'Local' refers to the partner who lived in our university's city and had the telepresence robot at their home. 'Remote' refers to the partner living afar who connected into the telepresence robot. The study included one married couple and six dating couples with a range of relationship lengths from five months to five years. The average age of participants was 27 (range: 20-40; SD: 5.78). There was an equal number of male and female participants. The distances between partners ranged from ~115km to ~11,200km. These couples represented common long distance scenarios of being separated for work or educational purposes (Maguire & Kinney, 2010; Stafford, 2005). As well, participants ranged from self-described tech-resistant to tech-savvy. Two

couples lived within the same time zone, while the rest of the couples lived in time zones with three to fifteen hour time differences. Two local partners lived alone, while the rest lived with roommates or family members. The local partner from Couples #1, 2, 6 lived with similarly aged roommates, the local partner from Couple #4 lived with her family members, and the local partner from Couple #5 lived with a family from whom he was renting his room (two parents and a child). All couples were in heterosexual relationships and did not have children.

Method

For each couple, we brought a Beam+ telepresence robot (hereafter called a Beam) (Figure 7) to the local partner's home. Each couple used a telepresence robot over a period of four weeks, during which we conducted three semi-structured interviews. The first interview was at the start of the first week (Time 1), the second interview was at the start of the second week (Time 2), and the third interview was at the end of the last week (Time 3).

Prior to the first visit to the local homes, we had the partners set up accounts for access to the Beam. During our first visit, we taught the partners how the Beam was controlled. We introduced the partners to the Beam controls by having the remote partner Beam in. We explained the camera views, had the remote partner navigate around the apartment, and showed them how to park the Beam. This orientation process took approximately 10-15 minutes.

During the study, remote partners controlled the Beam via an app, using a device of their choice (ie. computer or mobile phone). Once the remote partner logged into the app, the local partner was notified by a melodic sound and they could see and hear the remote partner through the robot.

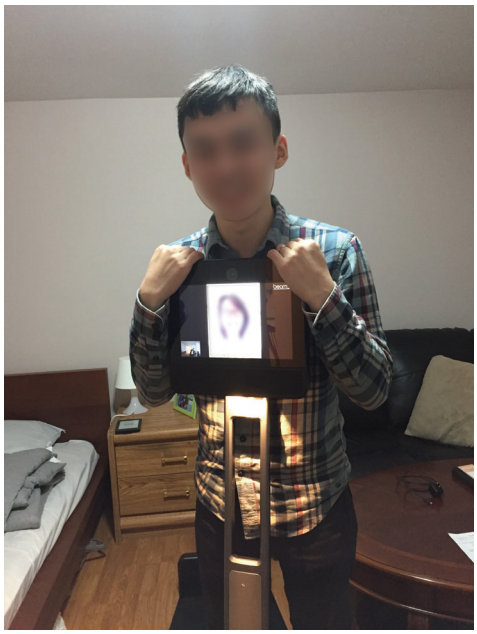

Figure 7: Couple using telepresence robot (shown with permission).

During the first interview, we asked about the couples' relationships, and gained an in-depth understanding of how the couples communicated prior to using the telepresence robot. This introductory interview took an average of ~35 minutes and included questions about the couple's relationship and existing communication patterns, prior to experiencing life with the telepresence robot. For example, we asked, "What tools do you use to talk to each other?" and "What are the biggest challenges to communicating while you're apart?" These introductory interviews showed a pattern of couples using text-based messaging while at work and video calls when both partners were at home.

We used the second interview to check-in on the participants in case of any issues, and to get an understanding of their initial reactions to using the telepresence robot. This check-in interview took an average of ~15 minutes. It began with the open question "How is your experience using the Beam so far?" Any issues with the telepresence robot were brought up at this point. We were careful to probe for both positive and negative experiences that the couples might be having as we were interested in the benefits of the technology, as well as areas where it may not be working well.

During the final interview, we asked participants about how, when, where, and why they used the telepresence robot, as well as how the usage affected their

communication. This final interview went into more depth and took an average of 50 minutes. We also learned about situations where participants chose to use other CMC tools, and the reasons behind these choices. The final interview gave a detailed picture of how the telepresence robot fit into the couples' daily communication patterns and where, when, and why it did not work well for the couples. The interview began with one-on-one interviews with each participant regarding their experiences and how they felt in the role of user or interactant (i.e. the local person interacting with the telepresence robot). For example, we asked, "Tell me a story about your most memorable usage," and then probed with questions about the reported experiences. For the second half of the final interview, both partners were interviewed together. They were asked about usage patterns, comparisons with other tools, and feelings of connection through the telepresence robot. For example, we asked "What kinds of activities did you engage in with the Beam and why?" We also explicitly asked for moments and experiences were the Beam did not work well. We started by interviewing the partners separately for the final interview to ensure that each partner would have the opportunity to share their honest opinions without being influenced by their partner, or worrying about upsetting the other partner with sensitive responses.

Both the first and final interviews were conducted in person at the local partner's home (with the remote partner joining through their choice of CMC tool). For the check-in (i.e. second interview), we asked the couples whether they wanted to have the interview in-person or remotely (all couples chose to do the interviews remotely). For consistency, the same interviewer conducted all the interviews.

Couples were asked to use the telepresence robot a minimum of four times during the first week, and then to use it however they wanted after that. We chose to set a minimum usage in the first week, so the couples could familiarize themselves with using the telepresence robot, by utilizing it at least half the days of the first week. Following the first week, we had no usage rules, because we wanted to see how the couple would use the telepresence robot naturally, when there were no requirements. Due to the privacy challenges with observing a couple in their home over a period of time, we did not conduct extended observations of telepresence robot usage. However, we did observe couples using the telepresence robot during our initial visit and then during any interviews where participants connected in via the telepresence robot.

Data Collection and Analysis

All interviews were recorded. The recordings of the interviews were transcribed and the participants' names were changed to protect their identities. Memos were written during transcription as interesting points came up. The primary analysis was performed by the interviewer as this researcher had worked closely with the participants, including visiting their homes for interviews, and seeing how the couples interacted with and responded to the telepresence robot during the visits. A combination of open, axial, and selective coding was used to extract important themes from the interview data. Codes related to the understanding of use cases included for example [topics] which revealed the topics partners conversed on while using the system, [activities] which showed the kinds of activities partners engaged in through the system, and [position] which described how partners were spatially situated in relation to one another while using this system which uniquely supports movement and a physical presence. Codes related to the understanding of benefits and challenges included for example [asymmetry] which revealed if and how partners experience asymmetry and [feelings] which noted how partners felt when using the system. Our axial coding revealed categories around daily life interactions, normalcy, family, and privacy. From these, we used selective coding to clarify our main themes, which are described in our results section. Themes were generated, then refined as content was added under the themes. Analysis discussions were held between the interviewer and other project members about the codes and themes periodically throughout the analysis period to ensure that a variety of aspects were being considered in the analysis. We also discussed the results and themes in comparison to the related literature on long distance couples, telepresence robot usage, and computer-mediated communication. We did not test for interrater reliability because only one researcher actually performed the coding. Thus, even though one researcher conducted the primary analysis of the interview transcripts, multiple researchers reviewed the codes and themes and there were critical and detailed discussions at all stages of the analysis. Throughout our results, we report stories and quotes from our participants whose names have been anonymized.

	Couple #1	Couple #2	Couple #3	Couple #4	Couple #5	Couple #6	Couple #7
Average Call Duration (min.)	10.53 (SD: 12.39)	10.00 (SD: 11.33)	7.93 (SD: 8.32)	44.10 (SD: 55.63)	26.69 (SD: 28.76)	10.19 (SD: 13.33)	14.64 (SD: 14.17)
Range of Call Durations (min.)	2 - 44	1 - 47	1 - 26	1 - 180	1 - 120	1 - 60	1 - 48
Total Use for 30 Days (min.)	179	220	111	485	934	438	322

Table 2: Usage data.

Results

Throughout the study, technologies such as text messaging and phone calls were used by participant couples to keep in touch during the day when partners were at work. Yet, in contrast, the telepresence robot was used by partners during the mornings before work, and during evenings and weekends when partners arrived at home. For the times when partners would normally use video chat for longer calls, these were replaced by using the telepresence robot. Table 2 provides data on participants' connection durations. As can be seen, participants varied in terms of how long they would use the robot for at a time ranging from only a few minutes to several hours. Couples 4 and 5 tended to have longer connections than the other couples where they would connect in and leave the link going for upwards of two to three hours. Couples 1-3 and 6-7 had many short connections of 10-20 minutes, to briefly talk and say hi, as well as a few longer sessions up to 30 and 45 minutes. The longer sessions are similar to how some partners have been shown to use always-on connections through video chat (Neustaedter & Greenberg, 2011). Many couples described a typical day of communication as starting off with a quick connection in the morning on the Beam 'just to say hi,' then text messaging throughout the day with perhaps a phone call sometime during the day, then a telepresence robot session in the evening. When couples used the Beam to hang out or have conversations, the remote partner would sometimes move the Beam to a location and then park there, facing their partner, and other times, they would move around the home. While three couples reported time zone differences as their greatest challenge in being in a long distance relationship (Table 1), time zone issues were not often mentioned in our interviews. The couples mostly accepted the time zone differences as a fact of life and simply made small pockets of time to interact directly with one another (and at other times left each other messages). Most partners knew one another's schedules and typically conversed at somewhat regular times using

the telepresence robot. This was similar to their communication patterns prior to the study.

In our final interview, we asked participants about the asymmetry of the connection, where only one participant had a telepresence robot and not both. Responses from participants showed that many never thought about the asymmetry during the study and therefore had no strong feelings about it. It was possible that partners could resent either having to control the Beam or not having the control/access the Beam provided, but this was not what we found. Nonetheless, the asymmetry of the connection is something that did indeed influence behaviors and actions, whether participants realized it or not. We elaborate on this point in subsequent sections. Within the aforementioned behaviors, we found five themes emerge around the telepresence robot usage, where each theme exposed both the strengths and weaknesses of the technology. We describe each next.

Participating in Everyday Routines

First, most of the couples talked about how using the telepresence robot opened them up to the mundane parts of daily life. These were the activities that they generally carried out without even thinking about them. For example, this included getting ready in the morning or tidying up around the home. We found that these small, seemingly unimportant activities were in fact important, because there was a sense of intimacy and connection that came from knowing specific details about a partner's activities. Similarly, a sense of comfort came from seeing the predictability of routines. Prior to using the telepresence robot, participants relied almost exclusively on messaging, audio calling, and video calling through various apps, such as WhatsApp, Skype, Facebook Messenger, and WeChat. These interactions were largely limited to just talking and lacked what the couples felt were everyday mundane experiences that couples who lived together would see and participate in together on a daily basis. The types of experiences that were discussed included the experience of routine activities, as well as the experience of shared spaces. When participants talked about routine activities, they included things like being a part of chores (e.g. washing dishes or cleaning one's room), cooking and eating meals, spending time with family, and waking each other up in the morning. When participants talked about the experience of shared spaces, they spoke of how noticing things in the environment could spark conversation, and remote partners

often mentioned connecting to the robot just to check in on the space. Our participants had all explored their remote partners' spaces initially when connecting in to the telepresence robot, yet now they were able to obtain real-time updates and an ongoing awareness of the remote space. This fulfilled their desire to experience what their partner's environment was like *at that time*. As one remote partner phrased it, she would sometimes connect in to her partner's place just to "…see how it is over at his side of the world…" [Couple#5 remote partner - Mirna]. The following scenario illustrates the above points by exploring how Couple #5 used the telepresence robot to experience the everyday ordinary things that were not captured using other forms of CMC.

Alan is awake early in the morning and connects in to Ellie's apartment to check to see if she is still sleeping. Just as he expected, he sees that she is still in bed, so he wanders around her room. Before using the telepresence robot, he never had access to this part of Ellie's life - he couldn't look over at her while she was sleeping, and wander around the home checking on things like one might do when living with their partner. He does these same things when they are together in person visiting each other, including checking in on her pet birds to see what they are up to. It feels nice for him to be able to experience the simple sensation of being *there* with his partner in the *same* home, and to have the certainty that everything is okay, because he's seen it for himself in the telepresence robot. Eventually, he decides to wake Ellie up. For some reason, calling her cellphone doesn't work, but he's able to wake her up using his telepresence robot. He moves around with her through the room as she gets ready. These are the moments when the telepresence robot allows him to feel really connected to his partner - when he can see her going about her morning routine. It is so familiar to him that he feels he can even guess her next move.

> *"So usually when you are sleeping or when you are doing something in the room, I log in to the Beam to see what is happening around the room - like usually what I would be doing in the house, I try to feel the same experience, like moving around, maybe like making fun of you or looking at the birds and then I can stare at you, what you are doing. I mean things that you usually do in the house I can't see from the mobile right? But when I'm in the house, like when I used to be, right? Like when we were together. It feels good to see you moving around,*

walking around, you doing your stuff, cleaning the bed or maybe things like that." Couple #6 (Remote Partner – Alan)

Other couples had similar experiences to Alan and Ellie. For example, Mirna and Arnie (Couple 5) enjoyed being able to hang out with one another in the kitchen as Arnie made dinner. This was something that the couple had previously never experienced together while being apart. While seemingly mundane, both the remote and local partner said the experience was special to them.

"One time, this was the first I actually used Beam to follow him out and see how he was having dinner and just watching him like uh move around the kitchen, washing dishes, that was a very intimate moment…" Couple #5 (Remote Partner - Mirna)

"…I was cooking and she just followed me around and it was actually one of the very first days that we had Beam and she just followed me around the house where I was cooking and she hadn't seen the house before that…" Couple #5 (Local Partner - Arnie)

The specific time zone differences each couple experienced determined which parts of each partner's life the other could share in. As an example for Mirna/Arnie (separated by 13 hours), if Mirna was up in the morning around 8AM, she could Beam in and accompany Arnie if he made dinner around 7PM. That said, while certain time zones aligned in a way that let remote partners share in the local partner's experiences using the telepresence robot, these asymmetric experiences were still not ideal. Time zone differences have been previously reported to be a challenge for long distance couples and families more generally (Neustaedter & Greenberg, 2011), and while telepresence robots may enrich the leisure times that overlap, the difference in experiences remains.

We also found that having a telepresence robot for communication could lead to small and meaningful interactions that were more spatial in nature when compared to the sending of a text message or having a phone call. Because the remote partner could physically move through the space, items or messages could be left in locations throughout the home where the locations might provide additional meaning. For

example, one local partner left Post-It notes with messages on them around the home for the remote partner to find if she connected in while he was not at home.

> *"He left Post-Its around the apartment with notes on them so I could find them with the Beam even if he wasn't there…ya, it was just really sweet to be able to interact that way. I don't think, you know, it's not something that we could have done with Skype or through email so ya that was really sweet." Couple #3 (Remote Partner - Laetitia)*

Naturally, the telepresence robot was not able to support all of the everyday, mundane acts that couples might like. Physical interactions like hugs or gentle touches between partners was not possible, though some couples did try to recreate them using the telepresence robot. For example, Alan offered his girlfriend a hug to celebrate moments when she was particularly happy as well as when she was sad. Ellie hugged the telepresence robot and noted that it felt nice because of the warmth, but that it was still just 'hugging rods.' She told us that "something fluffy if not something interactive" would feel better for hugging.

Another challenge when using the telepresence robot for participating in aspects of everyday life was the limits to mobility. While the telepresence robot could handle various terrains, it could not go up stairs or even raised floors. This meant that the telepresence robot could not get to certain parts of the home for couples with certain home layouts. Couple #6 was especially restricted by this and the remote partner was never able to visit the kitchen, study, or bathroom areas using the telepresence robot, thus missing out on all the interactions that take place in these spaces. The local partner resorted to using her phone in these locations of the home.

Furthermore, there were social implications because of the asymmetrical dynamic of the telepresence robot being in one partner's home and not both. Going back to the scenario with Alan and Ellie, we learned that Alan (who liked to check in on his partner) also wanted to be the one who was checked in on sometimes. Using the telepresence robot, Alan is able to show care through attentiveness and interest in Ellie's life by connecting in to see her go about her day, but Ellie could not reciprocate in the same way.

"…[S]ometimes I also want her to like come check me, like what I'm doing, maybe interact with me. When I'm cooking something or when I try to show her things outside from a balcony I just have to carry my mobile around." Couple #6 (Remote Partner - Alan)

Sharing A Home

Second, interacting through a telepresence robot at home led to moments where couples felt like they were actually *sharing* a home. This was very different than the feelings they received from connection with apps on their phone or laptop, which did not provide the same sense of a shared space. For local partners, this feeling came from the spontaneous and fluid nature by which their partner could come and go. For remote partners, this feeling came from being able to experience the home in an embodied and unrestricted manner - looking around as they pleased and being in the home even when their partner was not there. This worked well for partners who were separated across large time zones because it meant they could feel like they were sharing a home with their partner even without the partner having to be there when they connected in. When connected into the home, remote partners felt a strong sense of presence when they bumped into things, and when they were able to move things around in the local partner's home. The following scenario illustrates some of these points by exploring how Couple #1 used the telepresence robot to be home *together*, and how both purposeful and unexpected interactions through the telepresence robot led to feelings of presence in a shared home.

Ron is home working on his graduate thesis. At around 5PM, he sends a good morning message to his partner on WeChat, knowing that she will be up soon. Their time difference is 15 hours, so it is 8AM the next day in South Asia where she is living. Unexpectedly, Ron hears the familiar melody of the Beam activating. When he realizes that Kelly is connecting in, he feels happy - this is a nice surprise. Kelly moves over to talk to him through her telepresence robot and accidentally bumps his chair, pushing it back. In the moment of surprise, Kelly feels fully present in Ron's room. It is such a familiar physical interaction that Ron also feels like his partner is there with him, rather than a day ahead and halfway across the world. A few minutes of conversation pass and then Kelly moves away to let Ron work. She settles herself behind Ron's chair where she can see both him and his computer screen. She cannot clearly see Ron's computer screen through the telepresence robot, but she still gets the opportunity to glance every

now and then to see if he is working and feel like she is involved in his life. When Kelly starts to feel bored, she pushes Ron's chair with her telepresence robot to get his attention. Ron likes that his wife can interact with him in this way.

> *"Sometimes she used the Beam unexpectedly, like I didn't know she would Beam in … I was focusing on my work and she was standing by using the Beam. She can use the wheel, bump my chair, and push me forward, so I cannot really neglect her. Sometimes when we do the video chatting, although the audio is going, but I'm too focused on my work and sometimes neglect her and she says, 'hey, you don't even know what I'm talking about, you weren't listening,' but this way you always have to because she can really interact with your life so you can get really a sense of she's being there and you cannot really neglect her … that's one of the better, one of the best experiences I have." Couple #1 (Local Partner - Ron)*

> *"When I can walk around his room, I feel like a little bit. Cause I can investigate his room. I think it's...sometimes I walk on, I mean the device walks on some of the stuff he just put on the floor or when I accidentally hit something, it feels like I'm walking in the room. I think it's the interaction between the Beam and other things makes me feel I'm there." Couple #1 (Remote Partner - Kelly)*

The above scenario also begins to reveal the potential privacy challenges that can arise with a telepresence robot, given its mobility. Unlike the other technologies that participant couples used, the telepresence robot gave them autonomy and access to the remote partner's space in an unencumbered way. For example, with video chat over Skype, participant couples could purposely choose the camera's direction to show certain aspects of their location. With the telepresence robot, the remote viewer was in control of the camera and its location. This was more similar to the way a person would see and move through a space when they were there in person, but was not preferred by some couples and would sometimes create concerns, albeit mostly mild ones. While not a concern for Ron, who enjoyed having his wife watching over him while he worked, this was a concern for Stan from Couple #2 who was very aware of his partner seeing how messy his home was. Mirna from Couple #5 was concerned about contacting her

partner too much and invading his personal space. Thus, even though they felt like they were *sharing* the remote environment, there was still some sense that it belonged more to the partner local to it. Here we see the asymmetry of the telepresence robot setup and living situation coming into play. It should be noted that neither Couple #2 or #5 had lived together prior to becoming long distance. While none of our participants reported concerns with their partners connecting in when they were not home (e.g., due to time zone differences), it is certainly a possibility that such behaviors could bother some partners, particularly those early on in their relationships.

> *"I think it was late on a Friday night and I was going to bed and [Laetitia] was at a party in [City], and so Beamed in from the party and so it was a very quiet apartment, like me on the couch reading a book, and then all of a sudden there was like a party in the living room, and like I was in my pyjamas. So it was something that like wouldn't have come up in a phone call, because there's not the video screen in the phone call, so, and it was something that I realized we had never talked about, was like what context is appropriate to like Beam into the apartment. Um so that was just like mildly uncomfortable." Couple #3 (Local Partner - Gary)*

Connecting with One's Partner's Family and Friends

Third, using a telepresence robot, remote partners were able to connect with the network of family and friends around the local partner. The embodiment of the telepresence robot gave remote partners a physical presence and autonomy that led to acknowledgment and inclusion from the people nearby who might be visiting or living in the remote partner's home. This was not a common experience for the couples in our study prior to their usage of the telepresence robot, since their communication across other applications like text messaging or video chat were one-to-one conversations given the design of the technologies and their usage around them. In contrast, because the telepresence robot allowed remote partners to just 'be around' in the remote space, they might be connected in when family or friends visited the home. The following scenario demonstrates how the remote partner in Couple #4 developed meaningful interactions with his local partner's family member using the telepresence robot.

Beth lives with her parents and two sisters, and the whole family is currently at home. Carl connects in so that he and Beth can simultaneously stream a movie. This allows Carl to watch the movie with Beth and her sisters in the living room. Beth's dad notices Carl and comes over to greet him and they have a conversation. In the past, whenever Beth had him on video chat, he would say hello to her dad if he was nearby, but they never had a conversation. In the living room, Carl positions his telepresence robot next to the couch where the sisters are sitting. He uses his telepresence robot to look around at people to gauge their reactions to the movie. Beth's parents drop by intermittently and tease Carl about watching the movie through the telepresence robot. He feels involved in the family activity, and jokes around with Elsie and her sisters during the movie.

> *"I felt like they were more interested in interacting with him because without the Beam I know that they don't have him on Skype since they don't use Skype and they don't have him on WeChat, so it's kind of harder for them to communicate with him, so if they're curious about something about him they would ask me instead of directly asking him, whereas like with the Beam here if they have a question and [Carl] is like out and about around the house then they can just stop by and be like 'hey [remote partner] how are you?'" "…it makes like my whole family more playful and more sarcastic and willing to joke around more." Couple #4 (Local Partner - Beth)*

The above example shows how the local partner's family members became more involved with the remote partner. We also found that this worked in the opposite direction as well – the remote partner's family members could also become more involved with the local partner. In Couple #1, the remote partner shared the telepresence robot with her mother so that her mother could get a better sense of the local partner's life in Canada.

> *"So she shared that Beam with her mom, which is my mother-in-law, so they both started watching me making a dough for baking...because my mother is the first time try this, so she's very interest[ed]...so I show her around. How do I live in Canada, what my house looks like, and then I was making dough in front of her which is really interesting. So I*

was making food and she was kind of saying 'What are you doing? What is this? What is that?' It was pretty fun." Couple #1 (Local Partner - Ron)

While the telepresence robot was able to support interactions with friends and family, the current design of the telepresence robot did not encourage remote partners to actively seek out these interactions and to initiate communication with the local partner's family and friends. Only if family and friends happened to be coming by did the remote partners interact with them. Participants were sometimes hesitant to explore homes containing other people. For example, the remote partner in Couple #4, whose partner lived with her parents, explained that he felt it was intrusive to leave his partner's room when she was not around. This was despite the fact that the parents did not have any concerns with robot moving throughout their home. Overall, this brings up possible concerns around access levels for remote partners that connect into shared homes, and not just a space used by their partner. The scenarios also bring up issues around asymmetric access to the technologies. There is a chance that only the remote partner is able to gain access to the local partner's family and friends network since they are the only ones to connect into the remote space where family and friends might be. Ron, from Couple #1, was able to see his partner's mom, but only because his partner made a special effort to bring her on-screen and in front of the camera.

Increased Helpfulness

Fourth, in relationships, sharing tasks is a form of relationship maintenance (Stafford, 2005). It involves helping one another finish tasks that need to be done as well as each partner taking on specific tasks such that there is a shared sense of responsibility across household tasks. There are many tasks that are difficult or impossible for partners to help with over distance, such as picking up groceries, or feeding the cat, so long distance partners are limited in ways they can help one another. We found that even with a simple, armless telepresence robot, remote partners were able to be more helpful to their local partners when using the telepresence robot compared to video chat and other communication technologies that they already were using. Some partners found creative ways to use the telepresence robot to provide help. For example, we describe a scenario from Couple #6's experiences next.

Ellie is in her bedroom, and Alan is connecting in from Eastern Canada. Ellie's birds have been making a racket, continuously screaming, and Ellie is tired of trying to stop them. In her frustration, Ellie asks Alan for help. To her delight, Alan moves over to the birds in his telepresence robot and manages to frighten the birds into quieting down. Ellie felt it was very nice that she could have Alan there helping her even while he was on the other side of the country. Helping her quiet the birds was something he would do when he was with her in person, but he had never been able to help her in that way through video chat or text messaging.

