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Master's Thesis
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Knotting: Mediating Mutual Intimacy and Communication in Long-Distance Relationships through Physical Surrogates

Keio University
Graduate School of Media Design

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A Master's Thesis
submitted to Keio University Graduate School of Media Design
in partial fulfillment of the requirements for the degree of
Master of Media Design

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Abstract of Master's Thesis of Academic Year 2022

Knotting: Mediating Mutual Intimacy and Communication in Long-Distance Relationships through Physical Surrogates

Category: Design

Summary

How to keep couples in long-distance romantic relationships (LDRRs) connected? The past four decades have witnessed continuous efforts of the human-computer interaction (HCI) community to mediate intimacy between LDRR couples. Still, physical contact, a significant foundation of intimate relationships, remains a much-understudied area in relationship research. This project thus purported to develop innovative physical surrogates to address this suffering problem faced by LDRR couples. Based on a human-centered design process, it started with a brainstorming session with LDRR couples to identify their specific needs untapped by existing communication technologies. The discussion enabled this project to decide upon an implicit messaging channel to communicate touch over distance.Afterwards, the prototype, Knotting, was created and modified to ensure that the product achieved its intended goals and provided a comfortable way for couples to have a healthier relationship. Made of TPU, it was a pair of short, chubby, elf-shaped devices, with a red heart at the center of the front side and a pair of leaf-like wings in each device. Knotting adopted a visual-touch-eye contact integrated sensory communication mechanism through which LDRR couples have different types of lightweight physical experiences. It was then put into short and long trials to evaluate the design concepts and prototype. The short trial was performed at the exhibition held by the PLAY Project of the Graduate School of Media Design, Keio University, while the lengthy trial observed the unstructured use of Knotting and used patterns over a more extended period. The user test proved that the interactive actions via Knotting were beneficial to proving the presence and eliciting the feeling of togetherness between LDRR couples, though

it could be less instrumental in many contexts, such as where the couple was in a fierce fight with each other. Finally, the research ended up with suggestions for further improvement and design space of Knotting, including contextualization, customization, and increased mobility.

Keywords:

LDRRs, surrogates, knotting, lightweight physical experience, sensory communication, presence, togetherness

Keio University Graduate School of Media Design

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Chapter 1
Introduction

In this industrialized and globalized world, while enjoying increased mobility, people also face the unprecedented challenges of geographical separation that involves them in long-distance relationships (LDRs). According to Peterson [1], a long-distance relationship refers to a relationship where geographically separated people are unable to have an in-person visit with each other without some form of travel expenses. When the distance barrier sets in, people in long-distance relationships, especially couples, are always troubled with communication and intimacy. Statistics have it that up to 40% of long-distance couples broke down [2]. Optimists are of the view that LDRs are not as problematic as statistics have reported, arguing that communication technologies can compensate for the deficits in face-to-face interaction and intimacy in long-distance relationships [3] [4]. Admittedly, long-distance couples today do have more ways to keep their relationships fresh while far apart, such as text messages, video calls, and a wide array of social media tools. However, the problems of long-distance romantic relationships are still salient in the digital context. New problems may also arise in using communication technologies, such as increased jealousy and monitoring of faithfulness and commitment [5]. This thesis is thus interested in developing an innovative technology to assist romantic partners in long-distance relationships by focusing on what they really need and what existing solutions have yet to provide. It will focus exclusively on the issue of "physicalness", a less-researched area in creating relatedness and mediating intimate relationships over distance [6]. Particularly, given that most extant physical devices for managing long-distance relationships transmit information in one direction, this thesis aims to design a bidirectional delivery surrogate to satisfy the unmet needs of long-distant couples.

1.1. Key Purposes

This section will provide a brief introduction of key purposes at play in this research to clarify the themes and focuses of this thesis.

1.1.1 Long-Distance Relationships (LDRs)

The sheer number of people involved in personal relationships maintained across distance has been on a continuous rise in recent years on account of numerous societal trends, including globalization, digitization, and industrialization, thus drawing growing scholarly attention to such a phenomenon known as long-distance relationships. Aylor [7] generalized a long-distance relationship as one "in which people involved are not able to see each other, face-to-face, most days", in juxtaposition to a geographically-close relationship where individuals within the relationship can meet each other most days. In terms of what functions as a barrier to daily physical togetherness, scholars have been deputed. Schwbel et al. set 50 miles as the threshold distance associated with LDRs [8], whereas Lydon et al. [9] used 200 miles alternatively to denote a long-distance relationship. However varied, these scholars agreed upon a mile traveled-specific definition. Stafford [10]nevertheless rejected a precise definition of LDRs and instead adopted a guiding principle. In his famous book on LDRs, he noted that LDRs had been a widespread phenomenon not limited to romantic partners but also parents, children, friends, and relatives across residences. For him, a long-distance relationship exists not only because of geographic parameters that restrict communication opportunities but also due to the expectations for a continued close connection of individuals within the relationship. Following Stafford, Pistole and Roberts [11] pointed out that using geographic distance as the criteria to identify a long-distance relationship can be misleading, suggesting that long-distance relationship and geographically-close relationship do not reflect sharply distinct constructs. They provided a case where participants separated by 250 miles were reported as being in a geographically-close relationship in contrast to another in which couples living in the same city were considered as in a long-distance relationship because they kept two residences and could be physically together only in weekend. Overall, the geographic distance alone does not qualify a long-distance

