Designing Communication Technologies for Couples to Support Touch Over Distance

by

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B.Tech., Jaypee Institute of Information Technology, 2012

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Abstract

Many couples live apart due to work, educational situations, or frequent travel. While technology can help mediate these relationships, there is a lack of designs that allow couples to share a sense of touch over distance. I present a design case study of a tangible communication system called Flex-N-Feel—a pair of gloves that allows distance-separated couples to feel the flexing of their remote partners’ fingers through vibrotactile sensations on their skin. I evaluated this design with nine couples where the system was augmented with either a Skype audio call or a video connection. This study showed that participants enjoyed their conversation more with the gloves, felt more emotionally connected, and experienced intimate moments together. Couples used the glove for shared actions, playful episodes, intimate touches, and to simply feel each other’s presence. Video was important to aid couples in understanding each other’s actions. The results illustrate that designs focusing on physical touch over distance should be open to improvisation and likely support appropriation such that they can augment existing communication routines and technologies.

**Keywords:** Long Distance Relationships; Intimacy; Haptic; Touch; Vibrotactile, Gloves; Tangible, Wearable.
Dedication

This thesis work is dedicated to my parents who have always loved me unconditionally and their upbringing has taught me to work hard for the things I aspire to achieve. This work is also dedicated to my girlfriend, who has been a constant source of support and encouragement during the challenges of graduate school and life. Thank you for being the pillows, role models, cheerleading squad and sounding boards I have needed.
Research Acknowledgements

Portions of my research were conducted in collaboration with others; here I make clear the role of each person.

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Second, I owe great thanks to Yee Loong Ooi, an undergraduate student at the time, for his role in my research. Yee helped me conduct the study, interviewed half of the participants and helped in data analysis.

I would also like to thank Alissa Antle for her continuous support and guidance during the design of Flex-N-Feel during the Spring 2016 term. Lastly, all research presented in this thesis was conducted in collaboration with my supervisor, Carman Neustaedter, where he acted in an advisory role.
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I would like to thank SIAT faculty members who and laid the foundation of research: Thecla Schiphorst, Alissa Antle, Brian Fisher, Bernhard Riecke, Lyn Bartram, and William Odom. I would like to thank you all for teaching me how to do research and guiding my research for the last two years.

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Publications

Materials, ideas from this thesis have appeared in the following publication:


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**List of Acronyms**

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<th>Full Form</th>
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<tr>
<td>CSCW</td>
<td>Computer Supported Cooperative Work</td>
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<tr>
<td>CMC</td>
<td>Computer–Mediated Communication</td>
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<tr>
<td>HCI</td>
<td>Human Computer Interaction</td>
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<tr>
<td>LDRs</td>
<td>Long Distance Relationships</td>
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<tr>
<td>LED</td>
<td>Light Emitting Diode</td>
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<td>ICT</td>
<td>Information and Communication Technologies</td>
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Chapter 1. Introduction

This work is motivated by my personal experience and through the stories of my friends who were in a long-distance relationship (LDR) at some point in their life. The first time I was separated from my girlfriend, I realized it was a completely different feeling of communicating through texts, voice calls and video calls. Although we had been using these computer–mediated communication (CMC) technologies as a co-located couple, it was quite different to use them when we were separated, i.e. video and voice calls can’t always capture laughter, smirks or sighs of frustration, sometimes a joke becomes a fight because the tone of a text is misinterpreted, and long silences after arguments can’t be broken by reaching across the table and holding the person’s hand. Soon, there was a feeling of absence, where we were unable to emotionally connect and feel each other’s presence in our daily lives. One aspect that was missing was the ability to touch and feel your partner in the form of simple gestures like a hug, holding hands or a simple caress. Research has shown that these affective touches are critical for the physical and mental well-being of couples (Field, 2003).

I feel touch plays a significant role in expressing an important part of intimacy that is better expressed through sensory evocations rather than linguistics. Being in a LDR, distance had led to the absence of the physical being of my partner in my daily life, depriving us of the haptic experiences from these affective touches. This is a serious problem in general as it strongly affects the intimacy and connectedness of romantic relationships. Therefore, this thesis explores the design and evaluation of a system capable of sending remote touch between long-distance partners. Mediating affective touches through technology is a potential solution to address this problem by providing a haptic communication channel to trigger “presence-in-absence” in long-distance couples, exchange affective touch gestures, and express intimacy through a new modality of communication.
1.1. Background

In an increasingly globalized world, long-distance relationships are becoming more and more common. Couples could be separated for a long span of time due to career or study related obligations, or frequently occurring short spans of time due to travel, long work hours or conflicting schedule shifts (Holmes, 2004; Stafford, 2005). Hence couples find themselves living apart, in different cities or even countries, experiencing the challenges of a LDR. Couples in LDRs may easily face difficulties in maintaining and supporting their relationship (Stafford, 2005). This is mainly because they lack traditional intimacy-building interactions, such as touching, non-verbal communication and presence (Kjeldskov et al., 2004). This makes computer-mediated communication systems like email, texts, phone calls, and video chat beneficial for maintaining and supporting their relationships (Aguila, 2011; Neustaedter & Greenberg, 2012), if they can afford and have access to such technologies.

Video communication technologies have become a popular tool for supporting such needs as they allow LDR couples to simulate a face-to-face conversation over distance and even engage in acts of ‘shared living’ (Neustaedter et al., 2015; Neustaedter & Greenberg, 2012) to simulate acts of living together by doing the same activities together over a video link. Yet the challenge is that video communication systems, as well as other computer-mediated communication systems, do not fully address the remote lovers’ emotional needs, encourage intimate interactions such as experiencing the sensation of a physical touch (Saadatian et al., 2014) and a provide a strong sense of connectedness. Hence there is a growing number of attempts to develop affective technologies specifically for mediating intimacy. In the context of mediating intimacy, these technologies can be categorized into two groups.

First, prototypes have focused on interconnected physical or digital objects that users can interact with to cause an effect on one or more properties of the remote partner’s object. We have seen prototypes in the form of interactive photo frames using ambient light (Chang et al., 2001) and prototypes designed to facilitate shared activities like co-drinking (Chung et al., 2006) and sending “Goodnight” messages (Gooch & Watts, 2012a). Overall, the general trend in these prototypes is conveying illusive co-presence and
awareness in an emotionally evocative manner through an everyday object in the home. The limitation of this work is that the prototypes do not provide an expressive and rich medium for communication. They only provide passive awareness sharing through ambient mediums. Moreover, these prototypes are bound to an indoor location restraining couples from using them throughout the day in a mobile fashion, considering the busy schedules and routines of a LDR.

Second, prototypes have been designed for partners to feel physical interactions directly on their body. For example, physiological signals such as heartbeats could be sent between partners through vibrations in a ring (Werner et al., 2008) or interconnected beds (Dodge, 1997). Touch is an expressive and powerful modality in affect conveyance and can express an array of subtle messages to a loved one (Collier, 1985). A simple touch, such as a hug, handholding or a caress can elicit strong feelings of affection both in the touch initiator and recipient. Prototypes have even been designed to convey acts of touching such as hugging over distance via an inflatable vest (Mueller et al., 2005; Teh et al., 2009), squeezing your partners arm through an armband (Wang, 2012) or the use of gloves to experience holding hands through movement and heat sensations (Gooch & Watts, 2012b). These studies resulted in people using touch to communicate positive emotions and express support, appreciation, sexual interest/intent, and affection. To build on this work, I explored how to convey a sense of touch through explicit physical acts with a focus on the hands. Until now within HCI literature, there is very little research based around sharing virtual touches through hand gestures. Delivering touch over a distance to a long-distance partner has been an appealing concept for both researchers and designers in the recent years.

Past research has suggested that physical touches could be replicated through vibrotactile technology (Rantala et al., 2013). We have also seen that different tactile sensations can be created by varying the frequency, amplitude, duration and rhythm of vibrotactile sensations (Brewster et al., 2004). We have seen prototypes designed using vibrotactile sensations to simulate remote touch (Park et al., 2012; Rantala et al., 2013; Wang, 2012). Most of the previous work mapped vibrotactile actuators to a specific body part for use in a very specific manner. This is limited in terms of an open-ended design exploration, anthropomorphism, mobility and flexibility of usage, correspondence between
the perceived and sent action, and considering the privacy of intimate touch gestures. To date, researchers have not yet explored the design space of an open-ended remote touch system using vibrotactile sensations for long-distance couples.

1.2. Thesis Problems

This thesis investigates the design, use and evaluation of systems to support physical touch over distance for long distance couples. It addresses the overarching research problem: we do not yet know how to best design a system to transmit touch over distance for long-distance couples. To more easily address this overarching research problem, I have broken my main problem into three sub-problems:

**Problem 1: We do not know how to apply the needs of LDRs to the design of a system capable of transmitting remote touch.** There have been some prototypes developed for supporting communication in long-distance relationships through physical artifacts in the home (Joi et al., 2015; Kowalsk et al., 2013). More specifically we have also witnessed some research investigating remote touch for long-distance couples in the form of wearable devices (Bonanni et al., 2006; Gooch & Watts, 2012b). Yet most of the earlier prototypes were either limited to a part of the body, used in a very specific way or limited in terms of mobility. There is less focus on designing an open-ended prototype which allows couples to experience touch on any part of their body that could be used anytime and at any-place, and allow couples to perform different kinds of touch actions/interactions with the prototype.

**Problem 2: We do not know how long-distance couples would use an open-ended system capable of transmitting touch.** We have seen previous studies with prototypes capable of sending remote touch to increase the feeling of closeness among couples (Park et al., 2012), amplifying positive affect (Wang, 2012) and feeling others presence in one’s daily life (Gooch & Watts, 2012b). But we have not yet seen how couples would use an open-ended design to transmit touch. A further step in the comprehension of a design capable of transmitting remote touch is to understand how couples would use such a system. This further breaks down into what kind of actions/interaction would couples perform and the kind of meaning and affects conveyed by these interactions with the
system. Understanding how couples will interact and use such a system will further inform our design decisions.

**Problem 3: We do not know how couples would use remote touch in conjunction with existing communication tools.** Most of the previous studies have evaluated prototypes without a complimentary communication channel. We know long-distance couples tend to rely heavily on voice calls and video communication (Neustaedter & Greenberg, 2012). I decided to use touch in conjunction with these existing communication channels so couples can talk while touching each other, but we do not know how long-distance couples would use a new modality of communication (touch) in conjunction with their existing communication channels (audio and video). We need to understand how couples would integrate audio and video channels and how this would aid in the development of meaningful experiences of remote touch.

![Figure 1.1 Flex-N-Feel is a pair of gloves to transmit touch over distance](image)

**1.3. Thesis Goals**

My primary goal for this thesis is to: *design a system capable of sending remote touch for long-distance couples and understand how couples would interact and use this system along with their existing communication channels*. To achieve this goal, I seek to address the following objectives, where each one maps to the corresponding problem in Section 1.2.
**Objective 1:** Design a research prototype capable of sending remote touch based on the needs and requirements of long-distance couples. The design requirements for my problem emerged from the related literature described in Chapter 2. The design requirements are based on the mobility of the system, direct mapping of actions and intentions, flexibility of use and ensuring privacy and subtleness in the touch. Based on these requirements, I designed a tangible communication system called Flex-N-Feel: a pair of gloves that allows distance-separated couples to feel the flexing of their remote partners’ fingers through vibrotactile sensations on their skin (see Figure 1.1, The left image shows the flex glove which sends the touch and this touch is received on the feel glove on the right image). Through this design, I will be investigating what are the important design characteristics of a system to support touch over distance.

**Objective 2:** Understand the usage patterns of an open-ended remote touch system by long-distance couples through an evaluation. In Chapter 4, I present an exploratory lab study to investigate how couples use Flex-N-Feel for sending touch over distance. I investigated the different categories of interaction couples performed with Flex-N-Feel and the meaning and affect conveyed by these interactions in the lab study. Through our study, I found couples used the gloves in a variety of different ways, many of which I had not envisioned as a designer. These related to four themes: shared actions, playfulness, intimate touches, and presence described.

**Objective 3:** Investigate the ways in which long-distance couples would use remote touch in conjunction with their existing communication channels. I further investigated how video and audio connections would hinder or support the use of Flex-N-Feel. As part of the aforementioned study, I designed a within subject activity that augmented the system with two communication channels, which are often used by couples in LDRs (Neustaedter & Greenberg, 2012): voice calls and video communication. Couples preferred to the use the gloves with the Skype video connection compared to audio-only. This was mainly because they wanted to see their partners’ reactions and facial expression while using the gloves and it was a richer experience with the video link.
1.4. Methodological Approach

My research focuses on understanding how long-distance couples might use remote touch. Figure 1.2 illustrates how this topic fits into the field of Human-Computer Interaction (HCI). HCI is a multi-disciplinary field investigating the human factors of computing systems to understand how to design computational devices that are both useable and useful for individuals (Dix, 1998). Within HCI, my focus is on Ubiquitous Computing: investigating technologies that are continuously available and spread throughout the environment making computing to appear anytime and everywhere (Weiser, 1999). I further narrow my focus to domestic computing. This subfield involves studying everyday domestic practices and needs through technology design and evaluations. Under this field, I’m looking at Computer-Mediated Communication (CMC) which involves human communication that occurs through the use of two or more electronic devices (McQuail, 2010). Under CMC, I further narrow my main focus for this thesis to Remote Touch (Figure 1.2, innermost area) especially for long-distance partners which can be used anyplace and anytime.
This thesis addresses the design and evaluation of a system capable of sending remote touch over distance for long-distance couples. I gathered my design requirements from the related work done in this field by other researchers and the needs of couples in LDRs. Next was the initial concept design phase where I poured my imagination and ideas into a tangible, coherent set of thoughts and sketches. I created multiple sketches reflecting different ideas of how the system should look and slowly started incorporating the design requirements of the system into my sketches. This was an iterative process where I sketched out several design ideas to improve the theme and usability of my system. Once this ideation and conceptual sketching phase was completed, I received feedback from my supervisor, course instructor, and lab members and incorporated them into my sketches.

Next, I started building the prototype by testing out various hardware components suitable for my design. This mainly meant testing out the various hardware alternatives available in the market and figuring out the ones that were the right fit in terms of size, power consumption, and compatibility. Finally, after spending ample time to figure out the appropriate hardware based on the design of my prototype, I built my system and named it Flex-N-Feel. Flex-N-Feel was developed with the intent to explore the design potential around what it could mean to create a system to send remote touch gestures over distance.

I adopted a qualitative approach to understand the meaningful qualities of Flex-N-Feel from users and how it can impact couples’ emotional connection and intimacy when using the system. I conducted a qualitative observational and interview-based lab study to investigate the three research problems outlined in Section 1.2. Qualitative techniques help in explaining why particular process are undertaken and clearly explain the reasoning behind the observed phenomena (Maxwell, 2013). Since each couple might have their own meanings associated with touch, it was important to elicit each couple’s own understanding and meaning. This lends itself to a qualitative approach. My complete process of designing and testing Flex-N-Feel is shown in Figure 1.3.
My study was conducted in a lab setting consisting of two private rooms to simulate a long-distance connection. My decision for a lab-based study emerged from the problems that arise in field experiments which are time consuming, require complicated data collection processes, reliability of the prototype (prototype can function properly without the intervention of the researcher for a long-time), ability to control the experiment, and field studies are unacceptably intrusive (Kjeldskov & Skov, 2014; Kjeldskov & Stage, 2004; Raptis et al., 2005). Lab studies are generally not burdened with the problems that arise in field experiments, especially with sophisticated technical prototypes, as the conditions for the experiment can be controlled, and it is possible to employ facilities for the collection of high-quality data, such as video recording in my case. In the past, it has been argued that traditional laboratory experiments do not adequately simulate the context and lack the desired ecological validity (Esbjörnsson et al., 2006). This may lead to less valid data, where there is a potential disconnect between stated preferences, intentions, and actual experiences. To overcome this limitation, I added contextual richness to lab settings through scenarios and context simulation, which contribute to the realism of the experiment while maintaining the benefits of a controlled setting. The extent to which simulated scenarios represent a real-life situation is a critical determinant of the validity of the study.

I used lab observations in the form of video recording to gather data of all the interactions performed with the prototype. I adopted semi-structured interviews as a method because they give both the interviewer and interviewee the freedom to expand on open-ended questions and talk about new topics emerging from the interview (Schensul et al., 1999). I focused on individuals rather than couples since many relational concepts (e.g. emotional connection, intimacy, relational satisfaction) operate on an individual level-
different members of the couples may feel differently about the relationship or communication acts. During the interviews, I could probe and discuss the different types of gestures made by the participants from the observational data collected, and ask open questions regarding the kind of touch interactions they performed, why, and what was the meaning or significance of each interaction. I also explored the quantitative aspects of emotional connection and intimacy by asking them to rate their levels of emotional connection and intimacy before and after the use of Flex-N-Feel.

1.5. Organizational Overview

In Chapter 2, I provide a literature review. I discuss how long-distance couples use technology to mediate their communication. I provide a detailed literature review about the existing prototypes developed for long-distance couples along with their shortcomings. And lastly, I describe vibrotactile technology along with previous work done to simulate remote touch.

In Chapter 3, I discuss the design of Flex-N-Feel, a pair of gloves that transmit touch over distance. First, I describe the design requirements which emerged from the related literature mentioned in Chapter 2 followed by the prototype design that I iteratively created. In addition, I introduce some speculative scenarios of how I imagine Flex-N-Feel would be used by couples over distance.