> *"My birds were screaming and I was so tired of telling them 'don't scream, don't scream,' so I was like '[Alan] control them,' and then he comes in the Beam and then he like goes towards the birds to scare them so they stop screaming. That was nice." "If he had been here he would have been shouting at them, it's like doing the same action through the beam, trying to scare them." Couple #6 (Local Partner - Ellie)*

For Couple #2, the local partner found his remote partner very helpful in the kitchen. Since his partner was a vegetarian, she was able to watch his cooking process and provide tips to help him with vegetarian dishes. The telepresence robot allowed her to move around to observe the whole process without him having to manage the camera view on a mobile phone while he was cooking.

While the telepresence robot gave remote partners slightly more capacity to be helpful, the opportunities to help out were still minimal. The lack of appendages on the telepresence robot was very limiting, and local partners told us that they would like telepresence robots to have arms and hands, so that their remote partners could help hold or carry things. The ability to help at the remote location was also limited to being only one-way help. This meant that while one partner could offer forms of help in the remote space (albeit still limited forms of help), the other could not. Again, this reflects the challenges with the asymmetric nature of the telepresence robot setup.

Quiet Companionship

Fifth, the physical embodiment and autonomy of the telepresence robot empowered partners to be near each other without feeling the need to necessarily speak

to one another. This dynamic allowed partners to enjoy moments of quiet companionship. It is evident from past research that quiet companionship is something that long distance couples value (Neustaedter & Greenberg, 2011). We found that the experience of quiet companionship with the telepresence robots was similar to the experience of using a traditional video chat system for "always-on" connections (Neustaedter & Greenberg, 2011) in that remote partners would find a place to 'settle in' with the telepresence robot and stay there. That is, they would move the robot to a specific location, and leave it 'parked' for a period of time, despite having the ability to easily move around the remote space. Compared to video chat and leaving a video stream open, with a telepresence robot, the remote partner chooses where to place themselves and has the option to reposition themselves if their partner moves around. When using video chat systems, participants tended to always position their device such that they could see their partner's face and be face-to-face with them. With the telepresence robot, we found that the remote partner sometimes chose other positions, such as standing behind their partner and looking over their shoulder. For example, as previously described, this type of situation arose for Couple #1 when Kelly would position the telepresence robot and periodically watch Ron work.

One of the couples in our study talked about the social challenges that came with video chat calls where they felt obligated to stay on camera, much like the related literature has reported (Harper et al., 2017). For this reason, they tended to only use Skype for shorter conversations, rather than leaving the connection open longer term to 'hangout,' as the related literature has found for some couples (Neustaedter & Greenberg, 2011). They told us that connecting in via a telepresence robot and leaving the video link open was less awkward and they did not feel like they needed to stay talking with one another while connected. Being able to move around using the telepresence robot made it natural to transition from having a conversation to hanging out silently.

> *"…[W]hen we're Skyping there's just that feeling that you're always entertain- like you're always making eye contact with the person on Skype and like it's very intense conversation. When you're Beaming in, like it is different, like it feels more relaxed and like if I'm bored, I mean if you get bored, you just walk, Beam around. It's not like I'm feeling like I'm entertaining you…Like with Skype it was always if we're not*

talking it feels a little awkward, and then you know somebody would be like 'ok, well, bye'. But with the Beam, at least with the Beam if there was a silence, it wasn't weird, like it was kind of natural." Couple #3 (Local Partner - Gary)

Although using the telepresence robot supported more natural interactions than with traditional video chat systems, sometimes partners still chose to use their other video chat systems because using the telepresence robot was more work for the remote partner who had to look at their screen to control the robot. For example, even slight movements to the telepresence robot took cognitive effort and this took away from the feeling of quietly being with one's partner.

Discussion and Conclusions

The goal of our research was to understand how long distance couples would use telepresence robots in the home, and how the usage may influence their communication, in order to uncover the design factors that are important for developing telepresence robots for supporting long distance relationships in the home context. Overall, we found that communication became less reliant on verbal interactions, and broke free from the one-on-one/face-to-face convention of standard video chat. We now summarize our results and discuss design opportunities.

Mundane Life

First, our results revealed the value that participants found in being able to see and be a part of the mundane happenings within the local partner's home. This was one of the main ways that telepresence robots changed participants' interaction and communication over distance. While we do not know of telepresence robot research that has similarly drawn out this benefit, the concept of being a part of the 'unremarkable' aspects of domestic life is similar to findings from ethnographic studies of home environments (Tolmie et al., 2002). In our study, we found that these were relatively well supported by telepresence robots. However, there were still mobility limitations (e.g. stairs and floors). These results suggest that there are open design opportunities to explore ways to better support being a part of and noticing things that may seem to be unremarkable in one's daily activities, but are still very important to feeling like one is part of another person's life. As suggested by other researchers, this may involve better cameras with a wider field of view (S. Johnson et al., 2015; Jouppi, 2002; Kimura et al.,

2007). Designs could also look at ways to improve mobility in environments that are small and cluttered, with the ability to safely navigate over common household features, such as wires on the floor, stairs, and narrow passageways. Designs could also support interactions with objects in the remote space in order to help out or to make the shared space more comfortable for oneself (e.g., turn lights on/off), or to lend a 'helping hand' to a remote partner.

Asymmetry

Second, our study revealed how partners accommodated the asymmetry of the telepresence robot setup (only one partner had a robot). We saw, for example, remote participants being able to watch others do activities (e.g., cooking). Remote partners were also able to check in on the home when their partner was not there. Even though our participants did not take issue with the asymmetry of the experience, there is a strong possibility that issues around asymmetry could arise over long term usage. It is possible that participants were still focused on the benefits of the technology, which brought them new and enhanced ways of communicating, thus they did not begin to think about or dwell on the fact that only one partner was able to perform some of the remote activities. This raises opportunities and questions around if and how symmetry can be supported. Reciprocity is important within relationships and without it, they can suffer (Stafford, 2005).

Naturally, one could consider ways of allowing both partners to use a telepresence robot, one in each location. Yet introducing a second telepresence robot complicates the experience. Certainly, telepresence robots could be placed in both environments and users could take turns as to who remotely connects in. Yet this may create cost issues. Overall, this shows that there are design opportunities for exploring how two locations could be connected at the same time, especially in ways that consider if and how users are tethered to devices such as telepresence robots or not. Other research has explored symmetric connections of long distance partners through virtual reality-based video conferencing (Pan et al., 2017); however, we have yet to see designs exploring these problems and potential solutions with telepresence robots.

Always-On Access

Third, we found that partners liked the direct access available to the telepresence robot and being able to connect in without the local partner having to accept the connection. This form of access could be likened to living with one's partner who has a key to the home. While this provided partners with the cozy feeling of sharing a home together, occasionally, the direct access caused issues where people's privacy was sometimes compromised (e.g., a 'house party' connecting to a partner in pajamas). Similar issues surrounding privacy and mixed contexts have emerged in the related literature for other settings (Neustaedter et al., 2016; O'Hara et al., 2009). The challenge is that homes are often considered to be private spaces (Hindus et al., 2001), yet this privacy is brought into question with remote access by a partner at any point in the day. Partners could establish rules around using the telepresence robot, however, this could possibly constrain the relationship and present social barriers. Alternatively, technology could be implemented to ensure that the local partner is given ample warning about incoming connections in order to create peace of mind. For example, local partners could be given information on whether someone other than the remote partner is on the other end of an incoming connection, or local video feeds could appear obscured and slowly reveal themselves, giving the local party an opportunity to stop the connection from fully engaging. Other possible design solutions may include availability modes like "do not disturb," yet this could be too much of a restriction for an intimate couple. Telepresence robots could also be augmented with additional communication mediums. For example, a message board might allow partners to leave notes for one another such that they can explain if they are currently busy or not prior to a person connecting in (e.g., "trying to get my big project done – meet for dinner at 6PM?"). Placement of such messages within the telepresence robot system itself would make it so such notes would be highly visible when people tried to connect.

Family and Friends

Fourth, we found that using a telepresence robot made it possible for remote partners to connect with not only their local partner, but also with the local partner's close network of family and friends. This is similar to related work that found that some remote workers reported sensing greater acknowledgment of their presence in meetings when attending through a telepresence robot compared to video conferencing (K. M. Tsui et al., 2011). While the greater integration into the local partner's social network

was seen as a positive, there were also concerns, again, about privacy issues coming from both remote and local partners. Couples mentioned concerns about the privacy of the family members and roommates living with the local partner, although no complaints from these parties were reported. This lack of conflict was likely due to the fact that couples were very sensitive to the possibility of privacy invasion, and therefore tended to keep telepresence robot usage away from common areas unless the local partner was also there. Again, these results point to design opportunities. In these situations, it could be valuable for telepresence robot users to have better awareness of who is at the remote home through mediums outside of the robot itself. This might, for example, allow them to know if people are present in certain rooms before going into them. Similarly, local users could benefit from knowing if a person is connected into a telepresence robot in different rooms of the home before entering them. The telepresence robots we used tended to make motor noises when people were connected to them and so it was sometimes possible to hear if the robot was approaching. While this might be considered a design flaw, such noises are indicators of presence and may be beneficial in giving people a sense of whether remote people are 'present' in the space before seeing a telepresence robot.

Quiet Companionship

Fifth, we learned that people found value in the embodied way which the telepresence robot supported times of quiet companionship. Similar to what previous research has found, the embodiment of the telepresence robot created a strong sense of presence (Kristoffersson et al., 2011; Neustaedter et al., 2016). During times when the remote partner wanted to fully relax (e.g., as they were going to bed), it was preferable to not have to look at a screen and control a telepresence robot. This suggests design opportunities for automating control and movement of a telepresence robot in a remote space to alleviate the need for direct work by the remote partner. For example, it could be valuable for a telepresence robot to automatically move between a living room and a bedroom before bed so that partners could stay together while allowing the remote user to quietly share a moment with her partner without having to think about driving the robot. This could allow remote partners to better relax. As proposed by Koceski and Koceska, the telepresence robot's level of autonomy could increase from teleoperation (i.e. the user is in complete control) to safeguarded operation to shared control, and

finally to autonomous control (i.e. the user transfers control to the telepresence robot) (Koceski & Koceska, 2016).

Limitations

While we feel our study has opened up and explored a valuable area for telepresence robot research and design, our study does come with its limitations. There is a chance that participant behaviors were influenced by the novelty factor of a new technology. Additional usage of a telepresence robot over a longer period of time than we were able to study would be valuable to validate our findings and extend them. Our couples were also quite similar in nature. They were all relatively young adults, in a heterosexual relationship, and had established routines that provided overlapping time periods of availability. Our convenience sampling method may have also skewed participants to be similar to us as researchers (e.g., more technically inclined), though we note that some participants were skeptical of the technology and their participation in the study at the onset. We feel this rendered them with a somewhat critical eye towards the technology and their experiences in the study. While our participants had a range of time zone differences, it could be valuable for future studies to explore more couples within the various groupings of time zone separation (e.g., small time zone differences, large time zone differences). This would help to understand whether our findings were tied to any particular idiosyncrasies of our couples, or if our findings were more generally applicable to a range of couples who might face similar time zone separations. Together, these points suggest further studies with a more diverse set of couples.

Chapter 4.

Long Distance Partners Shopping with a Telepresence Robot

4.1. Overview

Loved ones living over distance want to share the different parts of their lives, including activities outside of the home (Massimi & Neustaedter, 2014; Yang & Neustaedter, 2018). However, the challenges of mobile video work can diminish the experience for both the local partner that is managing the video connection and the remote partner receiving the video stream (Jones et al., 2015). The telepresence robot allows the remote partner to manage their own view through a physical embodiment, and this autonomy may have positive implications for sharing joint activities over distance.

The second research question of my thesis is: *How does a telepresence robot support or hinder couples in performing the act of shopping as a relationship maintenance behavior and how do the experiences of using a telepresence robot while shopping compare to using video chat on a tablet?*

The objective is to explore the affordances and hindrances that the telepresence robot creates. As a point of comparison, we also looked at the use of traditional video chat through a tablet to understand the effects of mobility and physical embodiment on the experience of the joint activity.

The paper included in this chapter addresses this topic and is published as:

Lillian Yang, Brennan Jones, Carman Neustaedter, and Samarth Singhal. 2018. Shopping Over Distance through a Telepresence Robot. Proc. ACM Hum.-Comput. Interact. 2, CSCW, Article 191 (November 2018), 18 pages.

4.2. Shopping Over Distance through a Telepresence Robot

Abstract

Computer mediated-communication tools (CMC) support loved ones in maintaining connections with one another over distance, yet it can be difficult to actually do activities together. We studied the use of telepresence robots for supporting distance-separated loved ones in engaging in the joint activity of shopping over distance. One partner shopped in person while the other used a telepresence robot from a remote location. As a point of comparison, we had a second group of participants use video chat on a tablet, instead of a telepresence robot. Compared to the tablet group, we found that when partners communicated through a telepresence robot, the remote partner's personality and presence were strongly expressed through the movements and physicality of the medium. However, the use of the telepresence robot introduced tension between partners regarding responsibility, dependency, and contribution to the act of shopping. These results demonstrate the benefits of a mobile embodiment for remote partners, as well as the need for greater physical capabilities to support both physical connection and remote contribution to leisure activities.

Introduction

Many family members, couples, and close friends rely on computer-mediated communication (CMC) tools to maintain their relationships over distance (Aguila, 2011; Judge & Neustaedter, 2010; Neustaedter & Greenberg, 2011; Stafford, 2005). CMC tools such as video chat are used to keep updated on one another's lives through conversations and the viewing of remote activities (Judge & Neustaedter, 2010; Neustaedter & Greenberg, 2011). As the ability to share activities through video streaming has become more convenient and portable, people are sharing a greater number and variety of activities over distance, e.g., playing outdoor games, visiting zoos, sightseeing, attending weddings (Inkpen et al., 2013; Massimi & Neustaedter, 2014; Neustaedter et al., 2017). Yet the practice of sharing activities over distance using current CMC tools has repeatedly shown challenges. This often relates to camera work—continuous efforts to provide remote users with a good view—and a lack of embodiment in the remote space (Brubaker et al., 2012; Jones et al., 2015; Massimi & Neustaedter, 2014).

Our research focuses on efforts to address these problems. We explore how distance-separated loved ones can participate in activities *together* over distance through the use of telepresence robots with a particular emphasis on leisure activities. Telepresence robots are CMC tools that mediate audio, video, and motion via a physical embodiment (Rae et al., 2014). Studies have explored varied contexts, including workplaces, conferences, schools, etc. (Kristoffersson et al., 2013). However, there is a lack of research that explores if and how telepresence robots might support shared leisure activities by family members or close friends in public settings, an important context for supporting the maintenance of family and friend relationships. We also see a lack of research studies that explore the effects of telepresence robot design on social relationships and relationship dynamics, from the perspective of both the remote and local user in dyadic situations.

To build on the existing research, we conducted an exploratory study that investigates the use of telepresence robots for joint leisure activities in a shopping mall. We imagined a future where people may bring their family or friends on shopping activities from remote locations where telepresence robots may be made available by malls or shopping venues somewhat similar to how mobile scooters are presently available for those with mobility challenges to rent or use. This idea builds on suggestions from prior work on family communication over distance (e.g., (Massimi & Neustaedter, 2014)) and also reflects the increasing amount of shopping that people do remotely from physical stores, albeit via online web pages and not robots (Hillman & Neustaedter, 2017).

Our study focuses on couples as an exemplar form of a close relationship as this type of relationship typically requires a broad range of communication requirements. We focused on the joint activity of shopping as it contains a variety of activities important for relationship maintenance (Stafford, 2005) and is a common activity (Santos et al., 2011). This includes joint decision-making (e.g., about items to purchase and which stores to visit), shared tasks (buying items on a shopping list), and conversing. We had partners shop together with one person physically in the mall while another used a telepresence robot from a remote location. We compared this experience to the use of video chat on a tablet, a more common method for sharing experiences with people remotely (Massimi & Neustaedter, 2014). Our study focuses on understanding how a telepresence robot supports or hinders people in jointly participating in the shopping activity over distance

and what design factors are important for the design of telepresence robots to support close personal interactions during the shared activity. Our goal was to understand how to design telepresence robot solutions to better support remote leisure activities between family and close friends over distance.

Our results reveal that the use of a telepresence robot for joint activities over distance can allow loved ones to express their personalities and affection through familiar behaviors and playful interactions. Yet our findings also reveal lingering challenges and shortcomings related to a lack of full autonomy when using a telepresence robot and issues related to responsibility, dependency, and the ability to contribute to the activity. We conclude that when designing telepresence robots to support joint leisure activities over distance, designs should empower the remote partner with unique abilities that contribute to the joint activity, so that the remote partner's virtual presence is more valued by the local partner who is with the robot. In addition, telepresence robots should be designed to allow for more intuitive control, making spontaneous acts of playfulness easier to perform, and to better support intimate interactions.

Related Work

Sharing Activities Over Distance

There is a rich body of literature on the use of video mediated communication systems for sharing activities over distance amongst family and friends. Within the home, this has involved studies of shared television watching (Forghani et al., 2014), working jointly on homework amongst teenagers (Buhler et al., 2013), children reading books with grandparents (Raffle et al., 2010), and more. Together this research has shown the challenges around keeping people engaged in shared activities over video (Raffle et al., 2010) and supporting the camera work necessary to present desirable views to the remote viewer (Brubaker et al., 2012; Buhler et al., 2013; Forghani et al., 2014). Outside the home, researchers have studied and designed systems to support sharing activities where a remote person watches via a video link (e.g., weddings, picnics, sightseeing) (Inkpen et al., 2013; Massimi & Neustaedter, 2014). We have also seen the study of parallel activities where two people both engage in an outdoor activity and stream video to one another so they can see what the other is doing, e.g., geocaching, bicycling (Neustaedter et al., 2017). Furthermore, researchers have

explored augmenting shared video/audio streams with additional information, such as contextual information provided by an additional camera view and a mapping of partner locations (S. Kim et al., 2014). In all of these cases, video was supported through the use of mobile phones or tablets with relatively small displays. Camera work was again a challenge and sometimes took away from participating in the activity (Inkpen et al., 2013; Jones et al., 2015; Massimi & Neustaedter, 2014; Procyk et al., 2014). Holding a mobile phone to show a good view was sometimes socially awkward (Jones et al., 2015; O'Hara et al., 2006) and it was hard to gesture at particular objects or locations in the scene (Jones et al., 2015). Remote users also wanted to have more control over what they saw (Jones et al., 2015). Work on 360-degree cameras has shown that they can help overcome this issue as they allow remote users to independently look around, yet this creates the new issue of not knowing where the remote user is looking (Tang et al., 2017). The use of mobile video streaming in public settings also raises issues around privacy and surreptitious streaming of video (Procyk et al., 2014).

Our work expands on this research by moving beyond wearable cameras and handheld devices for video chat to explore the use of a telepresence robot that can provide autonomy and mobility for the remote viewer that is not dependent on others. We compare this experience to the use of a tablet, commonly found in the related literature.

Telepresence Robots

Telepresence robots have been studied in a variety of settings, including offices, schools, elderly care, healthcare settings (Kristoffersson et al., 2013), and conferences (Neustaedter et al., 2016; Rae & Neustaedter, 2017). Studies have found that the physicality and mobility of telepresence robots can create strong feelings of social presence (Neustaedter et al., 2016; Rae et al., 2014). Telepresence robots used for remote office work have been shown to allow remote workers to join social events and have impromptu conversations (Lee & Takayama, 2011). Similar findings have been found for remote conference attendance (Neustaedter et al., 2016; Rae & Neustaedter, 2017). Telepresence robots are also beneficial for supporting awareness of the activities of others in the workplace given that they require explicit movement between locations (Lee & Takayama, 2011). They can also help people strengthen social connections over distance (Lee & Takayama, 2011). In educational contexts, telepresence robots can

support varied remote student needs, such as extended absences (Newhart, 2014; Newhart & Olson, 2017).

Many challenges exist when using telepresence robots. These include difficulties in understanding body language (Neustaedter et al., 2016), grasping objects (Newhart, 2014), driving while performing other tasks (Lee & Takayama, 2011; Rae et al., 2014), and understanding how one sounds and looks in the remote space (Lee & Takayama, 2011; Neustaedter et al., 2016; Paepcke et al., 2011; Takayama & Harris, 2013; K. M. Tsui et al., 2011). Remote collaborators (via a robot) are also at a disadvantage compared to in-person collaborators who tend to focus on each other more than the remote user (Stoll et al., 2018). Wide field or panoramic views are needed for supporting peripheral awareness (S. Johnson et al., 2015; Jouppi, 2002; Kimura et al., 2007, p. 2), varying audio levels are needed for conversations (Jouppi, 2002), and adjustable heights can be valuable for supporting persuasiveness (Rae et al., 2013b). Often, users require help when operating a telepresence robot in order to avoid obstacles, overcome connectivity issues, and navigate tight spaces (S. Johnson et al., 2015; Lee & Takayama, 2011; Neustaedter et al., 2016). Telepresence robots can also create undesirable attention from others (Lee & Takayama, 2011; Neustaedter et al., 2016; Newhart, 2014; Newhart & Olson, 2017; Rae & Neustaedter, 2017). Remote users often face privacy challenges from being in mixed contexts (e.g., connecting home to school) (Neustaedter et al., 2016; Newhart, 2014; Newhart & Olson, 2017). Sometimes telepresence robots need to be transported to different locations in order to be used by remote users (Herring, 2013).

While focus has been placed on use within organizations, there has been growing interest in the use of telepresence robots as a part of domestic life, such as use between long distance partners (Yang et al., 2017b) and an elderly person and remote family members (Aaltonen et al., 2017). Telepresence robots have been shown to support displays of affection or displeasure through robot-based body language (Yang et al., 2017b), yet interactions still raise challenges (Aaltonen et al., 2017). While there is limited work that explores telepresence robot usage for leisure activities occurring outside of the home, a notable exception is work on the use of telepresence robots in a museum and restaurant (Rae et al., 2015). A series of studies raised questions around how users may depend on each other when using a telepresence robot and how this may affect relationships. We build on this work to directly explore such questions.

Commerce and Shopping Over Distance

There is a broad range of research that explores shopping behaviours and practices. People shopping in physical stores sometimes take pictures of items they want to purchase and send them to family or friends for suggestions (Morris et al., 2014; Tohidi & Warr, 2013). Sometimes it is difficult for people to take pictures of themselves wearing clothing items because of camera work issues (e.g., framing, flash) (Morris et al., 2014). People also enjoy connecting with friends and family through online shopping (Hillman et al., 2013) and often take recommendations from them (Hillman et al., 2012). This reflects the growing volume of people who shop online through ecommerce web sites and mobile commerce applications on phones (Hillman & Neustaedter, 2017). Despite these research studies, we do not know of any that explore remote shopping through a telepresence robot.

Study Method

We conducted an exploratory study on the use of telepresence robots for remote shopping with a focus on couples as an example of a close personal relationship. We compared this experience to remote shopping using a tablet and video chat software. The comparison allowed us to more clearly draw out the benefits and pitfalls of telepresence robots. Overall, our focus was on understanding how telepresence robots supported or hindered the experience of shopping over distance, and what design factors were important for the design of telepresence robots to support shared leisure activities, like shopping, over distance. The study was approved by our research ethics board.

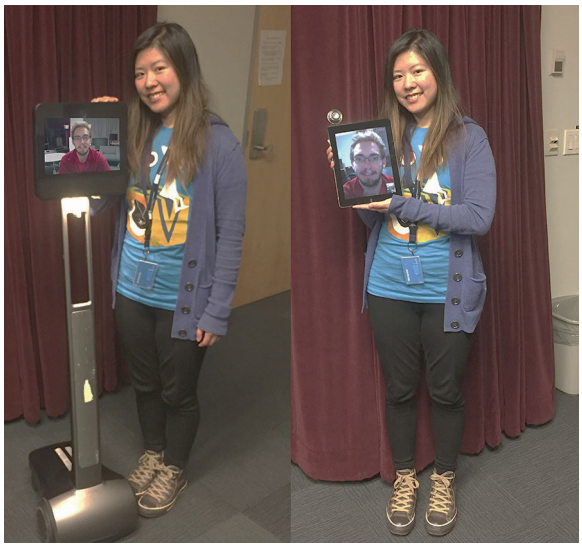

Figure 8: Telepresence robot (left) and tablet (right).

Participants

We recruited participants through various channels at our university including posters, announcements in undergrad classes, and emails to student lists. Flyers were also distributed in the nearby mall and recreation centre. We recruited couples in order to focus on a specific type of close relationship that often requires communication with greater nuance and depth. Fourteen couples participated in the study. *Seven couples used a telepresence robot* (6 female/male, 1 male/male; age range = 19-46 years old, average age = 24.6, SD = 8.7; relationship duration range = 4-120 months; average relationship duration = 33.5 months). Information for relationship duration was missing for one telepresence robot couple. *Seven couples used a tablet* (5 female/male, 1 female/female, 1 female/gender non-binary; age range = 19-30 years old, average age = 22.3, SD = 3.1; relationship duration range = 1-48 months; average relationship duration = 18.1 months). One couple (using the telepresence robot) was in a common law relationship (i.e. in our country, this is a couple that has lived together for 2+ years and has assumed the same legal rights as married couples). The rest of the couples were in dating relationships. Thus, we studied participants in both new and longer-term relationships.