relationship. Rather, it it is the attachment-related feelings and thoughts manifested when separation are is of sufficient distance and duration that constitute a long-distance relationship.

1.1.2 Long-Distance Romantic Relationships (LDRRs)

Long-distance romantic relationships (LDRRs), or relationships where romantic partners are separated by geographical distance, are the most prevalent form of long-distance relationship. Estimates suggested a significant number of LDRRs in the college population, with up to 70% [12] to 75% [13] student reporting having been involved in an LDRR. According to Roberts and Pistole [14], the long-distance romantic relationship is a relational structure punctuated and maintained by a separation–reunion cycle. Specifically, partners choose to dwell in geographically distant locations for a period of time and travel to be together for a short period; afterward, they separate again for another length of time. Within the relationship literature, LDRRs are often explored as an antithesis of proximal romantic relationships (PRRs) since they differ significantly, especially in terms of the frequency of face-to-face communication and physically intimate encounters [15]. Despite this consensus, scholars have offered different definitions of LDRRs. In addition to the widely adopted "mile separated" criteria, LDRR status can also be determined by other factors. For instance, scholars once conceptualized an LDRR as partners spending two days apart during the work week [16]. Participants responses to statements such as "my partner lives far enough away from me that it would be very difficult or impossible to see him or her every day" and their own perception of their relationships as either an LDRR or a PRR are among other ways to conceptualize an LDRR [17].

1.1.3 Intimacy

Intimacy has been a central pillar of relationship research. It is generally perceived as what are developed through verbal and nonverbal interaction between partners, such as self-disclosure and immediacy behaviors. As Moss and Schwebel noted, intimacy, determined by "the level of commitment and positive affective, cognitive, and physical closeness one experiences with a partner in a reciprocal

(although not necessarily symmetrical) relationship", is pivotal in developing enduring and satisfying romantic relationships. That intimacy, for many scholars, is best formulated on a face-to-face basis [18]. Sternberg, on the other hand, argued that intimacy can be divided into latent and manifest forms [19]. Latent intimacy, internally-oriented, refers to a sense of connectedness of individuals. Manifest intimacy, in contrast, stems from the implementation of specific immediacy behaviors. That is, unlike manifest intimacy, latent intimacy is less dependent on the physical togetherness or face-to-face interaction between partners. According to him, latent intimacy is the most crucial for maintaining long-term relational stability and quality and can be formulated and sustained through intrapersonal processes, such as relationship-focused cognition [20]. It is Sternberg's conceptualization of intimacy that this research grounds on to experiment with creative technologies for sustainable long-distance romantic relationships.

1.2. Research Background

This research is built on the mixed results of existing research on the effects of distance on romantic relationships. Hypothetically, one may assume that the reduced amount of face-to-face interactions and physically intimate encounters will lead to a lower level of perceived relationship quality and a higher probability of breakups. However, there are studies indicating that the level of satisfaction of LDDR couples can be as high, if not higher, as that of PRR partners [18]. In this sense, this section will provide a nuanced analysis of the merits and demerits of LDRR, thus sorting out the issues that emerge between LDRR partners.

1.2.1 The Advantages of Long-Distance Romantic Relationships

Most relationship studies long-distance romantic relationships as the rational calculation of pains and gains of couples. In a case study of Indonesia marriage couples with long-distance relationship [21], Suminar and Kaddi provided compelling examples of how economic development and educational improvement had driven individuals in places such as Sumatra, Sulawesi, Kalimantan to temporarily

leave their partners and move to big cities such as Jakarta, Surabaya, Yogyakarta, and Bandung in the pursuit for higher income and educational attainment.