In Chapter 4, I discuss the methodology for a lab-based qualitative and quantitative study that investigates the use of Flex-N-Feel. The study uses semi-structured interview and video observation to gather data with 9 couples and seeks to understand how they interacted with the system and how they would use it in conjunction with their existing communication channels.

In Chapter 5, I discuss the results of the study, which includes an evaluation of the design characteristics of the prototype, the interaction themes which emerged from the initial use of Flex-N-Feel, and how couples used it with audio and video channels.
In Chapter 6, I discuss the results and identify the design implications for future systems transmitting remote touch for LDR. This involves discussing the positives (what worked out well) and negatives (what didn’t work out well) considering the limitations of my design and study.

In Chapter 7, I conclude my thesis by revisiting my research goals and reflecting on how I achieved each one. I also list my research contributions and suggest areas for future work.
Chapter 2. Related Work

In this chapter I review the related literature. First, I review the importance of relationships, define long distance relationships (LDRs) and discuss related work on how LDRs currently communicate to maintain and support their relationship. Secondly, I review systems developed for LDRs to communicate and stay connected with an emphasis on transmitting touch. I further narrow down to previous work done in this area focusing of wearables and vibrotactile technology.

2.1. Relationships

The word “family” is no more defined by the network of only blood relatives. Now family includes parents, children’s, grandparents, partners, and various other relations (Neustaedter et al., 2013). Huijnen et al. (2004) discussed categorizing family groups as primary or secondary, where primary groups are small, close-knit groups such as friendship cliques, children's playgroups, emotionally close peers, and neighborhoods. Secondary groups, on the other hand, are larger and more formally organized and tend to be shorter in duration and less emotionally involving than primary groups. The important point is that the grouping of contacts implies that there is some difference between different types of relationships. The determination of which relationship is in which group comes down to two main factors: frequency of contact and the intimacy of the relationship. Therefore, this categorization of contacts based on the frequency and nature of relationship is of interest.

Work investigating novel communication technology has found similar results, reporting that most participants have a select group of people that they feel they should always be available for (Chen et al., 2006). The frequency of contact is determined by active factors (genetically related people, emotional closeness) but also by passive factors such as distance; the time since last contact increases as distance to the individual increases (Hill & Dunbar, 2003). Given that I am primarily interested in spatially separated relationships, this provides some initial evidence that distance does have a significant impact on people's relationships and communication habits.
This link between frequency of contact and relationships has been made by other researchers. Fehr argues that day-to-day contact is instrumental to the formation of friendships (Fehr, 2000) and that people report more positive feelings the more frequently they interact with someone. These positive feelings help in creating an intimate emotional bond between the physically separated, sustaining their personal relationship. Another study supports that individuals had a strong need to maintain awareness for loved ones and at the same time experienced a duty to be available for intimate people. Depending on how close people already feel, they are willing to share more or less details, more or less often (Neustaedter et al., 2006).

2.2. Long-Distance Relationships

It is evident from past research that distance plays a significant impact on people’s relationships. The aim of this thesis is to develop an understanding of how to support long distance relationships through the design of communication technologies. To do so, I need to first discuss what is known about Long Distance Relationships (LDRs). Throughout this thesis, the terms ‘distant separated couples’ or ‘long distance couples’ both refer to LDRs.

Relationships may suffer through periods of separation for numerous reasons. Couples could be separated for a long span of time due to career or study related obligations, or for frequently occurring short spans of time due to travel, long work hours or conflicting schedule shifts (Holmes, 2004; Stafford, 2005). Hence couples find themselves living apart, in different cities or even countries. These may include couples at different stages of relationships: from recently-introduced dating couples to established couples including partners and even married ones. Estimates have suggested that between 25% to 50% of students will be in an LDR at any given time, with up to 75% of college students being involved in an LDR at some point (Jenkins et al., 1994). Estimates have suggested that up to one million people annually belong to a long-distance relationship in the USA (Maines, 1993) and LDRs have been reported as being as prevalent on college campuses as geographically close dating relationships (Stafford et al., 2006). Regardless of the exact numbers or proportions of people in LDRs, it is clear that there are a large number of people living away from the person they love.
There is a cultural assumption that face-to-face contact is necessary for forming and maintaining close relational ties and that geographic proximity is necessary for close relationships (Stafford, 2005). Similar concerns exist between co-located and distant friendships (Becker et al., 2009). “A majority of both lay people and researchers believe that long-distance relationships (LDRs) usually fail” (Guldner & Swensen, 1995). In addition to cultural assumptions, researchers have argued that LDRs are “fraught with uncertainty and ambiguity” (Lydon et al., 1997). 66% of college students believe that LDRs will not endure (Helgeson, 1994). Stafford et al. (2006) found that around half of LDRs broke up whilst still long distance. This is perhaps unsurprising given the length of time that relationships can be maintained at a distance. Other work has suggested that long-distance partners experience difficulties in meeting each other’s relational needs especially intimacy, sexual, companionship, security and emotional needs (Le & Agnew, 2001), though social and cultural dislocation could introduce different relational needs for LDRs.

Viewing LDRs as being weak is not groundless; geographical separation is a time when some students end romantic relationships. Living far apart has been reported as a reason for relationship termination even if the researchers found no such significant difference between LDRs and co-located couples (Horn et al., 1997). Although I acknowledge that LDRs may have some weaknesses, there is a substantial body of evidence which argues that LDRs can be as successful as co-located couples. Work has found no significant difference in satisfaction between co-located couples and LDRs (Jenkins et al., 1994; Horn et al., 1997). Guldner & Swensen (Guldner & Swensen, 1995) found that relationship satisfaction, intimacy, trust, and commitment are not significantly different between LDRs and co-located couples. LDRs have also been associated with positive relational traits such as a greater belief that their relationship will work out in the long-term (Horn et al., 1997) or that they will marry at some point in the future (Stafford et al., 2006) compared to co-located couples. Jenkins et al. (Jenkins et al., 1994) found no significant difference in feelings of intimacy between LDRs and co-located couples using the Personal Assessment of Intimacy in Relationships (PAIR) measure. They go on to argue that as LDRs recorded less face-to-face communication; intimacy must be created through other communication technologies.
LDRs have many positive facets which are missed when the couple becomes geographically close. These include the amount of autonomy an individual has within an LDR, the freedom to allocate their own time to the activities that the individual wants to undertake and the excitement and sense of specialness an individual has of being in an LDR. This transition from living at a distance to living nearby caused a third of couples to terminate within 3 months of their reunion (Stafford et al., 2006). Two main reasons were given for these breakups. The first was that people missed the anticipation of seeing the other person and found it hard to adjust their day-to-day behavior. The second reason was based on idealization which meant that partners had to adjust their learning and understanding of the other person. Sahlstein (2004) argues that being distant is neither a positive nor negative experience but that it has elements of both. Distance is simply something which presents special challenges for managing availability, especially with regards to developing new communication habits and routines, and personal understanding.

2.2.1. Communication in LDRs

My focus is on the design of communication technologies with high levels of presence through touch. I am concerned with supporting the relationship, assuming that feelings of presence through touch are integral to the maintenance, rather than the ‘success’, of the relationship. It is generally accepted that “relationships are both based in mutual interactions and go beyond interactions” although other factors, such as kinship, are also used to determine them (Stafford et al., 2006). This highlights the importance of communication in relationships.

This thesis is not focused on the detailed theoretical approaches to relational maintenance (Pistole et al., 2010; Stafford, 2005). These are behaviors that people perform to maintain their relationship the way they want it. Canary et al. (1993) demonstrated that these strategies differ between different relationship types. All involve communication to some extent, especially those strategies which focus on meaning as a form of relational maintenance. Duck & Pitmann has argued that mundane face to face conversation is integral to maintaining romantic ties (Duck & Pitmann, 1994) and that
relationships are contingent on shared meaning (Duck & Pitmann, 1994). Pistole et al. (2010) found that although LDRs have unique stressors (such as expense of travel and relational disruption of travel), they do not suffer day-to-day relational stressors due to the distance between partners. This thesis is focused on understanding how we can design technologies to support relationally meaningful communication in terms of the feelings experienced and expressed in the interaction.

Some work has argued that there is an association between face to face communication and relational success. Holt and Stone (1998) reported that college partners who saw one another less than once a month (and were 250 miles apart) were less satisfied than couples who saw one another more frequently. Dainton and Aylor (2001) asked participants how often they saw their partner. Those who answered “never” were less satisfied than those who had regular face to face contact. These findings are limited as the phrasing of the question appeared to operate over a single week rather than a longer period. Based on interview data, Arditti and Kauman (Arditti & Kauffman, 2004) report that communication was essential to the maintenance of distance relationships for students aged 23-35. Distance had no effect on how well the participants believed they knew their partner. Part of the reason that distant relationships remained strong was based on the belief that the relational distance was only temporary and would end at the end of their educational period. This is of great relevance to this thesis, given the focus on youth where their separation period is believed to be of a fixed length in the minds of LDRs. Dainton and Aylor (2002) found that different technologies were associated with different levels of relational success. Telephone time and internet use being positive indicators of increased satisfaction for couples. The classification of media is somewhat crude - the ‘internet’ could contain email, IM messages, newsgroups or video conferencing. Neustaedter & Greenberg (2012) found how couples make use of video chat to stay connected, create a shared sense of presence, and intimacy by opening video links for extended periods of time. They suggest video chat systems allow partners to be part of each other’s lives and being their day-to-day companions. They emphasize that the presence of one’s partner through video chat can help couples establish intimacy.

LDRs have less opportunities for face to face communication than co-located couples but no more opportunities for mediated communication (Stafford & Merolla, 2007).
To maintain their relationships, individuals in LDRs were found to characterize their everyday talk as more intimate in focus than co-located couples (Stafford, 2010). It could be that people in LDRs are prepared to invest more effort and significance in their mediated exchanges than people in co-located relationships. This could account for the fact that LDRs perceived their communication to be of a higher quality than co-located couples (Stafford & Merolla, 2007).

To briefly summarize, we have established that communication technologies are important to LDRs and that the design of these technologies can have a strong impact upon relationships.

2.3. Technology Probes

With emerging Information and Communication Technologies (ICT), several remote communication tools like email, phone calls, online texts, audio and video chat are often adapted for facilitating and maintaining connections for LDRs. As these tools cannot fully address the remote lovers’ emotional needs and encourage intimate interactions, there are a growing number of attempts to develop affective technologies specifically for mediating intimacy. In the context of mediated intimacy, these technologies can be categorized into two groups: those which are mediating non-physical dimensions of intimacy and those which are inspired by physically intimate behaviors. I talk about each of these areas in turn next.

2.3.1. Non-physical dimensions of Intimacy

First, prototypes have focused on interconnected physical or digital objects that users can interact with to cause an effect on one or more properties of the remote partner’s object. One of the prominent themes in this category is the use of ambient communication through interactions.
For example, Chang et al. (2001) developed a pair of interactive picture frames called LumiTouch (shown in Figure 2.1). When one of the remote users touches their respective picture frame, the other picture frame lights up. This touch is translated to light over an Internet connection. LumiTouch is designed to be used like a picture frame and remain visible in everyday life. The use of light as both an ambient representation and active data transmission allows the user’s attention to transition between passive and active. LumiTouch is designed to be an asymmetric, bi-directional channel of communication. LumiTouch supports three types of interactions and awareness.

1. **Passive Communication**: When a user is in front of her LumiTouch, the corresponding remote LumiTouch will emit an ambient glow to indicate their remote presence.

2. **Active Communication**: When a user picks up the picture frame and squeezes, the feedback display area illuminates to show that the picture frame has been squeezed. The display colors are transmitted over the Internet to the corresponding remote LumiTouch. The display varies depending on the squeeze attributes: where, how hard, and how long the user squeezed.
3. **Interpersonal Language**: The system was intended to allow users to develop an abstract form of emotional language. People could communicate in real-time by sending each other color mixtures and light patterns. The combination of colors and force created a grammar, while the duration of squeeze provided syntax for creative interpersonal dialect between two people.

Kowalski et al. (2013) proposed Cubble, a hybrid communication concept consisting of a stationary home-use object in the form of a cube as well as a mobile application for on-the-go use. Cubble’s hybrid approach establishes a continuous, bidirectional, exclusive and private channel for couples via light, vibration, and heat. Depending on client activity logs, messages are received in either the home or mobile client. Cubble provides three message types.

1. **Nudge**: is a short emotional ping from a partner. It consists of a color, which is selected by touching the sides of the hardware or according to buttons of the mobile interface. It is sent by a single tap on the hardware’s front or mobile device’s screen and received as a single-color flash (matching the color previously determined by the sender) and a simple vibration.

2. **Tap patterns**: These offer a more diverse exchange and the creation of private languages. They are presented as repeated light bursts and vibrations in the rhythm as entered.

3. **Holding hands**: This creates a live connection as both partners’ touch Cubble at the same time, resulting in a yellow pulsation and a warming-up of the clients.

Through a small qualitative explorative study, they found that couples favor the hybrid communication concept and found that this fostered their intimate communication by providing emotional closeness.
Another design theme is mutual activity, which refers to the technologies that facilitate shared activities that normally happen when couples are co-located. This contains inter-connected objects though the emphasis is on creating a mutual experience on both sides. One such example is co-drinking with your loved one over distance. Chang et al. (Chung et al., 2006) developed a pair of cups called Lover’s Cups (refer Figure 2.2) to explore the idea of sharing feelings of drinking between two people in different places by using cups as communication interfaces of drinking. Two cups are connected with each other, and respond when the other cup is used. A person can see in his/her own cup how much liquid is in the other’s cup and when s/he is drinking by which side. Overlapped on their own real liquid, these kinds of displays can help people to feel as if they are drinking together and even sharing the same cups and the same liquid. This interface introduces interactive drinking opportunities for emotional interaction, health care, family care, and social activities.

Another shared activity was sharing “GoodNight” messaged through a pillow and picture frame. SleepyWhispers (Gooch & Watts, 2012a) is a way of sending recorded sound messages to your partner. The system consists of a pillow and a photo frame.
Messages are listened to through a speaker, hidden inside the pillow. Messages are played when the listener presses the button embedded into the photo frame. The system contains one further detail based on our interest in fleeting and realized outputs. Each message can only be listened to once; after which it is deleted and cannot be listened to again. In this way, the messages are clearly fleeting. The prototype was intended to explore the design potential around creating a communication system based on the behavioral qualities of sharing goodnight messages. The authors undertook a case study involving a single couple for 8 weeks and found that the couples used it to solidify their relationship by joking around using the system. It was hard to generalize based on the limited number of users but this leads to further exploration of how voice messages could be better utilized for long-distance couples.

Fictitious co-habiting is another design perspective in which a sense of co-habitation is conveyed through sharing homes, furniture, or other objects in the home. For example, “The bed” (Dodge, 1997) is an environment providing a new form of abstracted presence for intimate, non-verbal inter-personal communication. “Peek-a-drawer” (Siio et al., 2002) is a set of virtual shared drawers that connect family members who are located at a distance. When a user puts something in the upper drawer and closes it, a photograph is taken automatically and the image appears in the lower drawer at a distant place. “Habitat” (Patel & Agamanolis, 2003) is a range of connected furniture for background awareness between distant partners, focused on conveying the patterns of daily routines and biorhythms that underlie our well-being, in order to provide a sense of reassurance and a context for communication between people in relationships. “SyncDecor” (Tsujita et al., 2007) synchronizes pairs of appliances, such as lights, trash boxes, and TVs, that are located at a distance from each other to create a virtual “togetherness” experience. Lastly, “Digital Selves” (Grivas, 2006) are electronic devices that receive and send signals indicating the use of connected household devices to provide a sense of partners’ activity and presence, manifested in each other’s physical house, as if the couples are inhabiting a common intimate space.

Personalization and embodying the media with features of the remote partner is another design theme. Examples include “Mini-surrogate” (Saadatian et al., 2013) in which the appearance of a telepresence robot corresponds to the remote partner, and “magic
“sock drawer” (Gooch & Watts, 2011) which supports the serendipitous sharing of handwritten notes in a drawer as a private location.

Overall, the general trend that can be seen in all of the aforementioned designs is conveying illusive co-presence and awareness. The limitation of this work is that these prototypes do not provide an expressive and rich medium of communication. They only provide passive awareness sharing through ambient mediums in the environment which lacks affection and intimacy.

2.3.2. Physical intimate dimensions

In order to support physical intimacy across distance, some prototypes have been proposed, which are designed based on the mimicry of co-located physical intimacy between couples. The researchers have approached this area by mimicking the nonverbal cues perceived due to close physical proximity. These nonverbal cues could be either physiological signals (heartbeats, tactile pressure, vibrations, heat, whispers) felt on one’s body, the whole intimate gesture (i.e. performing a gesture with your partner through an artifact or wearable device), or the combination of both.