Procedure

We had couples use either a telepresence robot or a tablet (and not both) in order to avoid participant fatigue, as the study took up to 2 hours per couple. Driving a telepresence robot through large spaces like a mall can be time-consuming given the

speed of the robot; thus, we were cognisant of the effect of task time on participants. In the first group, the remote partner explored the mall through a telepresence robot. The driver used a computer in a private room in our university to control a Beam+ telepresence robot (henceforth referred to as “Beam"). Our university is adjacent to the mall, but it is not possible to see the mall from the location of the remote viewer; thus, it reasonably reflects a situation where one might be even further away and shopping over distance. Some participants had been to the mall before, but had not visited all of the locations/stores that they had to in the study; therefore, they would have a basic understanding of the layout of the mall and know some of its stores. This is somewhat akin to situations where a long-distance partner would have visited the location of their significant other and spent some time there but not be present all the time.

The Beam was 52.9 inches tall (134 cm), with a 10-inch (25.4 cm) LCD monitor, two HDR cameras (one pointing forwards and one pointed downwards), a 4-microphone array for high fidelity sound, and a 15-Watt speaker. In the tablet group, the remote partner connected to a participant in the mall using Skype on a tablet. A tablet (3rd generation 64GB iPad with a 9.7-inch display (24.6 cm) and a resolution of 1536x2048 pixels) was chosen for this group based on precedence set by similar work (Rae et al., 2015) and the goal of assessing the usage outcomes that result from mobility, while keeping screen sizes approximately equal across both groups. We attached a small (1.7 inches/4.3 cm long) Leadsound Crystal 3W speaker to the iPad to make it audible above the ambient noise of the mall (Figure 8, right).

Two researchers were present to run each study session, which consisted of one pair of participants at a time. Our study followed several stages:

1. Introduction: First, the researchers explained the study procedure to the participants. Vignettes were then given to participants to describe a long-distance relationship scenario which would necessitate the need to shop over distance together as opposed to collocated couples who would likely just shop together in person. Participants were instructed to imagine they were in the described relationship. The scenario explained that the partners were in a committed relationship and that the remote partner had moved to Denver, USA for work, about a 3-hour flight away and in the same time zone. They were using a telepresence robot to spend some quality time together by going on a shopping trip. Given the lack of any extreme time zone

separations, this type of activity would be plausible for long distance couples in the future. Once the partners had read their vignettes, we gave both partners a brief training session on the telepresence device that they would be using. This was to ensure that participants had a basic level of competency.

2. Tasks: After training, the partners were given three tasks to complete in the mall. These included: finding a gift for the remote partner's mother's birthday (maximum $30); trying on a piece of clothing to show the remote partner (for the mother's birthday party); and, buying a drink at Starbucks. They were instructed to do the tasks in any order, as long as they completed the Starbucks task in between the other two. This ordering allowed for flexible shopping, the need for some joint decision making around what order to perform the activities in, and the requirement to have to use the telepresence device both with and without holding other objects (e.g., a beverage). We felt that buying a coffee would also lead to two regular shopping experiences: 1) waiting in line with not much else happening, which can lead to idle conversation with one's partner and 2) being burdened by carrying an item while trying on and assessing clothing. The second point explicitly raises the issue of the remote person not being able to physically hold the item in order to better support (and collaborate) with one's partner while trying clothes on.

Overall, the tasks were chosen for their normalcy as part of regular shopping trips and because they would likely require some joint input from both partners. The local partner was given a shopping to-do list as a reminder of the tasks and a $5 Starbucks gift card. We framed this as a lunch-time shopping trip and told participants that they had 45 minutes to complete the tasks.

3. Interviews: When the tasks were completed or time ran out, the partners were separately interviewed so we could understand each person's (possibly) unique perspective. Interviews were semi-structured, and participants were asked for their perspectives on the tasks and their experience of presence through the telepresence device they used. For example, questions included, "What did you like/not like about using the telepresence robot/tablet?", "What types of things made the tasks a challenge?", "Did you feel like your partner was in the mall with you? Why or Why not?", and "How was this experience similar/different to shopping in-person with your partner?" We also asked participants to tell us about the last time they went shopping with their

partner so we could understand how the activity was commonly performed in relationship to how it occurred during the study. Interviews lasted 10 to 30 minutes. Each participant was compensated with either one course credit per hour or $15. The study lasted 1.5 to 2 hours in total.

Data Collection and Analysis

We collected three sources of data. First, we recorded the screen of the remote user's computer. This recorded their actions when using the Beam telepresence robot or the tablet. Second, we wrote down observations about participant behaviors, interactions with the environment and with their partner, and bystander reactions in the mall. One researcher followed the person physically in the mall (from a distance) while another researcher observed the participant operating the telepresence robot/tablet in a private office. We were unable to perform video recording of the participant in the mall due to mall regulations around video capture. Thus, our method brings the risk that the researcher observing each participant could be biased in their observations. To combat this, we had both observers discuss what occurred in the study after each session since the remote observer could also see the mall context through the Beam. Third, we collected audio recordings of our interviews. These were transcribed for analysis.

We began our analysis of the data with open, axial, and selective coding on the interview transcriptions and observation notes from both researchers, aided by the screen captures. Analysis was completed by the researcher who accompanied the couples in the mall and observed the interactions in person. When there was uncertainty regarding interpretations of observations, the researcher who accompanied the remote partner was consulted for their perspective. During this process, we looked for connections between the interview answers and the observations. Codes from the observational notes included for example [issue] which reported observed issues such as a hanger getting under the telepresence robot wheels, and [bystander] which noted bystander reactions and interactions. Codes from the transcripts included for example [realism] which noted similarities to in-person experiences, [difference] which noted differences to in-person experiences, and [body language] which showed the ways in which the telepresence robot physically conveyed understanding between partners. Our axial coding revealed categories around expressions of familiarity and closeness, interactivity between partners, autonomy, responsibility, dependency, contributions to

the joint activity, and interactions with bystanders**.** From these, we used selective coding to refine our main themes, which are described in our results sections. When presenting our findings, we identify each couple with the technology they used, followed by a numerical indicator. *Local* refers to the participant physically in the mall. Remote refers to the participant driving the robot or using the tablet.

Familiar Patterns and Behaviors

First, participants talked about the routine nature of shopping in-person and how they had familiar patterns of 'shopping behaviour' that they normally ascribed to with their partner. For example, some would normally walk side-by-side; some would enter a store, split up, and then reconvene; and, some always liked to stay together and look at items at the same time. Participants recognized and understood these behaviours and they were often an important part of their shopping experience. Through the telepresence robot, remote partners had a physical embodiment that they could use to explore the mall. As remote partners moved, some identifiable behaviors emerged through their movements and activities. For example, when shopping together in person, one couple said they would typically split up in a store to cover more ground, then reconvene after a period of time to share ideas. This familiar pattern of behaviors emerged when they used the telepresence robot to go shopping. For example, as soon as this couple entered a store in our study, they moved to opposite ends of the store, looked around, and then reconvened to discuss promising items for purchase.

> *"That part also kind of…made me feel like she was there…The thing is, that's what we do! That's kind of like how we do things. We don't like necessarily go like individually at the same time looking at things. We just kind of like spread out and then convene." - Beam 6, Local*

Participants also talked about in-person shopping in terms of the person they were with and placing value in being *with* that person. In addition to familiar behaviors, they valued the person's personality and specific mannerisms because they made them feel close to that person. For example, some enjoyed that their partners were extroverted and talked a lot with them while shopping. Others appreciated the sense of humor of their partner, or the fact that they were slightly clumsy. Local partners said they were able to recognize these familiar personality traits and mannerisms as they reappeared when using the telepresence robot. This made them able to relate to their

remote partners in a natural way and fall into familiar patterns of being with their partner and shopping. Participants also felt that these nuances helped strengthen the feeling that their remote partner was actually physically present in the mall with them.

"…[T]hat's pretty much how we are when we go shopping. We joke around a lot…What you see there was pretty much us in the store." – Beam 4, Remote

"He mostly just ran into me a lot. It was definitely an accident, but it wasn't an unusual thing. We're both pretty clumsy. So it felt like it was supposed to happen." – Beam 3, Local

We observed that not all familiar behaviors were easy to achieve through the telepresence robot though. For example, most partners felt that it was important to them to be able to walk side-by-side with their partner while shopping, akin to what they would normally do. This was difficult due to the telepresence robot's limited speed options and its cameras' field of view (FOV). Walking side-by-side was important enough that some partners did so even though it was inconvenient—one could not see the partner's face on the screen. Others felt it was more important for the local partner to walk slightly in front to make sure the remote partner could see and hear them, but this was not how they normally walked together in-person.

"The thing about standing next to someone is that it is a sign of like you are with the person, whether you're friends or you're in a relationship. There's this idea, like in the corner of your eye, you can see their body, you can see their head… If I had to talk to it I had to get in front of it and make sure that they could see me and hear me." – Beam 4, Local

" [W]e couldn't like stand next to each other. Cause like I don't know where she's going to try to go. Right? She can't even see me unless I stand in front of her." – Beam 6, Local

Another familiar behavior that was unsupported by the telepresence robot was hand-holding. Many partners expressed that they missed this physical connection.

"I think things like you can't hold his hand, you know, like I said 'you want to hold my hand?' he's like 'no I can't.' So I guess the physical stuff that you can't do…" – Beam 4, Remote

In contrast, remote partners using the tablet did not have an embodiment that they could control, and therefore in comparison to the telepresence robot group they had less opportunities to project certain aspects of themselves as part of their remote presence. Rather than having the autonomy to express personal interests (by approaching items of interest), displaying qualities such as clumsiness (by bumping into things often) or independence (by going off on one's own to explore other areas of the stores), remote partners in the tablet group were only able to express themselves through their voices. This was because they were being carried (via the tablet) by the participant in the mall. We observed that familiar behaviours and personality traits that were communicated by the tablet group remote partners were restricted to things that the participants would say through the audio channel. For example, some people utilized their sense of humor during conversations. Furthermore, because the tablet screen was most often held facing outwards so that the remote participant could see the environment and objects in the stores, the participant in the mall could not easily see the remote participant's face. This meant that any body language shown over the video link was nearly always out-of-view. These findings serve to highlight the value that the telepresence robot brought to the shopping experience for couples. Because of its physical embodiment and mobility, familiar behaviors were seen through the telepresence robot with physical 'body' movements, as well as in conversation, supporting a far more diverse set of behaviors. In contrast, the tablet only sufficed to support conversation-based personality traits.

Playfulness

Participants talked about the act of shopping as being a social outing where an important part of the experience was the interactions that occurred. That is, shopping was not just about looking at items and buying them, despite being under time constraints. It was also about being playful and enjoying time with others. When using the telepresence robot, we observed participants engaging in playful interactions that reflected this viewpoint. Because the remote participant had a moving 'body,' participants playfully prompted one another to engage in interactions that were physical in nature and utilized their entire body, be it the robot or the local participant's own body.

For example, one local partner danced in front of his remote partner in a store (Beam 2 Couple), and another local partner jumped out in front of his remote partner as a 'jump scare' (Beam 6 Couple). Remote partners sometimes displayed playfulness by spinning or getting right up close to their partner in the Beam. The spinning prompted one local partner to engage by walking around the Beam in the opposite direction that her partner was spinning. These actions caused partners using the telepresence robot to switch their focus between the tasks and their partner repeatedly in an enjoyable fashion.

"We did have a bit of fun with that too, because it's like he was going in a circle and I was going the opposite way in a circle, so that was kind of cool." – Beam 7, Local

"I would like run up to him and then stop, like I was just messing with him." – Beam 6, Remote

While such playful interactions were appreciated, the challenge was that telepresence robots are limited in expressivity and any actions performed by the remote user had to focus solely on turning the robot or changing speeds (e.g., rapidly stopping). These movements were not nearly as dynamic as those exhibited by the local person.

We observed that participants using a tablet were much more task-focused than the participants in the telepresence robot group. The tablet group partners focused on completing the shopping tasks without taking time to engage one another by being playful. While some partners in the tablet group were more attentive than others and made the effort to include the remote partner in the shopping experience by giving them a good view of the mall, acts that could be considered playful were nearly non-existent. Any forms of playfulness that did occur were through the audio channel only, in the form of jokes. Again, participants in the mall did not often look at the tablet screen since they were holding the tablet facing outwards. Remote participants appeared to recognize this and mostly restricted their behaviour and interactions to the audio link as a result. This was sometimes coupled with looking at things in the environment, but it was not always easy to do so.

"…[W]e make a lot of jokes so we definitely would have laughed at a lot of different things if they had been able to see them…" – Tablet 1, Local

As can be seen, the tablet experience highlighted the value of being playful through large-scale interactions (e.g., full body movements) with the telepresence robot. Such interactions helped shift the shopping experience from being just about 'shopping' to more of a social outing. However it should be noted that, while the tablet promoted utilitarian rather than playful behavior, this may be preferable to some partners that prefer shopping trips to be about efficiency over leisure.

> *"I think this kind of setup is very good for the type of person like me who doesn't go for the shopping experience - just wants to you know go there and buy something. I don't want to get distracted by all the advertisements and all the other distractions throughout the mall."*
> *Tablet 9, Remote*

Attention

Because participants using the telepresence robot could move around, they were able to attract the attention of their local partner somewhat easily. For example, they could do this by moving towards them, or changing movement patterns such that they could be seen in the local participant's periphery. On the other hand, participants using the tablet had a much harder time gaining their partner's attention at times. Tablet users did not have the ability to move around like the telepresence robots to gain their partner's attention; thus, they had to solely rely on their voice. This was problematic and meant that they were sometimes ignored by their partner. Local partners tended to prioritize interacting with co-located people (who were strangers in the mall) over interacting with their remote partner (who was a close loved one). In all cases where the local partners were conversing with a co-located person, such as a shop attendant, we saw them lower the tablet with no observable concern for the remote partner's view or involvement. For example, the local partner from Tablet 3 did this when she was ordering from Starbucks. The remote partner was trying to get the local partner's attention, but she was being ignored.

> *"Stop ignoring me! […] You just ignored me!" – Tablet 3, Remote (speaking to local partner during the study)*

The telepresence robots also received a great deal of attention from bystanders in the mall. This is akin to what has been seen in research on the use of telepresence robots for remote conference attendance (Neustaedter et al., 2016; Rae & Neustaedter, 2017).

Many bystanders directly engaged the remote participants in conversation through the telepresence robot. Participants said that the acknowledgement of the remote partner by the bystanders in the mall made both the local and remote partner feel more strongly that the remote partner was in fact *in* the mall.

> *"One thing I noticed right away was that when I would walk into a store, the cashier or whatever would be like 'Oh!' - they would notice me right away and it was kind of fun and I felt kind of included. Like I felt like I was part of the room…I felt like I had a presence." – Beam 6, Remote*

> *"Everyone seemed a lot friendlier because of the robot - like they seemed really accommodating…which I don't find in my normal life a lot." – Beam 3, Local*

While bystander reactions were overwhelmingly positive and characterized by curiosity and friendliness towards the telepresence robot users, the few incidences of negative attention were found to be intimidating. These included one bystander who shouted "what the hell is that?" and people joking about kidnapping the robot. During one such incident, the remote participant appeared to be intimidated by the bystander and backed away. Furthermore, excessive bystander attention disrupted participants' ability to complete tasks, as participants were often stopped to engage in conversations.

In contrast, for the partners that shopped together through a tablet, the only attention received from bystanders was from store employees warning the local partner not to take photos of the merchandise. Thus, unlike with the telepresence robot group, bystanders did not reinforce the presence of the remote partner when the remote partner appeared through a tablet. However, the limited attention received by the tablet group did grant the partners using tablets with more privacy, which was valued during intimate communication. Again, it also afforded them with the ability to be more efficient with their shopping tasks, if desired.

Relationship Challenges

We found that at times there was a disconnect between how the local and remote partners viewed the remote partner's level of autonomy and competence. This

created an imbalance of perceived dependency, responsibility, and equality in the participants' partnerships.

Dependency

First, we learned that remote shopping through a telepresence robot generated new feelings around dependency within some of the couples' relationships that was not normally the case when they shopped together in person. This meant that remote partners often depended on the local person to guide the shopping experience and take a leadership role. This dynamic was in stark contrast to the way participants normally interacted where a leadership role was typically 'passed back and forth' when shopping. The increased dependency and new power dynamic was typically a result of the local participant's increased physical abilities, e.g., the person moved faster than the robot, had better control over movements, had a wider FOV, and was not dependent on a reliable Internet connection. Two participants brought up the analogy of a pet/owner relationship, describing the local partner as the owner and the remote partner as the pet. Through our observations we found that the experience was often akin to how a parent might lead a child through a store when shopping with them. Remote participants only lead the way in cases where there were strong enough reasons to work past the limited physical capabilities of the telepresence robot. For example, one remote partner pointed out to her partner that "we're taking the long way back" (Beam 4, Remote) and lead her partner on a new path. It was clear that local partners did not resent the agency that their remote partners gained through using the telepresence robot, but instead appreciated it.

> *"It did feel more personable. She was there. When I was changing, she was like, 'I'm going to go see if I could, you know, look at other things'. And she can do that right? I don't have to carry her around and like introduce her to things. She flips around, moves around at her own will. So that's kind of nice." – Beam 6, Local*

For those using the tablet, the remote partner was completely physically dependent on the local partner who carried the tablet through the mall. This was not ideal as it meant that the remote partner's quality of experience was completely dependent on the amount of care their local partner put into purposefully directing the tablet's camera to provide a good view. When it came to leadership and taking charge, remote participants could sometimes dictate where they went through conversation. Yet

actions had to be negotiated first through conversation with the local participant. The remote participant's plan had to be carefully explained, discussed, and then acted on, if desired. As well, local partners in the tablet group felt that they had the final say in things, as was explicitly expressed by one local partner in the tablet group. *"I preferred to take the final decision of what we are buying because he is not with me so I can do whatever I want"* (Tablet 5, Local). In contrast, with the telepresence robot, it was sometimes enough to just tell the local participant that one had an 'idea,' and then begin to enact it through movements of the robot (e.g., telling the local participant to come 'here'). Furthermore, even if local partners in the tablet condition wanted to provide a good view for their remote partners, there were scenarios that made this challenging – notably the scenario of using changerooms and subsequently trying to show the remote partner one's outfit. One local partner in the tablet group noted that she put the tablet down in the changeroom, blocking the camera. Another local partner in the tablet group explained how she could not show her entire outfit with the tablet because holding it at arm's length was not far enough. As well, it is not possible to show the back of one's outfit without a mirror when using a tablet.

> *"It was difficult to show to [partner] with the tablet, because if I show him with the back camera, the tablet covers a part of me, and if I show it through front camera, I cannot pull my hands really far away to show the whole view of how it looks with my pants. So it was not very satisfactory." – Tablet 5, Local*

In contrast, with the telepresence robot, the remote partner could back up as much as they needed to in order to view the local partner's entire outfit, and the local partner could simply turn around if they wanted to show the back of the outfit.

Responsibility

Second, we found there was a disconnect in terms of who was responsible for whom. This was different than dependency and who directed or led the shopping activity. Instead, it related to if and how participants felt responsible for the telepresence robot, e.g., bumping into people, being in people's way, knocking over and breaking items in a store. During the interviews, we asked each participant about who they felt should be responsible if the telepresence robot (or tablet) broke an item in a store. In the telepresence robot group, all but one remote partner felt they should be responsible. Yet,

similarly, all local participants claimed the responsibility for the remote partner's actions within the mall. Thus, while the robot embodiment gave remote participants a strong sense of agency in the remote environment, leading them to feel responsible for their own actions, their local partners did not recognize the same level of agency in their remote partners.

> *"[I'd feel more responsible] because I drove into it and I broke it, not her. Although granted, she could spot for me, but I have two cameras at my disposal." – Beam 7, Remote*

> *"I have to take the fall for it ultimately, simply because I'm the one that's there that's more capable of handling the situation because of my actual presence." – Beam 4, Local*

Without being prompted to, all local partners took on the responsibility of helping their remote partner navigate the space of the mall, which included the challenges of maneuvering around other shoppers and tight aisles in stores. This help was offered even when it appeared to be unnecessary or even perhaps unwanted. For example, one remote partner responded to the local partner's help with "*Don't worry about me! Just go!"* (Beam 1, Remote).

Overall, we found that the feelings of responsibility that local participants had were very different than how they normally experienced shopping. Normally, each person was solely responsible for their own actions because they were considered to be competent adults. Thus, the relationship dynamic shifted when using the telepresence robot and created the potential for additional strain between the local and remote participant.

When the idea of responsibility was discussed with participants using the tablet, responsibility for actions in the mall were nearly always mutually understood to be left with the local participant. For example, when asked who would be responsible for breaking an item in a store, local partners took responsibility. Similarly, remote partners believed that their partners should take responsibility unless the remote partner had been very distracting at the time of the accident.

> *"If we're in a very like, we're really into this conversation and he suddenly bumped into something, I'd probably feel a little bit more*

responsible…but if he's not saying anything, he's just looking around and he accidentally bumped into something, I probably wouldn't feel as responsible." – Tablet 7, Remote

Ability to Contribute

While increased autonomy and ability to control one's view has the potential to increase a remote partner's ability to contribute—since it would give them greater agency to look around and develop their own ideas—the robot in its current form still had limitations that caused the remote partner to feel like they were not contributing as strongly to the shopping activity as they would have liked. The fact that the robot was slow and could normally not keep up with the local participant was one of those limitations. Remote participants also said that not being able to pick up or inspect items up close without the help of the local partner was another limitation. Pairs who felt that both partners contributed equally to the shopping activity reasoned that both partners contributed opinions that helped in choosing items for purchase. Thus, contributions had to be through verbal exchanges rather than physical help.

"I would provide my thoughts on what my mom would like …and she provided the feedback about which store seemed more in that theme so there was that back and forth." – Beam 1, Remote

When it came to helping out with carrying shopping items, local participants using both technology setups obviously could not get help from their remote partners. Yet participants said this was an important part of the shared experience because it reflected their normal shopping behaviors and desire to feel like they were helping out. A lack of being able to contribute in this way created negative feelings with some participants. This inequality was more poignant for those using the tablet as the local partner struggled with completing the tasks with one hand occupied by the tablet.

"There was a part where I kind of felt bad because he had to hold everything […] whereas normally when we're out together, like I can offer to help him hold something. You know, if he has a lot of stuff, I'll like hold something for him. Or even when he went to go try on the shirt, it was like, I wanted to help him hold the coffee ..." – Beam 6, Remote

“When he is with me, he is a help for me, not a load. Right?[...] When he’s with me he would carry my stuff, now when he’s not with me, I need to carry him in my hand.” – Tablet 2, Local

When it came to making decisions about purchases, the pairs using the tablet were less capable of making joint decisions as the local partner largely dictated the remote participant’s view. Sometimes local participants would only show their preferred items to the remote partner. Shopping in this manner meant that remote partners could contribute less to the pool of ideas regarding what items the pair should consider purchasing.

"It was a bit annoying because I wanted to give her more suggestions or my views, but I was actually unable to do that. Say I like something which I thought maybe it looks like this or maybe it's that, but when she picks it up it's like 'oh no' that's not what I was thinking." – Tablet 2, Remote

“Yes, she listened to my opinions, but sometimes I think I keep my own ideas. For example, the dress - the style I want to wear in the mother’s party. I think she probably want me to have skirt, have dress, but actually I just like wearing casual or simple style, and if it’s not face-to-face, if it’s just with a tablet, probably I can just ignore her ideas sometimes.” – Tablet 3, Local

Discussion

We now explore and discuss our findings to understand how they shed light on new areas of design thinking around the creation and use of telepresence robots during shared leisure activities over distance. To date, the research agenda around telepresence robots has largely been about designing telepresence robots for activities that one could argue are largely task-driven in nature, such as supporting distance learning (e.g., (Newhart & Olson, 2017)), remote workplace interactions (e.g., (Lee & Takayama, 2011)), or remote conference attendance (e.g., (Neustaedter et al., 2016; Rae & Neustaedter, 2017)). In contrast, we explore design themes that we feel are important when people participate in activities that are largely social and personal in nature, rather than utilitarian. While shopping does contain notions of ‘tasks,’ such tasks are interwoven with personal, social dynamics as a part of family and friend

relationships. Overall, our study points to the expectations that people have for the ways they should socially interact and engage with others during leisure activities over distance, where there are strong needs to support familiar behaviors and routines, shared control over the activity, and contributions from both parties to the activity.

Familiar Patterns

First, it was clear from our study that shopping with family and friends involves familiar patterns of behaviors and personality idiosyncrasies. These are what help to make the activity social in nature. We found that, when separated by distance, being able to see these behaviors and idiosyncrasies can help people to feel like they are actually performing the activity with a remote person and that the person is 'there.' Other shared leisure activities performed by family and friends over distance that are similarly social in nature (e.g., hiking, sight-seeing) are likely to have similar traits. Here, too, one would expect that being able to recognize familiar behaviors over distance would aid the experience. To date, the related research around telepresence robots does not explore this aspect of experience, perhaps because of the focus on more utilitarian-type situations (e.g., workplace activities). The tablet in our study failed to support these acts in a rich way, while the telepresence robot benefitted participants because of its mobility. Yet not all desirable behaviors were supported (or they were constrained), which suggests opportunities for additional design explorations related to telepresence robots. Certain changes, which are also suggested by others, could help interactions. This includes a wider FOV camera (S. Johnson et al., 2015; Jouppi, 2002; Kimura et al., 2007) or faster 'walking' speeds (Lee & Takayama, 2011).