1.2.2 The Disadvantages of Long-Distance Romantic Relationships

Most researchers assured that geographical distance could serve as a relational stressor that brings about negative outcomes in romantic relationships [13]. In the material sense, the restricted face-to-face communication opportunity could mean additional traveling expenses for romantic partners to reunite. Though geographical separation has always resulted from the rational choice of romantic partners and the material gains of a long-distance relationship might far exceed the financial burden it entails, it could yield undesirable consequences beyond the economic domain. A prevailing concern is the relational uncertainty of entering into an LDRR, as distance restricts partners' choices for developing and sustaining intimacy. Theoretically, as the attachment theory illustrates, physical separation from the attachment figure is one of the most salient threats to one's close relationships in his/her life span starting from childhood to adulthood, simulating an invariant cascade of emotional and behavioral responses [22]. While adults are seemingly less vulnerable to separation from their attachment figure as compared to children, attachment theorists claimed that the undermining impacts on felt security of physical separation from one's romantic partners could be as devastating as that of a child experiencing prolonged separations from his/her caregivers. The physical absence of one's romantic partners means the unavailability of one's secure base, thus threatening and destabilizing his/her sense of security. The scare face-to-face interaction also has the potential to produce downstream psychological effects such as increased mistrust in terms of loyalty, commitment and fidelity to the romantic relationship [14].

1.3. Relational Maintenance Strategies

In keeping with the notions that long-distance romantic relationships are characterized as attachment bonding across distance and that intimacy can be tactfully

built without geographical proximity, it is of importance to explicate the ways in which geographically separated partners sustain intimacy despite constrained face-to-face interaction opportunities and is particularly so given that several studies pinpointed a similar level of satisfaction between long-distance romantic relationships and proximal romantic relationship [17] [18]. In other words, the distance may not pose an obstacle to romantic partners as long as they adjust their understanding of intimacy in the absence of physical togetherness and adopt positive strategies to sustain intimacy. According to Stafford, these strategies serve to protect the nature of the romantic relationship to the satisfaction of partners [18] since they function as relational inputs and rewards. In contemporary digitization contexts, it has been prevalent for LDRR partners to use existing digital technologies such as social media platforms to facilitate communication. However, as Bhandari and Bardzell [23] revealed, these efforts are always inadequate and deficient, with problems exacerbated by time zone differences. Through these years, human-computer interaction (HCI) community has also increasingly invested in the mediation of human exchanges. This section thus attempts to identify major relational maintenance strategies in reference to Hassenzahl et al.'s [6] overarching effort to analyze 143 constructional artifacts for the continuity of LDRR that sometimes appear in isolation and sometimes intermingle in a single installation.

1.3.1 Awareness

The awareness strategy is associated with the cognitive system of humans that brings their loved ones who are physically absent in mind. Generally, the awareness strategy aims to help partners keep equal level of awareness even though they are geographically separated. In most cases, awareness technologies create communication channel to convey lightweight message to enable a sense of awareness of each other between partners. Unlike explicit technologies such as telephone and video calling, the awareness designs are generally implicit and ambient, fitting into the daily routines of partners without causing much disruption, such as stimulating conservation, to both sides. That is, awareness systems appear as peripheral and unobtrusive that demand less attention [24].In terms of what types of information are conveyed via awareness devices to create a feeling of relatedness without direct communication, presence, activity, and mood are mentioned. Specifically,

in addition to simply displaying presence through daily physical objects of habitual, social and domestic use such as picture frames, system developers have also experimented with technologies to allow individuals to know the current activities and emotional status of their loved ones without clearly expressed requirement.

1.3.2 Expressivity

Equally explicit have been the expressivity devices operating on the principle of "phatic communication" [25], that is, the exchange itself, instead of the content, stands at the center of interaction. By this "explicit", Hassenzahl et al. referred to the codified expression of emotions and feelings transmitted through on-off and symbols in either a synchronous or asynchronous way subject to individual interpretation. These scholars recognize the promising prospects of expressivity systems given that the communication of emotions and affections are of paramount importance to romantic relationships, yet they suggest that these systems might not be as effective as expected in mediating intimacy in emotionally complex negative moments or when individuals are unable to accurately express their emotions or understand the symbols sent by their partners. Meanwhile, they also highlighted the reciprocity in system design, namely to enable a contingent reply to an expressive signal, considering the expectation of individuals for the response to their emotional inputs.

1.3.3 Physicalness

Notwithstanding these diverse approaches to intimacy, physical contact remains to be an untouched area of existing solutions. According to Werner et al. [26], however, physical intimacy featured by affluent emotions and sensual co-experience is always the most suffering aspect of LDRR. For any attempt to allow for mediated physical intimacy, Hassenzahl and his colleges identified several challenges in actualizing physicalness between romantic partners. Most significantly, the simultaneity where romantic partners build up their presence and exchange their emotions in synchronous ways is always undermined in the mediation process supported by technology. At the same time, there might be contextual constraints that refrain individuals from initiating or responding to a mediated intimate act.

For instance, one may fail to receive a reciprocate act for physical closeness from his/her partner who is on work duty and unable to do so. Plus, these scholars also mentioned factors such as the public attention caught by public intimacy constructed through communication devices that might dampen the effectiveness of these technologies. For these reasons, physcalness is assumed to be one of the most unattainable aspect of relational maintenance behaviors.