Previous work has focused on augmenting artifacts; taking everyday objects and adding sensors and actuators in order to create communication systems. For example, ComSlippers (Chen et al., 2006) is a traditional slipper augmented with technology to create a sense of connection to others. It allows the wearer to use body gestures and tactile manipulation to feel and express emotions and availability to distant loved ones. Pressure points on either pair of slippers are connected to a LED and heat pad in the other pair. Various interactions (such as foot tapping) lead to different outputs. The device illustrates some important concepts. The first is the use of an existing personal artifact to create a communication system. The intention appears to utilize existing feelings to increase the emotional meaning behind any message that is sent. The second is the use of minimal interactions and outputs to create a phatic link between participants. ComSlipper provides warmth, light, and vibration as the output mechanism that is emotional but ambient. This paper presents the device as being activated unconsciously.
from behavior emerging from a person's mood and further assumes that foot movements reflect the emotional state of a person. I feel this needs solid backing either from an extended study or by strong evidence in the related literature. Another concern is whether participants were informed of this intention, and that certain emotional behavior matches certain output, then there is a large scope for confusion and misunderstanding. The lack of a user study opens a debate to this question.

![Image of a hugging cushion](image)

**Figure 2.3 The Hug concept**
Source: Publications (Gemperle et al, 2003)

We have also seen devices been designed to mimic couples' behaviors over distance. These include hugging, hand-holding, kissing and entering a room. Of these, hugging has received the most attention. DiSalvo et al. (2003) present the design of a hugging cushion (refer Figure 2.3), styled in the shape and form most suited for hugging. The paper presents new opportunities for interaction through its anthropomorphic form, but the actual social and emotional aspect of the connection is not evaluated. Without evaluation, how do you know the design has achieved its objective?
Mueller et al. (2005), on the other hand, have presented an air-inflatable vest (shown in Figure 2.4), designed to mimic a hug. The vest was inspired from cultural probes investigating what people would like as a communication device to support their intimate relationships. The vest is activated by a partner rubbing a koala soft toy (shown in Figure 2.6 on the left), an interesting and novel way to activate the device, intended to make the activation a playful mimic of hugging. The device also sends an acknowledgment back to the koala, creating a kissing sound. This actively involves and thanks the partner, creating a two-way link between the users, even if the links are not of the same kind.

The authors explicitly state that their intention is not to accurately recreate the physical and emotional experience of a real hug. Rather, it is the user's interpretation of the phatic signal which leads to the association of emotion with the message. When presented with the device, participants liked the idea but were concerned about many of the practicalities of using the device. It was bulky, loud, could not be reciprocated (i.e. only one vest) and ‘weird’. However, they could not experience its use in the ‘real-world’ and it is likely that they could not separate their concerns over the pragmatics with the
conceptual nature of the device. Participants also noted that with current ‘real’ hugs, people can reject them. This is interesting and not something which is generally considered, however, users could decide to turn the device off or refuse to wear the vest.

![Image of Kissenger device](image)

**Figure 2.5 Kissenger**
Source: Publications (Saadatian et al., 2014)

The Kissenger device is the only prototype which attempts to create a communication system based on kissing (Saadatian et al., 2014). The system consists of two miniature heads which have moveable lips attached to the smartphones (shown in Figure 2.5). When manipulating one set of lips (presumably using your own lips), the paired head replicates these manipulations. The device was evaluated through an experiment involving seven couples, some of whom were friends. Although it is beneficial that the device has been evaluated, the evaluation process suffers from some weaknesses. Participants had to simulate an ‘intimate conversation’ and were forced to use ‘kisses’ within the conversation. This is hardly a natural situation, invalidating the contextual validity of the evaluation. Additionally, the device was compared against video-chat kisses rather than other forms of intimate communication that could be used to replace the absence of kisses. This limited evaluation of the prototype, without reporting
any deep insights of users’ experiences, gives us minimal confidence in the design of the device and couples’ perceived value of kissing over distance.

Gooch & Watts (2012b) made several attempts to mimic hand-holding by designing three prototypes. They use movement and heat to present hand holding and hand shaking. In Your Gloves, a pair of robotic hands covered by a soft haptic glove simulate handholding. In HotHands and HotMits this gesture is emulated by thermal insulation. Based on their design work, Gooch and Watts explain that the design of intimate communication devices for couples should carefully consider factors such as personalization, evocation and metaphor. First, they mention that the act of co-creation is a form of super-personalization that creates a strong personal memory and embedding this memory in the creation or use of technology is beneficial for LDRs. They found that stronger metaphors of co-located hand-holding were less enjoyed by users and hence indicate that metaphors such as hand-holding should be used as a starting point for design but should not be simply replicated in the design. Finally, spontaneity was highlighted as a design factor worth considering. Spontaneity is something which can easily be lost within the routine of an LDR and, as such, designing it into couples’ communication ecology could be beneficial.

### 2.3.2.1 Touch via vibrotactile technology

This section looks at the behavior of transmitting different gestures of touch via vibrotactile sensations. Past research has suggested that physical touches could be replicated through vibrotactile technology (Rantala et al., 2013) as the sensory medium. Tactile technology has been used in several studies through actuators such as vibration motors which are easily embedded in mobile and wearable devices (Bonanni et al., 2006; Chang et al., 2002; Joi et al., 2015; Park et al., 2010; Wang, 2012). This is because to date there are no such sensors that could emulate the sensations of a human touch. Past research has considered movement, pressure, heat, vibrations or the combination of these to replicate human touch.

Most of the systems developed using vibrotactile technologies are either designed to be a communication artifact (i.e. hand-held devices) or are in the form of wearables (i.e.
jewelry, garments, wrist bands etc.). Let me start by introducing the communication artifacts designed to facilitate touch via vibrotactile sensations.

Figure 2.6 ComTouch
Source: Website (http://tangible.media.mit.edu/project/comtouch/)

First, ComTouch (Chang et al., 2002) is a hand-held device (shown in Figure 2.6) intended to be used in conjunction with other communication channels, specifically voice, combining the best facets of multiple communication types. The device converts hand pressure to vibrational intensity, experienced through holding the mobile phone. The authors reported results by performing a preliminary study. Though there is a well-constructed evaluation, it focuses more upon the ergonomics and ability to feel touch rather than ComTouch’s ability to support people’s relationships. The central finding of the preliminary trials was that there is a relationship between the audio and tactile channels. As expected, the information transmitted over the tactile channel was meaningful and proved that vibrotactile mappings can be used. But some gestures were found to be redundant like emphasis (synchronizing tactile pattern to speech). Mimicry (echoing the
same complex pattern), at the other extreme, was largely independent of the audio channel.

Figure 2.7 CheekTouch
Source: Publications (Park et al., 2010)

Park and et. al. (Park et al., 2010) presented the CheekTouch that supports bidirectional vibrotactile transmission during a phone call. It combines tactile feedback delivered via the cheek and multi-finger input while speaking on the mobile phone (shown in Figure 2.7). It is natural to use because it maintains the posture of speaking on the phone. Also, adding a tactile interface on the cheek can compensate for non-verbal cues during voice communication. They reported a user study (Park et al., 2012) of observing the free form conversations of four romantic couples using CheekTouch in a lab setting over five consecutive days. Their results showed six types of usage of remote touch: persuading, conveying status, delivering information, emphasizing emotion and words, calling for attention, and being playful. CheekTouch could help phone calls in terms of supporting non-verbal communication and delivering telepresence. CheekTouch can be used effectively to give comfort and lead a conversation in a positive way, which might have flowed in a negative way with voice alone.
Next, I focus on systems designed to be used as wearables. To start with we have seen the United-Pulse ring (Werner et al., 2008), designed based on the aim to develop a device that allows people to share remote intimacy. United-pulse is composed of two rings. Each partner receives one ring. The inside of each ring contains a pulse measure system. In order to feel the partner’s pulse, a small gap in the ring must be filled (pulse measure gesture). The shape must be completed to feel the partner’s pulse. United-Pulse was designed with the intention that a pulse could remind partners of common “golden moments”. As a second metaphor for love and affinity, the ring shape was chosen. The ring symbolizes a common bond (wedding, signet-ring) where the round, ‘whole shape’ suggests completeness. Experimental evaluation appears to indicate that the concept is a pleasant one, but with no working prototype, a field study could not be conducted to validate such an idea. In the study, it was not clear how the users interacted with the united-pulse ring on the preferred direction or mode of transmission.

TapTap (Bonanni et al., 2006) simulates touch through vibration, pressure, short pokes, and heat via a scarf-like device. The goal is to record and replay patterns of touch through a series of vibrator pads located in four pockets in the scarf. This device aims at providing emotional support “nurturing human contact”, but no user study was presented to support the claims. Anecdotal evidence was reported that women preferred more gentle vibrating motors and disliked more violent solenoid-produced motions. Men were reported to have the opposite preferences.

We have also seen commercial products like Fundawear (Fundawear, 2013), which transmits touch to personal parts of the body using a mobile application and undergarment, and Alert Shirt (Alert Shirt, 2014), a fan jersey to experience what players feel during the game. Neither has been publicly evaluated to understand user reactions to them.

Haans et al. (2007) developed a “Tactile Vest” in the form of a waist strap embedded with vibrotactile devices. With this device, they performed a study to determine if users regarded remote touch the same way they do real touches. Their hypotheses were that if males and females reacted to within gender and cross gender remote touches in
similar ways as people do to real touches under similar conditions as reported in the
gender-touch papers, then remote touch response can effectively simulate real touch
emotions. They tested on the location of the touch as well as the gender of the remote
touch originator. Their results were significant for body location of the touch. They found
that touch over the stomach region was disliked and touch over the upper arm was
positively received by the participants. The gender difference scores for within and cross-
gender dyads for both males and females were similar to those reported by a real human
touch. Haans et al. concluded that their results provided “partial support for the assumption
that mediated social touch is actually perceived as a real touch”.

A brief touch on people’s upper arm can increase people’s willingness to comply
with a request. Haans et al. (2014) presented a study “The Virtual Midas Touch” to
investigate whether the similar effect would also occur under mediated conditions. In this
study they randomly divided participants into three conditions; 1) Touch Condition, in
which participants received vibrations via the arm strap from the confederate; 2) A No
Touch-System Failure condition, in which participants didn’t receive any stimulation, but
were made to believe that the confederate did initiate the virtual touches but it is not
transmitted due to a system failure; and, 3) A No Touch-Intentionality condition, in which
participants received no virtual touch and was put forward that confederate didn’t use
virtual touches. Participants and a confederate sit at two sides of a room (divided by an
opaque board) for a question-and-answer session through a messaging system that can
transmit text as well as haptic touches on participants’ shoulder. Their hypothesis was that
participants in the touch condition would be more forthcoming in helping to pick up coins
that a confederate dropped out of her wallet at the end of the experiment session. Although
helping behavior was more frequent in the touch condition, compared to the no touch
condition, this difference was not found to be statistically significant. One possible
explanation for such a failure to find response similarities between vibrotactile stimulation
and real (i.e., unmediated) physical contact is that the researcher deliberately isolated the
touching act from the other means of nonverbal behavior with which it is naturally
confounded.
Figure 2.8 Touch gestures of squeeze (a) and finger touch (b).
Source: Publications (Rantala et al., 2013)

Rantala et al. (Rantala et al., 2013) introduced a hand-held device (shown in Figure 2.8) using vibrotactile stimulation to imitate different touch gestures. The device can detect squeeze, strokes or moving hands and was transferred to a user’s palm and fingers via four actuators. When one user squeezed his device, or touched it with their finger(s), another user felt the corresponding vibrotactile stimulation on her device via four vibrating actuators. Through a study, they found squeezing was found to be easier and a seamless method for creating haptic content. The results showed that squeeze was better at communicating unpleasant feelings and aroused emotional intention, while finger touching was better at communicating pleasant and relaxed emotional intentions.

Wang et al. (Wang & Quek, 2010) developed an inflatable wearable tactile device for arms and showed positive emotions were amplified and negative emotions were reduced by using their device along with vocal context. Their primary design guidelines are that the touch channel needs to be coupled with other communication channels to clarify its meaning and they encourage the use of touch as an immediate channel by not assigning any symbolic meaning to touch interactions. Wang's work categorizes remote touch into four categories based on couples’ usage of an inflatable armband augmented with a small squeezable device and audio-only communication. Uses included pre-defined codes and testing; touch conveying positive affect; playful touches; and, conversational touches.
Most of the previous work has designed technologies to mediate remote touch without a thorough evaluation. We have seen a few prototypes which have performed extensive evaluation with users, resulting in using touch to communicate positive emotions and express support, appreciation, sexual interest/intent, and affection through remote touch for distance separated lovers. But, most of the previous work mapped these physical sensations to a specific body part for use in a very specific manner. This is limited in terms of mobility of usage, the mapping between the perceived and sent action, and flexibility of usage. To date, researchers have not yet explored the design space of an open-ended remote touch system using vibrotactile sensations for long-distance couples.

Table 2.1 Systems mediating non-physical dimensions of Intimacy

<table>
<thead>
<tr>
<th>System Name</th>
<th>Goal</th>
<th>Sensory Medium</th>
<th>Interaction Capabilities</th>
<th>Study Type</th>
<th>Main Findings</th>
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</thead>
<tbody>
<tr>
<td>LumiTouch (Chang et al., 2001)</td>
<td>A pair of picture frames to communicate emotional content and presence of your partner.</td>
<td>Ambient Light</td>
<td>Touching and squeezing the picture frame.</td>
<td>Preliminary Observation / testing</td>
<td>LumiTouch aids in explorations of the development of interpersonal emotional language.</td>
</tr>
<tr>
<td>Cubble (Kowalski et al., 2013)</td>
<td>Enable partners to share their emotions and remote presence via hybrid communication concept.</td>
<td>Light, vibration and heat</td>
<td>Touching and sensing the cube.</td>
<td>Initial user exploration (short study with limited participants)</td>
<td>Cubble fostered couple’s intimate communication by providing emotional closeness.</td>
</tr>
<tr>
<td>Lover’s Cup (Chung et al., 2006)</td>
<td>Explores the idea of sharing feelings of drinking between two remote people by using cups.</td>
<td>Light</td>
<td>Holding, shaking and toasting the cups.</td>
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<td>This interface introduces opportunities for emotional interaction, health care, family care, and social</td>
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<td>SleepyWhisper (Gooch et al., 2012)</td>
<td>A prototype device intended to allow distant lovers to share goodnight messages</td>
<td>Voice</td>
<td>Interacting with a picture frame and pillow to send and receive voice messages.</td>
<td>Single user case study</td>
<td>Couples found it useful for solidification of their relationship.</td>
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<td>SyncDecor (Tsujita et al., 2007)</td>
<td>The use of day-to-day items to create a virtual &quot;togetherness&quot; that enables couples to share their daily activities</td>
<td>Video, light and movement.</td>
<td>Interactions with a Lamp, TV and trash can.</td>
<td>Field Study</td>
<td>SyncDecor helped couples increase their feelings for their partners.</td>
</tr>
</tbody>
</table>

Table 2.2 Systems mediating physical dimensions of Intimacy

<table>
<thead>
<tr>
<th>System Name</th>
<th>Goal</th>
<th>Sensory Medium</th>
<th>Interaction Capabilities</th>
<th>Study Type</th>
<th>Main Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>ComSlippers (Chen et al., 2006)</td>
<td>Exploring how wearable, expressive communication devices could facilitate lightweight, emotional communication</td>
<td>Light, Heat and tactile response.</td>
<td>Movement of foot and visual indicators.</td>
<td>--</td>
<td>ComSlipper provides a natural and intimate way of communicating, and facilitates the development of intimate relationships</td>
</tr>
<tr>
<td>The Hug (DiSalvo et al., 2003)</td>
<td>A prototype concept that explores how telecommunication and sensing technology can support social and emotional</td>
<td>Voice, pressure and light.</td>
<td>Squeezing, stroke, hug and pet.</td>
<td>Informal evaluation</td>
<td>The Hug offers new opportunities for interaction through its anthropomorph ic form, simple controls, and</td>
</tr>
<tr>
<td><strong>Hug over distance</strong> (Mueller et al., 2005)</td>
<td>Design an interface to facilitate and encourage social, even intimate interaction.</td>
<td>Pressure</td>
<td>Interaction with a koala soft toy.</td>
<td>Participative design workshop.</td>
<td>The prototype enhanced the couples’ understanding of the researchers’ methods, suggesting that prototypes can serve as tools to make participatory design volunteers aware of their research.</td>
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<tr>
<td><strong>Kissenger</strong> (Saadatian et al., 2014)</td>
<td>Designed to mimic the behavior of kissing your remote partner via an interactive device.</td>
<td>Haptic and movement</td>
<td>Kissing and holding the device.</td>
<td>Field study</td>
<td>Study suggested possibility of meaningfulness of Kissenger in the daily life of couples. Iterative design process highlighted the potential design pitfalls for designers.</td>
</tr>
<tr>
<td><strong>Your Gloves</strong> (Gooch &amp; Watts, 2012b)</td>
<td>Design of intimate communication devices based on personalization, evocation of memories and metaphorical.</td>
<td>Haptic movement</td>
<td>Interacting with a hand glove.</td>
<td>Lab Study</td>
<td>Design of intimate devices should be based around small, tangible, intimate behaviors intended for long distance couples.</td>
</tr>
<tr>
<td>System Name</td>
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<td>Sensory Medium</td>
<td>Interaction Capabilities</td>
<td>Study Type</td>
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<tr>
<td>ComTouch (Chang et al., 2002)</td>
<td>Enrich interpersonal communication by complementing voice with a tactile channel.</td>
<td>Voice and vibration.</td>
<td>Interacting with a hand-held device.</td>
<td>Preliminary user study.</td>
<td>Demonstrated the potential and advantages of the tactile channel to enhance the existing voice communication channel.</td>
</tr>
<tr>
<td>CheekTouch (Park et al., 2010)</td>
<td>Embedding affective interaction techniques that maintains natural voice communication</td>
<td>Voice and vibration.</td>
<td>Interacting with a smartphone and feeling vibrations.</td>
<td>Exploratory Lab Study</td>
<td>CheekTouch could effectively support audio-tactile communication in various ways – persuading, conveying status, delivering information, emphasizing emotion/words, calling for attention, and being playful.</td>
</tr>
<tr>
<td>United-Pulse</td>
<td>Design and develop a device that allows people to share remote intimacy in the form of a ring.</td>
<td>Vibrations in the form of pulse.</td>
<td>Wearing the vibrotactile ring.</td>
<td>Preliminary user testing.</td>
<td>United pulse is a unique way for people to connect by tactile stimuli which is nearly invisible for the public.</td>
</tr>
<tr>
<td>Tap-Tap (Bonnani et al., 2006)</td>
<td>Design of a wearable haptic system that allows asynchronous distributed</td>
<td>Vibration patterns.</td>
<td>Using the wearable garment-scarf with vibrotactile sensations</td>
<td>--</td>
<td>This system presents the first steps towards recording, broadcasting,</td>
</tr>
<tr>
<td>Fundawear</td>
<td>Design of inner wear for remote lovers to meet their desire for sexual intimacy.</td>
<td>Vibrations</td>
<td>Wearing the innerwear and interacting with a mobile app to send remote vibrations.</td>
<td>--</td>
<td>How vibrotactile sensors can be embed in inner wear for supporting sexual intimacy.</td>
</tr>
<tr>
<td>Tactile vest (Haans et al., 2007)</td>
<td>To investigate whether Midas Touch effect would also occur under mediated conditions</td>
<td>Vibrations via tactile vest and arm straps.</td>
<td>Interacting and feeling vibrations via vest and armband.</td>
<td>Experimenta l design</td>
<td>Mediated social touch is partially perceived as a real touch through their study.</td>
</tr>
<tr>
<td>Hand-held device (Rantala et al., 2013)</td>
<td>To investigate the imitated touch gestures (squeeze and finger touch) can convey intended emotions over distance.</td>
<td>Vibration s</td>
<td>Squeeze and finger touch via hand-held device</td>
<td>Lab Study</td>
<td>Each gesture was found to be better at conveying a set of emotional intentions. These suggest choosing and embedding touch gestures that matches the desire emotions</td>
</tr>
</tbody>
</table>
Inflatable wrist band (Wang et al., 2010)
To propose a model of immediacy of the touch channel for conveyance of affect based on psychological and sociological literature of touch.
Voice and vibration.
Interaction with
Lab Study
Remote touch can reduce sadness emotion significantly and has a trend to reduce general negative mood and to reinforce joviality.