Other needs are more complex, such as hand-holding, which would require additional features or add-ons to telepresence robots (e.g., vibro-tactile gloves (Singhal et al., 2017) could be worn by people). Yet, while seemingly simple, such design changes are likely quite complex in practice. For example, they may introduce additional cognitive load or social expectations. It could also be very challenging to actually control a robotic hand remotely (Eric Paulos & Canny, 1998). Given these thoughts, we feel what is most important is that designers and researchers begin to consider how telepresence robots can allow people to easily support familiar behaviors and controls that allow them to be performed in a lightweight manner. This may involve exploring input mechanisms beyond current telepresence robot controls involving mouse/keyboard

or gaming controllers, to input modalities that allow for a richer set of small-scale mannerisms within a telepresence robot (e.g., nodding one's head, tilting one's body, gently touching another's hand). In turn, explorations are needed around the social implications of having these additional interaction and embodiment modalities.

Playfulness

Second, our results point to the value of being playful during a shared leisure activity that is social in nature like shopping. Playfulness enhanced the experience in our study by creating fun situations. It also made it so remote participants could draw in the attention of their local partner. These behaviors were very challenging to achieve with a tablet because of the size of the device, its orientation facing outwards, and the remote user's reliance on the local person moving the device. The telepresence robot used in our study supported basic levels of playfulness (e.g., turning, moving, changing speeds), yet beyond these actions, participants were limited in what they could do. Participants using the tablet had an experience that was not nearly as rich given the tablet's inability to support playfulness beyond conversational interactions. This further emphasizes the value in designing to support playfulness. Telepresence robot controls that are more intuitive and less time consuming to use may better support spontaneous acts of playfulness. Many of the playful behaviors we saw relied on quick, impromptu actions that may not always be easy to do with a telepresence robot given the current controls (with mouse/keyboard or gaming controllers).

Designs that focus on a richer set of playful acts would also benefit people. For example, when in person, playful acts often involve touching others. People might sneak up behind others, tap each other on the shoulder, 'high-five' one another, etc. Yet actions like these are not possible with most telepresence robot designs. Most telepresence robots lack arms and hands. Adding such features may begin to address the limitations our participants found in our study, however, they may also create new challenges around how to interact with such features. Other design approaches that focus on supporting a richer set of actions with the body of a telepresence robot could hold promise as well (e.g., making it easier to sneak up on a user for fun, supporting subtle rather than overt nudges). Existing research has explored this with head movements, for example (Adalgeirsson & Breazeal, 2010).

Telepresence robots should also be designed to make it easier for the *local* partner to be playful with the remote partner. In our study, some participants touched the robot in playful or affectionate ways (e.g., head tapping); however, these touches could not be felt by the remote partner, even though, in some cases, the remote partners could see that their local partners were touching 'them'. Incorporating transmission and reception of touches through a telepresence robot could potentially enhance the experience of such interactions, similar to how touch has been shown to enhance more standard video calls (Singhal et al., 2017). Looking across the related literature, we do not see exploration of playfulness and physical touch when it comes to telepresence robots, perhaps, again, because of the largely utilitarian and work-centric focus of the research to date. There are also likely other ways to support playful actions with the remote user that move beyond just touch. This creates a ripe area for design exploration.

Autonomy and Social Relationships

Perhaps the largest difference that we see between our work and the related literature is the likely effect of telepresence robot design on domestic social relationships and the power dynamics that come with them. Past work has discussed issues with a lack of autonomy in relation to losing connectivity (Lee & Takayama, 2011); our research extends this to explore a broader range of challenges. Here we point to design challenges with telepresence robots focused on autonomy and agency where the device's limitations can create relationship issues between family or friends. These challenges relate to feelings and perceptions around responsibility, dependency, and contribution during a leisure activity. These issues tended to be exacerbated when participants used the tablets compared to the telepresence robots, given remote user's heavy reliance on the local user to hold and orient the tablet. Thus, telepresence robots created an improved experience over tablets, however, the problems still persisted. While our study does not draw out the long-term effects from negative feelings that might come with, for example, feelings of dependence on others, it is reasonable to expect that such feelings could create relationship challenges over time. These issues point to an open and important design space that should be explored such that personal social relationships can be adequately supported and not hindered.

Over time, commercial telepresence robots are likely going to increase in their capabilities, which should help to lessen the discrepancy between the abilities of the local and remote person when participating in a leisure activity. Researchers should continue to explore ways to bring greater parity in skills between remote and local users. Alternatively, there would also be great value in exploring design options that bring unique capabilities to the remote user that map to particular leisure activities. This might allow them to contribute to the activity in ways that the local person is not able to, given their differing context. For example, with shopping, designs focused on giving the remote user enhanced capabilities to compare items or prices, or better determine store options could let them feel like they are contributing to the activity in important ways. Such solutions would need to be cautious though, so they do not take the remote user 'away' from the remote environment too much and ruin feelings of immersion in the remote space. Overall, this is a ripe area for design exploration that moves telepresence robot design beyond just the robot itself to explorations of designs that can augment the robot to provide new capabilities for the remote user.

Conclusion

Overall, we feel that our study has helped to open up an important design space that explores how telepresence robots can be used and what design opportunities exist when telepresence robots move beyond the more typical settings explored in the related work, such as workplace interactions, remote conference attendance, education, etc. In the case of shopping over distance, we see that when compared to tablets for video calling, telepresence robots are able to allow partners to see familiar patterns and shopping behaviors, engage in acts of playfulness, and more easily garner the attention of one's partner. Yet telepresence robots can also create challenges that stem from a lack of interaction modalities (e.g., touch, hand holding, easy body movements). There is also the chance that telepresence robot usage will create relationship challenges due to issues around dependency, responsibility, and one's ability to contribute to a shared task. Together, these challenges bring forward a range of design opportunities that warrant further exploration.

Our results likely generalize to other joint activities that take place in public settings and require a similar amount of joint decision-making and exploration of the environment. For example, it would be reasonable to expect that studies of remote site-

seeing or outdoor walking would find similar results because they would both involve walking around a public area, deciding which direction to go, and conversing as one moves. For activities that differ (e.g., remotely attending sporting events or concerts where space is tighter and there are more people, the ambient noise is louder), further studies are needed to understand if and how our findings might apply given the change in number of people present and the nature of the activity.

Our results are limited in that we only studied people who were in a couple relationship. While it is likely that our findings around the benefits and challenges of performing certain types of interactions and actions with the telepresence setups generalize beyond just couples to other family member pairs or close friends, future studies should explore these relationships more specifically. Our study also comes with the limitation that partners were asked to imagine themselves as a long-distance couple. This was done to provide a stronger rationale for why the couple would want to shop together using a telepresence system rather than just going together in person. Yet it does mean that the situation may not have reflected their own relationship as well as it could have. It also means that our results may not be indicative of actual long-distance couples. These limitations should be considered when interpreting our findings and design suggestions. Of course, there is also the chance that couples may not want to actually shop over distance in the ways that we have focused on in our study. The related research suggests that remote leisure activities are desirable (Massimi & Neustaedter, 2014), however, we do not know for sure if such technologies were readily available for usage.

Our study focused on one type of telepresence robot and clearly there are many other commercial telepresence robots available with varying capabilities. Some of our findings are likely specific to the particular type of telepresence robot that we studied. That said, we have presented our findings and design suggestions around several high-level themes that we feel represent important considerations for telepresence robot design more generally. These are likely to hold as design considerations regardless of the specific telepresence robot being used. Lastly, participants were experiencing shopping with a telepresence technology for the first time and it is difficult to know how behaviours and needs may change over time and with experience. This suggests longer-term exploratory studies as part of future work.

Chapter 5.

Telepresence Robots with Smart Home Tools

5.1. Overview

Telepresence robots designed for communication purposes need to be simple to control, since cognitive demands of controlling the robot detract attention from social engagement (Lee & Takayama, 2011). However, the simple form of many telepresence robots is also limiting for users who cannot open doors (Lee & Takayama, 2011) or help carry bags (Yang et al., 2018). It is important to consider how we can design for more functionality without significantly increasing the difficulty of controlling a telepresence robot.

The third research question of my thesis is: *How does the ability to affect the shared home environment influence the experience of sharing a home through a telepresence robot as part of a long distance relationship?*

The objective is to explore the use of smart home tools as a way to extend the agency of telepresence robot users in the home setting. These tools can be activated through voice and grant the user the ability to control aspects of their environment without adding new controls that users have to learn and operate.

The paper included in this chapter addresses this topic and is conditionally accepted as:

> Lillian Yang & Carman Neustaedter. 2020. An Autobiographical Design Study of a Long Distance Relationship: When Telepresence Robots Meet Smart Home Tools. Conditionally accepted to Proceedings of the 2020 Designing Interactive Systems Conference (DIS '20). Association for Computing Machinery, New York, NY, USA.

5.2. An Autobiographical Design Study of a Long Distance Relationship: When Telepresence Robots Meet Smart Home Tools

Abstract

Long distance couples often face challenges in maintaining their relationship over distance because computer-mediated communication tools typically only support a limited range of relationship maintenance behaviors. To explore a broader design space that might help combat this problem, we conducted an autobiographical design study that explores the usage of a telepresence robot coupled with voice-activated smart home devices. The telepresence robot provided an embodiment for one remote partner who could talk through the robot to control the smart devices in the remote location. We studied how the setup was used by a long distance couple over a three month period to share their home and nurture and maintain their relationship. The study revealed how such a setup can promote feelings of ownership, belonging, and normalcy, as well as a diversity of interactions and social connections. Implications for design include the importance of supporting effortful, personalized, varied, and shared interactions.

Introduction

Long distance relationships are a common experience for many people as a result of situations in life, such as work relocations, family obligations, moving to attend a specific school, etc. (Stafford, 2005). The distance makes it difficult to maintain relationships as partners become limited in how they can interact with and support one another when they are physically apart (Dainton & Aylor, 2001). Computer-mediated communication (CMC) tools are important for long distance partners because these tools enable partners to see, hear, and write to one another, thus allowing partners to express positivity, assurances, and support (Stafford, 2005). These are a subset of actions termed “maintenance behaviors”, which are necessary for the continuation and health of relationships (Stafford, 2005). However, current remote communication tools are limited in the types of maintenance behaviors that can be performed and the extent to which they can be performed. For example, it can be particularly difficult for long distance partners to share tasks and engage in joint activities using traditional CMC tools, such as video chat (Brubaker et al., 2012).

Our work builds on existing research on the potential for telepresence robot usage for personal/private interactions over distance. We chose to study the use of telepresence robots in conjunction with smart home tools because past research has found that while telepresence robots support long distance partners in sharing home life, being largely unable to manipulate the environment meant that partners were still very limited in ways they could help one another, express their affection, or participate in activities together (Yang et al., 2018; Yang & Neustaedter, 2018). We were interested in how the ability to control various items in a home would affect the experience of sharing a home over distance through a telepresence robot.

Our research focused on answering the following questions: a) how might long distance partners more flexibly express mutual care beyond just verbally conveying it? and b) how does this influence the experience of sharing a home? In order to answer these questions, we used autobiographical design, which is a research method that involves the researcher as the user and designer of the system being studied (Neustaedter et al., 2015). The choice of this method stems from the need for an exceptional level of access to a couple's private life and home. Having the researcher be the user allows us to monitor the day-to-day interactions in the home space, including access to intimate details of usage that might otherwise be kept private. This method serves to reveal the complexities of usage in daily life and supports the ability to quickly iterate on designs (Neustaedter et al., 2015). We were able to utilize the method of autobiographical design because the researcher had a genuine need for a long distance communication solution and a real stake in designing a telepresence home setup that could help her maintain her relationship with her fiancé.

The telepresence home setup involved various smart home tools (e.g. vacuum, lights) controlled by the remote partner by voice projected through the telepresence robot (Figure 9). We selected smart devices to specifically support four types of relationship maintenance behaviors: joint activities, support, sharing tasks, and affection. Through our study, we found that by coupling a telepresence robot with smart home devices, remote partners were able to expand on the ways that they were able to support their relationship over distance. This included feeling ownership and belonging in the shared home space, as well as a sense of normalcy, diversity of interactions, and continued involvement in social groups after moving away. Our findings illustrate the

value that designs can bring when they support effortful, personalized, varied, and shared interactions.

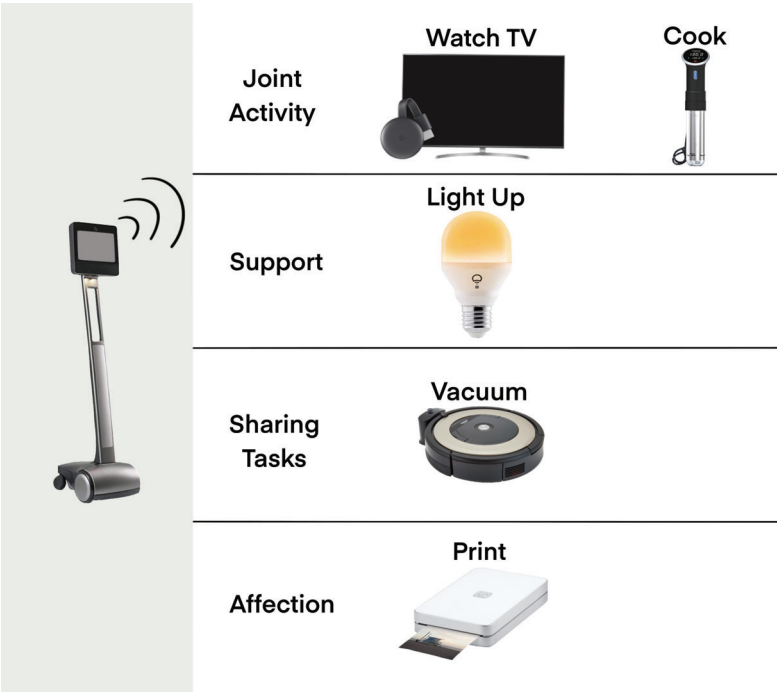

Figure 9: This figure shows the household items controlled by the telepresence robot over distance in our telepresence setup.

Maintaining relationships is challenging for long distance couples as it limits the options that couples have for sharing with and caring for one another. It has been found that the availability of CMC tools makes the separation more acceptable to partners (Aguila, 2011). The variety of CMC tools, such as video chat and instant messaging, support different communication needs that couples have (H. Kim et al., 2007). However, CMC tools typically transmit only visual and audial information and thus limits flexibility in expressing mutual care and support.

As mentioned in a previous section, the relationship literature has defined a core set of behaviors that couples perform to nurture their relationships (for example, sharing tasks, joint activities, and support). These are called “maintenance behaviors” because these are behaviors that partners continue to do throughout a relationship in order to *maintain* the relationship (Stafford, 2005). Using current CMC tools, the relationship maintenance behaviors that couples can use are mostly ones that can be expressed verbally. For example, through video chat, partners can express positivity and affection, provide assurance and advice, and engage in small talk and humor. However, research

on “always-on” video communication (i.e. when partners keep a video call on even when not directly engaging with one another) shows the importance of non-verbal communication as long distance partners often use video chat even when not talking to one another (Neustaedter & Greenberg, 2011).

Research on designing artifacts for mediating intimacy suggest that such artifacts support factors like expressivity, memories, and awareness (Hassenzahl et al., 2012). Early work in mediating intimacy explored devices that expressed emotion and supported awareness without any exchange of information (Strong & Gaver, 1996). This has included a large range of devices, often focused on simply letting one’s partner know they are thinking of them (Bales et al., 2011; Grivas, 2006; Joi et al., 2015; Lottridge et al., 2009). There are also devices, such as Cubble (Kowalski et al., 2013), Sensing Beds (Goodman & Misilim, 2003), and Flex-N-Feel (Singhal et al., 2017) that support awareness and expressivity through touch sensations of heat or vibration.

Sharing Activities Over Distance

Researchers have also studied how people can share activities over distance. Mobile video chat is being used in progressively more scenarios, such as sharing graduations, weddings, and family reunions over live video calls with remote family and friends (Massimi & Neustaedter, 2014). The perceived value of being able to share these experiences with loved ones is high enough to justify taking on the burden of making the connection happen (Massimi & Neustaedter, 2014). However, the challenges of the mobile video work can diminish the experience for both the local attendee that is managing the video connection and the remote attendee (Buhler et al., 2013; Inkpen et al., 2013; Massimi & Neustaedter, 2014). For example, it can be difficult for the local sharer to maintain a good framing of the activities for the remote viewer (Inkpen et al., 2013; Massimi & Neustaedter, 2014). Furthermore, the remote viewers can feel that they are creating a burden for the local sharer who has to carry a device to the event, manage the camera view, and troubleshoot the connection (Massimi & Neustaedter, 2014).

A central challenge with sharing activities over distance is the lack of embodiment (Heshmat et al., 2018). There is a limitation to how much one can explore a space and interact with others when one does not have a physical presence and autonomy of movement. We have seen from past research how remote partners want to

view things from different angles and approach spaces in a way that helps them build an understanding of the environment (Jones et al., 2015; Massimi & Neustaedter, 2014). Previous research has also shown that remote partners could benefit from an embodiment in social interactions as they could be better acknowledged by people in the surroundings (Neustaedter et al., 2017). As well, the autonomy of a mobile physical embodiment can support more interactivity (Yang et al., 2018; Yang & Neustaedter, 2018).

Telepresence Robots

The telepresence robot is a communication tool that provides a physical embodiment for the remote user, alongside audiovisual channels of communication. The typical design includes: a display that shows the user's face at roughly human height; a front-facing camera which provides the user with a view of the environment; a floor-facing camera which shows the ground to aid in obstacle avoidance; a microphone for hearing the environment; and a speaker for the user to communicate through (Desai et al., 2011; Kristoffersson et al., 2013). This is used in scenarios where audiovisual communication is deemed not enough to support the needs of the social interactions in that context. For example, telepresence robots are used in the workplace to allow remote workers to have a more normalized working experience, including spontaneous meetings and conversations with co-workers (Lee & Takayama, 2011).

More recent work has explored the use of telepresence robots for connecting loved ones in sharing activities and daily life (Heshmat et al., 2018; Yang et al., 2018, 2017b; Yang & Neustaedter, 2018). Reported benefits were the support of autonomy and spontaneity, and reported challenges were situations where partners felt limited in how they could help one another (Heshmat et al., 2018; Yang et al., 2018). The constraint of not having appendages continues to be a limiting factor for interactivity through telepresence robots. However, the telepresence robot form factor is simple for a reason – having a conversation while driving a telepresence robot is already a distraction without added appendages (Lee & Takayama, 2011) and further controls would add cognitive load that would impede on communication. Thus, in order to give the remote user more control over their surroundings, while maintaining the simplicity of controls and focus on communication, this study explores the use of voice controlled smart home tools.

In this study, we explore how couples can share a home and perform relationship maintenance behaviors through a telepresence home setup (i.e. a home outfitted with smart home devices that can be controlled by voice through a telepresence robot). To our knowledge, no other study has explored the pairing of a telepresence robot with voice-controlled smart home tools. There has been research similarly exploring the control of remote devices through a telepresence robot, but the method was using a computer plugin which added to the user's cognitive load, and the context was for remote work (Kaptelinin et al., 2017). As well, other researchers have explored systems of smart homes which interact with a service robot to create automated home care (Broxvall et al., 2006; Saunders et al., 2016). While these papers share our concept of robot-environment integration, the direction of their work differs greatly as they are moving towards the removal of explicit human input while our work encourages human involvement and focuses on social interactions. There is also research exploring remote control of devices to support long distance relationships (Chien & Hassenzahl, 2017), but without exploring the remote control as an embodied experience through a telepresence robot. The goal of our work is to explore the complementary potential of telepresence robots and voice-controlled home devices in the context of sharing a home and maintaining a relationship over distance.

Autobiographical Design Study Method

To explore the aforementioned design space, we utilized autobiographical design: "design research drawing on extensive, genuine usage by those creating or building the system" (Neustaedter & Sengers, 2012, p. 514). While autobiographical design does not allow one to generalize study findings, it is highly suited for early design explorations such as ours where little is known about how a technology will be used. Autobiographical design also allowed us to gain exceptional access to a real-world long distance couple, rich data collection, and uncommonly candid insights into possibly sensitive topics. There is also the chance that we could have put one or more couples' relationships in jeopardy with technology setups that may have not actually helped their relationship or, worse, caused them to deteriorate. Our method also provided us with the ability to rapidly iterate on home device implementations. While some autobiographical design studies involve large amounts of programming and development efforts to create new software or hardware (e.g., (Chien et al., 2016; Neustaedter et al., 2015)), our design and iteration efforts were focused on choosing and altering which smart devices

we coupled with the telepresence robot and setting them up within a home environment. Autobiographical design work has been found to range from weeks to years of extensive usage (Neustaedter & Sengers, 2012). Our autobiographical design study lasted three months, given the needs of the couple, and the telepresence home setup was used extensively due to the necessity for the long distance couple to stay in close contact.

Participants

This autobiographical design study involves the first author, Tessa (alias), and her partner, Stanley (alias). Tessa is a PhD candidate in human-computer interaction and her partner is a software engineer. They met through mutual friends and have been together for 7 years. When living together, they share a one-bedroom apartment and are currently engaged. Tessa and Stanley spend most evenings and weekends together. The couple became physically separated and in a long distance relationship for three months while Tessa was away for an internship. During this time, Tessa and Stanley lived in two major metropolitan cities in Western North America, separated by ~950 miles but in the same timezone.

Initial Telepresence Home Setup

Before the couple became long distance, the initial set of voice-controlled smart home tools were set up and a telepresence robot was brought to their *shared home*. For the remainder of the paper, this is how we shall refer to the home shared by the couple before becoming long distance. The telepresence robot's charging dock was placed in a corner near the front door where it would be the least obtrusive. The *remote partner*—Tessa—was granted 24/7 access to use of the telepresence robot. That is, she could connect into the robot at any point in time without needing her partner to 'answer' the call on the robot. The couple purposely chose their existing home to place the telepresence robot and devices in as opposed to the new home that Tessa would be moving to. This place already represented 'home' to them both and they wanted to maintain that aspect of their relationship. Alternatively, they could have chosen to place a telepresence robot in *both* homes so that both partners would have the same opportunities to connect in to the other's location. However, this did not fit the couple's needs nor the situation at Tessa's remote residence which was an apartment shared with a roommate. The couple felt it would be awkward for Stanley to connect into a shared living arrangement.

Figure 10: The telepresence robot in the shared home.

The devices we chose to pair with the telepresence robot (Figure 10) for the initial setup were chosen through consideration of both partners' inputs. Around a month prior to assembling the initial telepresence home setup, we began collecting a diary log of daily interactions and conducted a preliminary interview to discuss the couple's relationship i.e. how they interact with one another, what activities they do together, and what types of relationship maintenance behaviors they perform. These self-reflective activities led to the implementation of three initial smart home elements that were connected to a Nest Home Hub to enable voice control.

The first device to be set up was lighting. We set up voice-controlled lights in the couple's main work area, the front entrance, and the bedroom. For the partner staying in the shared home, going home to an apartment with the lights turned on and his partner present felt very important. In the past when he has come home to a dark and empty apartment, it has made him feel dispirited, so he recognized how impactful light was for the atmosphere of the home. For the partner who was moving away, she felt that being able to turn the lights on and off would support her in feeling a sense of belonging in the home. For example, when visiting through the telepresence robot, if it is too dark she would be able to turn on the lights to see, rather than being unable to control her environment and feeling like an intruder.

The second device to be set up was a Chromecast for TV control. With this set up, the long distance partner could go to the TV in her telepresence robot embodiment

and turn it on or off, start specific Netflix shows, play and pause, and change the volume all through voice controls. For the couple, watching their favorite shows together is something they do every evening while having dinner. On a typical night, one partner would get the show ready to play while the other plated up food to bring over. Being able to control the TV through the telepresence robot was important as this could support the couple in maintaining their daily routine.

The third device was a vacuum. We set up a Roomba 895 so that the remote partner could ask it to start cleaning and also tell it to stop and go back to its charging dock. Both partners in this relationship take part in cleaning the home. Especially for the partner who was moving away, this was something she would do when she knew that her partner was having a rough day, since a clean environment helps him to relax when he gets home. It was important for her to continue having the capability to help out around the home and to create a clean environment for her partner to enjoy.

During Long Distance

The remote partner moved away during summer and moved into an apartment with a roommate. She started using the telepresence robot on the first day apart. During the three months of long distance, the couple spent most of their evenings and weekends together sharing a home through the telepresence home setup. The remote partner moved around the home through the telepresence robot and could control the lights, TV, and vacuum through voice commands. In her remote apartment, she controlled the telepresence robot through various devices - she typically used her laptop to control the telepresence robot if she wasn't using it to work at home, her tablet if she was using her laptop, and her smartphone if she was at her workplace.

The couple also continued to use the communication tools they used to stay connected throughout the day while co-located (i.e. Messenger and text messaging) and added Discord (a chat app) to their daily communication routine in order to share video streams.

As a result of needs that emerged during the study, two devices were added during the course of the study. The first item was a printer that would allow the remote partner to print letters and photos for her partner in his apartment. We attached the printer to the telepresence robot so that the remote partner could move around the home

and leave printed messages in specific places. We also attached a portable battery to keep the printer charged. This device could not be voice controlled but was controlled over distance through an app. The second item we added was a sous vide cooker that could have its temperature and timer set using voice commands. The reasoning for the sous vide cooker was to allow the couple to cook together as a joint activity.

Data Collection and Analysis

We collected data from several sources. Daily interactions were recorded by the remote partner (first author) in diary format starting prior to long distance (61/72 days logged) and continued to be logged during the three months of long distance (44/88 days logged). A camera with a view of the entire apartment (except the bedroom and bathroom) was on 24/7 and clips of notable interactions were saved. A semi-structured interview was conducted in person prior to beginning long distance in order to get the local partner's perspective on how the couple shows mutual care through maintenance behaviors, and which interactions are important for the relationship, as well as how the couple interacts and shares home life more generally. Then semi-structured interviews were conducted over video conferencing on most weekends when neither partner was travelling. The semi-structured interviews lasted an average of 17 minutes each and were conducted by the first author.