1.3.4 Gift Giving

Gift giving, though commonly seen in proximate romantic relationships, has been widely adopted to support LDRR due to various functionality of gifts. In general, gift giving can be seen as a symbolic communication where romantic messages, intimate knowledge, and complex positive feelings are exchanged. Specifically, as Mick and Demoss [27] defined, gift is loaded with explicit and implicit meaning of love, thus making gift-giving an act of revealing and expressing affections. In tandem, since selecting a gift is concerned with the preference, taste, and desire that requires intimate knowledge of the other person in a LDRR, the process of choosing, sending, and receiving a gift could reinforce the intimacy between romantic partners. Furthermore, a gift always comes as a surprise and triggers positive emotional responses.

1.3.5 Joint Action

While gift-giving is much a one-way communication, shared activities to create behavioral interdependence between romantic partners can function as a relationship enhancer as they simulate concurrent and subsequent communication. Within a joint action, one's action has implications for the other person and vice versa, thus creating a sense of relatedness. A joint action also serve to create a ritual experience [28] that colors uneventful mundane lives and constructs meanings between romantic partners. According to Myerhoff [29], ritual, a frame of designated behavior and interaction, could mark out special moment and embody a certain culture. As such, a joint action between romantic partners could cultivate meaning of love and crystallize emotion and affection. Of critical debate is what kinds of joint action is best suited to LDRR, starting new routines or relying on

the established routines? For Hassenzahl et al., the answer remains ambiguous as the development of joint activities for LDRR partners is still at a rudimentary stage. Those new routines, such as games, usually introduce additional and artificial activities, whereas those designs based on mundane routines are less different from awareness devices.

1.3.6 Memories

The strategy of memories aims to allow one to recall romantic experiences in the past without involving and disrupting the other person in the moment of separation. This strategy differs from awareness devices as it is used in the cases where the one cannot contact his/her partner or does not want his/her partner to know his/her feeling. Belk [30] stressed the "tangibility" of scared object for reexperience the romantic past, as the physical contact of the an object endowed with special meaning about the past could reinforce the memory.

1.4. Research Focus

Admittedly, emerging technologies based on the strategies introduced in previous sections have allowed for more maneuvering space for LDRR partners to communicate and maintain their relationships. However, as mentioned earlier, there are various untapped areas in relational research. In order to understand the challenges and unmet needs of LDRR partners, this research chose to begin with an exploratory approach to collect data from couples who are or have been in long-distance romantic relationships. We used it as the opportunity to frame this project and to identify specific activities in a participatory, human-centered design process. Through a brainstorming session and a need analysis, the project's central theme was experimenting with physical surrogates that enable the social presence of the person physically absent from his/her loved one. Following this process, we then detailed and implemented the design concepts before the prototype was put in field test and user study. After significant modifications, the final version of this design was finished.

Chapter 2
Related Works

Relationship researchers have long invested in innovative ways for intimacy-building, especially for those focusing on long-distance relationship short of traditional intimate interactions such as physical presence and contacts. This chapter will review related works that have adopted different relational maintenance strategies to help with the sustainability of long-distance romantic relationship. It will illustrate the ways in which these strategies are deployed separately and coordinately in these works and identify understudies areas for further research and experiment.

2.1. Awareness Systems

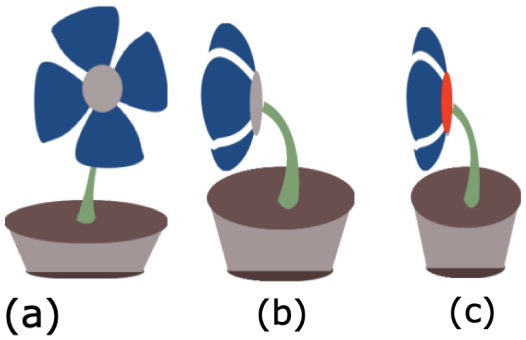
Much has been done to explore effective awareness systems to invoke the sense of social presence between LDRR couples. One strand of work focuses on the peripheral display of information of one's partner that contains affective properties or practical aspects. While this approach is largely featured by physical object that produce a linger scent to the partner, another line of research is more concerned with two-way, reciprocate interactions.

2.1.1 Forget Me Not

Forget Me Not is an ambient display project, built on the flower concept, that conveys communication frequency in the hope of promoting awareness of communication between LDRR partners for a healthier relationship, which deals with the problems of restricted face-to-face communication and limited opportunities for couples to provide each other with emotional support in remote setups [31]. Each partner in a long-distance romantic relationship has a flower that represents the health of the intimate relationship. Specifically, the flower booms when

one communicates frequently with his/her partners and starts to bend the stem with waning communication. The flower also changes its color if one indicates his negative feelings and desires for more attention from his/her partners.