Table 2.1 Table summarizing all the systems mediating forms intimacy.

2.4. Summary

Many couples in LDRs rely heavily on computer-mediated communication tools to connect over distance and these systems provide an ever-increasing range of ways to stay connected. For example, text messaging is often used throughout the day by couples to share details about one’s ongoing happenings or to ask quick questions. We also see couples use video communication to engage in intimate activities and even sleep together with a video link open. Computer-mediated communication tools have been shown to increase feelings of closeness between couples, build mutual trust, and improve relationship satisfaction, yet they lack one of the most important tangible aspects of face-to-face conversation: the power of touch, which can express an array of various subtle messages.

There are a growing number of attempts to develop affective technologies specifically for mediating intimacy for LDR couples. First, prototypes have focused on interconnected physical or digital objects that users can interact with to cause an effect on one or more properties of the remote partner’s object. One of the prominent themes in this category is the use of ambient communication and porotypes facilitating shared activities. The limitation of this work is that these prototypes do not provide an expressive and rich
medium of communication. They only provide passive awareness sharing through ambient mediums.

Second, prototypes have been designed for partners to feel physical interactions directly on their body. For example, physiological signals such as heartbeats could be sent between partners or using sending different touch gesture such as a squeeze, hug, or mimicking hand holding using various sensory mediums. The aforementioned prototypes represent physiological signals either through explicit acts (e.g., touching, squeezing or hugging) or implicit ones (e.g., heart rate, sleep patterns). Past research has suggested that physical touches could be replicated through vibrotactile technology. Tactile technology has been used in several studies through actuators such as vibration motors which are easily embedded in mobile and wearable devices. Through these prototype evaluations with users’ researchers found remote touch aids in the communication of positive emotions and expressing support, appreciation, sexual interest/intent, and affection for distance separated lovers. I have provided a detailed summary of all the system mentioned in this chapter as per the categories mentioned (refer to Table 2.1).

Yet most of the previous work mapped these physical sensations to a specific body part for use in a very specific manner. This is limited in terms of mobility of usage, the mapping between the perceived and sent action, flexibility of usage. To date, researchers have not yet explored the design space of an open-ended remote touch system using vibrotactile sensations for long-distance couples. My approach was not to limit the touch to any specific part of the body; instead, I wanted our design to convey an understanding that touch could be felt anywhere and it was up to couples to decide.
Chapter 3. Designing Flex-N-Feel

In this chapter I present the complete design process for Flex-N-Feel addressing my first research question on how to translate the needs of LDRs to the design of a system capable of transmitting remote touch. I start with the design requirements emerging from the related literature described in the previous chapter. Based on these requirements I present initial design sketches which were continuously iterated to improve the overall theme and usability. Next, I present the final design along with the technical implementation of the system. Lastly, I present the design rationale behind each of the design components of Flex-N-Feel. In addition, I introduce a few scenarios that I imagine a system like Flex-N-Fell could be used in.

3.1. Design Requirements

I began the design process by reflecting on the related literature on the needs of LDRs, as well as the ways in which co-located couples interact with each other. Based on these efforts, I came up with four design requirements for the design of my prototype.

1. Mobility - I wanted the prototype to be able to be used by couples on the go, anywhere, and at any time of the day. This would help couples stay connected and feel each other’s presence at any point in time that they desired. This meant moving away from designing an object that is confined to couples’ home or personal space and focussing more on something small and tangible that could be easily carried or worn at various points in the day. For these reasons, I decided to look at the current trend of wearables to explore the space of new interaction styles and experiences.

2. Direct Mapping - I wanted to go beyond the form and appearance of the prototype and focus more on the design of the interaction with the prototype itself. I wanted to design the prototype’s interactions such that the interactions themselves would convey the partner’s intension, a touch. That is, I wanted a one-to-one mapping between a partner’s action and how it was received, rather than the action being abstracted. This is similar to other prototypes where, for example, a hug at one end of the connection simulates a hug
at the other end (Mueller et al., 2005). This was important because the way couples interact with my prototype should itself serve as a reminder and feeling as if their partner is sitting next to them and they are touching their partner (Djadadiningrat et al., 2002). This way the emotional connection would be formed more by the interaction itself.

3. **Flexible** - I realized that couples are unique in terms of how they want to share touches with each other. As such, I wanted to design my prototype so that it could support a range of touch interactions rather than being limited to just one touch gesture. Also, I wanted to allow touch to be accessible to different parts of the body, which was missing in most of the prototypes presented in Chapter 2. In this way, I anticipated that my prototype would fit into couples’ existing patterns of touching one another, which in turn might help couples understand the relations between their actions and the likely effects on their partner (Hornecker & Buur, 2006).

4. **Private and Subtle** - Touch between partners is sometimes an act that is meant to be private and unnoticed by others. For this reason, I wanted to select a sensory medium that would allow distance-separated couples to experience touch in a private and subtle manner, nearly invisible to the public. My hope was that this would make the remote touch more intimate and increase couples comfort level to use it anywhere.

### 3.2. Initial Design Sketches

I started to conceptualize these requirements into initial design sketches. I poured my imagination and ideas into a tangible, coherent set of thoughts in design sketches. I came up with multiple forms of transmitting touch via different sort of wearable technologies. I came with several ideas such as:
1. **Shoulder-waist strap**: a diagonal strap meant to be used as a bag (Figure 3.1). The strap would have pressure sensors to emulate the effect of a squeeze or a hug and vibrotactile sensors to give the feeling of stroking fingers. The challenge with this design was that the touch would just be limited to the upper abdomen area (stomach and back). Additionally, it would be hard to think of different kinds of interactions one makes with a strap.

Figure 3.1 Conceptual sketch of a shoulder-waist strap

Figure 3.2 Conceptual sketch of a scarf
2. **Scarf**: a wearable scarf which could be wrapped around ones’ body in different ways around the neck or waist (Figure 3.2). The ends of the scarf could be attached to make it a waist strap and simulate the squeeze effect around the waist using vibrotactile sensations. The major problem with this design was with the sensation from the vibrotactile sensors. To feel the sensations, the vibrotactile sensors needs to be placed tightly against ones' skin. With a scarf the sensors might not be always in close contact with the skin due to the wearability of a scarf which is meant to be loose and comforting.

![Conceptual sketch of a wrist band to simulate touch.](image)

Figure 3.3 Conceptual sketch of a wrist band to simulate touch.

3. **Wrist band**: to simulate a squeeze effect (Figure 3.3) on ones’ arm using pressure sensors. The wrist band could also be worn on the ankles to could simulate different vibrotactile patterns to give a feeling of stroking, tapping and squeezing. This design did not meet one of my requirements of flexibility, i.e. the touch would be just limited to the hand.
4. **Gloves**: a pair of gloves to simulate touch via finger movements (Figure 3.4). The gloves would sense the finger movements via flex sensors and transmit these to the other glove via vibrotactile sensations. This design met all my design requirements and I could easily speculate around couples using the gloves at various points of the day. Using the glove, one could design many interactions with the hand or the individual fingers.

Figure 3.4 Conceptual sketch of a glove to simulate touch

Figure 3.5 Conceptual sketch of an arm band to simulate touch
5. **Arm band**: An arm band to sense and transmit touch to the entire arm (Figure 3.5) via flex sensors to measure the arm movement and heat and vibration sensors to simulate the touch. This design was similar to the gloves but it would sense the arm movement rather than the hand movements. The only issue with this design was with the wearability of the arm band. It would be cumbersome to wear the band throughout the day or taking it on and off could be a challenging task for users.

Based on the sketches outlined above, I decided to go ahead and refine the idea of using gloves to share finger movements as a sense of touch. I selected the gloves as it could potentially meet all the four design requirements if carefully designed. I further started brainstorming on the properties of the gloves i.e. placement of sensors, interaction with the gloves, materiality etc. and started embedding these into my sketches. After drafting several sketches, I came up with the final sketch shown in Figure 3.6. The system consists of a pair of gloves. One of the gloves measures the amount of bend in the fingers and transfers it to the other glove in the form of vibrotactile sensations. Based on this interaction of flexing ones’ fingers and feeling the vibrations on the other glove, I named my system Flex-N-Feel. Next, I will present the design rationale for each component of the glove.
3.3. Design Rationale

In this section will I will describe the design characteristics taken into consideration for each component of Flex-N-Feel.

3.3.1. Flex Interaction

I came up with the interaction of flexing or bending ones’ fingers to mediate a sense of touch. I felt that flexing one’s fingers was a gentle, subtle and caring way to touch a partner. I also recognized that touches most often come from the fingers rather than the palm of one’s hand. For these reasons, I designed my prototype to sense finger movement rather than the overall movement of the hand. This decision made the gloves the most prominent candidate out of the initial drafts mentioned in the previous section.
Figure 3.7 DIY Flex sensors made of Velostat

The Flex glove contains flex sensors that measure the amount of bend or flex in the wearer’s fingers (Figure 3.7, left). That is, the flex sensor acts as a variable resistor that reacts to the amount of bend or flex in the glove’s fingers. I developed custom flex sensors based on the relative lengths of each finger using Velostat and copper tape. These sensors were placed on top of each finger as shown (Figure 3.7, right). These flex sensors provided the Teensy 3.2 microcontroller with a numeric value based on the amount of the bend/flex. These values were from the Flex glove were then transferred to the Feel glove using a Wi-Fi module on both the ends. I used the ESP8266 Wi-Fi module on the both the gloves to talk to one another.
Figure 3.8 Tiny Vibrating Motors (2mm)

Figure 3.9 Feel glove showing the 12 vibrating actuators
3.3.2. Feel Sensations

The Feel glove contains three linear coin-shaped actuators (shown in Figure 3.8) placed on the back of each finger to form an array of 12 actuators on the glove (Figure 3.9). The three actuators on each finger of the Feel glove map to each finger on the Flex glove. Thus, if the index finger is flexed on the Flex glove, the three actuators on the index finger of the Feel glove vibrate.

Figure 3.10 Mapping of actuators to a finger

I mapped three actuators to each finger because of the structure of the human finger (Figure 3.10). The human finger is composed of three phalanx bones, which are visible when looking at one’s finger. Every region has pulp of fleshy mass, which is the first point of contact on any surface. Based on this I mapped an actuator for each region. I decided to use small coin shaped actuators as their surface area is same to each region on a human finger (shown in Figure 3.8)

Initially I decided to place the array of actuators on the outside / top of the hand, this would be similar to resting hands on top of your partner’s hand. This was due to the fact that there are a large number of nerves in this part of the hand, which are more receptive to vibrations. Although the limitation with this design was that the touch would be limited to only one part of the body as it is unnatural to place the topside of one’s hand on body parts to transfer vibrations.
Instead, I decided to place the actuators on the palm side of the fingers so that the partner wearing the Feel glove could move his or her hand to different parts of the body. This ensures that the touch is not limited to their hands only. This is similar to the design of TapTap (Bonanni et al., 2006), a scarf intended to be worn in a number of ways where actuators can touch any body part that the wearer desires. One of the limitations with vibrotactile sensation is that the vibrating actuators are not capable of replicating the pressure of a touch. But with my design, couples could adjust the amount of pressure of the touch themselves by placing their hand either gently against their body or with added pressure.

![Amplitude vs Time Graph]

\[ \text{Max} = \text{function(} \text{flex} \text{)} \]

**Figure 3.11 Vibrotactile pattern on the finger**

### 3.3.3. Vibrotactile Pattern

I wanted to design a vibrotactile pattern which simulates a stroking or caressing pattern on one’s skin. Research has shown that different tactile sensations can be created by varying the frequency, amplitude, duration and rhythm of vibrotactile sensations (Brewster et al., 2004). The flex actions could be translated to vibrotactile sensations as if a partner’s fingers were slowly moving down one’s skin. Gentle movement of fingers forms a stronger emotional connection rather than the movement of a complete hand. I created
this sensation by creating a waveform (as shown in Figure 3.11) in which the actuators reach their maximum amplitude and then slowly reduce it by transferring the sensation to the next actuator in a linear fashion. The maximum amplitude or the peak of the vibrotactile sensations was determined by the strength of the flex action of each finger transmitted through the flex glove, i.e., if the fingers are flexed more on the Flex glove, the amplitude would be higher and hence the vibration would be more intense on the Feel glove.

Figure 3.11 A user pressing the soft-switch

3.3.4. Initiation

I felt that it would be unnatural for partners to be able to initiate a touch at any point in the day without the other partner knowing, e.g., receiving a touch in the middle of the workday, partners living in different time zones and receiving a touch in the middle of the night. Thus, I wanted partners to have a subtle way to ask the other person if it is okay to
initiate a touch. As such, communication between the gloves is initiated by a softswitch on the ends of both gloves (Figure 3.12).

A soft-switch is a flexible textile composite fabric that acts as a switch under finger pressure. Either partner can initiate the touch by pressing the soft-switch on their glove. Once it is pressed, a small green LED starts blinking on both the gloves. When the other partner notices the blinking LED on his or her glove, they can choose to respond to the request by pressing the soft-switch on their own glove. This causes the LED to turn on indefinitely, which indicates that the remote touch has been initiated. Partners can now share touches between the gloves.

3.3.5. Form

I selected a glove based on properties of materiality and the glove’s fitting. Firstly, I chose a glove made of Lycra fabric, which has a soft texture that can potentially emulate human skin. Secondly, I selected a tightly-fitting glove so that the tightness and warmth of the glove can provide a sense of intimacy. Both of these properties were important for vibrotactile sensations to be felt on the skin because a loosely-fitted glove and thick material would absorb most of the vibrotactile sensations.

3.3.6. Asymmetry

As a first step, and in order to test the basic design idea, the gloves are currently designed in an asymmetric fashion where one partner sends a touch to a remote partner, and not vice versa. One could imagine by using an asymmetric design with couples that they could develop a strong sense of power over touching each other. Long-term usage of this kind of asymmetric design may create feelings of dominance and hierarchy between partners because one of them is always in control of the touches, despite an initiation sequence. In contrast, I realize that there is a need for mutuality with a touch, since a touch gesture is a two-way interaction when co-located where both of the partners receive some feedback that a touch is occurring. I expect couples mentioning about this design asymmetry during my study, but for my thesis I decided initially to develop a single pair of gloves in order to understand users’ early reactions to the new concept. That said, one
could imagine having a second pair of gloves such that partners wear both a Flex and Feel glove, one on each hand. This would allow both partners to share touches at the same time.

3.4. Usage Scenario

I imagined couples would want to use Flex-N-Feel in a way that reflects their own relationship needs and experiences. The following scenarios detail two ideas as initial base cases and I anticipate that the design will be used in a number of additional ways as couples adapt and adopt them as part of their own relationship to reflect their needs.