These interviews discussed the experience of sharing a home over distance through the telepresence home setup. For example, "In what ways do you think the telepresence setup helped us share the home?" "What were some positive moments using the system?" "What were some negative moments using the system?" As well, the researcher asked questions about interactions that happened in the week leading up to each interview. For example, "So this week your mom came over…How do you think that our set up influenced that interaction?" "What did you think about our experience trying to cook together?" The local partner was also asked about his thoughts on how the setup could be improved. For example, "But off the top of your head, can you think of how a smart home telepresence set up could be improved for this scenario of having a shared friend group over?" "Can you tell me about incidents when you wish that not just the telepresence robot but also the smart home set up was done up in a way that could make things more helpful or interactive?"

To analyze the diary data that came from the remote partner, we coded each of the documented interactions by the relationship maintenance behavior that was being accomplished by the action. For example, the code of [joint activity] reported the types of activities that the couple engaged in together through the telepresence home setup (such as cooking and watching shows together), while the code of [support] noted acts of supportiveness (such as welcoming a partner home after a hard day at work). Furthermore, thoughts on the shared home experience were coded as positive, negative, and neutral. To analyze the interview data that provided the local partner's perspective, we transcribed the interviews and recorded each of the interactions that were mentioned in the interviews that corresponded to a maintenance behavior. We gathered quotes from the transcriptions regarding any benefits and challenges that were identified by the participant. These were organized by the maintenance behaviors the responses pertained to. Photo and video data provided rich documentation that could be referred back to for clarification, for example, to see how the telepresence robot was positioned when partners watched TV together, but were not used beyond that for data analysis as the activities captured were already reported on in the diary and interview data. Data analysis was performed by the first author who was experiencing the system with her partner. Findings and themes were discussed with the second author and this led to further iteration on the categories and classifications identified. The analysis resulted in a list of maintenance behaviors that were performed, the specific activities involved in performing these maintenance behaviors, and the challenges and benefits that were reported regarding these activities.

	Sun	Mon	Tues	Wed	Thurs	Fri	Sat
Week 1				1hr 19min	4hr 14min	2hr 57min	4hr 17min
Week 2	2hr 53min	0	2hr 3 min	1hr 43min	2hr 27min	1hr 40min	4hr 3min
Week 3	10hr 21min	1hr 44	4hr 29min	2hr 48min	1hr 42min	41min	5hr 45min
Week 4	7hr 59min	21min	3hr 48min	1hr 12min	1hr 23min	3hr 44min	3hr 45min
Week 5	7hr 6min	1hr 42min	4hr 22min	4hr	local partner visiting	local partner visiting	local partner visiting
Week 6	local partner visiting	4hr	2hr 36min	local partner travel	4hr 48min	local partner travel	local partner travel
Week 7	1hr 14min	54min	3hr 42min	34min	4hr 13min	48min	7hr 36min
Week 8	9hr 39min	1hr 32min	2hr 3min	2hr 16min	2hr 11min	5hr 33min	24min
Week 9	55min	remote partner travel	remote partner travel	remote partner travel	remote partner travel	remote partner travel	remote partner travel
Week 10	remote partner travel	8hr 42min	4hr	1hr 51min	1hr 57min	35min	5hr 25min
Week 11	6hr 51min	1hr 1min	1hr 46min	2hr 43min	2hr 21min	1hr 49min	9hr 52min
Week 12	7hr 33min	3hr 59min	remote partner travel	remote partner travel	remote partner travel	remote partner travel	35min
Week 13	5hr 10min	0	15min	2hr 40min	4hr 19min	2hr 24min	57min
Average	5hr 58min	2hr 10min	2hr 54min	2hr 11min	2hr 58min	2hr 15min	4hr 16min

Table 3: The usage of the telepresence robot over thirteen weeks of long distance.

Results

Over the course of three months, the telepresence robot was used for a total of 226 hours and 54 minutes, averaging 3 hours and 14 minutes of use per day. On weekends the average use was 5 hours and 7 minutes a day, while during weekdays the average use was 2 hours and 29 minutes a day (Table 3). Longer usage periods were seen over the weekends as the couple stayed home and spent time together. These numbers were taken from the telepresence robot's usage log. The individual smart home tools did not log usage time, however, we know that the lights were used almost daily while other devices were used a handful of times. The sous vide was only used once due to interaction issues (described later). Overall, the couple felt that the telepresence setup was preferential over traditional video chat but also had its own limitations.

Ownership and Belonging

With the telepresence home setup, the remote partner was able to control the state of the home in many of the ways that the local partner could. Being able to control the state of the home meant that the remote partner could keep the environment a comfortable space to be in. For example, if it got too dark, she could turn on the lights, or if the music was too loud, she could turn down the volume. This allowed the remote partner to feel at home in the space, rather than feeling like a visiting guest or even an intruder.

Having not only a physical presence in the space (through the telepresence robot embodiment) but also having control of household features (through the smart home tools), the remote partner was not simply a presence in the home, she was someone who was living in it and adjusting it to her needs. Thus, the home was accommodating to both the local and remote partners, making it a space that both partners could feel a sense of belonging in regardless of their physical differences as human and telepresence robot.

The remote partner felt a lot of comfort from spending time in her shared home, especially when she moved around the space and could see her things around the home. Sometimes she would purposefully go to a place to get a familiar perspective (for example, she would go to her side of the bed just to be there) or do something familiar (for example, she would turn on her desk lights even though she wasn't working there). To allow the remote partner to spend time where she was comfortable, the local partner moved the robot's charger to the remote partner's desk.

> *"I really like seeing my stuff scattered around the home. It gives me déjàvu of stepping around my things in person." – Remote Partner*

Both partners were also able to take ownership of the space by keeping it clean and checking on things. For example, the remote partner could run the vacuum to keep the apartment clean, check if the front door was locked at night, turn the lights off when no one was going to be home, and check on the health of the basil plants in the kitchen. For the remote partner, this further cemented the feeling that she was not just visiting – this was still her home and she had the responsibility and capability to care for it. Furthermore, the remote partner enjoyed being able to help her partner with chores. In

relationship literature, this is a maintenance behavior termed “sharing tasks”. Showing care through helping out felt more impactful than showing care through affectionate words.

“For me, I felt amazing that I could help my partner and make him feel like I could still be there for him” – Remote Partner

“[The vacuuming] made me feel like it was a nice thing to be able to, it felt like a normal thing, you know?” – Local Partner

Aside from helping out by vacuuming the home, the remote partner was limited to helping out in small ways, such as by turning off the lights when her partner was going out. There were several times when the remote partner wanted to help out, but could not. For example, when the local partner brought home a new bookshelf, the remote partner was able to contribute advice for where to put it, but she could not help move the bookshelf to where they decided to put it. Similarly, the remote partner often wanted to help take out the garbage but had no way to pick it up or throw it out due to the simple, appendage-free form of the telepresence robot. The limits to helpfulness were also felt by the local partner.

“In terms of like chores, I don't think there's a whole lot we can really split. It's more like we can do stuff together and that you can come along and like, you know, observe and like maybe I'll even ask you to look at something and just tell me if something is somewhere, you know?” – Local Partner

“I mean, I think without the ability to really physically interact with the environment, it's kind of limited, right? I mean like, you know, like the ability to run the dishwasher and to run the laundry would be nice because there's times where I can't do that at night.” – Local Partner

The couple also wished that the remote partner could help run the dishwasher and laundry machines, because these were tasks that she often took care of while they were co-located. Such voice-activated appliances exist, however, we chose not to pursue them because a malfunction could cause serious water damage with possibly nobody local to stop it. Together, these tasks reveal the limitations of the minimalistic form of the telepresence robot. The first limitation has been brought up in other papers –

without arms, telepresence robots can't help carry things (Yang et al., 2018) e.g. carrying food to the table, taking out the garbage, or moving furniture. The second limitation is that telepresence robots can not flexibly respond when devices malfunction or require troubleshooting. For example, if the vacuum got caught on a wire or if the internet connection needed to be reset, the local partner would need to take care of these issues.

A Sense of Normalcy

The telepresence home setup supported an atmosphere of normality in the home. It allowed the couple to interact in many of the same ways that they would in person. When the couple lived together in person, they would casually ask one another to help out in little ways and this continued when they were apart. For example, the local partner would sometimes ask his partner to help him check if the front door was locked while he checked the balcony door at night. On one occasion, the remote partner purposefully created a sense of normalcy by turning on the TV in preparation for her partner coming home after a workout, so that he would come home and see her in the home, doing her own thing, as he normally would when they were co-located (see Figure 11).

Figure 11: Stanley coming home to find Tessa watching TV.

Any day the remote partner could get home before her partner, she would rush home and make sure that she turned the lights on and waited for him. It was important to her that her partner did not feel like he was living alone and coming home to a dark and

empty home. Instead, he often came home to his partner greeting him at the door and the lights turned on, just as it often was when they were co-located. Sometimes, for the sake of variety, she would also choose a song to play on the Nest Home Hub so that the home would be filled with music that he liked as well.

> *"The last little while you have been sometimes turning on the lights or putting on music for when I come home, which has been very nice cause it shows like, you know, it's like it makes me feel a bit more like I'm coming home to you actually being here and it also is like a clear indication of something nice that you're trying to do for me." – Local Partner*

The normalcy of coming home to a space that felt lived-in had a positive impact on the local partner's mental state, slowing down the onset of anxiety that typically emerged when he was apart from his partner.

> *"Like I think, you know, like in the past when you've been gone for like any period of time, I tend to get anxious…[a]nd I think having like the [telepresence setup]…has like slowed that process." – Local Partner*

We asked the local partner whether he'd get the same benefit from an automated system that would turn the lights on when he was near, but he noted that having his partner be the one who turned on the lights was significant. The act of turning on the lights showed that his partner thought of him and put in the effort to care for him.

> *"…[H]aving the other person actually being the one who is putting in the effort to do that stuff matters." – Local Partner*

Even when things did not go according to plan, such as when the telepresence robot's battery died while the remote partner had been waiting at the door, the show of effort was enough to make the local partner feel cared for.

> *"There was like another time where like you had taken the [telepresence robot] off the dock to wait for me, uh, at the door and I guess the [telepresence robot] had died while you were waiting. Um, but it wasn't a bad moment. Like I actually was like, actually it actually*

was very sweet cause I could see what you'd been doing." – Local Partner

Diversity of Interactions

Over time, the long distance couple noted the value of being able to interact in diverse ways through the telepresence home setup. Both partners felt a desire to interact in different ways rather than being constrained to the same set of behaviors every day (e.g. coming home, watching a show together, then hanging out). When asked about whether it mattered to him that his partner could express affection in different ways, the remote partner responded that variety has value. If there was only one way to express affection then it would begin to feel rote and less meaningful.

"Like if you just do the exact same thing every single day, um, it sort of becomes like, it's more like it's a routine than an actual thought. So like, you know, if you don't turn on the light some days I don't think anything of it. But if you turn on the light like some days and like, you know, turn on some music some days it feels more like you're actually thinking about it rather than just doing the thing that you do." – Local Partner

Figure 12: Cards that Tessa printed for Stanley.

Normally very physically affectionate, the remote partner needed new ways to show affection over distance. She often left messages on the telepresence robot's screen, such as "Stanley Rules!" or "You are so special". However, leaving these messages did not feel satisfactory and instead felt similar to leaving regular text messages. As a result of the remote partner's desire to express herself in more personalized and varied ways, we added a printer to the telepresence robot. This allowed her to print out physical cards and photos and to drop them where she wanted

the local partner to find them (Figure 12). The act of creating these cards (using a drawing app on her tablet) made her feel that she was doing something effortful and special for her partner and her partner enjoyed getting the cards and photos like little surprise gifts.

Aside from the messages, cards, and photos, the couple could also express physical affection, albeit in a limited way. The local partner would often touch the remote partner's robot body. For the remote partner, this felt very intimate because she could see her partner's hand on her "body" because of the downward facing camera which was meant to help with navigation. Thus, simply seeing the physical representation of one's body being touched can be a powerfully intimate sensation.

> *"It's just like for me it's, it's just like the way I would like reach out and touch you. Like obviously it's not the, it's not the same sensation, but it's the same like instinct to do that. And it's nice to be able to feel like I'm having a little bit of a physical connection." – Local Partner*

> *"Like I already feel like, you know, that you're touching my body cause I can see it and that's like a pretty strong sense for me, but like knowing that like you also feel that definitely like reinforces that." – Remote Partner*

For this couple, the physical presence of the telepresence robot was only used to support non-sexual forms of intimacy. Even though the local partner generally regarded and treated the telepresence robot as his partner's representation, he did not want to engage with it in a sexual manner.

> *"Honestly it's like I like being intimate with you and the idea of being like somehow like having some like intimacy with a machine, even though it's a representation of you, it's just something that I find uncomfortable." – Local Partner*

Aside from diverse ways of showing affection and support, the couple also wanted to do different types of activities together. Most evenings, they ate dinner together while watching a show. On special occasions, such as their anniversary, they bought the same type of food to enhance the feeling of eating together. Rather than watching the shows in the living room area where they would normally watch shows in

person, they most often sat in front of their computers and streamed the shows through chat software. This was because the audiovisual quality of watching shows through the telepresence robot was low and the limited field of view (104 degrees) made it difficult to see both the local partner and the TV at the same time. Furthermore, the local partner expressed that the telepresence home setup did not provide additional benefits to the couple's enjoyment of watching TV or playing video games together.

> *"…[M]ost of the joint activities we tend to do are things that can be done through like a remote share, right? Or like, you know, we play video games together or watch shows together so it doesn't help or hinder those things at all." – Local Partner*

The partners' experiences suggest that for joint activities like watching shows and playing video games, the virtual space becomes the shared space, and thus a co-located physical experience is of secondary importance for these activities. While the remote partner delighted in the idea of watching TV in the living room as they did while co-located, she realized that she paid little attention to the physical surroundings once she was engrossed in the media.

While the couple enjoyed watching shows together each night, this routine lacked variety and they missed doing activities together. In response, they planned a night to cook a meal together. They used a sous vide machine to heat up the water for cooking chicken, asparagus, and carrots. The intention was for the remote partner to be able to control the temperature of the water using voice controls. However the system would not connect to the Nest Home Hub for voice control, so instead she took on the role of reading out the recipe to guide her partner through the steps. The remote partner could move around to get a closer look at the ingredients and process. She noticed that it was difficult to see the small numbers on the sous vide device that indicated the temperature. Given that monitoring temperatures and timing are the main contributions that a remote partner can manage in a long distance cooking scenario, the visibility of indicators is an important element to consider.

The local partner's biggest issue with the joint cooking activity was that the remote partner did not get to eat the nice meal at the end. He was particularly uncomfortable with the fact that the remote partner ate leftovers while he ate the nice meal they had made together. Thus the local partner noted that cooking the same meal

in parallel with one another would be an option that would allow them to share the same meal at the end.

> *"I think that the only thing that I, that I that was I think a negative about it was that I felt very guilty at the end cause like I, we were like, we were making food but I was the only person who got to eat it, whereas you were just eating like a leftover sandwich, which I found like I felt really bad about." – Local Partner*

Both partners agreed that they preferred to eat the same food for dinner as that increased their feelings of togetherness. However, it can be difficult to cook the same things when long distance as partners may have different access to ingredients, and in the case of this couple they had differeing access to cooking appliances.

Social Connections

Having a telepresence robot embodiment made it possible for the remote partner to be present and part of the group when friends (Figure 13) and family came over. For example, the couple's mutual friends came over for their usual tabletop role playing game as well as a local co-op video game night. The remote partner's autonomy allowed her to move around with the group and to direct her attention to the people she wanted to speak to. While she could not play the video games during games night, this was no different than how she would usually participate by watching in order to let the guests have the controllers. The challenge during the role playing game was that she could not turn the robot very quickly when her attention moved between players. However, she felt involved with the group in both situations even though her telepresence robot embodiment rendered her movements more sluggish than usual.

Figure 13: The remote partner spending time with friends at home.

While the telepresence home setup was not designed to support connections outside of the couple, it could be adapted to do so. On one occasion when her partner's younger brother came over, the remote partner printed a photo of his family for him as a small gift which made him happy. The younger brother affectionately gave the remote partner's telepresence robot embodiment a hug when he left. This positive outcome for the remote partner and her relationship with her future brother-in-law shows that telepresence home designs should support the user in flexibly expressing affection not only for her partner but for family and friends as well.

While the telepresence robot embodiment helped the remote partner feel part of the group, the challenge in having guests over was that the remote partner felt that she did not contribute to hosting the guests. She wanted to help her partner tidy the apartment (beyond vacuuming) and move things around to create space, and she wanted to be able to offer drinks and make sure that everyone was comfortable when the guests arrived. Future telepresence home setups could benefit from considering how to support connections with not only one's partner, but also family and friends. This would involve supporting hosting tasks and also supporting joint activities and interactions with more than one person.

Discussion

Unlike previous studies on the use of telepresence robots in the home space (Yang et al., 2017b; Yang & Neustaedter, 2018), we considered ways to provide greater affordances to the telepresence robot embodiment through smart home devices. The following is a discussion of the design implications from our study.

Ownership and Belonging

Our findings reveal how having greater control over a remote home space through a telepresence robot embodiment can create intangible benefits, such as feelings of ownership and belonging. Having control over aspects of the environment, such as how bright the room is, allows the remote partner to make themselves comfortable in the space. This supports long periods of time spent in the shared home space, including time spent there even when the local partner isn't home. Given the ability to clean the shared home space, the remote partner can perform the relationship maintenance behavior of *sharing tasks* and thus maintain closeness with the local partner by jointly caring for the home.

These findings suggest that there is value in designing telepresence home setups that allow the remote partner to contribute to caring for the home. Of course, there are a growing number of smart home devices that might offer the types of support that couples would find valuable for their relationship. We studied only a small number. Regardless, what seems to be most important is that the devices that one is able to make use of when coupled with a telepresence robot are those that maintain relationship consistency. That is, setups will likely be particularly beneficial to couples when the shared tasks that are supported are the same tasks they shared when co-located, thus keeping the relationship dynamic stable. This is consistent with research on relationships transitioning between being long distance and being geographically close which has found that the shock of transitioning can result in breakups (Stafford & Merolla, 2007).

While pairing the telepresence robot with smart home devices allowed the remote user to accomplish more through the telepresence robot embodiment, the lack of appendages still presented challenges. First of all, the remote partner could not troubleshoot if devices malfunctioned, and, secondly, the remote partner could not move anything around. If these types of challenges are to be solved, there is a chance they could require complex robotics engineering as a solution if one was to look at ways of providing the telepresence robot with more capabilities and/or appendages. Alternatively, designers could explore ways of creating smart devices such that they can be further managed while remote, especially in the case of malfunctions. In our case, all devices were controlled via voice through the robot. Designers could explore ways to

couple such controls with ‘backup’ interfaces (e.g., a web portal) if voice activation fails, for example.

A Sense of Normalcy

Another consequence of having an embodied presence which can utilize the amenities in the home is the ability to maintain patterns of co-located living. In our study, the remote partner continued to perform the relationship maintenance behavior of *support* even over distance by turning on the lights at the shared home and greeting the local partner at the door when he arrived home from long work days. The ability to carry over a sense of normality after becoming a long distance couple alleviated some of the stress that came with moving apart. Furthermore, the acts of support were valued by the local partner because they were performed by the remote partner, rather than simply automated. The design implication is that, within the context of long distance relationships, a telepresence home setup should support initiative over automation. Activating devices in the home, whether it’s a coffee machine or a dishwasher, are all opportunities for partners to take action and show care.

We also recognize that what was lacking in our couples’ situation was the ability for the *local* partner to show support for the remote partner. Opportunities for providing support were mostly asymmetrical because the telepresence setup was only in one home and not both. This was done because of the living conditions in the remote home, which was shared. Yet it still raises interesting questions around how designers could create symmetrical setups and how they would be used. Would couples actually want to have telepresence home setups in both locations? Which home would they virtually cohabit, or would it be both? If telepresence setups were in both, would it create too much of a burden for both partners to manage and care for both locations? We leave these questions for future explorations.

Diversity of interactions

Over time, the value of variety became apparent. The same displays of affection became less meaningful when not adapted or personalized. Since we were using devices external to the telepresence robot, we were not limited to the functions of the telepresence robot. During the study, we were able to add devices (printer and sous vide machine) to the telepresence home setup so the couple was able to perform the

relationship maintenance behaviors of *affection* and *joint activities* in a variety of ways. It was found that effort, variety, and personalization were factors that helped to make their interactions more meaningful. These findings suggest that when designing a telepresence system for couples, it could be valuable to support diverse expressions of care that convey effort and allow personalization. This could come from having a variety of devices that one can utilize over time, or the ability to easily add devices when couples begin to feel like interactions are becoming stale or they feel like they want more diversity.

Of course, one would not necessarily want to continue to buy new smart devices to keep having valuable experiences and creating a diversity of interactions. Here we feel what is valuable are smart devices that can support a range of behaviours as a part of relationship maintenance activities. For example, in our case, the printer appeared to work really well because there was nearly an endless amount of things that it could be used for by the couple. That is, the remote person could create any notes or drawings that she liked, and the robot could be moved to nearly any location to leave the note there as it came out of the printer. On the other hand, smart items like lights are relatively fixed when it comes to their usage and could grow stale as a way to show support. Thus, designers could find great value in continuing to explore the design of devices, like the printer, that provide couples with a multitude of possible uses where one can creatively tailor that usage in the moment.

Social Connections

The telepresence home setup was beneficial for the relationship maintenance behavior of *social network* as it allowed the remote partner to maintain social connections with family and friends. However, the remote partner's inability to help host the guests presents a design opportunity. Future home setups could consider how a remote partner may want to be involved in hosting guests and participating in multi-person joint activities. This might involve, for example, further aspects of planning and preparation. We already explored sharing tasks such as vacuuming. Moving beyond this relatively simple activity, one could imagine other acts like checking what groceries are in the fridge remotely (via a smart fridge) and ordering them online for delivery, configuring a music list to play in the home, etc. In terms of multi-person joint activities,

one could imagine activities such as board game playing over distance. Potential design opportunities are endless.

Together our findings demonstrate the advantage of designing a telepresence *system*, rather than thinking of the telepresence robot as a solitary unit. As Broxvall et al. explain, a decentralized system supports “piece-wise development” (Broxvall et al., 2006, p. 213) that can be incrementally worked on. In our case, the voice-controlled devices expanded what the telepresence robot could do without having to solve the complex problem of adding dexterous, load-bearing appendages to telepresence robots, and managing to do so with simple enough controls that there is minimal mental load for controlling the robot. Moreover, this was done at a relatively affordable price.

Perhaps most importantly, our findings point to a direction for designing these devices without necessarily relying on automated initiation. For example, rather than having automated lights that turn on at a certain time, a remote partner can be given the ability to turn on the light for their partner. Long distance relationships benefit from the opportunities to perform actions that show thoughtfulness and caring. While we are not saying that automation should never be used, we are saying that there are places where user control and action can provide additional support for relationship maintenance.

Limitations and Future Work

While autobiographical design allowed for exceptional access to the private home life of a long distance couple, this method has inherent limitations. Firstly, the findings are specific to one couple with a unique relationship dynamic. The dynamics of other couples will certainly differ. As such, our research is best thought of as exploratory where we are able to suggest directions for designers to explore that will likely have promise, given what we saw in our work. It is not the case that what we saw should generalize to other couples as this is not the goal of autobiographical design.

Secondly, self-usage reports often raise concerns about a lack of rigorous data collection and a potential bias towards the success of the system being investigated. Being aware of these concerns, we were very careful to collect extensive data about the couple’s experiences through a variety of data sources. We were also careful to ensure that the researcher had a genuine need for the system, they used the system

extensively, the data was collected in a structured manner, and design implications were reflected on (Neustaedter & Sengers, 2012).

Our study lasted three months, which is not as long as some pieces of autobiographical design research (Neustaedter & Sengers, 2012). This is a fair critique, however, in our situation, studying this couple longer would have been impossible since Tessa returned to her home after three months. Alternatively, we could have studied a different couple over a longer time period, but this would come with the caveat that we would have reduced access to the couple's real activities. For example, with Tessa and Stanley, we were able to capture live video as data for analysis throughout the entire study period. It's unlikely that such data would be available for an external couple.

We also recognize that the telepresence home setup comprised of a small number of smart devices. In choosing the selection of devices, there were pragmatic constraints around concerns of damage to the home (e.g., flooding from a malfunctioning smart dishwasher). That said, we did make sure to choose devices that represented the categories of maintenance behaviors that were particularly limited by traditional computer-mediated communication tools, such as sharing tasks (vacuum) and joint activities (Chromecast and sous vide machine). Of course, there are many more smart devices that we could have chosen, but we wanted to ensure we were authentic in terms of what matched the relationship needs of the couple. The devices we chose were prioritized by their relevancy to the couple in the study, based on data collected from before they became long distance. Other couples may value different ways of showing care, such as preparing coffee in the morning or making the bed, and we see value in exploring more devices in future studies. Other couples may also differ in their desire to explore tools to support sexual intimacy, and future studies focused on this aspect of relationships through telepresence robots may be of interest to this field.

Chapter 6.