As an ambient design, Forget Me Not aims to make the frequency of communication between LDRR couples visible for both sides, thus increasing their awareness of each other and the status of their relationship. It is created with a belief that communication between LDRR couples stands at the center of their relationship as it help one better understand the thoughts and feelings of his/her partner.



(a)Flower when there is good communication
(b)Flower when one partner has neglected relationship
(c)Flower when feeling sad or need more attention from a partner

(Source:Forget Me Not: An Ambient Display to Increase Communication Between Partners by Enabling Feeling Expression and Increasing Awareness [31])

Figure 2.1 Forget me not

Flower and Intimacy

The design is essentially grounded on the universally accepted symbolic meanings of flowers in relation to romance [32]. In this particular project, the flower is used to act as a proxy to represent the feeling of "miss you" that easily takes place in a long-distance romantic relationship. Within the framework of flower symbolism, Forget Me Not equals the communication between LDRR couples to

the water and the positive feelings to light, which define the health of the flower that symbolizes the sustainability of the intimate relationship. By showing the status of the flower, either booming or decaying, the project is able to raise the awareness between couples about the health of their relationship.

Peripheral Awareness

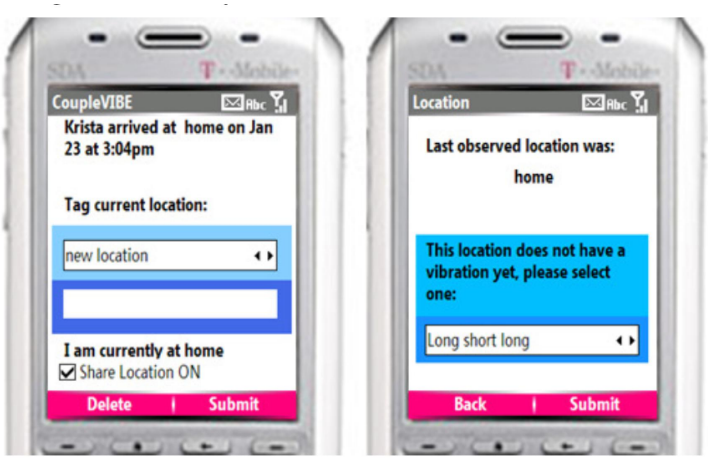
Forget Me Not monitors the communication between LDRR couples through a mobile application capable of checking the call histories between them, identifying the frequency of their communication, and sending a message to the flower via Bluetooth to be upright or drop. The whole process proceeds automatically without requiring each party to manipulate the flower, thus mainly mediating intimacy between couples in an implicit way that demands less engagement from the users. Still, it allows partners to explicate their negative feelings such as distress and pessimism.

2.1.2 CoupleVIBE

Despite the availability of communication technologies such as SMS, LDR partners still face the challenges of lacking awareness cues associated with geographical distance. CoupleVIBE, a location-based mobile application developed by Bales, Li and Griwsold [33], seeks to address this communication challenge by supporting mobile implicit communication. It focuses exclusively on locational information as the team believes that location can denote the availability of people and people can infer detailed status information from the location of their partners. It serves an implicit messaging channel where a user's location information is updated automatically and synchronically to his/her partner's mobile phone. To be specific, one side can receive specialized vibrations promptly as the other side moves from places to places, without either party taking the initiative to do so. In this sense, CoupleVIBE is able to create a privacy-friendly, unobtrusive communication channel. The key fundamentals of CoupleVIBE include:

Ubiquity

Unlike implicit communication designs embodied in physical objects with tangible qualities such as AmBird that are bonded to fixed locations, CoupleVIBE is more flexible as mobile phones are becoming an integral part of people's day-to-day lives that people get used to taking their phones everywhere they go. It is based



(Source:CoupleVIBE: mobile implicit communication to improve awareness for (long-distance) couples [33])

Figure 2.2 CoupleVIBE

upon the concept of person-to-person touch, but does not necessarily include any mediating object but a mobile phone to be carried around. In this regard, CoupleVIBE is more capable of keeping LDRR couples in sync with each other throughout their days.

Unobtrusiveness

CoupleVIBE also addresses the concerns of intrusive designs. It conveys vibrotactile messages instead of auditory cues that would otherwise be problematic in public settings. These messages are limited in terms of types and amounts to be sent so that they are less distracting for the receiver. Specifically, users can have control over the locational information to be communicated. They can stop sharing the information by simply removing the checked option "share location ON" without notifying their partners. They can also decide what locations to be shared and link the information to a specific vibrotactile cue.

Implicit Communication

CoupleVIBE is operated within the framework of implicit communication that emancipates both parties from reciprocal obligation to respond to the messages they receive. As a lightweight message system, it only informs the receiver of the locational change of the sender, without requiring response action or incurring the feelings of reciprocity.The receiver side is unable to shun from receiving these

vibrotactile messages to ensure that users can gain the desired attention from their partners. The whole communication processes thus more comfort to implicit communication.