1) Thomas and Laura recently became separated due to their jobs. Although they live in the same country and share the same time zone, they are miles apart. They used to watch television together after dinner when they were living together. During this time, they would hold hands. Now that they are apart, they use Flex-N-Feel to simulate shared touch while they watch TV together. They use Skype to see each other and both start watching a TV show on their own TVs at the same time. Thomas wears the Flex glove and Laura wears the Feel glove. Thomas flexes his fingers as if he is grabbing Laura’s hands, while Laura simply places the Feel glove on her wrist as if Thomas is holding her hand and stroking her fingers.

2) Ron and Anna became separated when Anna moved to Chicago to complete her PhD. Anna told Ron that she used to really enjoy giving each other massages and caressing each other’s shoulders as they lay next to each other in bed. Ron decided to gift Anna Flex-N-Feel and now they use it just before bedtime so they can replicate the way they use to massage each other’s shoulders. Anna wears the Flex glove and bends her fingers in the same way she used to when rubbing Ron’s shoulders. Ron wears the Feel glove and rests his hand on his shoulder so he can feel Anna’s movements. This makes Anna and Ron feel more connected and as if Anna is touching Ron while sitting next to him.

Overall, Flex-N-Feel was designed to be mobile so that couples can stay connected throughout their day; flexible such that couples can appropriate it in a way that
makes sense for their relationship; and, subtle and private so that touches can be discreet, if desired. Certainly, not all acts of touch are possible with the gloves. For example, it would be very difficult to give a full back massage to a remote partner given the reach of one’s hands. Instead, the design is flexible within reason where a person could perform a large range of touch actions for their partner, rather than all types of touch. While I intended the gloves to support private interactions, it is possible that the gloves may be easily noticed in certain settings (e.g., indoors at the workplace when gloves are not normally worn). Thus, even though the vibrations may be unnoticed by others, the gloves might be noticeable which may affect usage and restrict what people do.

3.5. Summary

In this chapter, I discussed my design requirements which emerged from the needs of LDRs mentioned in the related literature, how co-located couples interact with each other and from the shortcomings of the previous systems. Next, I explored several conceptual design sketches and assess how they meet my design requirements. Based on these efforts, I present my final conceptual sketch of Flex-N-Feel. Flex-N-Feel is composed of a pair of gloves. Each partner receives one of the gloves. When one person bends their fingers in the Flex glove, they are translated and sent as vibrotactile sensations to the Feel glove wirelessly. Next, I discuss the design rationale for each design component of my system along with the technical implementation. Lastly, I explored various examples and scenarios I envision for Flex-N-Feel to be used in a long-distance relationship.
Chapter 4. Evaluating Flex-N-Feel

In this chapter, I discuss the method used to evaluate Flex-N-Feel. The evaluation method used in this research takes an exploratory approach through a lab-based study, where I look to see how couples use and improvised with the technology in ways I never envisioned as a designer and understand the meaningful qualities of Flex-N-Feel from couples and how it can impact couples’ emotional connection and intimacy when using the system. Since each couple might have their own meanings associated with a touch, it was important to elicit each couple’s own understanding and meaning which lends itself to a qualitative approach for this study. Thus, the evaluation method described in this chapter addresses my second and third research goal of couples usage patterns of an open-ended remote touch system and how couples use an open-ended system in conjunction with existing communication tools. These research goals further address the following research questions: what design characteristics are important for facilitating a sense of touch between remote partners when using vibrotactile gloves; how do couples use vibrotactile gloves for supporting touch; and, how video and audio connections support or hinder the use of vibrotactile gloves. I begin by describing the participants, then the study methods, and conclude with the data collection and analysis.

4.1. Participants

I recruited 18 people in total—nine heterosexual couples via a snowball sampling technique. I sent e-mails within our university inviting people to participate in my study and asked them to forward this call to their friends and family members. Participants who expressed interest to the study recruitment poster (Appendix A) were emailed a brief set of requirements and if they agreed to participate, I scheduled a time to meet with them. Specifically, I wanted a broad range of participants based on mixed ages, different backgrounds and various professions (not limited to university students), in order to capture a wide range of couples from various age groups and cultures to potentially explore wider usage of Flex-N-Feel.
It was hard to run this study with distance-separate couples, hence my only requirement for the study was that couples should have been separated from each other. I was specifically looking for couples who had witnessed this separation either for a short or long period of time due to work, study, frequent travel or any other reasons. For my study, 5 of 18 participants were between 20 and 25 years old, 9 were between 26 and 30 years, and 4 were between 31 and 40; thus, my participants generally represented a young demographic. 3 of 9 couples were in a relationship for more than 4 years, 3 couples between 1-4 years, and 3 were between 4-12 months. 7 of the 9 couples had been in a long-distance relationship, separated from their partner for a long period of time (4 months–2 years) due to work or education. Two of the couples were separated for shorter
periods of time (1-2 weeks) due to their travel plans. Most of the couples said they used phone calls, text messages (SMS, WhatsApp, etc.), video chat (Facetime, Skype etc.) and email to stay connected with their partners during their separation. All of them said they used video calls to connect emotionally with their partner when apart. This data has been summarized in table 4.1.

Naturally, one caveat of my study is that participants were not currently in a long distance relationship. While it would have been better to get such participants, doing so would have made the study pragmatically very difficult to conduct as I would have needed to send remote partners one of the gloves for each study session. As such, I used collocated couples who had previously been in a long distance relationship as a reasonable proxy for my study. Nonetheless, my study results should be interpreted with this limitation in mind.

4.2. Method

I designed a within subject study that augmented the gloves with two communication modes, which are often used by couples in LDRs: voice calls and video communication. My decision for a lab-based study emerged from the problems that arise in field experiments which are time consuming, require complicated data collection processes, reliability of the prototype (prototype can function properly without the intervention of the researcher for a long-time), ability to control the experiment, and field studies are unacceptably intrusive (Kjeldskov & Skov, 2014; Kjeldskov & Stage, 2004; Raptis, Tselios, & Avouris, 2005). Lab studies are generally not burdened with the problems that arise in field experiments, especially with sophisticated technical prototypes like Flex-N-Feel, as the conditions for the experiment can be controlled, and it is possible to employ facilities for the collection of high-quality data, such as video recording in my case. Next, I describe the details of the study with rationale.

4.2.1. Initial Survey

Once participants had volunteered to participate in the study, they were invited to a lab space in Simon Fraser University surrey campus as per their availability of time. I
was helped by another undergraduate student from SFU- Yee Loong Ooi to help me conduct this study. He helped me run the study since the study needed to be in two rooms. First, participants completed an Office of Research Ethics informed consent form in the lab. After that I conducted a pre-test questionnaire (Appendix A) with each participant to gather their demographics and obtain background information about their relationship including how frequently they saw each other, the length of their relationship, details of their existing communication routine, how they maintained an emotional connection, and how they expressed intimacy with each other. I gathered this data from each participant individually in a paper-based survey that couples were asked to fill out in different rooms. The survey took ~10 minutes to complete. I purposely had partners do it separately so that we could get their responses without being influenced by one’s partner.

4.2.2. Prototype Usage

Next, I demonstrated the technology together to the couple in our common room and asked them to try the gloves for 1-2 minutes to help them get familiar with this new modality of communication. I taught them how to initiate the touch and interact using the flex glove. I asked them to switch the gloves and repeated the above process. I made sure we taught them only the basics of how the design worked such that I would not bias their own usage of it during the remainder of the study.

Figure 4.1: The room setup for lab study
Next, the partners were asked to go into two separate private rooms within the lab space. This was done in order to simulate a long distance connection. The room consisted of a table and a comfortable chair in front of a computer screen (shown in Figure 4.1). Next, I gave participants a scenario that described their relationship as one where they were separated from each other over distance.

**Scenario A:** Imagine that you are currently living apart with your partner due to work commitments for a long period of time. You just arrive home tired after a day at work. As you haven’t been talking to your partner recently due to your busy schedule, you decided to give him or her a call.

While conversing with him or her, please try on the gloves. You are free to try anything with them and see what you find them most useful for.

**Scenario B:** Imagine that you are now living together with your partner. However, you guys are seldom physically together as your partner often has to travel regularly for work. Your partner is currently on a business trip to the United States for 4-5 days and you are waiting to talk with him or her.

While conversing with him or her, please try on the gloves. You are free to try anything with them and see what you find them most useful for.

These scenarios were used because, in the past, it has been argued that traditional laboratory experiments do not adequately simulate the context and lack the desired ecological validity (Esbjörnsson et al., 2006). This may lead to less valid data, where there is a potential disconnect between stated preferences, intentions, and actual experiences. To overcome this limitation, I added contextual richness to lab settings through scenarios and context simulation, which contribute to the realism of the experiment while maintaining the benefits of a controlled setting. The extent to which simulated scenarios represent a real-life situation is a critical determinant of the validity of the study. For these reasons, I prepared two scenarios: one for couples who had been separated for a long period of time and one for couples separated for a short period of time. The scenarios were meant to reflect the same period of time when they were separated from their partners.
I then asked the couples to use the glove for 20 minutes, the first 10 minutes with a Skype video connection open and the remaining 10 minutes with Skype audio going and no video. I interchanged their gloves midway in each session to make sure partners experienced both the Flex and the Feel glove as shown in Figure 4.2. I counterbalanced the order of Skype video and audio—five couples started with Skype video and four with Skype audio—such that there would no order effects across all participants during their experience.

Participants were not given specific instructions in terms of how they should use our prototype. I asked them to use the gloves freely and in whatever way they wanted. In this study stage I was interested in seeing how couples used and improvised with Flex-N-Feel, their emotional state and feeling while using the gloves, and how audio and video impacted their communication and usage.

4.2.3. Final Questionnaire and Interview

After participants’ usage for 20 minutes with Flex-N-Feel, participants independently completed a post-test questionnaire (still in separate rooms) asking them about the usability of the interface where they rated their level of emotional connection and intimacy on a 5-point Likert scale. I defined intimacy for the participants as the experience of affectionate elements of touching (hugs, kisses, hand-holding, etc.) with one’s partner, which makes one feel more connected to that partner. I defined emotional connection...
connection as what happens when two people knowingly feel and perceive the same thing at the same time. This was important as these terms can have different meaning based on the context and a touch can convey a variety of feelings.

Next, I conducted a semi-structured interview with both partners separately to capture their individual perspectives without being influenced by their partner. The interviews were conducted in parallel with the partners with the help of another male researcher. I designed my interview questions (Appendix B) to ask them about specific properties of the glove and how they mapped to in-person touch, their experience while using both the gloves, their preference to use the glove with Skype video or audio, their emotions while using the glove, and, finally, whether they would like to use the glove in their own relationship and, if so, how, when, and where. I kept the interview quite open-ended allowing participants to express their experience relating to past experiences or stories, allowing them to diverge from the questions hence allowing us to collect more data regarding their experience with Flex-N-Feel. I designed the post-test and interview questions (refer to Appendix A) such that the participants could easily write down their private thoughts on a piece of paper rather than sharing it with the researcher.

### 4.3. Data Collection and Analysis

All semi-interviews were audio recorded and later transcribed. I analyzed the interview transcripts using thematic analysis to understand the main and recurring themes in our data. My approach to Thematic Analysis (Spradley, 1980) involved a six-phase process:

1. **Familiarization with the data**: This phase involved reading and re-reading the interview transcripts, to become immersed and intimately familiar with the content i.e. the responses from the participants.

2. **Coding**: This phase involved generating succinct labels (codes) that identify important features of the gloves and its usage based on my research questions. This stage involved
me coding the entire dataset, and after that, collating all the codes and all relevant data extracts, together for later stages of analysis.

![Figure 4.2 Searching for themes during a white board session](image)

3. **Searching for themes**: This phase involves examining the codes and collated data to identify significant broader patterns of meaning (potential themes). Figure 4.2 depicts a whiteboard session where myself and Yee Loong Ooi explored these codes and their connections.

4. **Reviewing themes**: This phase involves checking the themes against the dataset, to determine that they tell a convincing and a coherent story of the data. In this phase, themes were typically refined, i.e. they were split, combined, or discarded.
5. **Defining and naming themes:** This phase involves developing a detailed analysis of each theme, working out the scope and focus of each theme, determining the ‘story’ of each and placing relevant participant quotes to enhance the richness of this story.

6. **Writing up:** This final phase involves weaving together the analytic narrative and data extracts, and contextualizing the analysis in relation to existing literature or patterns I expected for a paper submission.

   Throughout the study, I periodically coded observations and interview responses to highlight seemingly important concepts and insights. When I had collected data from the first eight participants, I began to categorize these findings into larger groups with the help of the second researcher and input from my supervisor. Although these phases were sequential, and each build on the previous, my analysis was typically a recursive process, with movement back and forth between different phases.
I also recorded the 20-minute session of the couple where they were asked to use the gloves. I recorded participants with a secondary camera that captured their hand movements only (Figure 4.3). I coded the video recordings of the study sessions to learn what different types of uses and actions they performed with the gloves. This was done by noting down the time, type of interaction and frequency of such interactions among each couple. Unfortunately, I was unable to analyze the associated audio as most of the couples switched to their native languages when using the gloves. Later, they mentioned this was because it was more natural for them to express their emotions in their native language and that is what they were used to. These interactions were then coded to find the high-level themes similar to the process for my interview transcripts. I identified interactions with the gloves such as using the glove for a gentle massage, scratching their back, tickling, playing hand guessing games, moving the gloves to intimate parts of the body like their chest, couples clapping their hands, or giving a high five or a pinky swear. These interactions were then noted down on a sticky note for each participant along with their frequency. We then organized these interactions according to the behavior, i.e. looking for patterns of mutuality, synchronization, uniqueness and personalization among these various interactions. Finally, we were able to group all of these interactions into four main interaction patterns: shared actions, intimate gestures, playful activities and gestures to feel ones’ presence.

4.4. Summary

In this chapter, I discussed the recruitment and backgrounds of participants as well as the methods used to collect and analyze my data. In summary, my study involved a lab-based study where couples used Flex-N-Feel in an exploratory fashion in conjunction with their existing communication channels (audio and video). My study was qualitative in nature, primarily relying on the use of semi-structured interviews to probe participants about their open-ended experience with Flex-N-Feel. I took the advantage of a lab-based study by recording my participants’ video during its use for a much richer analysis of their interactions with Flex-N-Feel. After data was collected, I used thematic analysis to
organize findings, identify important patterns, and group the results into high-level themes. In the next chapter, I present my main findings of my study where my analysis revealed themes around couples' speculative usage patterns, their interaction patterns, preference for audio vs video, and usability of individual components of the gloves.
Chapter 5. Results

In this chapter, I address three research questions: what design characteristics are important for facilitating a sense of touch between remote partners when using vibrotactile gloves? (Research Question 1); how do couples use vibrotactile gloves for supporting touch? (Research Question 2); and, how video and audio connections support or hinder the use of vibrotactile gloves? (Research Question 3). This chapter starts with a qualitative evaluation of the design characteristics of Flex-N-Feel probing couples about different design characteristics and their experiences. Following this, I describe the interaction themes that emerged from the initial use of Flex-N-Feel, and lastly this chapter will detail how couples used Flex-N-Feel in conjunction with audio and video channels and their preference for audio or video.

For participant quotes, I refer to each person with the abbreviation, CXY, where X indicates the couple number and Y shows whether it is from the male (M) or female (F) partner.

5.1. Design Characteristics of Flex-N-Feel

Overall, all participants enjoyed using the gloves with their partners during the study. Participants expressed similar sentiments and feelings with their partner as an in-person touch while using Flex-N-Feel such as the emotional connection they felt with the simulated touch. They said it was fun to play with and use the gloves to mediate a sense of touch. They mentioned Flex-N-Feel was ‘cool’, a ‘novel’ idea and appreciated the creativity of the concept and technology. At the end of the interview, 17 of 18 participants said they would like to use Flex-N-Feel if they found themselves in a LDR again. During this time couples emphasized that physical intimacy is important and affectionate touch gesture act like pillars in strengthening their relationship especially when they are separated.

“With a hug or a kiss you can show your emotional connection with them, like you can support them, give a sense of security, a lot of things.” – C3M
“I think it's just a human need to be touched. You don't get touched for few months. It's like you have a need that's not being met.” – C6M

Participants also rated the usability of the gloves quantitatively on the post-study questionnaire. This was captured with a Likert scale from 1-Strongly Disagree to 5-Strongly Agree for the statements “I found the gloves easy to use” (mean= 4.33, stdev= 0.84) and “It was easy to learn how to use the gloves” (mean= 4.77, stdev= 0.42). Thus, overall, we can see that the usability of the gloves was high. The next section will further highlight the results from my interview questions probing participants about the individual design components of the gloves.

5.1.1. Initiation Mechanism

Couples appreciated the initiation mechanism I incorporated into the gloves. They felt it was easy to use and understand the LED status as a start to communicate with your partner. They mentioned that it gave them the freedom to accept or reject the touch at any point of the day. Some couples even mentioned that this feature would be highly beneficial for couples who were living in different time zones and usually unaware of their partner’s routine or schedule.