Design Considerations

In this chapter, I discuss the design implications resulting from my compilation of studies. In studying real world long distance couples using telepresence robots for communication, my research has identified how this segment of users employs this tool. To begin, my initial study identified how participants used their existing communication tools to understand how telepresence robots fit in to their array of tools. My next study focused on how the physical embodiment and mobility of the telepresence robot influences the performance of joint activities, which is a relationship maintenance behavior that is valued by couples but poorly supported by current communication tools. My final study explored the use of voice-controlled devices to expand the potential for interacting through a telepresence robot and sharing life as a couple over distance. This collection of studies provides insights into the spectrum of activities that long distance couples engage in and explores how these interactions take place through telepresence robots. These findings inform the following design discussion.

6.1. Living Together Through A Telepresence Robot

Having a telepresence robot embodiment in a partner's home has many similarities to living together. Assuming that no restrictions are imposed on call-in times, the remote partner can come and go as they please, which is reminiscent of having a pair of keys to the home. Remote partners can even visit the home when the local partner is not there. This may be especially beneficial for long distance partners that contend with timezone differences and/or different work schedules that result in them being home at different times, because remote partners can spend time in the shared home and feel connected to their partner in their shared private space even when the local partner is not present. The shared home experience is unique to the telepresence robot and is valued by long distance couples who want to feel their loved one's presence in the home. Thus a broad design consideration is – how can we strengthen the feeling of a shared home for telepresence robot communication?

6.1.1. Belonging and Accessibility

In order to support a shared home experience, the home should be welcoming and accessible for both the local partner and the remote partner who experiences the home through a telepresence robot. Studies on telepresence robot usage have long recognized issues with mobility caused by terrain and obstacles as everyday paths contain stairs, doors, etc (E. Paulos & Canny, 1998). Consider that a home may have a set of stairs that prevents the remote partner from ever going to the kitchen on the first floor. Even a slightly raised floor in an apartment can keep a remote user from an entire area in a home. In the context of long distance partner usage, these challenges to mobility can keep partners from sharing parts of their everyday routines, as well as from sharing certain tasks, and actvities with one another.

Currently, in social telepresence robot research, the issue of stairs and other obstacles are often responded to with detection and avoidance (Michaud et al., 2010; K. Tsui & Yanco, 2013), however this does not support accessibility for the remote user. An exception is an early telepresence design utilizing a floating blimp form factor which could simply float over stairs (E. Paulos & Canny, 1996). The blimp had an additional notable benefit for intimate interaction as it could get very close, and even bump into, an interactant without fear or hurting them. However, it was awkward to pilot due to its floaty movements and could carry limited hardware (it did not have a screen) (Eric Paulos & Canny, 1998). Some version of legs may be necessary for traversing stairs. This could require the engineering of balancing mechanisms as weight is shifted from one foot to the other. Perhaps the robot could adopt a shuffling gait to minimize the need for balancing, but also allow the separation of legs for taking stairs. Safety would be of primary concern for designers who may consider retracting the height of the telepresence robot prior to taking stairs as this would lower the center of gravity and also minimize the length of the robot if it falls. Another area of concern would be the maintenance of a simple control interface. Controlling a telepresence robot with more advanced terrain management capabilities would require designers to think about how to keep the controls simple enough that users can keep their focus on the social interactions around them.

Typically increasing accessibility also increases privacy concerns. In the context of couples that live together, privacy concerns are diminished because the nature of the

relationship includes access to intimate knowledge. My studies have found that privacy concerns are instead directed at other people that might also share the home space – roommates or family members. The other members of the home likely do not have an intimate relationship with the remote partner and can reasonably be uncomfortable with the remote partner having access to their home life. Part of the solution is a discussion on boundaries for the remote partner's access to common spaces, such as a shared kitchen, but this is also an area that designers can consider solutions for. For example, could the telepresence robot be mapped to the home and restricted from moving into certain areas without permission from a designated person? Should the telepresence robot make louder noises when moving closer to shared spaces in order to announce the approach?

Summary Point #1: Remote partners using a telepresence robot embodiment should be able to access the different areas of the home. Consideration should be made for the privacy of other people (roommates or family members) sharing the home.

Aside from being able to access different parts of a shared home, partners should be able to use features of the home. For example, if the home is too dark, the remote user should be able to turn on the lights. Being able to adapt the home so that it is comfortable to be in creates a sense of belonging. However, the lack of arms and hands presents limitations to interacting with a home (e.g. switching on/off lights, locking/unlocking the door, turning on/off music, etc). The engineering complexities and cost of designing a telerobotic arm to be safely controlled by a casual remote user has left this feature off of most telepresence robots. Instead, if a social telepresence robot has arms at all, designers have opted for arms limited to the simpler act of gesturing. For example, Paulos and Canny's early telepresence robot design work included an arm with two degrees of freedom and a laser pointer at the end, and this was meant for pointing and conversational gestures (Eric Paulos & Canny, 2001).

Even more recent design solutions remain focused on the more attainable goal of gesturing over object interaction, for example using computer vision to identify a user's arm movements and replicate those with robot arms (Deng et al., 2014). Unlike gesturing, which can be successfully performed with vague movements, object interaction requires accuracy. To perform the simple act of turning a doorknob requires judging distance, manipulating several degrees of freedom at once to wrap a hand

around the doorknob, then applying an appropriate amount of pressure to grip the doorknob, before twisting and pulling. To accomplish this through visual feedback alone, without proprioception and touch sensations would be challenging. Then consider designing a telepresence robot that can also grab the remote control and turn on the TV, grab a speaker knob and turn down the volume, flick a light switch, and the variety of other interactions that one has with the features of a home and the complexity becomes clear. So how do we overcome limitations on interactivity without using arms and hands?

The solution may be to think about the telepresence robot as part of a home system, rather than a new inhabitant placed into an unwelcome environment. Rather than focusing on only redesigning the telepresence robot, designers can think about how to design the home space around the robot. In order to achieve accessibility so that the remote user feels a sense of belonging, designers can consider the design of future home features that can be used by both the remote (telepresence robot) and local (human) users. In my research, I explored the use of voice control as a natural way for both the remote and local users to be able to control features of the home. This opened up new possibilities for sharing a home together, for example the remote user was able to help maintain the home (e.g. vacuuming, checking if doors are locked) and therefore felt a sense of belonging, ownership, and responsibility over the space.

Designers should not only think about how remote users access home features, but also how they experience them. How is the experience of the visual, audial, and tactile feedback? If a remote user turns on the TV, how can we improve the experience of the visual quality through the telepresence robot embodiment? If a remote user turns on music, how can we help the user assess how loud it is for the local interactants? As the possibilities for interactivity increase, researchers may explore further questions. What role might other sensual feedback play? How might these changes influence the experience of sharing a home life together?

Summary Point #2: Home features (e.g. lights, television) should be usable by both local and remote partners. The remote partner should be able to experience the effects of their interactions.

As the remote user's existence in the shared home is through a telepresence robot embodiment, designers can think about how the home might include a dedicated

area for the telepresence robot. Perhaps the docking station where the telepresence robot is recharged can be personalized and placed strategically where the remote user may want to spend time. Maybe there can be a message board where the local user can leave messages that they know the remote user will see. Here the local user can leave notes to show affection, to coordinate activities, etc. This may also be a space where the local partner can see a view of the remote partner's living area, thus gaining understanding and empathy for the remote partner's living situation. Designers should be cognizant of the asymmetry that is created by sharing a single home space when each partner has their own homes.

While a shared home space allows long distance partners to share the intimate details of everyday life, it is the local partner who gets to share these moments with the remote partner who is present through the telepresence robot. For example, the remote partner might be there for the local partner when they wake up and accompany the local partner as they get up and get ready for the day, but the lack of reciprocation may cause issues over time if not recognized and attended to. Expanding the capabilities of a telepresence robot gives the remote partner more ways to care for the local partner than the other way around. Designers should consider ways to support and encourage the local partner to also perform relationship maintenance behaviors, such as spending time with the remote partner's friend and family or helping with tasks in the remote partner's home. For example, Chien's autoethnographical work has explored ways to intimately connect remote homes and one of the systems, called SwitchU, was designed so that paired devices would mimic activity originating from either partners' homes (the first author used this to boil water with kettles) (Chien & Hassenzahl, 2017).

Summary Point #3: Designers should recognize the asymmetrical experience of sharing one home and work to support reciprocation.

6.1.2. Lived-In Feeling

For the local partner, a positive effect of the telepresence robot embodiment is that the remote partner's presence can make the home feel lived-in. This can be beneficial to the local partner's psychological well-being. For example, instead of coming home to a dark and empty space, a local partner might come home from work and find the lights turned on and the remote partner at home hanging out. For the remote partner,

being able to continue sharing a home in this way can also be a source of reassurance amidst the changes of moving away. Designers can think about how to support the comforting atmosphere of a lived-in home. This can mean designing ways to support the feeling that one's partner is at home with you, or that one's partner was home recently.

Consider something as simple as a shared plant that the remote and local partners can both water. Seeing that the plant is freshly watered is like seeing a trace of one's partner's actions. Another idea that has been explored is the recreation of the warmth that a partner's body creates when they lie in bed (Goodman & Misilim, 2003). Imagine that the home registers the activities of the telepresence robot so that traces of these activities are apparent. For example, if the remote partner relaxes at the couch, the couch cushion can warm up in the same way that a human body would warm it up.

Summary Point #4: The teleperesence robot's activities in the home should be apparent, thus creating a "lived-in" feeling.

6.2. Sharing Tasks

As mentioned before, having control over the state of the home can reinstate feelings of ownership and responsibility that might otherwise be lost due to a lack of control over the remote space. As well, when the remote partner contributes to caring for the shared home, this can be an extension of caring for the local partner. On the flip side, the local partner can also clean the home to benefit the remote partner. For example, making sure the floor is clear of obstacles and keeping the home decluttered so there is more room to move around. Thus sharing home tasks provides opportunities for long distance partners to care for one another and also helps the remote partner feel involved with the state of the home. Designers can consider the various upkeep tasks that couples do to maintain a home – vacuuming, washing clothes, washing dishes, and tidying up. How can these tasks be accomplished remotely through a telepresence robot embodiment? I explore the topic of sharing tasks in the following section.

6.2.1. Showing Care Through Helping

Partners living over distance can feel that they are unable to help their partners and this can be frustrating. For example, watching one's partner struggle with moving a

heavy piece of furniture can elicit feelings of helplessness. Remote partners in my study on shopping together over distance repeatedly expressed their desire to help their partner carry items, but could only watch as their partners juggled items. Designers can think about the types of everyday tasks that partners may want to help each other with (for example, being able to help check if the doors are locked each night, being able to help carry a plate to the table, etc.) and how to design a telepresence robot system that can help with these things. Aside from sharing cleaning tasks, partners may also want to share other responsibilities, such as the care and training of a pet. For example, Chien described in his autoethnographical paper that he would remotely turn the lights on for his partner's dog and also designed a remote feeder to help her feed the dog (Chien & Hassenzahl, 2017). Being aware of the dog's needs and working together with his partner to help take care of those needs helped the author feel close to his partner and her beloved pet (Chien & Hassenzahl, 2017).

While smart home devices can be set to operate at predetermined times and conditions, my research has found that automation takes away opportunities for long distance partners to do things for each other. Relationship literature identifies sharing tasks as a form of relationship maintenance (Stafford, 2005). Designers should consider the idea of initiation over automation when it comes to designing technology for long distance couples. Partners should have ample opportunities to show they care. For example, rather than have an automated vacuum cleaner that runs every 2 weeks, partners should be able to take the initiative of running the vacuum cleaner as a relationship maintenance behavior.

Summary Point #5: When home devices are activated by the remote partner, the thought and effort associated with the action is meaningful. Therefore, opt for supporting initiation over automation.

6.2.2. Ownership and Responsibility

The ability to participate in maintaining a home can provide a sense of ownership and responsibility over the space. Designers can think about how to generate a sense of home pride by supporting the remote partner in being able to appreciate the outcome of their efforts. For example, if a remote partner initiates the vacuum cleaner, their camera resolution should be high enough to see the difference from before and after the

cleaning session. Perhaps additional information can be displayed for the remote user, such as a dust meter to provide feedback regarding the cleaning. Such feedback can make the actions more rewarding even over distance.

Designers should also think about how remote partners might troubleshoot issues remotely. For example, if the vacuum gets trapped on a wire or caught in a corner, how might the remote partner be able to respond? If an appliance malfunctions, what steps can be taken remotely to minimize damage? Such questions are particularly important when an appliance can cause severe damage upon malfunction, such as a dishwasher which can cause costly water damage upon leakage.

Summary Point #6: Given the ability to control home devices, remote partners can feel a sense of ownership and responsibility in maintaining the home. Designers should consider how to support remote troubleshooting when devices malfunction.

6.3. Intimacy

For couples, it is important to be able to show affection. Examples of devices designed for this include WearLove (which allows partners to send heart symbols to one another's wristbands) (Joi et al., 2015), Virtual Intimate Object (which lets partners activate a red dot in their partner's computer task bar) (Kaye et al., 2005), and Cubble (which allows partners to communicate affection through light, vibration, and heat) (Kowalski et al., 2013). Designers should consider how partners can show affection through a telepresence robot embodiment.

6.3.1. Physical Affection

My research has found that local partners are physically affectionate with their remote partners by interacting with the telepresence robot embodiment. One local partner noted how the warmth of the telepresence robot's screen was comforting when she hugged the embodiment, but also that the hug would have felt better if the embodiment was softer. Since romantic partners can get very physically close when interacting, designers should think about how to mediate intimate interactions. For example, different materials can be considered for the surface of the telepresence robot to make the body softer to touch. As well, different methods of stimulating touch can be

considered, such as warmth, vibration (Singhal et al., 2017), or heartbeat pulsation. For the remote partner, even without feeling touch, it's possible to feel affection just from seeing that one is being touched. However, the limited field of view means that touches on area such as the top of the head or the back of the body can be missed. Thus designers should think of other ways to signal to the remote partner that they are being touched when they cannot see it. On the discussion of closeness, it will also be important for designers to consider how remote partners can move closer to their partners without risk of injury. Telepresence robots need to be able to ease their speed down to a crawl, rather than only being able to start and stop abruptly. As well, the height of the telepresence robot should be adjustable so that partners can stay close to eye level when standing, sitting, or lying down.

Summary Point #7: The telepresence robot embodiment can mediate the sense of touch between partners. Designers should consider ways to enhance this sensation through material choices that evoke warmth and softness.

6.3.2. Non-Physical Affection

Designers should explore opportunities for expressing non-physical forms of affection through telepresence robots. Regarding the expression of affection, my research reports the importance of variety and effort. When affection is repeatedly shown in the same way, it can become routine and lose meaning. Therefore designers can consider how to take advantage of the mobility of the telepresence robot embodiment to support partners in expression affection in different areas of the home. For example, affection may be shown by leaving notes on your partner's pillow, or preparing a hot pot of tea in the morning, or playing their favorite song when they get home, or in any number of ways. In one study, I attached a printer to the telepresence robot embodiment so that personalized cards could be printed out and left for the local partner to find. This design proved to be effective in how flexibly it allowed the remote partner to express affection through different card designs and card placements.

Summary Point #8: In designing methods to express affection, it is important to support variety as the same expression of affection can lose meaning over time.

6.4. Joint activities

Designers should also think about joint activities that partners do to spend time with one another. One such activity is cooking. Long distance partners can either cook in parallel in their respective homes or work on the same meal together. When cooking in parallel, the advantage is that both partners can eat the same meal. However, long distance partners might live in cities with differing access to ingredients and cooking appliances. Thus, couples may choose to work together on the same meal. How can a telepresence robot embodiment support this type of activity? Given the current design, remote partners can move around the kitchen and offer cooking tips or help with reading the recipe. Using a telepresence robot alongside voice controlled kitchen appliances could expand the ways that the remote partner can be involved in the cooking process. For example, the remote partner may be able to set the temperature of boiling water, start preheating the oven, etc.

Currently, long distance partners are limited in the types of joint activities they can engage in. Even with a telepresence robot embodiment, partners remain limited by the simplistic form factor. Out of 143 artifacts identified by a review paper on mediating intimacy, only four were designed for joint action (Chien et al., 2016; Hassenzahl et al., 2012). For example, Lover's Cup includes a set of cups that glow most brightly when both partners are drinking from them at the same time (Chung et al., 2006). The review noted that more complicated joint activities, such as cooking and cleaning were not supported by any of the reviewed work (Hassenzahl et al., 2012). However, thinking about the telepresence robot as part of a system that works in tangent with smart objects around it can potentially expand the complexity and variety of couple's interactions over distance. Designers should think about how telepresence robots paired with complementary devices can support activities such as playing board games, working on art projects together, etc.

Summary Point #9: Thinking about the telepresence robot as part of a system that works in tangent with smart objects around it can expand the possibility of interactions over distance.

When doing joint activities, partners are often oriented side-by-side. Current telepresence robot designs are not optimized for interacting when side-by-side, since the

field of view can limit the remote partner from seeing their partner beside them, and the local partner is only able to see the side of the remote partner's screen. Various solutions can be considered to better support side-by-side interactions. For example, the screen of the telepresence robot can be curved to accommodate viewing from the side, and the the FOV can be expanded. The ability to turn the telepresence robot "head" from side to side can also help partners occassionally make eye contact while standing or sitting side-by-side.

Summary Point #10: Joint activities are often performed side-by-side rather than face-to-face so telepresence robot design should allow partners to see each other when side-by-side.

Couples not only want to do activities together at home, they also want to go out. For example, when couples are together in person they can go for walks and go out for dinner. However, while the physical embodiment of the telepresence robot grants mobility, it detracts from portability. Telepresence robots can be large and heavy so they are not easy to transport to be used In different places. This was a limiting factor for participants in my study on shopping as a joint activity. When we asked participants whether they could see themselves going out to shop together with the telepresence robot again, participants felt that transporting the telepresence robot would be too cumbersome. Furthermore, the need for a reliable internet connection makes outside usage difficult. Designing for use outside of the home will involve overcoming these issues. Currently, using telepresence robots in public places also attracts a lot of bystander attention that can make certain users uncomfortable (Heshmat et al., 2018). In my shopping study, which took place in a mall, I observed that most interactions were friendly, but very occassionally bystanders did respond with distrust. Furthermore, even positive interactions can be unwanted for couples that want to spend time together without intrusions. Researching public attitudes towards this technology may help designers uncover design elements that deter more negative responses and unwanted interactions.

Summary Point #11: Designing telepresence robots for use outside of the home will necessitate an understanding of public attitudes towards this technology and designing to mitigate negative interactions.

6.5. Connecting with Friends and Family

One social advantage of the telepresence robot embodiment is that it promotes acknowledgment and interactions with people around it. In contrast, with video chat, remote callers may not be acknowledged and engaged with by family and friends sharing the space with the local partner. Thus telepresence robots are suitable for supporting remote partners in making and keeping a connection with friends and family visiting the shared home. Designers can think about how to involve remote partners in hosting activities, such as prepping the home for guests and making them comfortable upon arrival. This might involve cleaning, preparing food, and moving some furniture around to accommodate more people in the space.

Thus far I have discussed joint activities for two people, but designers should also think about setups that support multi-person joint activities, so that remote partners can participate in group interactions when friends and family visit. Maintaining a relationship with a partner's social network is a part of relationship maintenance (Stafford, 2005). For example, family may come over for dinner, especially to celebrate special occassions like birthdays. The telepresence embodiment should allow head turning so that the remote user can quickly redirect attention to different people. The head orientation will also help group members understand where the remote's attention is directed. For group activities centered on television screens (for example watching a movie or playing co-op video games) it will be important for the remote partner to be able to see the screen and hear the audio with minimal distortion.

Summary Point #12: As staying connected with a loved one's family and friends is important, designers should also consider designing for interacting in group scenarios.

Chapter 7.

Conclusions

This thesis presents the research and findings on telepresence robot communication in long distance relationships. The goal of this work was to explore the use of telepresence robots for supporting long distance relationships. This research was undertaken in a series of three studies. In this final chapter, I summarize the resulting contributions of this work. The findings contribute to informing future designs of telepresence robots to support long distance relationship communication. Findings may also more broadly contribute to understanding of telepresence robot use in the home space, and for personal communication between famly and friends.

The overarching research goal for this body of work is to understand ***how long distance partners use telepresence robots to maintain their relationships and share life, and how future design work may improve their experience.*** The following research questions were investigated, leading to the research contributions presented in this chapter.

Research Question 1

How do long distance couples use telepresence robots in the home and what are the benefits and challenges that come from such usage?

Research Question 2

How does a telepresence robot support or hinder couples in performing the act of shopping as a relationship maintenance behavior and how do the experiences of using a telepresence robot while shopping compare to using video chat on a tablet?

Research Question 3

How does the ability to affect the shared home environment influence the experience of sharing a home through a telepresence robot as part of a long distance relationship?

7.1. Contributions

Research Objective 1: To gain early insights into the use of telepresence robots in the context of long distance couples' communication.

Research Question 1: How do long distance couples use telepresence robots in the home and what are the benefits and challenges that come from such usage?

I conducted a field study with seven long distance couples, each using a telepresence robot for one month. Data was collected through semi-structured interviews at the beginning, middle, and end of the monthlong usage periods. The transcribed interviews were coded to reveal themes for understanding the data.The following are the contributions of this work:

This work identified patterns of telepresence robot usage by long distance couples. This research revealed that telepresence robots tend to be used during evenings and weekends, which are times when couples would often be together in-person. This finding provides us with an understanding of the types of activities that should be considered in designing a telepresence robot for long distance relationship communication. The types of activities that happen during evenings and weekends include resting at home, completing chores, having meals, enjoying entertainment, going out together, being intimate, working on hobbies, spending time with friends and family, etc. Many of the technologies targeted towards supporting long distance partners have focused on a display of affection while other aspects of connecting to one's partner remain neglected. Other relationship maintenance behaviors such as sharing activities and doing joint activities have been poorly supported, but my work explores how these everyday interactions are experienced through a telepresence robot.

In my study, participants engaged in everyday routines through the telepresence robot. Interviews revealed that the current telepresence robot design lets remote partners accompany their partners during activities such as cleaning or cooking and also offer advice and conversation. This work shows that couples value being able to share these mundane moments of everyday life. While parts of everyday routines (such as getting dressed in the morning) may be too unimportant to talk about, experiencing these small moments of everyday life fosters an intimate connection.

My work also informs the field of telepresence robot research to break away from the standard face-to-face orientation in interactions. This is a significant change from the longstanding conventions of video chat. My research has found that the face-to-face orientation of traditional video chat is not ideal for always-on usage as it creates a pressure to keep talking, rather than allowing partners to relax with one another. This highlights the importance of designing to support side-by-side interactions, which allows partners to see one another from the corner of the eye or by head-turning. This means that the typical design of a flat screen as the "head" of the telepresence robot is not ideal as a local partner can not look over and see their partner's face from the side.

This research also found that having a telepresence robot emobdiment creates opportunities to connect with friends and family. Maintaining a relationship with one's partner's loved ones is part of relationship maintenance as established by relationship literature (Stafford, 2005). Similar to telepresence robot research in the workplace context where colleagues would have spontaneous meetings in hallways (Lee & Takayama, 2011), a remote partner can spontaneously encounter family members living in the same household as the local partner and have a conversation. Remote partners can also spend time with visiting friends. Furthermore, the local partner can also form a deeper connection with the remote partner's family. In my study, one remote partner's mother was able to "visit" the local partner's home through the telepresence robot and get a sense of how we was living.

Research Objective 2: To explore how telepresence robot interaction can be extended outside of the home space to support relationship maintenance through a joint activity.

Research Question 2: How does a telepresence robot support or hinder couples in performing the act of shopping as a relationship maintenance behavior and how do the experiences of using a telepresence robot while shopping compare to using video chat on a tablet?

I conducted a between groups study with seven couples using a telepresence robot and seven couples using a tablet to distill the influence of having a physical embodiment and mobility on performing the activity. Data collection came from observations and interviews, and open, axial, and selective coding were performed to

analyze the transcribed interviews, with the observations (captured as notes and video) available for reference. The following are the contributions of this work:

This work identified how the factors of physical embodiment and mobility contribute to the experience of a common joint activity (i.e. shopping). I found that using the telepresence robot allowed the remote partner's personality to emerge through their movements. The local partner could recognize their partner's traits, such as independence or clumsiness, when interacting through the telepresence robot. Furthermore, since both partners could move around freely, they behaved more playfully. Thus the support of personality and playfulness are positive effects of doing joint activities together through a telepresence robot. Couples in the tablet condition were more task-focused than partner-focused.

By choosing a joint activity which involves joint decision-making, my study reveals power dynamics resulting from using a telepresence robot compared to a tablet. My observations found that those in the tablet condition were more likely to override the remote partner's ideas about which items to buy. Furthermore, those in the tablet condition were only shown items that the local partner was showing them, while those in the telepresence condition could go off to look at other items. Within the telepresence robot condition there was also also a power differential between the local person and the remote user who was limited by the telepresence robot embodiment, which could not move or see as well as the local partner. The relationship was even described by participants as a pet (remote partner using telepresence robot) and owner (local partner) relationship as issues with the telepresence robot (such as resolution drops and loss of connection) left the remote user dependent on the local partner. Asking the couples which partner would be responsible if the remote user accidentally broke something in a store with the telepresence robot revealed a difference in opinion. Most remote partners felt responsible for the outcomes of their own actions, while all the local partners felt that they were responsible for their remote partner's actions. This difference of opinion was based on differences in the perceived capability of the remote user in navigating the local environment.