2.2. Expressive Designs

Expressive designs for LDRR couples, in a general view, can be described within the umbrella of "phatic technology", an idea developed by Gibbs et al. [34]. These tools are typically built to establish, maintain, and enhance bonds between couples instead of exchanging any particular thought or fact. In terms of what types of bonds these technologies focus on, both non-physical and physical dimensions are explored extensively. The prototypes such as AmBird, usually themes on ambient communication that promotes poetic interactions, which convey illusive connectedness in an emotionally provocative manner.

2.2.1 AmBird

AmBird is a ambient system composed of two physical bird-shaped modules, with each module containing an Arduino Yún, a microcontroller board, to connect with the another module [35]. It purports to provide LDRR couples who do not share the same physical space the opportunity to engage and perform physically intimate activities in an unobtrusive manner, that is, tangible but implicit.

(Source:AmBird: Mediating Intimacy for Long-distance Relationships through an Ambient Awareness System [35])

Figure 2.3 AmBird

Expressiveness and Secrecy

The core idea of AmBird design is to support awareness and expressiveness through "the augmentation of everyday artifacts or dynamic changes in physical spaces that better fit everyday settings". Aesthetically, the designers were in an effort to make the system more pleasing and suitable for interior decoration. Inspired by the communication properties of carrier pigeons, AmBird takes the shape of an augmented, wall-mounted, plywood bird capable of being placed anywhere at home. Compared to most of existing systems based on physical objects such as picture frame that only include a discrete change in the common artifact and send simple messages, AmBird is dedicated to enabling multiple content-rich intimate acts between LDRR couples by allowing them to send color messages via AmBird. Although the designer team have incorporated a fixed set of six distinct colors in the system design, they leave enough room for LDRR couples to endow semantic meanings to these colors subject to their own interpretations. LDRR couples can perform multiple intimate acts in front of third parties without worrying about their privacy issues.

Reciprocity

Wirelessly connected in pairs, AmBird support reciprocal interactions within an intimate relationship. A module will change its color based on the user's hand position and send the color messages to the other module when whistling to it. Ambird is able to achieve these functions by deploying a microcontroller board in each module to manage the input and output sensors. There are two input sensors, including an infrared sensor and a microphone. The infrared sensor can detect different positions and distances of a hand above the bird. People can select from six different colors by moving one of their hands up and down on top of the bird. Once making the color decision, people hold their hands above the bird. The microphone is used to send the color message to the other bird after people whistle to it when a color is selected. The output sensor consists of RBG LEDs that can display different colors according to information from the input sensors. Once the color message of the bird is sent to the other bird, the RBG LEDs in the sending bird will flash three times in that color to confirm that the color message has been successfully sent. The RBG LEDs in the receiving bird then light up and stay in the same color until the contacted person wave one of

their hands above the receiving bird to turn the light off.

2.3. Physical Technologies

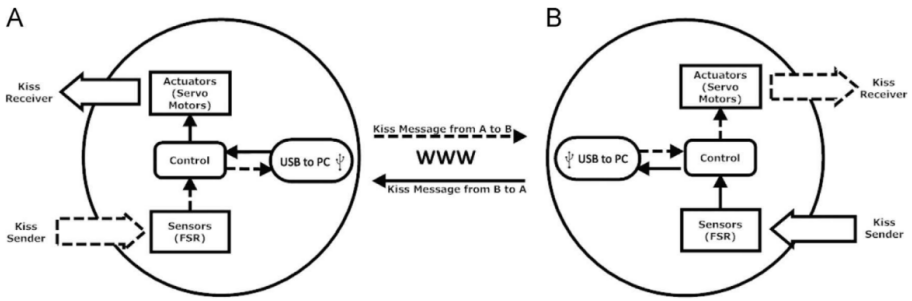
For LDRR partners, one of the most challenging parts of their relationships is associated with the lack of opportunities to have haptic experiences from affective touches due to the absence of the physical being of their partners. Given that geographical separation makes the reduced physically intimate encounters inevitable, there is a burgeoning presence of HCI designs with a focus on providing physical experiences for LDRR couples. Particularly, these tactile technologies seek to address the limitations of existing communication technologies that are confined to textual, verbal, and visual mediums.

2.3.1 Kissenger

Kissenger is a telepresence kiss medium that hopes to provide more natural and bi-directional intimate kiss for long distance romantic couples, thereby facilitating the exchange of emotional content between them. According to Saadatian et al. [36], the system involves a pair of devices with a lip-shaped segment containing both sensors, actuators, and an embedded circuit that controls the sensors and actuators in each device. LDRR couples are able to send and receive a kiss simultaneously through Kissenger. Instead of replacing existing phatic technologies, Kissenger intends to augment these methods by creating a new dimension for LDRR couples to express themselves, namely the affective touch of kiss prevalent in proximal romantic relationships.