“That was pretty simple. You just flick it and you know ... you get the response. If there was no LED, it would be confusing.” – C3M

“Yeah, it's cool because it's awesome that once he initiates that I get to choose about if I want to respond, maybe that day I don't want to respond, then I don't. It's nice because it gives both of us a chance to opt in or out.” – C5F

That said, couples said the initiation mechanism did not feel natural or similar to the way they would have initiated an in-person touch with their partner. Participants mentioned that when in person they would not ask their partners if they could touch them nor wait for their permission. A touch would just happen between them without any prior request or notification. Some participants mentioned that did not like the fact they had to wait for their partner to accept the touch. They responded to this by saying:
“No. There’s no back and forth [when we’re together]. You just touch.” – C6F

“No, because of these initiating and accepting phases. It was not natural for me.” – C1M

Instead, some participants wanted a more personalized way to initiate the touch or make such a request. They said that an LED might be missed amidst one’s daily activities and suggested other modalities with personalization like a whisper in the ear, a gentle vibration pattern or voice activated messages along with the LED as feedback.

5.1.2. Vibrotactile Patterns

Half of the participants did not recognize the vibrotactile pattern that was embedded in the Feel glove. That is, they did not recognize the pattern of the vibrations travelling from the bottom of the finger to the top of their fingers. The other half of the participants said that they felt these vibration patterns but they were too intense, i.e., the amplitude was very high. I observed after using Flex-N-Feel for a while, the partner using the Feel glove typically figured out how to control the intensity (by pressing harder or softer on their body) and figured out the mapping of vibrations to individual fingers. Sometimes the partner using the Flex glove found it difficult to control the intensity of the vibrations by flexing their fingers at different levels. At times, the partner using the Feel glove asked their partner to flex their fingers less to reduce the intensity.

“We tried to like, I don’t know how you would call it in humans, but for dogs and stuff, it’s like petting yourself. So we tried that and it felt better than just holding somewhere. We were also worried that it was too intense, so when we were petting it felt better.” – C1F

Some couples recognized the vibrotactile pattern very well, but they said it did not feel like a caress or a gentle stroke on their skin like their partner's in-person touch. They felt the intensity if these vibrations should be less and much slower.

“It lacked that softness of a touch but it feels somehow simulated.” – C1F
“The pattern should change. I think right now, it’s very monotonous. I think it should be varied, it should be left to right, up to down, down to up, center to upwards, and different patterns. The way you hold it, the way you tighten it and loosen it up, says lots of things.” – C3F

I observed couples were flexing their fingers fast or slow and they thought the vibration would also follow the same pattern. But the flex glove was not designed to measure the speed of flex actions and, instead, just transferred the same vibrotactile pattern with varying amplitude. The flex glove only measures the flex/bends in the fingers and not how fast or slow the flex action was performed due to sensory limitations at this stage of the design. This made the vibration pattern monotonous and constant for some of the couples after using it for a while.

5.1.3. Form

Couples appreciated the use of the object (gloves) I had chosen to transmit and receive touch, although they felt the gloves should support more finger dexterity. For example, they wanted to perform more hand and finger interactions such as give a high five, fist bump, or hand shake, or play rock-paper scissors, etc. with the flex glove apart from flexing each finger. Overall, they said it was natural to use the gloves to send and receive touch. They even said that while using a glove they could move their hands to different parts of the body.

“I think it makes sense just because most of the touching we do, I guess would be with hands. I think it's intuitive to use gloves.” – C5F

But couples mentioned they would not prefer to use the gloves throughout the day and would prefer something much smaller and lighter to carry to be used at multiple times in the day. They even pointed to times when it might be difficult to wear a glove especially during summer and when using their touch-screen devices.
"I don't see that as an option to have it always on, like your hand. But if it was something wearable or a ring, I would have thought about it, but a glove is too much. Maybe in a place that is too cold, maybe you wear the glove more of the time. But I don't think I would ever use it or as something that I always wear." – C1F

Due to the asymmetric design of the gloves, where the flex glove could only sense finger movements and feel glove could only replicate these by vibrations, I saw couples had their own preference for the gloves. Nearly all couples enjoyed wearing the Feel glove more as they were always feeling the sensations from their partners. The partners using the Flex glove mentioned their experience was limited as they could not get any feedback of how their partners felt or what kind of sensations were being transferred to their partner.

“I was disappointed when I used the other glove, because I couldn’t feel it. I was like, “Oh, I want to feel it, but I cannot.”– C3F

I observed short instances of dominance and hierarchy among a small number of couples when using the flex gloves; they liked controlling the amplitude of the vibrotactile sensations without necessarily having their partner’s permission for the specific way the gloves were used. Two participants expressed that they preferred to use the Flex glove more as they liked that fact that they could be in control of the vibrations and send the touch when they desired.

5.1.4. Location

Most of the couples said they would prefer to use the gloves in their homes as normally touching happens at home or in a private place. They preferred not to use the gloves in a public space despite the fact that vibrotactile feedback is private and cannot easily be seen by people nearby. This was mainly because they desired to move their hands to various parts of their body and thought it would be inappropriate to do so in a public place even if the location of their hands was somewhat mundane, e.g., placement on their shoulders, leg, etc.

“I think that the touching part is more in the sphere of intimacy in the private sphere so I wouldn’t go around using it.”– C2F
Even still, some of the couples showed interest to use Flex-N-Feel outside of their home once they were comfortable using the technology. They mentioned they would start by using them in semi-private areas like at their office desk or in the back seat of their car. This points to one of the limitations of my study where it is primarily obtaining the initial reaction of couples. With a longer-term usage couples would likely be more comfortable with the technology and appropriate the technology to fit their own needs. This might mean they would not feel inappropriate using Flex-N-Feel in public places.

“Home would be a good start. Once I figure it out and if I'm comfortable with it, I could use it at work or traveling too. I would start at home.” – C6M

5.1.5. Intimacy and Emotional Connection

I asked participants to quantitatively compare their experience with Flex-N-Feel to the feelings they normally felt when using video communication tools over distance. This comparison was carried out irrespective of the associated communication channel (phone calls or Skype/ Facetime) as I wanted to get participants’ more general reaction to the gloves. That is, I asked them to rate the entire experience of Flex N' Feel, which included the use of audio/video as part of the experience. First, they rated their level of intimacy on a 5-point Likert scale from 1-Very Low to 5-Very High. A Wilcoxon signed-rank test showed couples elicit a statistically significant change ($Z=-2.005$, $p=0.0455$) in their rating of intimacy between their existing mode of communication, video communication, (Mdn=3) and Flex-N-Feel (Mdn=4).

Second, they rated their level of emotional connection on a 5-point Likert scale from 1-Very Low to 5-Very High. A Wilcoxon signed-rank test showed couples did not elicit a statistically significant change ($Z=-0.349$, $p=0.726$) in their rating of emotional connection between their existing mode of communication, video communication, (Mdn=3) and Flex-N-Feel (Mdn=4). Thus, overall, Flex-N-Feel was having some effects on the couples and their experience with each other. I describe this experience and its nuances qualitatively in the remainder of the sections.
5.2. Interaction Themes

Initially in the interview, couples talked about the importance of touch in maintaining and strengthening their relationship. Many couples described touch as a pillar of their relationship.

“With a hug or a kiss you can show your emotional connection with them, like you can support them, give a sense of security, a lot of things.” – C3M

They said that affectionate touches are important in one’s daily life and referred to it as a basic human need.

“I think it's just a human need to be touched. You don't get touched for few months. It's like you have a need that's not being met.” – C6M
“I think it is important because it just calms you down, but when you are apart you don’t have those options so it’s just like being frustrated. You cannot hold somebody to calm down.” – C1F

With Flex-N-Feel couples felt they could do much more over a video connection than just normal conversation. Through a careful examination of the audio and video recordings of their Flex-N-Feel usage, I found four main interaction themes emerge that reflected these values. Some of the interactions are likely a result of the novelty of the technology where participants were exploring the design and ‘trying it out’ it out to see what was possible. Thus, the interaction themes should be thought of as one possible range of actions that could be done with such a technology, where longer term studies would be needed to show what couples truly value as part of their relationship. The interaction themes also represent the nuanced ways that the couples thought about using the gloves as a first set of interactions, where the actions that were easy to perform may suggest longer-term usage. These four themes were playful episodes, intimate touches, shared action and simply presence as shown in Figure 5.1. Next, I describe each of them in detail.

5.2.1. Shared Actions

First, I observed instances in time where both partners performed the same action at the same time where they often tried to complete a gesture with their partner. This interaction took place when one partner reciprocated the other’s action. Seven of nine couples performed these shared actions at some point in their study session. For example, I observed partners imitating a ‘pinky swear’ with each other (shown in Figure 5.2) where they tried to lock their pinky fingers together in the air (a sign of significant promise); giving each other a ‘high five’ of ‘fist bump’ (often a sign of accomplishment); clasping hands together akin to hand holding; and, trying to simulate a hug by both holding their own computer monitor together. These actions were mostly initiated by the partner using the Flex glove and were only possible when they were using the gloves with the video link going as it was vital for the partners to synchronize their hand movements to feel the associated vibrotactile sensation with these interactions.
“We were trying different stuff and the best thing that work for us was the pinky. If he was only flexing the pinky, it was less vibration and it felt more emotional for me.” — C1F

I observed that most of the shared actions worked well for the participants and were easy to do. Larger body movements such as hugging the monitor, giving a high five or crossing arms for a hug did not work well because the gloves could not replicate the larger body movement found with a hug. Instead, the benefit from these actions came more from the video feed rather than the gloves since it could more clearly depict the action. On the other hand, shared interactions such as clasping hands, doing a pinky swear, or performing a fist bump were directly tied and felt by the gloves since these shared actions are accompanied by a vibrotactile stimuli, which made them more meaningful and affective for the couple as compared to just performing these over a video link.

5.2.2. Playfulness

Second, I observed couples engaging in their own unique form of personal playful activities that they said they would normally do together as a co-located couple. These
tended to be unique for each couple. Five of nine couples performed playful acts at some point in their study session. For example, partners imitated a massage on their partners’ shoulder or face (shown in Figure 5.3), scratched their partners back or head, tickled their partners on their ankle or belly, played hand guessing games, and played piano for their partners. Most of these actions—apart from massaging their body parts—were observed when couples were using the gloves with Skype video.

Figure 5.3 Playful interaction of a face massage imitated by actors

“I asked her to put the glove on her belly, and then I just bent my fingers and hear her really laugh, because it's really like tickling her. It was really good. We can call this flexing glove a tickling glove [laughs]” - C7M

There were some playful activities that did not work out as couples expected. This included acts predicated on the movement of one’s entire hand rather than the finger movements, such as, clapping hands and playing ‘rock-paper-scissors’, because the gloves were designed to only capture the movement of fingers rather than capturing the entire hand movement which is more intricate. The video and audio feeds helped partners
understand what each was trying to do so they could coordinate their actions, but the gloves themselves were not able to convey the somewhat-rich physical interactions of the entire gesture.

5.2.3. Intimate Touches

Figure 5.4 Intimate gesture of a face caress imitated by actors

Third, I observed partners using the gloves to perform intimate touches on sensitive or private parts of their body that others, besides their partner, typically did not touch. For example, partners using the Feel glove moved their hands to their face, neck, chest, stomach, or waist. One female participant even touched her private areas during the lab-study.

“My boobs, just to have fun of course and it’s, when you have the vibration gloves, it’s nice.” – C2F

Six of nine couples performed intimate touches during at least one point in their study session. While performing these intimate gestures, I observed few participants were expressing their intimate feelings from these vibrations. During these interactions the partner using the Flex glove was found imitating the same gesture in the air, near the
camera where their partners could see the hand movements. I realize that because this study was conducted in a lab, couples were aware of the fact that they were being recorded while using the gloves. The setup was certainly not like their home environment where they would likely feel more comfortable performing intimate touches. As such, some couples talked about wanting to intimately touch their partner when at home with Flex-N-Feel, but not in the lab setting. When asked about using the gloves for expressing intimacy, a few participants responded by saying:

“We tried face, we tried hand. What else did we do? I tried shoulder. And we were thinking about some other stuff but it was inappropriate.” – C1F

“I think it will be for different purpose like PG-13 purposes.” – C5F

5.2.4. Presence

Lastly, I observed all nine couples moving the Feel glove to various parts of their body to feel their partner’s presence over distance. That is, they wanted to know that their partner was there and connected to them. They described the gloves as adding an additional level of presence beyond what the video or audio links could provide. Example touches included moving the glove to their arms, face, shoulder and their nose (shown in Figure 5.5). As compared to the other themed interactions, participants described these touches in a different way; they were not so much about being playful or intimate, they were about knowing the partner was present and ‘there.’ I observed presence touches more often when partners were using the audio-only connection and were not able to see each other. Some couples described the experience as though they could feel their partners sitting next to them and touching them.
“The glove, added an embodied interaction with each other, which is really good, because your body can interact it. With the Skype you just have some visual cue from your partner.” – C7M

“With gloves it’s like a step forward towards your relationship. Like, phone call's good enough, but then they’d be like, "Oh, hey don't be sad." Your voice can only do that much. But with the gloves if I say, "It's okay. Don't be sad and stuff." She'll actually feel it and be more responsive.” – C5M

C3F was wearing a fitness band and she noticed her heartbeat would rise whenever she was feeling the vibrotactile sensation from her partner.

“When I was using a feel glove, you get to feel it, so the heart beat obviously will rise, because you know that somebody else is thinking about you. Somebody else is trying to hold your hand. There’s the direct connection which I wouldn’t be able to know that, unless I had this band over here. This band would tell me.” – C3F
5.3. Audio and Video Communication

Overall, most of the participants mentioned during the interview that they preferred to use the gloves with the Skype video connection compared to audio-only. This was mainly because they wanted to see their partners’ reactions and facial expression while using the gloves. That said, this result might be speculative because of the limited span of time couples used the gloves.

“With video actually we can see each other, see the emotion on the face and the actual gesture or what he’s doing and if he’s looking at me now.” – C8F

“It helped our intimacy, especially with video. Yeah, I guess it really worked.” – C7M

All the couples felt that Flex-N-Feel was a richer experience with video as their conversations were accompanied by affective vibrotactile sensations. The design was more intuitive and responsive and they felt more intimately connected. The action of interactions from the video link accompanied by the vibrotactile stimuli from the gloves made the overall experience of using Flex-N-Feel more affective for the couples.

“I think it [video] makes it more intimate, because we try hugging. I have my hands on my forearms. And he actually held his arm out and pressed his arms. I could feel the vibrations. Visually, I saw that he was reaching out to me. Things like that made it feel more intimate and more realistic.” – C5F

One participant expressed that the vibrotactile sensation along with the video made him blush:

“In the Skype video I was blushing. It is something that you would do, because you're not used to this, and if you get something like this intimate response, it's a legit connection.” – C3M

Using the gloves with an audio-only connection received a mixed response. Some partners found interaction with the gloves to be meaningless without a video link because
it was hard for them to map their partners action with the vibrotactile sensations. They said that things were left for the imagination, the intention of the haptic response was not clear, and there was an overhead in their communication as the partners had to verbally describe what they were doing.

“I didn’t like it as much as the video because I could not see his reaction, and it left a lot of things to your imagination.” – C1F

“It was confusing because I could feel the haptic but I didn’t know what my wife’s intention was.” – C3M

In contrast, some partners found the audio connection to be fun and exciting due to the imaginary nature of these sensations. They said it turned the interactions into a guessing game where their partners used their imagination to figure out the movement.

“It was fun to figure out the pattern my partner was making.” – C6M

“It provided us with a mystery feel because we didn’t know what each of us were doing behind the screen” – C5M

At the end of the study, I asked couples if they would like to use the gloves as a standalone communication device or in conjunction with video or audio. Most of them felt that it would not make sense to send random vibrations to their partner throughout the day, while a few of them said that such vibrations would indeed make them feel connected throughout the day. Overall, the couples felt it was important to see each other while using the gloves.

5.4. Summary

This chapter addressed my three research questions: what design characteristics are important for facilitating a sense of touch between remote partners when using vibrotactile gloves?; how do couples use vibrotactile gloves for supporting touch?; and, how video and audio connections support or hinder the use of vibrotactile gloves? First, I
present the results from a qualitative evaluation of the design characteristics of the gloves like the initiation mechanism, vibrotactile pattern, form of the prototype, participants preference for location, participants intimacy and emotional connection. This evaluation of Flex-N-Feel revealed that couples valued the experience of touch and enjoyed the interactions with Flex-N-Feel. Participants felt a strong sense of presence when using the gloves and felt more emotionally connected with their partner. Couples used the gloves in a variety of different ways, many of which I had not envisioned. These related to four themes: shared actions, playfulness, intimate touches, and presence. Lastly, I presented how couples used Flex-N-Feel in conjunction with audio and video channels and I found video was more important than audio to aid couples in understanding each other’s interactions and the associated meaning behind these interactions.
Chapter 6. Discussion

In this chapter I summarize the study’s main findings and discuss the implications for the design of technologies focusing on physical touch over distance. This chapter addresses all three research questions. I apply the knowledge of how long-distance couples used an open-ended remote touch system (Research Problem 2) and how did they use it in conjunction with their existing communication tools (Research Problem 3) to iterate on how to design a system capable of transmitting remote touch based on the needs and desires of long-distance couples (Research Problem 1).