The real world setting revealed public attitudes towards telepresence robots, which constituted mostly curiosity and amusement, with few negative interactions. This contrasts with the focus on negative interactions found in another study where a

telepresence robot was used in public during an outdoor geocaching task (Heshmat et al., 2018). This difference in attitudes in the city park context versus the mall context shows that public attitudes towards telepresence robots are complex and can depend on contextual factors. Furthermore, this research also showed how remote users respond to bystander attention. I found that the response to attention was dependent on the participant's personality, ranging from outgoing partners who enjoyed the interactions and more reserved partners who disliked the attention. Regardless of the participant's attitude towards the attention, it did detract from the partners focusing on one another in what was meant to be a joint activity for relationship maintenance.

A similar topic to bystander *attention* is bystander *acknowledgement*. When shopping through a telepresence robot, the remote partner's presence was acknowledged by other people in the mall. For example, store clerks would speak directly to the remote partner in the telepresence robot embodiment, whereas in the tablet condition the remote users were largely left out of local interactions. This acknowledgment means that remote partners can experience greater involvement and inclusion when present through a telepresence robot compared to a tablet.

Research Objective 3: To explore how the experience of sharing home life through a telepresence robot might be enriched through voice-controlled home devices.

Research Question 3: How does the ability to affect the shared home environment influence the experience of sharing a home through a telepresence robot as part of a long distance relationship?

I conducted a three month autobiographical design study. Multiple data sources were used, including diary logs, interviews, and video/photo documentation. Analysis involved coding maintenance behaviors in the diary logs and transcribed interviews, then gathering quotes regarding the benefits and challenges that emerged. The following are the contributions of this work:

Recognizing the persistent limitations of the appendage-free design of current socially-oriented telepresence robots, I explored the use of voice-controlled device in tandem with telepresence robots. This work showed that expanding the capabilities of the telepresence robot to be able to control features of the home can instill feelings of belonging and ownership towards the home. The simple act of being able to turn on the

lights allows the remote partner to be in the shared home and adjust the lighting to their liking even when the local partner is not home. Furthermore, through voice-control, both local and remote partners can take part in caring for the shared home and feeling a sense of ownership over the space.

This work stresses the importance of supporting variety in long distance relationship communication. Couples should be able to show affection in a variety of ways as repeating the same display of affection every day can cause the display to lose meaning over time. As well, couples want to be able to do activities together and should be given options for some activities they can do together over distance, such as cooking a meal or playing a board game. Designers should think of solutions for showing affection or doing activities together that can flexibly support novel expressions. For example, a system that lets partners draw cards for one another is more flexible than a system that only lets partners send heart emoticons to each other, and this can support longer term meaningful usage.

In Chapter 6, I contributed an in depth design discussion based on findings from my studies. Twelve design suggestions were presented, accompanied by supporting evidence from my studies and rationale based on existing literature. These design suggestions covered the topics of accessibility, reciprocation, task-sharing, intimacy, joint activities, and group interactions. Specific to the context of sharing life together as a couple through a telepresence robot, my design suggestions offer new considerations not touched upon by design guidelines born from other contexts.

7.2. Future Work

Given the early exploratory nature of my work, there is much room for future research. Here, I identify the areas where I believe additional research will be beneficial to our understanding of how the use of telepresence robots may have a positive or negative impact on long distance relationships.

Future work can explore additional ways for expanding the capabilities of the telepresence robot by thinking of it as a part of a system rather than a standalone device. In my autobiographical design study, I explored the use of voice-controlled devices alongside the telepresence robot embodiment to create greater opportunities for

interacting with my home and partner. Voice control allowed device interactions to be accomplished without appendages, while also bypassing any need for complicating the controls of the telepresence robot. I find Kaptelinin et al.'s terminology of "contactless object manipulation" descriptive for this form of interaction (Kaptelinin et al., 2017). Future research can explore the contactless control of many more devices. My choice of devices represented things important in my relationship with my partner and each couple has its own idiosyncrasies. Thus researchers and designers should identify the needs and desires of different long distance couples and implement devices to work alongside a telepresence robot. This research can uncover the unique benefits and challenges that arise with different devices used by different couples. I conceptualize ubiquitous computing in the home which supports a lived-in feeling where the telepresence robot is present. I conceptualize a home that is integrated with the telepresence robot in a way which reflects the remote user's activities around the home. For example, if the telepresence robot has been near the couch, the cushion warms up to reflect that someone spent time there. Researchers and designers can further explore factors such as the limitations of contactless interactions, methods for remote troubleshooting, and solutions for reciprocation.

Another important area for future research in this area is the consequences of long term telepresence robot usage. My longest term study lasted for three months. Longer term studies will be needed to understand how asymmetry might affect relationships over time. Although asymmetry did not arise as a prominent issue in my work, there is the potential for this to have an effect on long distance relationships that we don't yet understand. The asymmetry becomes even more drastic when the telepresence robot is paired with other devices, allowing the remote user to perform more relationship maintenance behaviors than the other, and also establishing the local home as the shared home. Likely this asymmetry will have different effects with different relationship dynamics.

Telepresence robots also have the potential for supporting couples' joint activities in public spaces, both indoors and outdoors. My research has found that interacting through a telepresence robot supports partner-focused and playful participation in activities, but interactivity remains limited. Integration of telepresence robot technology with other emerging technologies, such as augmented reality may open up possibilities for joint activities like board games that can be experienced in a shared space between

local interactants and a remote telepresence robot user. Another fruitful area of research and design may be to reconsider the form factor of the telepresence robot for portability and navigation of outdoor terrain features. Public excursions with a telepresence robot may become more common over time with improvements in internet connectivity and lowered data rates. Optimization for use outside the home will allow long distance partners to enjoy going out together, for example partners may go shopping at the mall or visit an art gallery.

7.3. Final Words

The studies included in this thesis are exploratory field studies of telepresence robot research usage in the context of long distance relationship maintenance. Based on the findings from this collection of studies this work presents a design discussion regarding telepresence robot design for long distance relationship communication. Design considerations are offered to guide telepresence robot design for supporting relationship maintenance behaviors, such as sharing tasks, sharing activities, doing joint activities, showing affection, and social networking with the partner's friends and family. Across the three studies, the limitation of the appendage-free telepresence robot design was apparent, and this led to my exploration of pairing the telepresence robot with voice-controlled devices in the home. This complementary pairing showed the potential of sharing a home through a telepresence robot. Overall, this work represents a new perspective on telepresence robot research and design from the standpoint of long distance couples.

References

Aaltonen, I., Niemelä, M., & Tammela, A. (2017). Please Call Me?: Calling Practices with Telepresence Robots for the Elderly. *Proceedings of the Companion of the 2017 ACM/IEEE International Conference on Human-Robot Interaction - HRI '17*, 55–56. https://doi.org/10.1145/3029798.3038396

Adalgeirsson, S. O., & Breazeal, C. (2010). *MeBot: A robotic platform for socially embodied telepresence*. 15–22. https://doi.org/10.1109/HRI.2010.5453272

Aguila, A. P. N. (2011). Living long-distance relationships through computer-mediated communication. *Social Science Diliman*, *5*(1 & 2). http://journals.upd.edu.ph/index.php/socialsciencediliman/article/viewArticle/2045

Bales, E., Li, K. A., & Griwsold, W. (2011). *CoupleVIBE: Mobile implicit communication to improve awareness for (long-distance) couples*. 65. https://doi.org/10.1145/1958824.1958835

Beer, J. M., & Takayama, L. (2011). Mobile remote presence systems for older adults: Acceptance, benefits, and concerns. *In Proceedings of the 6th International Conference on Human-Robot Interaction*, 8.

Bloss, R. (2011). High school student goes to class robotically. *Industrial Robot: An International Journal*, *38*(5), 465–468. https://doi.org/10.1108/01439911111154027

Broxvall, M., Gritti, M., Saffiotti, A., Beom-Su Seo, & Young-Jo Cho. (2006). PEIS Ecology: Integrating robots into smart environments. *Proceedings 2006 IEEE International Conference on Robotics and Automation, 2006. ICRA 2006.*, 212–218. https://doi.org/10.1109/ROBOT.2006.1641186

Brubaker, J. R., Venolia, G., & Tang, J. C. (2012). Focusing on shared experiences: Moving beyond the camera in video communication. *Proceedings of the Designing Interactive Systems Conference*, 96–105. http://dl.acm.org/citation.cfm?id=2317973

Buhler, T., Neustaedter, C., & Hillman, S. (2013). How and why teenagers use video chat. *Proceedings of the 2013 Conference on Computer Supported Cooperative Work*, 759–768. http://dl.acm.org/citation.cfm?id=2441861

Bureau, U. C. (n.d.). *Subject Definitions*. Retrieved December 11, 2016, from https://www.census.gov/programs-surveys/cps/technical-documentation/subject-definitions.html

Canary, D. J., Stafford, L., Hause, K. S., & Wallace, L. A. (1993). An inductive analysis of relational maintenance strategies: Comparisons among lovers, relatives, friends, and others. *Communication Research Reports*, *10*(1), 3–14. https://doi.org/10.1080/08824099309359913

Cesta, A., Cortellessa, G., Orlandini, A., & Tiberio, L. (2016). Long-Term Evaluation of a Telepresence Robot for the Elderly: Methodology and Ecological Case Study. *International Journal of Social Robotics*, *8*(3), 421–441. https://doi.org/10.1007/s12369-016-0337-z

Chien, W.-C., & Hassenzahl, M. (2017). Technology-Mediated Relationship Maintenance in Romantic Long-Distance Relationships: An Autoethnographical Research through Design. *Human–Computer Interaction*, 1–48. https://doi.org/10.1080/07370024.2017.1401927

Chien, W.-C., Hassenzahl, M., & Welge, J. (2016). Sharing a Robotic Pet as a Maintenance Strategy for Romantic Couples in Long-Distance Relationships.: An Autobiographical Design Exploration. *Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems - CHI EA '16*, 1375–1382. https://doi.org/10.1145/2851581.2892313

Chung, H., Lee, C.-H. J., & Selker, T. (2006). Lover's cups: Drinking interfaces as new communication channels. *CHI '06 Extended Abstracts on Human Factors in Computing Systems - CHI EA '06*, 375. https://doi.org/10.1145/1125451.1125532

Cohen, S. (2004). Social Relationships and Health. *American Psychologist*, 9.

Coyne, S. M., Stockdale, L., Busby, D., Iverson, B., & Grant, D. M. (2011). "I luv u:)!": A descriptive study of the media use of individuals in romantic relationships. *Family Relations*, *60*(2), 150–162.

Creswell, J. W. (2013). *Qualitative inquiry and research design: Choosing among five approaches / John W. Creswell.* (3rd ed.). Los Angeles : SAGE Publications.

Dainton, M., & Aylor, B. (2001). A relational uncertainty analysis of jealousy, trust, and maintenance in long-distance versus geographically close relationships. *Communication Quarterly*, *49*(2), 172–188. https://doi.org/10.1080/01463370109385624

Dainton, M., & Aylor, B. (2002). Patterns of communication channel use in the maintenance of long-distance relationships. *Communication Research Reports*, *19*(2), 118–129. https://doi.org/10.1080/08824090209384839

Deng, C., Lu, J., & Lam, T. L. (2014). Real-time vision-based telepresence robot hand control. *2014 IEEE International Conference on Robotics and Biomimetics (ROBIO 2014)*, 463–468. https://doi.org/10.1109/ROBIO.2014.7090374

Desai, M., Tsui, K. M., Yanco, H. A., & Uhlik, C. (2011). Essential features of telepresence robots. *2011 IEEE Conference on Technologies for Practical Robot Applications*, 15–20. http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=5753474

Dix, A. (1998). *Human-Computer Interaction* (2nd ed.). Prentice Hall Europe.

Du Bois, S. N., Sher, T. G., Grotkowski, K., Aizenman, T., Slesinger, N., & Cohen, M. (2016). Going the Distance: Health in Long-Distance Versus Proximal Relationships. *The Family Journal*, *24*(1), 5–14. https://doi.org/10.1177/1066480715616580

Ellison, L. M., Pinto, P. A., Kim, F., Ong, A. M., Patriciu, A., Stoianovici, D., Rubin, H., Jarrett, T., & Kavoussi, L. R. (2004). Telerounding and patient satisfaction after surgery. *Journal of the American College of Surgeons*, *199*(4), 523–530. https://doi.org/10.1016/j.jamcollsurg.2004.06.022

Field, T. (2014). *Touch*. MIT Press. http://ebookcentral.proquest.com/lib/sfu-ebooks/detail.action?docID=3339875

Forghani, A., Venolia, G., & Inkpen, K. (2014). *Media2gether: Sharing Media during a Call*. 142–151. https://doi.org/10.1145/2660398.2660417

Gooch, D., & Watts, L. (2011). *A Design Framework for Mediated Personal Relationship Devices*. 6.

Goodman, E., & Misilim, M. (2003). The Sensing Beds. *Ubicomp 2003 Workshop*, 3.

Grivas, K. (2006). Digital Selves: Devices for intimate communications between homes. *Personal and Ubiquitous Computing*, *10*(2–3), 66–76. https://doi.org/10.1007/s00779-005-0003-1

Guerrero, L. K., Eloy, S. V., & Wabnik, A. I. (1993). *Linking maintenance strategies to relationship development and disengagement: A reconceptualization*. *10*, 273–283.

Gunraj, D. N., Drumm-Hewitt, A. M., Dashow, E. M., Upadhyay, S. S. N., & Klin, C. M. (2016). Texting insincerely: The role of the period in text messaging. *Computers in Human Behavior*, *55*, 1067–1075. https://doi.org/10.1016/j.chb.2015.11.003

Guth, L., & Vander Meer, P. (2017). Telepresence robotics in an academic library: A study of exposure and adaptation among patrons and employees. *Library Hi Tech*, *35*(3), 408–420. https://doi.org/10.1108/LHT-03-2017-0059

Hampton, A. J., Rawlings, J., Treger, S., & Sprecher, S. (2017). Channels of computer-mediated communication and satisfaction in long-distance relationships. *Interpersona: An International Journal on Personal Relationships*, *11*(2), 171–187. https://doi.org/10.5964/ijpr.v11i2.273

Harper, R., Rintel, S., Watson, R., & O'Hara, K. (2017). The 'interrogative gaze': Making video calling and messaging 'accountable.' *Pragmatics*, *27*(3), 319–350. https://doi.org/10.1075/prag.27.3.02har

Hassenzahl, M., Heidecker, S., Eckoldt, K., Diefenbach, S., & Hillmann, U. (2012). All You Need is Love: Current Strategies of Mediating Intimate Relationships through Technology. *ACM Transactions on Computer-Human Interaction*, *19*(4), 1–19. https://doi.org/10.1145/2395131.2395137

Herring, S. C. (2013). Telepresence robots for academics: Telepresence Robots for Academics. *Proceedings of the American Society for Information Science and Technology*, *50*(1), 1–4. https://doi.org/10.1002/meet.14505001156

Heshmat, Y., Jones, B., Xiong, X., Neustaedter, C., Tang, A., Riecke, B. E., & Yang, L. (2018). Geocaching with a Beam: Shared Outdoor Activities through a Telepresence Robot with 360 Degree Viewing. *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems - CHI '18*, 1–13. https://doi.org/10.1145/3173574.3173933

Hillman, S., & Neustaedter, C. (2017). Trust and mobile commerce in North America. *Computers in Human Behavior*, *70*, 10–21. https://doi.org/10.1016/j.chb.2016.12.061

Hillman, S., Neustaedter, C., Bowes, J., & Antle, A. (2012). Soft trust and mCommerce shopping behaviours. *Proceedings of the 14th International Conference on Human-Computer Interaction with Mobile Devices and Services - MobileHCI '12*, 113. https://doi.org/10.1145/2371574.2371593

Hillman, S., Neustaedter, C., Pang, C., & Oduor, E. (2013). "Shared joy is double joy": The social practices of user networks within group shopping sites. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems - CHI '13*, 2417. https://doi.org/10.1145/2470654.2481335

Hindus, D., Mainwaring, S. D., Leduc, N., Hagström, A. E., & Bayley, O. (2001). *Casablanca: Designing social communication devices for the home*. 325–332. https://doi.org/10.1145/365024.383749

Holtzman, S., DeClerck, D., Turcotte, K., Lisi, D., & Woodworth, M. (2017). Emotional support during times of stress: Can text messaging compete with in-person interactions? *Computers in Human Behavior*, *71*, 130–139. https://doi.org/10.1016/j.chb.2017.01.043

Inkpen, K., Taylor, B., Junuzovic, S., Tang, J., & Venolia, G. (2013). Experiences2Go: Sharing kids' activities outside the home with remote family members. *Proceedings of the 2013 Conference on Computer Supported Cooperative Work*, 1329–1340. http://dl.acm.org/citation.cfm?id=2441926

Janning, M., Gao, W., & Snyder, E. (2018). Constructing Shared “Space”: Meaningfulness in Long-Distance Romantic Relationship Communication Formats. *Journal of Family Issues*, *39*(5), 1281–1303. https://doi.org/10.1177/0192513X17698726

Johnson, A. J., Haigh, M. M., Becker, J. A. H., Craig, E. A., & Wigley, S. (2008). College Students’ Use of Relational Management Strategies in Email in Long-Distance and Geographically Close Relationships. *Journal of Computer-Mediated Communication*, *13*(2), 381–404. https://doi.org/10.1111/j.1083-6101.2008.00401.x

Johnson, S., Rae, I., Mutlu, B., & Takayama, L. (2015). *Can You See Me Now?: How Field of View Affects Collaboration in Robotic Telepresence*. 2397–2406. https://doi.org/10.1145/2702123.2702526

Joi, Y. R., Jeong, B. T., Kim, J. H., Park, K. H., Lee, T., & Cho, J. D. (2015). *WearLove: Affective Communication via Wearable Device with Gamification*. 559–564. https://doi.org/10.1145/2793107.2810337

Jones, B., Witcraft, A., Bateman, S., Neustaedter, C., & Tang, A. (2015). *Mechanics of Camera Work in Mobile Video Collaboration*. 957–966. https://doi.org/10.1145/2702123.2702345

Jouppi, N. P. (2002). First steps towards mutually-immersive mobile telepresence. *Proceedings of the 2002 ACM Conference on Computer Supported Cooperative Work*, 354–363. http://dl.acm.org/citation.cfm?id=587128

Judge, T. K., & Neustaedter, C. (2015). *Studying and designing technology for domestic life: Lessons from home*. Elsevier/MK.

Judge, T. K., & Neustaedter, C. (2010). Sharing conversation and sharing life: Video conferencing in the home. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 655–658. http://dl.acm.org/citation.cfm?id=1753422

Kaptelinin, V., Björnfot, P., Danielsson, K., & Wiberg, M. U. (2017). Mobile Remote Presence Enhanced with Contactless Object Manipulation: An Exploratory Study. *Proceedings of the 2017 CHI Conference Extended Abstracts on Human Factors in Computing Systems - CHI EA ’17*, 2690–2697. https://doi.org/10.1145/3027063.3053204

Kaye, J. “Jofish,” Levitt, M. K., Nevins, J., Golden, J., & Schmidt, V. (2005). *Communicating intimacy one bit at a time*. 1529. https://doi.org/10.1145/1056808.1056958

Kim, H., Kim, G. J., Park, H. W., & Rice, R. E. (2007). Configurations of Relationships in Different Media: FtF, Email, Instant Messenger, Mobile Phone, and SMS. *Journal of Computer-Mediated Communication*, *12*(4), 1183–1207. https://doi.org/10.1111/j.1083-6101.2007.00369.x

Kim, S., Junuzovic, S., & Inkpen, K. (2014). *The Nomad and the Couch Potato: Enriching Mobile Shared Experiences with Contextual Information*. 167–177. https://doi.org/10.1145/2660398.2660409

Kimura, A., Ihara, M., Kobayashi, M., Manabe, Y., & Chihara, K. (2007). Visual feedback: Its effect on teleconferencing. *International Conference on Human-Computer Interaction*, 591–600. http://link.springer.com/chapter/10.1007/978-3-540-73111-5_67

Kirk, D. S., Sellen, A., & Cao, X. (2010). Home video communication: Mediating "closeness." *Proceedings of the 2010 ACM Conference on Computer Supported Cooperative Work*, 135–144. http://dl.acm.org/citation.cfm?id=1718945

Knox, D., Zusman, M. E., Daniels, V., & Brantley, A. (2002). Absence Makes the Heart Grow Fonder?: Long Distance Dating Relationships Among College Students. *College Student Journal*, *36*(3), 364.

Koceski, S., & Koceska, N. (2016). Evaluation of an Assistive Telepresence Robot for Elderly Healthcare. *Journal of Medical Systems*, *40*(5). https://doi.org/10.1007/s10916-016-0481-x

Kowalski, R., Loehmann, S., & Hausen, D. (2013). *cubble: A multi-device hybrid approach supporting communication in long-distance relationships*. 201. https://doi.org/10.1145/2460625.2460656

Kristoffersson, A., Coradeschi, S., & Loutfi, A. (2011). Towards evaluation of social robotic telepresence based on measures of social and spatial presence. *Human Robot Interaction*. http://www.diva-portal.org/smash/record.jsf?pid=diva2:542612

Kristoffersson, A., Coradeschi, S., & Loutfi, A. (2013). A Review of Mobile Robotic Telepresence. *Advances in Human-Computer Interaction*, *2013*, 1–17. https://doi.org/10.1155/2013/902316

Lee, M. K., & Takayama, L. (2011). Now, I have a body: Uses and social norms for mobile remote presence in the workplace. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 33–42. http://dl.acm.org/citation.cfm?id=1978950

Lottridge, D., Masson, N., & Mackay, W. (2009). *Sharing empty moments: Design for remote couples*. 2329. https://doi.org/10.1145/1518701.1519058

Maguire, K. C., & Kinney, T. A. (2010). When Distance is Problematic: Communication, Coping, and Relational Satisfaction in Female College Students' Long-Distance Dating Relationships. *Journal of Applied Communication Research*, *38*(1), 27–46. https://doi.org/10.1080/00909880903483573

Massimi, M., & Neustaedter, C. (2014). *Moving from talking heads to newlyweds: Exploring video chat use during major life events*. 43–52. https://doi.org/10.1145/2598510.2598570

Michaud, F., Boissy, P., Labonté, D., Brière, S., Perreault, K., Corriveau, H., Grant, A., Lauria, M., Cloutier, R., Roux, M.-A., Iannuzzi, D., Royer, M.-P., Ferland, F., Pomerleau, F., & Létourneau, D. (2010). Exploratory design and evaluation of a homecare teleassistive mobile robotic system. *Mechatronics*, *20*(7), 751–766. https://doi.org/10.1016/j.mechatronics.2010.01.010

Morris, M. R., Inkpen, K., & Venolia, G. (2014). Remote shopping advice: Enhancing in-store shopping with social technologies. *Proceedings of the 17th ACM Conference on Computer Supported Cooperative Work & Social Computing - CSCW '14*, 662–673. https://doi.org/10.1145/2531602.2531707

Nestel, D., Sains, P., Wetzel, C. M., Nolan, C., Tay, A., Kneebone, R. L., & Darzi, A. W. (2007). Communication skills for mobile remote presence technology in clinical interactions. *Journal of Telemedicine and Telecare*, *13*(2), 100–104.

Neustaedter, C., & Greenberg, S. (2011). Intimacy in long-distance relationships over video chat. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. ACM.

Neustaedter, C., Judge, T. K., & Sengers, P. (2015). Autobiographical Design in the Home. In *Studying and designing technology for domestic life: Lessons from home*. Elsevier/MK.

Neustaedter, C., Procyk, J., Chua, A., Forghani, A., & Pang, C. (2017). Mobile Video Conferencing for Sharing Outdoor Leisure Activities Over Distance. *Human–Computer Interaction*, 1–40. https://doi.org/10.1080/07370024.2017.1314186

Neustaedter, C., & Sengers, P. (2012). Autobiographical design in HCI research: Designing and learning through use-it-yourself. *Proceedings of the Designing Interactive Systems Conference*, 514–523.