Haptic Experiences for Affective Touches

As one of the most prominent modes of affective touch, kissing helps people express their sentiments in relation to intimacy, such as love, passion and affection. Aware of the expressive value of the kiss, Kissenger seeks to use the kiss as a mode of remote, intimate interaction with a haptic communication device. By invoking the haptic and intimate experiences of a kiss, Kissenger aims to build intimacy between LDRR couples. To mimic the affective touch of the kiss, Saadatian et al. have experimented with different kinds of materials and shapes for designing the system. Eventually, they selected the silicone rubber with a Room Temperature



(Source:Mediating intimacy in long-distance relationships using kiss messaging [36])

Figure 2.4 Kissenger

Vulcanizing (RTV) of 560 that was the most suitable for simulating the touch and movement of a human lip.

Asynchronous Design for Real-time Bi-directional Communication
The system of Kissenger incorporates a real-time two-way communication where each partner can send and receive kissing messages, while adopting an asynchronous design that does not require any synchronization steps prior to communication. The interaction mechanism is featured by:
(1)Input kiss sensing, where force sensitive resistors beneath the surface of the lip are able to sense and digitize various levels of soft touches before transmitting them wirelessly to the receiver device;
(2)Output kiss actuation, where servomotors distending the surface of the lip can produce the kiss sensation based on the received data about the soft touches sensed at the sender device;
(3)Control, where the lip on each device is connected to an embedded circuit with Arduino Pro Mini that directs the whole system and communicates wirelessly with another device. Data of sustainable change in the pressure on the lip is transmitted wirelessly to a receiver circuit to actuate servomotors in the receiver device to produce similar movement on the lip and create a kiss sensation for the users.

2.3.2 Flex-N-Feel

Similar to Kissenger, Flex-N-Feel, a vibrotactile glove, also aims to provide LDRR couples with the haptic experience of affective touch, though focusing on different sensory systems of humans. It consists of a pair of gloves with each partner wearing one of the gloves. The motion of fingers in one glove will be translated and sent as vibrotactile sensations to another glove. This emotive glove enables the users to feel the flex action of the fingers of their partners through vibrotactile sensations on their skin [37] and therefore to convey the intended emotions.

Left: Flex glove that captures the flex action of the fingers
Right: Feel glove that transmits the flex actions using vibrotactile sensors

(Source:Flex-N-Feel: Emotive Gloves for Physical Touch Over Distance [37])

Figure 2.5 Flex-N-Feel

Mobility

While there are plenty of prototypes mimicking the physical interactions between romantic couples by providing nonverbal cues, either physiological signals, physical gestures, or a combination of the both, they fit more into the indoor settings and are thus restricted to specific locations. Examples include Kissenger and the tangible intimate objects such as Drasler's [38] Look of the Cloud, a pair of pillows to mimic the physical feelings of being hugged by a remote partner. Flex-N-Feel, a glove that is more portable and wearable in day-to-day lives, instead is designed with the idea of mobility to allow LDRR couples to stay in sync with each other throughout their days.

Flexibility

Most of the existing technologies have tried to incorporate vibrotactile sensations in their designs in a highly specific manner. That is, the sensations are bonded to a particular part of human body. Flex-N-Feel, however, avoids connecting the touch with any specific part of human body and allowing the users to decide where and how the touch is felt. The flexing interaction mechanism is detailed as:
(1)DIY Flex Sensors: these sensors are developed via Velostat and attached to a Teensy 3.2 microcontroller to capture the flex actions of fingers and transmit the actions to the Feel glove using a Wi-Fi module;
(2)Actuators: the Feel glove contains a total amount of 12 actuators on the palm side of the fingers, with three actuators mapped to each finger of the Flex glove. In this sense, a partner wearing the Feel glove can move it to any part of his/her body and make the touch accessible to various parts of the human body. He/She can also adjust the amount of the pressure put against the touched part of the body. In terms of vibrotactile pattern, the system simulates the stroking or caressing pattern on one's skin through a waveform where the actuators would reach their maximum amplitude, and then transfer the sensations to another actuator in a linear fashion.
(3)Initiator: Flex-N-Feel includes an initiation mechanism by deploying a soft switch on each glove as a subtle way to allow one to ask for permission from his/her partner to initiate touch. Each partner can press the soft switch on the Flex glove to express their intention, which causes the small green LEDs on both the gloves to blink. The other partner can respond to the request by pressing the soft switch on the Feel glove to receive the touch when the LED light on the Feel glove stays on.

2.4. Gift-Giving Projects

The gift-giving projects usually integrate the gift-giving behaviors into communication device, with a purpose of enabling the full play of the value of gift. In most projects, gifts are the embodiment of efforts and affections in long-distance romantic relationships. The communication devices serve to amplify the significance and meaning of gifts for the LDRR couples.