6.1. Design for wearability

Flex-N-Feel’s form factor was designed to afford various kinds of tactile sensations. Most of the previously-built prototypes that present physiological signals through explicit acts of hugging (Gemperle et al., 2003; Mueller et al., 2005; Teh et al., 2009), squeezing (Rantala et al., 2013; Wang & Quek, 2010) or hand-holding (Gooch & Watts, 2012b) do not support mobility in their usage (Dodge, 1997; Gooch & Watts, 2012a; Kowalski et al., 2013), or support only a limited set of interactions (Chang et al., 2001; Gooch & Watts, 2012b; Joi et al., 2015; Park et al., 2010), or sensations are confined to only one part of the body (“Fundawear,” n.d.; Haans et al., 2014; Joi et al., 2015; Werner et al., 2008). Flex-N-Feel was designed to overcome these limitations, yet couples still wanted something lighter and smaller to carry and wear throughout the day. One could think of potential future solutions in the form of a wristband which could unwrap to form a glove when desired or a set of rings which could be unrolled to form the glove. This need raises the design question: how could devices for remote touch be made more smaller in size, ensure comfortable fit, unobtrusively placed and make it aesthetically pleasant? My design work does not directly address this overarching question of designing for wearability; however, it is certainly an open question for future research to integrate issues of wearability into this design space. My results point to the need for a design that fits into a variety of contexts and supports a range of interactions where people will value both the mobility of the design as well as its ability to be used covertly, if desired. Futuristic examples like these might enhance the wearability by making the design lightweight, more
aesthetically pleasing, comfortable to wear and allowing the users to control when they want to experience the touch. These above examples are just speculations based on the form and shape of commercial products already available in the market like fitness trackers and rings.

I selected a sensory medium that provided subtle and private sensations to partners along with the flexibility to feel the sensations on any part of their body. But most of the participants preferred to use the gloves in a private place, rather than as an ‘anytime, anywhere’ device. The location of use was an important factor when using such intimate, affective and emotional communication devices. For example, talking to your partner from you work phone at your desk feels different to talking from your home phone, even if the actual telephone is the same. This is due to mainly due to the intimacy facilitated by the location. This points to privacy, which is a concern with any communication system. Privacy was partially implemented in Flex-N-Feel via the use of vibrotactile sensations which allows distance-separated couples to feel the vibrations from their partner in a private and subtle manner, nearly invisible to the public. This result created an interesting juxtaposition: on one hand, couples valued a flexible communication tool, but, on the other hand, this flexibility raised potential privacy and mobility issues with this technology. This, in turn, raises the design question, how can one create a flexible communication tool for couples that supports mobility and flexible while still preserving privacy? Flex-N-Feel was reasonably successful with the form factor of gloves, but usage would certainly be limited in places and times when gloves are not normally worn. Potential future directions could explore embedding sensors in clothes to allow flexibility and privacy while experiencing touch. One could think of a hybrid communication system consisting of lightweight vibration sensors embedded in clothes along with a mobile application. The user could either send a remote touch by placing their hand on their clothes or by tapping on a human figure in the mobile application to send a remote touch to a particular part of the body. This would give the user the flexibility to either move their hands to send a touch or simply use an mobile application according to their context and needs. Further research is needed to continue the exploration of this question.
6.2. Embedding Vibrotactile Sensations

An analysis of participants’ reactions to vibrotactile sensations showed that the sensations were sometimes too intense and half of the participants did not recognize the patterns I had created and embedded. This is in line with work by previous researchers (Rantala et al., 2013) who showed that vibrotactile sensations with higher amplitude (i.e. intensity) were rated as more unpleasant and arousing than stimuli with lower amplitudes. This effect was observed when tactile stimulation is used to communicate emotional intention between two persons. Another reason for this intense stimulation was that Flex-N-Feel had more spatial variation compared to previous prototypes, which were limited to a specific part of the body, and hence some participants perceived these vibrations to be very strong and intense. This made the experience a bit unpleasant for the users. With some participants who could control the vibrotactile sensations by flexing their fingers accordingly, the receivers interpreted the stimulation created with the Feel glove as more pleasant and relaxed. This illustrates that subtle and slow vibrotactile sensations are more effective in conveying feelings of intimacy and emotional connection. Designers should consider this when exploring remote touch over distance using vibrotactile sensations. Participants also found it a bit difficult to flex individual fingers to express certain emotions. As such, I recommend that designers who choose to use vibrotactile sensations give users the option to control the properties of these vibrotactile sensations based on their interaction with the prototype. For example, if the flex gloves could sense how fast the flex action was performed it could be converted to the speed of the vibration. Different body parts could have varying sensations from these vibrotactile sensations based on the bone structure, skin density and nerves in that region. If the feel glove could sense which part of the body they are interacting with and could relatively adjust the minimum and maximum amplitude of these vibrations, the experience could be enhanced and possibly more pleasant.
6.3. Design to complement, not replace existing technologies

Using Flex-N-Feel with an additional communication system was seen to be a plus. My study found couples preferred to use remote touch in conjunction with a video connection to enrich their overall experience of remote touch. A minority of participants preferred to use it with only an audio connection as this made it more fun and playful. People usually build up strong routines within their relationships, especially regarding the communication technologies they use (Neustaedter & Greenberg, 2012). These become a necessary backdrop to significant communication activity. As such, augmenting a new modality of communication with couples’ existing communication tools can help overcome the concerns that people might have in using the device and integrating it into their existing communication practices. This may help to overcome the challenge described by couples who were not sure of how they would use remote touch as part of a standalone communication device without an audio or video connection as a start.

Based on this finding, I agree with Gooch et al. (Gooch & Watts, 2012b) that it is better to augment existing communication technologies with new ones in order for people to develop meaningful experiences and increase the chances of device being used and adopted. However, I feel that this is likely a starting point; once users know how to use a technology and have grown accustomed to it, they may find value in using it on its own. Of course, this requires further investigation.

Flex-N-Feel was augmented with video and audio links to enhance the experience of remote touch. Usually co-located touch is accompanied by vision and audio among couples. New modalities of touch should be accompanied by audio and/or vision to enhance the experience. Other mediums such as text chat require effort to type from the users and would disrupt the intimate and emotional connection of touch. A future system could also explore voice activated remote touch when using remote touch with audio or visual technologies. For example, if a user desires for a touch while conversing, the gloves could send or receive a touch from their partner. One could even explore gesture recognition on video communication software to send a touch to their remote partner, where hand gestures detected by a camera would be transmitted to the glove.
6.4. Open-ended Design for Exploration

My results showed that all participants were intrigued by the experience of being able to touch their partner over distance. The study observed a variety of ways that couples used the gloves, including, shared actions, being playful, providing intimate touches, and using the gloves to enable a sense of presence. These categories are similar to Wang’s work (2012) where they categorize remote touch into four categories based on couples’ usage of an inflatable armband augmented with a small squeezable device and audio-only communication. Their prototype usage included pre-defined codes and testing; touch conveying positive affect; playful touches; and, conversational touches. My work validates and extends this set of usage categories by showing how people behave when a video and audio connection augments remote touch and participants interact during an open ended, rather than a restricted task based study (which was the case for Wang’s work). The difference in the two categorizations is my inclusion of shared actions, which are likely easier to do when a video connection augments the remote touch since people need to align their hand movements. More broadly speaking, the ways in which users performed their actions with Flex N’ Feel was also quite different than how actions were performed in Wang’s prior work since the object of use was much different (e.g., gloves vs. a squeezable device) based on its form. Thus, while the categorization of actions was similar, the ways in which the actions manifested themselves were different.

The four categories I observed highlight the benefits of the open-ended design where couples used the gloves to match their own needs, desires, and explorations for touch. They also illustrate the types of behaviors that couples might elicit more generally if they had devices that allowed them to touch one another over distance. However, it is likely the case that because this study was conducted in a lab environment and participants’ behaviors were being observed that couples did not exhibit the full range of activities that they would use remote touch for. My study might have missed the everyday mundane touches partners perform in a home environment or intimate and affectionate touches as explained previously. Couples behaviors may also easily change over time and alter depending on the context. With this study I obtained the first set of interactions long-distance couples valued and wanted to perform with their partners. This set of interactions will later guide the next version of Flex-N-Feel to improve the existing design
to support these set of interactions to make a much richer experience of remote touch. Overall its shows that designing for appropriation is a key step especially when designing a new modality of communication which is not known to the users. This likely appropriation helps us to explore the design space and possibilities.

I had wondered if the open-ended design of the gloves would cause confusion in participants where they might not know how they could make the design relevant for their communication. Yet clearly this was not an issue and shows promise for open-ended designs to connect couples over distance. This idea has similarly been reported for video communication systems used by long distance couples (Neustaedter et al., 2015; Neustaedter & Greenberg, 2012). I show its relevance for designs supporting remote touch over distance.

Naturally, couples wanted more interaction capabilities with their hands than Flex-N-Feel was able to provide. For example, I observed couples trying different types of hand and finger movements with the glove during our study. While they were likely exploring the design to understand what it could do and not necessarily what they wanted it to do, it does suggest that users may anticipate a larger range of supported interactions. Technically, it is challenging to sense a large range of hand motions with a tangible prototype, especially since the dexterity of a human hand is enormous. Yet this would likely benefit users. As such, those designing systems that support remote touch over distance should consider a more diverse set of interactions for sending and conveying information to one’s partner, where all map to a user’s natural ways of interacting. The next version of Flex N’ Feel should explore how to enhance the richness of this set of interactions by sensing the hand interactions more accurately and precisely with additional hardware components like an accelerometer embedded on each glove’s finger. These interactions could be converted into their respective vibrotactile sensations by adjusting the amplitude and pattern of the sensations. This would also make each interaction unique and would help couples recognize the interaction when they might want to use it without a complimentary channel.
6.5. Asymmetry Design

Some of the participants in our study preferred to send feelings of touch while others preferred to receive them. While partners in our study did not develop a strong sense of a power relationship when using the gloves, given their asymmetric design, this is potentially because of the short duration of the study. It is possible that longer-term usage of asymmetric designs may create feelings of dominance and hierarchy between partners because one is in control of touches, despite an initiation sequence. Overall, couples felt there was a need for mutuality with a touch, since a touch gesture is a two-way interaction when co-located where both of the partners receive some feedback that a touch is occurring. I expected this reaction, but decided initially to develop a single pair of gloves in order to understand users’ early reactions to the concept. Our results suggest that remote touch would be more fun and emotive if both partners are able to send and receive touch at the same time.

Designing for symmetry involves the ability to send and receive touch. A few possible options could be a) each partner has a pair of gloves, one for sending and other for receiving, or b) each partner has one glove with an option to switch to either the sender or receiver mode. These design ideas are just speculative thoughts, one would need further research to design for this symmetry and how couples desire symmetry. One of the points that emerged from the study was the partner sending the touch never received any feedback of their own touch being sent or how it felt to their partner. This suggests embedding feedback to the same partner of the remote touch, however, this could complicate the design of the symmetric system unless feedback could be carefully timed so it was recognizable. It’s important for the partners to be able to distinguish their feedback and their partners touch.

6.6. Summary

In this chapter, I have summarized the study findings and discussed the implications for the design of future remote touch communication systems for long-distance couples. I have drawn out design implications around four areas to consider for
designing remote touch systems: design for wearability, how to embed vibrotactile sensations, designing for complementing existing technologies, and design open-ended systems.

Starting with the first one, future designers should consider the form and fit of the wearable/artifact. My study found out that participants desired to use an artifact/wearable that is smaller and easier to carry than a glove. This suggests designing for mobility, different contexts of use, and ability to use this artifact/wearable covertly. Secondly, designers should consider embedding slow and subtle vibrotactile sensations when exploring remote touch over distance and giving the users the option to control the different properties (amplitude, pattern, etc.) of these vibrotactile sensations via different types of interactions. Thirdly, designers should consider designing new technologies with a modality that can mesh with current communication mediums rather than replacing them. By focusing on filling the existing gap in implicit communication of long-distance couples, Flex-N-Feel did just that. Fourthly, designers should design for open-ended exploration such that couples could likely appropriate the prototype to match their own needs, desires, and explorations. Firstly, designing for open-ended exploration can provide designers and researchers with initial feedback on early ideas which can help them understand what couples value when connecting (and touching) over distance. Such interactions are vital for refining the design space of a new modality of communication (remote touch). Secondly designing an open-ended system to support appropriation or improvisation over initial and long term use of a technology makes it more acceptable and moreover shows that that the users understand and are comfortable enough with the technology to use it in their own ways. Overall, my research shows that it is possible to simulate touch over distance and that touch can be used as an important communication medium over distance. In the next chapter, I review the research contributions this thesis puts forward and add some final words.
Chapter 7. Conclusion

This final chapter summarizes the research contributions in this thesis. First I reiterate the research objectives I presented in Chapter 1. I then describe my research contributions by outlining how I achieved each of my thesis goals from Chapter 1. Lastly, I discuss opportunities for future work in the field of remote touch.

7.1. Thesis Problems

Chapter 1 outlined three research problems within the area of supporting physical touch over distance for long distance partners/couples. The overarching research problem addressed by this thesis is: *we do not yet know how to best design a system to transmit touch over distance for long-distance couples.*

**Research Problem 1: We do not know how to apply the needs of LDRs to the design of a system capable of transmitting remote touch.** There have been some prototypes developed for supporting communication in long-distance relationships through physical artifacts in the home (Joi et al., 2015; Kowalski et al., 2013) and remote touch for long-distance couples in the form of wearable devices (Bonanni et al., 2006; Gooch & Watts, 2012b). Yet most of the earlier prototypes were either limited to a part of the body, used in a very specific way or limited in terms of mobility. There is less focus on designing an open-ended prototype which allows couples to experience touch on any part of their body that could be used anytime and at any-place, and allow couples to perform different kinds of touch actions/interactions with the prototype.

**Research Problem 2: We do not know how long-distance couples would use an open-ended system capable of transmitting touch.** We have seen previous studies with prototypes capable of sending remote touch to increase the feeling of closeness among couples (Park et al., 2012), amplifying positive affect (Wang, Rongrong, 2012) and feeling others presence in one’s daily life (Gooch & Watts, 2012b). But we have not yet seen how couples would use an open-ended design to transmit touch. A further step in the comprehension of a design capable of transmitting remote touch is to understand how
couples would use such a system. This further breaks down into what kind of actions/interaction would couples perform and the kind of meaning and affects conveyed by these interactions with the system.

**Research Problem 3: We do not know how couples would use remote touch in conjunction with existing communication tools.** Most of the previous studies have evaluated prototypes without a complimentary communication channel. We know long-distance couples tend to rely heavily on voice calls and video communication (Neustaedter & Greenberg, 2012). I decided to use touch in conjunction with these existing communication channels so couples can talk while touching each other, but we do not know how long-distance couples would use a new modality of communication (touch) in conjunction with their existing communication channels (audio and video). We need to understand how couples would integrate audio and video channels and how this would aid in the development of meaningful experiences with remote touch.

### 7.2. Thesis Contributions

**Research Goal 1: Design of a research prototype capable of sending remote touch based on the needs and requirements of long-distance couples.** In Chapter 3, I came up with the design requirements for a system capable of sending remote touch by reflecting on the related literature that described the needs of LDRs, as well as the ways in which co-located couples interact with each other. These design requirements were based on the mobility of the system, direct mapping of the actions and intentions of partners, flexibility and ease of use, and ensuring privacy and subtleness in the remote touch between partners. Next based on these requirements, I presented the design of a tangible communication system called Flex-N-Feel: a pair of gloves that allows distance-separated couples to feel the flexing of their remote partners’ fingers through vibrotactile sensations on their skin based on my design requirements. Lastly, I discuss the design rationale for each design component of my system along with the technical implementation. This design rationale presents a set of principles for the design of remote touch technologies for long-distance couples when using vibrotactile sensations. Later in Chapter 5, I evaluated these design considerations and decisions with a lab-based exploratory study by long-distance couples. The results show that couples really enjoyed
using the gloves with their partners during the study. They appreciated the initiation mechanism and the sensations the vibrotactile sensors created on their body. Participants felt a strong sense of presence when using the gloves and felt more emotionally connected with their partner. The prototype was designed to be open-ended in nature i.e. allowing distance separated couples to experience touch on any part of their body, to be used anytime and at any-place, and allowing them to perform different kinds of touch actions/interactions/gestures with the prototype. That said there were certain elements in the glove that could be improved to enhance the wearability of the design, including using softer and more subtle vibrotactile sensations and making the gloves lightweight and comfortable to wear throughout the day.

**Research Goal 2:** Understand the usage patterns of an open-ended remote touch system by long-distance couples through an evaluation. In Chapter 4, I presented an exploratory lab study to investigate how couples use Flex-N-Feel for sending touch over distance. My results showed that all participants were intrigued by the experience of being able to touch their partner over distance. The study observed a variety of ways that couples used the gloves, the four major themes were shared actions, playful activities, intimate touches, and using the gloves to enable a sense of presence. These four categories highlight the benefits of the open-ended design where couples used the gloves to match their own needs, desires, and explorations for touch. They also illustrate the types of behaviors that couples might elicit more generally if they had devices that allowed them to touch one another over distance. This shows the promise for open-ended designs to connect couples over distance. With this study, I obtained the first set of interactions that long-distance couples valued and wanted to perform with their partners. This set of interactions will later guide the next version of Flex-N-Feel to improve the existing design to support these set of interactions to make a much richer experience for remote touch.