Neustaedter, C., Venolia, G., Procyk, J., & Hawkins, D. (2016). To Beam or Not to Beam: A Study of Remote Telepresence Attendance at an Academic Conference. *Proceedings of the 19th ACM Conference on Computer-Supported Cooperative Work & Social Computing*, 417–430. https://doi.org/10.1145/2818048.2819922

Newhart, V. A. (2014). Virtual inclusion via telepresence robots in the classroom. *Proceedings of the Extended Abstracts of the 32nd Annual ACM Conference on Human Factors in Computing Systems - CHI EA '14*, 951–956. https://doi.org/10.1145/2559206.2579417

Newhart, V. A., & Olson, J. S. (2017). *My Student is a Robot: How Schools Manage Telepresence Experiences for Students*. 342–347. https://doi.org/10.1145/3025453.3025809

Ogolsky, B. G., & Bowers, J. R. (2013). A meta-analytic review of relationship maintenance and its correlates. *Journal of Social and Personal Relationships*, *30*(3), 343–367. https://doi.org/10.1177/0265407512463338

O'Hara, K., Black, A., & Lipson, M. (2009). Media Spaces and Mobile Video Telephony. In S. Harrison (Ed.), *Media Space 20 + Years of Mediated Life* (pp. 303–323). Springer London. https://doi.org/10.1007/978-1-84882-483-6_19

O'Hara, K., Black, A., & Lipson, M. (2006). Everyday practices with mobile video telephony. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 871–880. http://dl.acm.org/citation.cfm?id=1124900

Orlandini, A., Kristoffersson, A., Almquist, L., Björkman, P., Cesta, A., Cortellessa, G., Galindo, C., Gonzalez-Jimenez, J., Gustafsson, K., Kiselev, A., Loutfi, A., Melendez, F., Nilsson, M., Hedman, L. O., Odontidou, E., Ruiz-Sarmiento, J.-R., Scherlund, M., Tiberio, L., von Rump, S., & Coradeschi, S. (2016). ExCITE Project: A Review of Forty-Two Months of Robotic Telepresence Technology Evolution. *Presence: Teleoperators and Virtual Environments*, *25*(3), 204–221. https://doi.org/10.1162/PRES_a_00262

Paepcke, A., Soto, B., Takayama, L., Koenig, F., & Gassend, B. (2011). Yelling in the hall: Using sidetone to address a problem with mobile remote presence systems. *Proceedings of the 24th Annual ACM Symposium on User Interface Software and Technology*, 107–116. http://dl.acm.org/citation.cfm?id=2047209

Pan, R., Singhal, S., Riecke, B. E., Cramer, E., & Neustaedter, C. (2017). *"MyEyes": The Design and Evaluation of First Person View Video Streaming for Long-Distance Couples*. 135–146. https://doi.org/10.1145/3064663.3064671

Paulos, E., & Canny, J. (1996). *Delivering real reality to the World Wide Web via telerobotics*. *2*, 1694–1699. https://doi.org/10.1109/ROBOT.1996.506956

Paulos, E., & Canny, J. (1998). Designing personal tele-embodiment. *Proceedings. 1998 IEEE International Conference on Robotics and Automation (Cat. No.98CH36146)*, *4*, 3173–3178. https://doi.org/10.1109/ROBOT.1998.680913

Paulos, Eric, & Canny, J. (2001). Social tele-embodiment: Understanding presence. *Autonomous Robots*, *11*(1), 87–95.

Paulos, Eric, & Canny, J. (1998). Personal Roving Presence. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 296–303.

Procyk, J., Neustaedter, C., Pang, C., Tang, A., & Judge, T. K. (2014). *Exploring video streaming in public settings: Shared geocaching over distance using mobile video chat*. 2163–2172. https://doi.org/10.1145/2556288.2557198

Rae, I. (2015). *How Telepresence Robots Shape Communication*. University of Wisconsin-Madison.

Rae, I., Mutlu, B., & Takayama, L. (2014). *Bodies in motion: Mobility, presence, and task awareness in telepresence*. 2153–2162. https://doi.org/10.1145/2556288.2557047

Rae, I., & Neustaedter, C. (2017). Robotic Telepresence at Scale. *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*, 313–324. https://doi.org/10.1145/3025453.3025855

Rae, I., Takayama, L., & Mutlu, B. (2013a). In-body experiences: Embodiment, control, and trust in robot-mediated communication. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 1921–1930. http://dl.acm.org/citation.cfm?id=2466253

Rae, I., Takayama, L., & Mutlu, B. (2012). One of the gang: Supporting in-group behavior for embodied mediated communication. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 3091–3100. http://dl.acm.org/citation.cfm?id=2208723

Rae, I., Takayama, L., & Mutlu, B. (2013b). The influence of height in robot-mediated communication. *Proceedings of the 8th ACM/IEEE International Conference on Human-Robot Interaction*, 1–8. http://dl.acm.org/citation.cfm?id=2447558

Rae, I., Venolia, G., Tang, J. C., & Molnar, D. (2015). *A Framework for Understanding and Designing Telepresence*. 1552–1566. https://doi.org/10.1145/2675133.2675141

Raffle, H., Ballagas, R., Revelle, G., Horii, H., Follmer, S., Go, J., Reardon, E., Mori, K., Kaye, J., & Spasojevic, M. (2010). Family story play: Reading with young children (and elmo) over a distance. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 1583–1592. http://dl.acm.org/citation.cfm?id=1753563

Rains, S. A., Brunner, S. R., Akers, C., Pavlich, C. A., & Goktas, S. (2017). Computer-mediated communication (CMC) and social support: Testing the effects of using CMC on support outcomes. *Journal of Social and Personal Relationships*, *34*(8), 1186–1205. https://doi.org/10.1177/0265407516670533

Santos, A., McCuckin, N., Nakamoto, H. Y., Gray, D., & Liss, S. (2011). *Summary of Travel Trends 2009 National Household Travel Survey*. https://doi.org/10.2172/885762

Saunders, J., Syrdal, D. S., Koay, K. L., Burke, N., & Dautenhahn, K. (2016). “Teach Me–Show Me”—End-User Personalization of a Smart Home and Companion Robot. *IEEE Transactions on Human-Machine Systems*, *46*(1), 27–40. https://doi.org/10.1109/THMS.2015.2445105

Singhal, S., & Neustaedter, C. (2016). *Be With Me: An Immersive Experience for Long Distance Couples*. CSCW.

Singhal, S., Neustaedter, C., Ooi, Y. L., Antle, A. N., & Matkin, B. (2017). *Flex-N-Feel: The Design and Evaluation of Emotive Gloves for Couples to Support Touch Over Distance*. 98–110. https://doi.org/10.1145/2998181.2998247

Skinner, B. (2005). Perceptions of college students in long distance relationships. *UW-L Journal of Undergraduate Research VIII*. http://www.uwlax.edu/urc/jur-online/PDF/2005/skinner.pdf

Spraggins, R. E. (2003). *Women and Men in the United States: March 2002*. US Census Bureau. https://www.census.gov/prod/2003pubs/p20-544.pdf

Stafford, L. (2005). *Maintaining Long-Distance and Cross-Residential Relationships*. Lawrence Erlbaum Associates, Inc.

Stafford, L. (2010). Geographic Distance and Communication During Courtship. *Communication Research*, *37*(2), 275–297. https://doi.org/10.1177/0093650209356390

Stafford, L., & Canary, D. J. (1991). Maintenance strategies and romantic relationship type, gender, and relational characteristics. *Journal of Social and Personal Relationships*, *8*, 217–242.

Stafford, L., & Merolla, A. J. (2007). Idealization, reunions, and stability in long-distance dating relationships. *Journal of Social and Personal Relationships*, *24*(1), 37–54. https://doi.org/10.1177/0265407507072578

Stoll, B., Reig, S., He, L., Kaplan, I., Jung, M. F., & Fussell, S. R. (2018). Wait, Can You Move the Robot?: Examining Telepresence Robot Use in Collaborative Teams. *Proceedings of the 2018 ACM/IEEE International Conference on Human-Robot Interaction*, 14–22. https://doi.org/10.1145/3171221.3171243

Strong, R., & Gaver, B. (1996). Feather, scent and shaker: Supporting simple intimacy. *Proceedings of CSCW*, *96*, 29–30. https://www.gold.ac.uk/media/migrated/media/goldsmiths/departments/researchcentres/interactionresearchstudio/pdf/16strong-gaver.feather.cscw96.pdf

Takayama, L., & Harris, H. (2013). Presentation of (telepresent) self: On the double-edged effects of mirrors. *2013 8th ACM/IEEE International Conference on Human-Robot Interaction (HRI)*, 381–388. https://doi.org/10.1109/HRI.2013.6483613

Tang, A., Fakourfar, O., Neustaedter, C., & Bateman, S. (2017). *Collaboration with 360° Videochat: Challenges and Opportunities*. 1327–1339. https://doi.org/10.1145/3064663.3064707

Tohidi, M., & Warr, A. (2013). The Bigger Picture: The Use of Mobile Photos in Shopping. In P. Kotzé, G. Marsden, G. Lindgaard, J. Wesson, & M. Winckler (Eds.), *Human-Computer Interaction – INTERACT 2013* (Vol. 8120, pp. 764–771). Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-642-40498-6_71

Tolmie, P., Pycock, J., Diggins, T., MacLean, A., & Karsenty, A. (2002). Unremarkable computing. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '02)*.

Tsui, K. M., Desai, M., Yanco, H. A., & Uhlik, C. (2011). Exploring use cases for telepresence robots. *2011 6th ACM/IEEE International Conference on Human-Robot Interaction (HRI)*, 11–18. http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=6281254

Tsui, K., & Yanco, H. (2013). Design Challenges and Guidelines for Social Interaction Using Mobile Telepresence Robots. *Reviews of Human Factors and Ergonomics*, *9*(1), 227–301. https://doi.org/10.1177/1557234X13502462

Vangelisti, A. L. (2012). Interpersonal Processes in Romantic Relationships. In *The Sage handbook of interpersonal communication* (4th ed.). SAGE Publications.

Venolia, G., Tang, J., Cervantes, R., Bly, S., Robertson, G., Lee, B., & Inkpen, K. (2010). Embodied social proxy: Mediating interpersonal connection in hub-and-satellite teams. *Proceedings of the 28th International Conference on Human Factors in Computing Systems - CHI '10*, 1049. https://doi.org/10.1145/1753326.1753482

Vespa, P. M., Miller, C., Hu, X., Nenov, V., Buxey, F., & Martin, N. A. (2007). Intensive care unit robotic telepresence facilitates rapid physician response to unstable patients and decreased cost in neurointensive care. *Surgical Neurology*, *67*(4), 331–337. https://doi.org/10.1016/j.surneu.2006.12.042

Vetere, F., Gibbs, M. R., Kjeldskov, J., Howard, S., Mueller, F. "Floyd," Pedell, S., Mecoles, K., & Bunyan, M. (2005). *Mediating intimacy: Designing technologies to support strong-tie relationships*. 471. https://doi.org/10.1145/1054972.1055038

Yang, L., Jones, B., Neustaedter, C., & Singhal, S. (2018). *Shopping Over Distance through a Telepresence Robot*. *2*, 18.

Yang, L., & Neustaedter, C. (2018). Our House: Living Long Distance with a Telepresence Robot. *Proceedings of the ACM on Human-Computer Interaction*, *2*(CSCW), 1–18. https://doi.org/10.1145/3274459

Yang, L., & Neustaedter, C. (2020). *An Autobiographical Design Study of a Long Distance Relationship: When Telepresence Robots Meet Smart Home Tools*. 12.

Yang, L., Neustaedter, C., & Schiphorst, T. (2017a). *Communicating Through A Telepresence Robot: A Study of Long Distance Relationships*. 3027–3033. https://doi.org/10.1145/3027063.3053240

Yang, L., Neustaedter, C., & Schiphorst, T. (2017b). Communicating Through A Telepresence Robot: A Study of Long Distance Relationships. *Proceedings of the 2017 CHI Conference Extended Abstracts on Human Factors in Computing Systems - CHI EA '17*, 3027–3033. https://doi.org/10.1145/3027063.3053240

Zhang, E. Y., Cheok, A. D., Nishiguchi, S., & Morisawa, Y. (2016). Kissenger: Development of a Remote Kissing Device for Affective Communication. *Proceedings of the 13th International Conference on Advances in Computer Entertainment Technology - ACE2016*, 1–6. https://doi.org/10.1145/3001773.3001831

Appendix A.

Study 1 Materials

Study 1 - Ethics Approval

Annual Renewal Approval

Study Number: 2013s0210

Study Title: Video Conferencing for Sharing Everyday Experiences

Annual Renewal Date: 2018 January 19
Principal Investigator: Neustaedter, Carman
SFU Position: Faculty
Expiry Date: 2019 January 19
Supervisor: n/a
Faculty/Department: Interactive Arts & Technology

SFU Collaborator: Procyk, Jason; Muntean, Reese; Singhal, Samarth; and Yang, Lillian.
External Collaborator: Massimi, Michael
Research Personnel: n/a

Funding Source: NSERC ENGAGE
Funding Title: Advanced Video Communication Systems for Families

Funding Source: NSERC Discovery Grant and Accelerator
Funding Title: Supporting shared family experiences with mobile media spaces

Document(s) Approved in this Application:

- Annual Renewal Report

The approval for this study expires on the **Expiry Date**. **Failure to submit an annual renewal form will lead to your study being suspended and potentially terminated.** If you intend to continue to collect data past the term of approval, you must submit an annual renewal form at least 4 weeks before the expiry date.

This letter is your official Annual Renewal Approval documentation for this project. Please keep this document for reference purposes.

The annual renewal for this study been approved by an authorized delegated reviewer.

Study 1 – Recruitment Poster

SFU SIMON FRASER UNIVERSITY
ENGAGING THE WORLD

Are You In A Long Distance Relationship?

Get a Telepresence Robot for one month to spend time with your partner.

We're looking for long distance couples

Sign up for the study and we'll bring a telepresence robot to your home! Use it for one month and tell us about your experience.

Who can participate?

Anyone 19+ with a long distance partner.

To sign up or learn more:

Email Lillian

Study 1 – Interview Questions

Initial Interview Questions

Asked Together:

- How did you meet? How long ago was that? How long have you been together in total?
- When did you start long distance? Why? How long have you been together part time?
- Do you normally live together?
- What tools do you use to talk to each other?
    - PROMPT: For example: Skype, FaceTime, etc.
- When do you usually use [the tool they mentioned]?
    - PROMPT: What time? Morning? Evening?
- Say you called your partner at [time they mentioned], how long do you talk for and what do you talk about?
- Are you ever doing other activities when you're chatting with your each other?
    - PROMPT: For example, browsing the web, going for a walk, cooking, etc.
- When you're not using video chat, how do you stay connected the rest of the day?
    - PROMPT: For example, do you use text? What do you use to text? There's regular texts, iMessage, Facebook Messenger, Line, WhatsApp etc. Why? How often?
    - PROMPT: For example, phone calls. Why? How often?
- How connected do you feel when you're chatting over [video chat tool they mentioned]?
- What about through text messaging?
- What are the biggest challenges to communicating while you're apart?
- Do you find that you communicate differently when you're in person?
    - PROMPT: For example, do you talk about different kinds of things when you're talking in-person? What kinds of things do you talk about when you're talking in-person?
    - PROMPT: For example, do you act differently?
- Have either of you used a telepresence robot before being involved in this study? (ask more ques eg. when? Where? With who? Which one?)
- Final Ques: Age/Occupation/City

Check-in Interview Questions

How is your experience using the Beam so far?

Have you experienced any issues?
PROMPT: Physical issues
PROMPT: Technological issues
PROMPT: Is it easy to use the Beam?

What do you think could make the Beam better for the way you use it? Eg. would you change the way the Beam is shaped? Would you add any functionalities?

How many times do you think you used the Beam this week?

Has the way you communicate changed at all using the Beam? How so? [Example: how long you talk for, when you talk, what you talk about, activities you do while talking]

Final Interview Questions

Asked Separately:

- What did you like about using the Beam? And Why?
- What did you not like? And Why?
- Tell me a story about the most memorable usage.
- Tell me a story about your best experience. [This might be the same as most memorable.]
- Tell me a story about your worst experience.
- Did you feel your partner was more present using the Beam? (compared to other tools)
- Any thoughts about what it was like being [the person controlling the Beam/the person interacting with the Beam?]

Asymmetry ques:

- How do you feel having one person control the Beam and the other person interact with the Beam affected the dynamic of your connection?
- Do you think you would have liked the other role better [i.e. to be the person controlling the Beam/the person interacting with the Beam?] Why?

Asked Together:

- How did you like having the Beam around?
- Can you tell me about any issues that came up?
- Did you feel more connection with each other in this past month using the Beam? Less? Why?
- How was it different than using previous tools?
  PROMPTS:
  - Can you elaborate on how it was better?
  - Can you elaborate on ways it was worse?
  - Was there an emotional impact on using the Beam rather than previous tools? What was the difference?
  - What kinds of things did you talk about using the Beam? What kinds of things did you talk about using traditional tools?
  - Did you end up spending more or less time connected through video chat than before?
- How often did you use the Beam? And at what times?
- What kinds of activities did you engage in with the Beam? Why?
  - What kind of activities do you use traditional tools, like Skype for?
- What did you not use it for but would have liked to use it for?
- What are things that prevented you from using Beam?
- Were there times you still ended up using your usual video chat tool [tool they mentioned]? What made you choose that video chat tool over the Beam?
- If you knew you could have a Beam permanently, do you think it would replace any of the communication tools you use? If so, which ones.
  - Like assuming you have a Beam, can you describe a regular day of communicating long distance? When would you talk throughout the day and which of your communication tools would you use?
- Final thoughts/insights?

Appendix B.

Study 2 Materials

Study 2 – Ethics Approval

Annual Renewal Approval

Study Number: 2013s0210

Study Title: Video Conferencing for Sharing Everyday Experiences

Annual Renewal Date: 2018 January 19
Expiry Date: 2019 January 19
Principal Investigator: Neustaedter, Carman
Supervisor: n/a
SFU Position: Faculty
Faculty/Department: Interactive Arts & Technology

SFU Collaborator: Procyk, Jason; Muntean, Reese; Singhal, Samarth; and Yang, Lillian.
External Collaborator: Massimi, Michael
Research Personnel: n/a

Funding Source: NSERC ENGAGE
Funding Title: Advanced Video Communication Systems for Families

Funding Source: NSERC Discovery Grant and Accelerator
Funding Title: Supporting shared family experiences with mobile media spaces

Document(s) Approved in this Application:

- Annual Renewal Report

The approval for this study expires on the **Expiry Date**. **Failure to submit an annual renewal form will lead to your study being suspended and potentially terminated.** If you intend to continue to collect data past the term of approval, you must submit an annual renewal form at least 4 weeks before the expiry date.

This letter is your official Annual Renewal Approval documentation for this project. Please keep this document for reference purposes.

The annual renewal for this study been approved by an authorized delegated reviewer.

Study 2 – Recruitment Poster

Come Drive A Telepresence Robot Like Sheldon!

What will you do?
Sign up in pairs, go to the mall, then answer some questions.
This should take up to 1 hour and 45 minutes.

What can I get out of it?
Each person is paid $15. It's also fun, and you're helping science!

How do I sign up?
Email with the subject "mall study"
(Participants must be 18+).

Study 2 – Vignette

Vignette (For Remote Partner)
You and your partner have been together for four years. You're in a committed and happy relationship. You're currently in Denver for work and have been for the past 3 weeks. You are using your new telepresence robot to spend some quality time together. You are going to the mall together for a shopping trip.

There are a couple things that the two of you want to do on this trip:

It's almost your mom's birthday and the two of you need to pick out a nice birthday present. You've decided you want to keep the price within around $30, and you also want the present to be a nice one!

Your partner is also looking for a new outfit, because the two of you are going to your mom's birthday party. It's not going to be fancy, but you know your partner wants to look nice.

Before you went to Denver, you left your partner a Starbucks gift card. Maybe your partner can use it on this shopping trip.

Vignette (For Local Partner)
You and your partner have been together for four years. You're in a committed and happy relationship. Your partner is currently in Denver for work and has been for the past 3 weeks. You are using your new telepresence robot to spend some quality time together. You are going to the mall together for a shopping trip.

There are a couple things that the two of you want to do on this trip:

It's almost your partner's mom's birthday and the two of you need to pick out a nice birthday present. You've decided you want to keep the price within around $30, and you also want the present to be a nice one!

You're also looking for a new outfit, because the two of you are going to your partner's mom's birthday party. It's not going to be fancy, but you want to look nice. You want to find something that stands out. This can be a shirt, pants, jacket, etc - anything you can try on. Be sure to try on whatever you pick, because you want your partner to see it and like it too.

Your partner left you a Starbucks gift card - how thoughtful! You want to use it on this shopping trip.

Study 2 – Tasks

Shopping To-Do List

** Do the two tasks in any order. Take a Starbucks break in-between the two tasks.
Note: Don't go to liquor store or Bentley's
Note: Don't actually buy the gift or clothing
Note: Do use the Starbucks gift card to actually buy a drink

1. Find a gift for your partner's mom - get your partner's opinion.

2. Pick a piece of clothing to wear to your partner's mother's birthday party. Try on at least one piece of clothing so your partner can see it and help you choose.

**Use the Starbucks card to buy any drink of your choice at Starbucks.

Study 2 – Interview Questions

Interview Questions - For Local Partner

Age/Gender/Occupation

What is the relationship you have with your partner? (eg. boyfriend/girlfriend/wife/husband etc)

- Tell me about your shopping trip as if I wasn't there.
- How was this experience was different than shopping with another person who's there in-person?
- How was this experience similar to shopping with another person who's there in-person?
- Tell me about the last time you went shopping with your partner? [Walk me through it.]
    - PROMPT: did either you or your partner guide each other or lead the shopping trip?
- Back to the shopping trip you just went on - did you feel like your partner was in the mall with you?
- What particularly made you feel like your partner was there? Event? Aspect?
- What made you feel like your partner was not actually there?
- What types of things made the tasks a challenge? Why were these things challenging?
- What types of things made the tasks easy? Why?
- How did you decide on which items to purchase?
- How did you negotiate about the budget (ie. $30 to spend on mom's present)
    - PROMPT: Were there disagreements? If so, how did you deal with them?
- How did you decide on which stores to visit?
    - PROMPT: Were they joint decisions or did one person decide?
- How did you feel about having the tablet with you in the changeroom? And how did you deal with it?
- What did you like about using the [tablet/telepresence robot] for communication?
- What did you not like?
- Did you feel that you and your partner contributed to the tasks equally?
    - PROMPT: Did you feel that [you were dependent on your partner/your partner was dependent on you?]
    - PROMPT: Why? How did that make you feel?
    - PROMPT: Did you feel like your opinions were heard?
- If you broke something in a store - would you feel you were more responsible or your partner was more responsible?
- @Beam Participants: How did your partner use their robot body to communicate with you?
- How did you [position yourself next to your partner/hold your tablet]? Why?
  Were there moments that surprised you? Tell me about them?
- Do you think you would use the [tablet/telepresence robot] to go shopping with your partner if you were long distance? Why?

- Other thoughts you want to share?

Interview Questions - For Remote Partner

Age/Gender/Occupation

What is the relationship you have with your partner?: (eg. boyfriend/girlfriend/wife/husband etc)

- Tell me about your shopping trip as if I wasn't there.
- How was this experience different than shopping with another person when both of you are there in-person?
- How was this experience similar to shopping with another person when both of you are there in-person?
- Tell me about the last time you went shopping with your partner. [Walk me through it.]
    - PROMPT: did either you or your partner guide each other or lead the shopping trip?
- Back to the shopping trip you just went on - did you feel like you were in the mall?
- What particularly made you feel like you were there? Event? Aspect?
- What made you feel like you were not actually there?
- What types of things made the tasks a challenge?
- What types of things made the tasks easy?
- How did you decide on which items to purchase?
- How did you negotiate about the budget (ie. $30 to spend on mom's present)
    - PROMPT: Were there disagreements? If so, how did you deal with them?
- How did you decide on which stores to visit?
    - PROMPT: Were they joint decisions or did one person decide?
- How did you feel about being brought into the changeroom?
- What did you like about using the tablet for communication?
- What did you not like?
- Did you feel that you and your partner contributed to the tasks equally?
    - PROMPT: Did you feel that [you were dependent on your partner/your partner was dependent on you?]
    - PROMPT: Why? How did that make you feel?
    - PROMPT: Did you feel like your opinions were heard?
- If you broke something in a store - would you feel you were more responsible or your partner was more responsible?
- Where did you focus on looking at [while using the robot/through the tablet]?
- Were there moments that surprised you? Tell me about them?
- Do you think you would use the tablet to go shopping with your partner if you were long distance? Why?

- Other thoughts you want to share?

Appendix C.

Study 3 Materials

Study 3 – Ethics Approval

Minimal Risk Approval – Delegated

Study Number: 2019s0228
Study Title: Exploration of Smart Home Tools for Supporting Telepresence

Approval Date: July 4, 2019
Principal Investigator: Yang, Lillian
SFU Position: Graduate Student

Expiry Date: July 4, 2020
Supervisor: Neustaedter, Carman
Faculty/Department: School of Interactive Arts & Technology

SFU Collaborator: N/A
External Collaborator: N/A
Research Personnel: N/A
Project Leader: N/A

Funding Source: NSERC Discovery Grant
Funding Title: Supporting Shared Family Experiences with Mobile Media Spaces

Document(s) Approved in this Application:

- Study Details dated June 20, 2019
- Consent Form dated June 20, 2019
- Interview Questions dated June 20, 2019

The application for ethical review and the document(s) listed above have been reviewed and the procedures were found to be acceptable on ethical grounds for research involving human participants.

The approval for this Study expires on the **Expiry Date. An annual renewal form must be completed every year prior to the Expiry Date. Failure to submit an annual renewal form will lead to your study being suspended and potentially terminated.** The Board reviews and may amend decisions or subsequent amendments made independently by the authorized delegated reviewer at its regular monthly meeting.

This letter is your official ethics approval documentation for this project. Please keep this document for reference purposes.

This study has been approved by an authorized delegated reviewer.

Study 3 – Interview Questions

Weekly Interview Questions

- In what ways do you think the telepresence setup helped us share the home?
    - What were some positive moments using the system?
    - What were some negative moments using the system? (e.g. something that triggered negative feelings, made you uncomfortable or lonely, something that just didn't work)

- In what ways do you think the telepresence setup helped us care for one another?
    - PROMPT: ask about maintenance behaviors
    - Can you tell me about incidents when it was unhelpful? challenging? negative?

- In what ways do you think the telepresence setup helped us interact with one another?
    - PROMPT: ask about maintenance behaviors
    - Can you tell me about incidents when it was unhelpful? challenging? negative?

- [Discuss the week's events from the diary log.]