**Research Goal 3:** Investigate the ways in which long-distance couples would use remote touch in conjunction with their existing communication channels. I further investigated how video and audio connections would hinder or support the use of Flex-N-Feel. As part of the aforementioned study, I designed a within subject activity that augmented the system with two communication channels often used by couples in LDRs (Neustaedter & Greenberg, 2012): voice calls and video communication. My study found
couples preferred to use remote touch in conjunction with a video connection to enrich their overall experience of remote touch. A minority of participants preferred to use it with only an audio connection as this made it more fun and playful. Augmenting a new modality of communication with couples’ existing communication tools can help overcome the concerns that users might have in using the device and integrating it into their existing communication practices. Based on this finding, I agree with Gooch et al. (Gooch & Watts, 2012b) that it is better to augment existing communication technologies with new ones in order for people to develop meaningful experiences and increase the chances of device being used and adopted. However, I feel that this is likely a starting point; once users know how to use a technology and have grown accustomed to it, they may find value in using it on its own.

7.3. Limitations and Future Work

Naturally, one caveat of my study is that participants were not currently in a long-distance relationship. While it would have been better to get such participants, doing so would have made the study pragmatically very difficult to conduct as I would have needed to send remote partners one of the gloves for each study session. As such, I used collocated couples who had previously been in a long-distance relationship as a reasonable proxy. I sampled couples who had witnessed a separation from their partner either for a short or long period of time due to work, study, frequent travel or any other reasons.

Secondly, the study was conducted in a lab environment where couples were observed. Yet a lab study does not adequately simulate the context of a real-life scenario of couple’s lives. This limitation was addressed by adding contextual richness to lab settings through scenarios and context simulation, which contribute to the realism of the experiment while maintaining the benefits of a controlled setting. But there were certain moments when couples realized or knew they were being recorded or observed. It is likely the case that couples did not exhibit the full range of activities that they would use remote touch for i.e. I observed couples were hesitant to move the glove to sensitive parts of their body. My study might have missed the everyday mundane touches partners perform in a home environment or intimate and affectionate touches. Couples’ behaviors may also
easily change over time and alter depending on the context. To overcome this limitation, a longer-term usage through a field study is required to understand what actions people find valuable when couples’ usage is learned, understood, and appropriated within real relationship settings. This means allowing the couples to explore the prototype over an extended period of being physically separated from each other. This would allow us to explore how couples use the prototype over a period of time and how such a system fits into their everyday routine and communication practices.

Another limitation was the asymmetric design of the gloves where the touch could travel in one way, i.e. only one partner could send the touch. While partners in our study did not develop a strong sense of a power relationships when using the gloves, given their asymmetric design, this is potentially because of the short duration of the study. It is possible that longer-term usage of asymmetric designs may create feelings of dominance and hierarchy between partners because one is in control of touches, despite an initiation sequence. Overall, couples felt there was a need for mutuality with a touch, since a touch gesture is a two-way interaction when co-located where both partners receive some feedback that a touch is occurring. I expected this reaction, but decided initially to develop a single pair of gloves in order to understand users’ early reactions to the concept. This result suggests that remote touch would be more fun and emotive if both partners are able to send and receive touch at the same time. Hence future work would focus on making the design symmetric and allowing couples to send and receive touch at the same time i.e. one could imagine having a second pair of gloves to send and receive touch at the same time.

Future work should consider enhancing the individual design components of the glove based on the results from my exploratory lab study. This includes enhancing the wearability of the prototype by making the design lightweight, more aesthetically pleasing, comfortable to wear and allowing users to control when they want to experience the touch. Designing and embedding subtle and soft vibrotactile sensations based on couples’ interaction with the gloves, i.e. providing autonomy in the use by allowing couples to adjust the different properties of these vibrotactile sensations. Naturally, couples wanted more interaction capabilities with their hands than Flex-N-Feel could provide. This means considering a more diverse set of interactions for sending and conveying information to
one’s partner and exploring how to enhance the richness of this set of interactions by sensing the hand interactions more accurately and precisely with additional hardware components.

Lastly, my next step will be the transition of this design from a prototype to a higher-fidelity research artifact. The first prototype version of Flex-N-Feel provided me with first-hand reactions and appreciation through active engagement with users. The design served as a filter-where I purposefully left out aspects of the design open-ended to explore the range of behaviors and interactions by couples. Next steps will include making the prototype more a) robust and independent: the research prototype should be able to operate effectively in the field for an extended period without the intervention of a researcher/developer (Odom et al., 2016), b) adding elements of personalization: customizing the artifact as per the users preference will enhance the usability of the prototype over the time, especially in a long-term field study. The overall concept is to overcome the limitations of research prototypes to create perspectives that are necessary to inquire into the complex matters of couples forming a bond with these technologies and how these technologies fit into their everyday communication practices and routines over an extended period via a field study.

7.4. Final Words

In an increasingly globalized world, long-distance relationships are becoming more and more common. While people wrote letters in the olden days, the next generation had the option of using a telephone or even the internet. In the last decade, new modes of communication tools exploded in the market such as Skype and FaceTime to help long-distance couples maintain and support their relationships. Yet there is a lack of physical contact or the real feeling that someone is physically there with you. Therefore, mediating intimacy over distance through the design of affective technologies will become more and more vital in the upcoming years.

This thesis presents the design and evaluation of Flex-N-Feel, a pair of tangible gloves that transmits touch over distance between two remotely connected lovers using vibrotactile sensations. The prototype has the potential to change the way people
communicate to enhance LDRs by enabling them to touch, talk and see each other. Designed to support open-ended interactions to allow couples to improvise or even appropriate the technology in long-term usage as per their own needs and desires, providing privacy, and supporting flexibility and autonomy in use. Enriching communication in this way can cross the boundaries of space and place between couples who are physically separated, by making the impossible experience of touching remarkable.

Moreover, in the upcoming years, wearables will go mainstream with hardware enhancements, more iterations, and significant functional changes to trigger the desired human behavior. Whether it will replace the existing market of smartphones will still be an open question. Instead wearables should be initially designed to augment the existing mainstream communication technologies much like the fitness bands in the market these days. For distance separated people, wearables may provide the missing element with existing communication technologies, i.e. physiological sensations which can help form tangible connections between loved ones over distance.

Hopefully, this thesis will inspire future researchers to design, develop and evolve the concept of mediated touch with the advent of wearable technologies. I hope that my design space will provide a resource for those researchers who are interested in exploring this area and that the design space itself enhances and extends itself to be applied across a wider range of contexts. I look forward to the time where physical separation will no longer be a barrier for humans to maintain close intimate relationships with their loved ones.
References


Kjeldskov, J., & Skov, M. B. (2014). Was it worth the hassle?: ten years of mobile HCI research discussions on lab and field evaluations (pp. 43–52). ACM Press. https://doi.org/10.1145/2628363.2628398


Appendix A. Ethics Approval

Amendment Approval – Delegated

Study Number: 20130210
Study Title: Video Conferencing for Sharing Everyday Experiences

Amendment Approval Date: 2016 May 04
Expiry Date: 2017 February 3
Principal Investigator: Neustaedter, Carman
Supervisor: n/a
SFU Position: Faculty
Faculty/Department: Interactive Arts and Technology

SFU Collaborator: Procyk, Jason; Muntean, Reese; Singhai, Samarth
External Collaborator: Massimi, Michael
Research Personnel: n/a
Project Leader: n/a

Funding Source: Natural Sciences and Engineering Council Engage
Funding Title: Advanced Video Communication Systems for Families

Funding Source: Natural Sciences and Engineering Council Discovery Grant and Accelerator
Funding Title: Supporting shared family experiences with mobile media spaces

Document(s) Approved in this Amendment:
- Amendment Request Form, uploaded 2016 May 2
- Study Details, version 3, dated 2016 May 2
- Consent Form, version 3, dated 2016 May 2

The amendment(s) 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.

Please note that approval of the amendment(s) does not change the expiry date on the current SFU REB approval of this study. 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.

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

The amendment to this study has been approved by an authorized delegated reviewer.
Appendix B. Study Recruitment Poster

Do you want to experience **touch** over distance?

![Image of two people touching hands](image1)

We are looking for Couples to participate in our study to experience touch over distance.

**WHO**: Couples above the age of 18

**WHEN**: May 9- May 20, 2016

**WHERE**: Simon Fraser University, Surrey Campus

**DURATION**: Approximately 50 minutes

**RENUMERATION**: $20 Gift card for each couple

If you are interested to participate in the study, or have any questions, please contact any of the researchers below:

Yee Loong Ooi
[...@sfu.ca](mailto:...@sfu.ca)
604-[...]

Samarth Singhal
[...@sfu.ca](mailto:...@sfu.ca)
604-[...]

Carman Neustaedter
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604-[...]
Appendix C. Consent Form

Title: Video Conferencing for Sharing Everyday Experiences
Principle Investigator: Dr. Carman Neustaedter, SIAT, Simon Fraser University
778-[…], […]@sfu.ca
Version: 3, May 2, 2016
Funding Agency: NSERC

The Simon Fraser University Research Ethics Board has approved this research study. This consent form, a copy of which is made available to you, is part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more details about something mentioned here, or information not included here, you should feel free to ask the investigator(s). Please take the time to read this carefully and to understand the information.

Purpose: This research project will examine the way in which video conferencing technologies are used by family members for sharing everyday experiences. We are interested in understanding how people use video conferencing in these situations and what limitations they may face with the technology. Our goal is to draw out implications for the design of new video conferencing systems and also gauge people’s reactions to prototype video conferencing systems.

Participant Recruitment and Selection: You must be over 19 years of age and have no major physical or cognitive disabilities.

Study Method: Participants will participate in one or more types of studies. These will include interviews in person or over Skype, the completion of a survey online, or the usage of a prototype system that we design where we will collect data via interviews throughout participants’ usage of the technology. If you choose to participate in the study using an online communication tool such as Skype, we cannot fully guarantee your anonymity because data is transmitted over the Internet. You have the option to participate (or not) over such mediums.
Benefits and Risks: Participants will not benefit directly by participating in the study though they will contribute to broader scientific knowledge and understand. The risks of the study are expected to be none or minimal as all questions are about mundane details about one’s use of video conferencing systems.

Data Collection: Data will be collected in the form of interview responses, which will be audio recorded with the participants’ permission, or survey responses in textual format. We will also record video of your usage of the video conferencing system, with your permission. All data will be kept anonymous and confidential as participants will not be required to enter any personal identifying information. Video data will be edited to mask your identity. Data will be stored on a hard drive on a secure server at SFU Surrey or on the hard drive of a computer kept in a secured office. Data will be kept for three years. At this point, it will be permanently destroyed.

Research results can be obtained by contacting: Dr. Carman Neustaedter, 778-782-9034, carman_neustaedter@sfu.ca.

Acceptance of this Form: By completing this form you: 1) understand to your satisfaction the information provided to you about your participation in this research project, and 2) agree to participate as a research subject.

In no way does this waive your legal rights nor release the investigators, sponsors, or involved institutions from their legal and professional responsibilities. You are free to withdraw from this research project at any time. You should feel free to ask for clarification or new information throughout your participation.

[ ] I agree to have my activity video recorded for analysis purposes.

To accept this form, please print your name below, sign, and date the form.

Participant’s Name: ________________________________
Signature: ________________________________
Date: ______________
Questions/Concerns:

If you have any concerns about the way you've been treated as a participant or concerns with the research project, please contact Dr. Jeff Toward, Director, Office of Research Ethics at: […]@sfu.ca or 778-[…].
Appendix D. Pre-Test Questionnaire

1. What is your age: ________

2. Have you ever been in a long distance relationship (e.g., lived in a different city from your partner, or travel very frequently)?
   - Yes
   - No

3. If you were in a long distance relationship, please describe it in terms of where you both lived, how frequently you saw each other, how long the relationship lasted, etc.

4. Tell me about your relationship with your study partner?

5. How long have you been in a relationship with your study partner?

   _______ months _______ years

6. Which mode of communication channel do you use to communicate with your partner on a regular basis? (check all that applies)
   - Postcards/Letters
   - Emails
   - Voice/Phone Calls
   - Text messages (SMS, Whatsapp, Messengers etc.)
   - Video Calls (Skype, Facetime etc.)
   - Others: ________________________________

7. Which communication technology do you find more effective when you want to connect emotionally or intimately or talk about emotional issues?

   - Postcards/Letters
   - Emails
8. How would you rate your level of emotional connection with your partner using the communication medium mentioned in Q7? *An Emotional Connection happens when two people knowingly feel and perceive the same thing at the same time.*

5 4 3 2 1

Very High High Moderate Low Very Low

9. How would you rate your level of intimacy with your partner using the communication medium mentioned in Q7? *Intimacy: The experience of affectionate elements of touching (hugs, kisses, hand-holding etc.) from your partner which makes you feel more connected with your partner.*

5 4 3 2 1

Very High High Moderate Low Very Low

10. How do you usually go about maintaining an emotional connection with your partner? *(An Emotional Connection happens when two people knowingly feel and perceive the same thing at the same time.)*

11. How do you usually express intimacy with your partner? *Intimacy: The experience of affectionate elements of touching (hugs, kisses, hand-holding etc.) from your partner which makes you feel more connected with your partner.*

12. What are some of the things you do when you are not directly beside your partner that helps in establishing an emotional connection with them?
13. Please rate the following statement:

I am the type of person that likes regular interaction with my partner.

1. Strongly disagree
2. Disagree
3. Neither agree nor disagree
4. Agree
5. Strongly agree

I feel close and connected with my partner throughout most days.

1. Not at all close and connected
2. Somewhat close and connected
3. Moderately close and connected
4. Very close and connected
5. Extremely close and connected

14. Have you use any form of wearable devices before?
   o Yes, please specify:
   o No

15. Do you have any motion difficulties, such as moving your arms or flexing your fingers?
   o Yes, please explain:
   o No
Appendix E. Interview Questions

Introductory

1. What are some of the things you miss if any, when you were apart from your partner?

2. How do you feel intimate interactions such as hugs, hand holdings and kisses can play a part in a strong relationship, if any?

3. What is your first impression about the gloves (Flex-N-Feel)?
   a. What are your thoughts on the use of the gloves as a way to transfer touch for distance separated couples?

4. Could you describe how you use the gloves?

Device Operations

5. Was there anything surprising about how you had to use the gloves?

6. What do you think about the way you had to initiate the touch through the gloves?

7. How is this initiation analogous to the way you would initiate a physical touch with your partner?

Affective Interactions (Flex)

8. Could you describe the experience when you were flexing your fingers to touch your partner?

Affective Interactions (Feel)

9. Could you describe the experience when you were feeling the vibrations from your partner?

10. Could you describe one of the best moments while you were using the glove with your partner?
11. What did you think about the vibration pattern? Was it similar to a hand stroke/caress by your partner? Prompts: intensity, speed, duration etc.

12. Did you try to move the gloves to different parts of your body? Why or Why not? (Mobility)

**Interactions with audio/video**

13. What are some of the things you did differently between using the gloves with audio only and using the gloves with both audio and video?

14. Which do you prefer: Skype(Audio) or Skype (Audio + video)? Why? Under which scenarios would you prefer each?

15. Would you use the glove as a standalone communication channel (without Skype)? Why?

**Feelings**

16. How do you think using Flex-N-Feel can affect your relationship?

17. How would you describe your feelings with your partner while you were using the gloves? Prompts: Close, connected, intimate

18. Where would you like to use it, if at all? Why? Prompts: home, at work, transit, watching TV etc.

19. Where would you not like to use it, if at all? Why? Prompts: home, at work, transit, watching TV etc.

**General emotions**

20. Was there anything you would have liked to have done which Flex-N-Feel didn’t support?

21. What are your thoughts about continuing to use Flex-N-Feel in your relationship (if possible)?

22. Is there anything else you’d like to tell us or discuss about Flex-N-Feel?
# Appendix F. Post-Test Questionnaire

1. Please rate how much you agree or disagree with each of the following statements:

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly disagree</th>
<th>Disagree</th>
<th>Undecided</th>
<th>Agree</th>
<th>Strongly agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>I found the interface easy to use.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>It was easy to learn how to use the interface when first tried it.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>It was a pleasant experience to use the interface.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

2. How would you rate your level of emotional connection with your partner after using Flex-N-Feel? (An Emotional Connection happens when two people knowingly feel and perceive the same thing at the same time.)

<table>
<thead>
<tr>
<th>Rating</th>
<th>Very High</th>
<th>High</th>
<th>Moderate</th>
<th>Low</th>
<th>Very Low</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

3. How would you rate your level of intimacy with your partner after using Flex-N-Feel? Intimacy: The experience of affectionate elements of touching (hugs, kisses, hand-holding etc.) from your partner which makes you feel more connected with your partner.

<table>
<thead>
<tr>
<th>Rating</th>
<th>Very High</th>
<th>High</th>
<th>Moderate</th>
<th>Low</th>
<th>Very Low</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>
4. What do you like about each mode of communication
   a. With Skype (Audio), why?
   b. With Skype (Audio + Video) why?

5. What were you thinking of, if anything, when you were flexing your fingers?
   o Were you thinking about your partner?
   o Were you thinking about your past experiences?
   o Were you thinking about other people?
   o Were you thinking about future events?
   o Other____________________________________

6. What were you thinking of, if anything, when you were feeling the vibrations?
   o Were you thinking about your partner?
   o Were you thinking about your past experiences?
   o Were you thinking about other people?
   o Were you thinking about future events?
   o Other____________________________________

7. Would you like to use the Flex-N-Feel if you are/were in a long-distance relationship?
   o Yes, why?
   o No, why?

8. If you could change 3 things in the interface, what would you change? Why?