2.4.1 Lovebox Spinning Heart Messenger

Lovebox, an adorable wooden box with a pixel-like red heart on its center, is a love note messenger that pairs with an app to work beyond regular communication and deliver special information about affection. Each partner is able to send photos, drawings, love notes, and personalized stickers digitally to the powered Lovebox of the loved one. Once a message is sent to the Lovebox, the heart on the box will spin around to remind the receiver of the new message until the lid is opened [39].

(Source:Modern Love: The Lovebox Spinning Heart Messenger [39])

Figure 2.6 Lovebox Spinning Heart Messenger

Explicit and Implicit Communication in Gift-giving Related Practices With the integration of the Lovebox app, the project allows people to create and

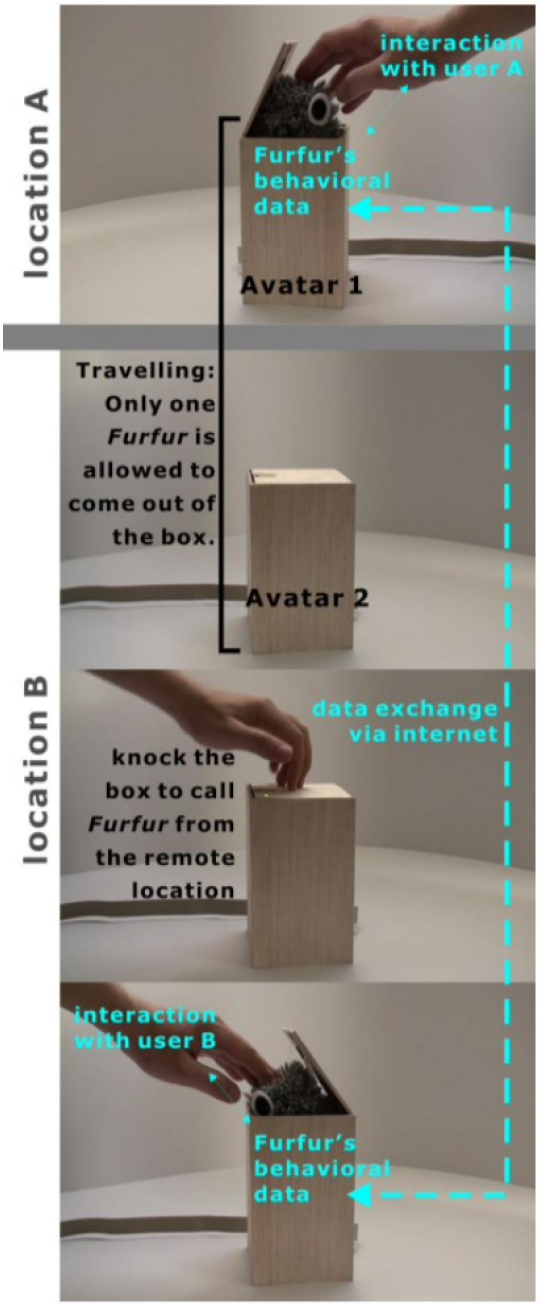
send love messages as gifts and meaningful "thinking of you's" to their remote partners wherever and whenever they want. Their partners can spin the heart and send a flood of hearts back to the app once receiving the love messages displayed on the Lovebox. In this sense, Lovebox is operated with an "agapic love model"of gift-giving [40], that stresses the expressive, spontaneous, and non-materialist nature of gifts. The love messages are markers of affection, passion, and intimacy between partners that have positive impacts on reducing the hazard of relationship dissolution. Meanwhile, when exchanging love messages, partners are able to engage in explicit communication with each other through direct, special, personalized messages. It is with this dual communication that Lovebox ensures LDRR couples stay emotionally connected throughout the day.

2.5. Joint Activities

There are mainly two types of joint activities for mediated LDRR designs: mutual activity and fictitious cohabiting. From a mutual activity perspective, technologies always seek to facilitate activities that are normal for co-located couples between LDRR couples. The other approach, cohabiting, instead attempts to convey a sense of cohabitation through sharing homes, furniture and objects despite partners being geographically separated.

2.5.1 Furfur

Furfur is designed as a shared robotic pet that invokes shared responsibility between LDRR couples. As both partners are involved in a pet-caring practice over distance, they are inevitably invited to subsequent communication and joint actions, thus helping reduce stress and loneliness in long-distance romantic relationships [41]. The system is built on two concepts: the illusion of travel and repertoire. Specifically, each partner has a box with a Furfur inside the box that can be summoned by knocking on the lid of the box. Furfur will appear only when the other Furfur is idle in its box. As such, the design is able to create an illusion of Furfur being a single creature taken care of by both partners, capable of moving between the two partners and accompanying both sides.



(Source:Sharing a robotic pet as a maintenance strategy for romantic couples in long-distance relationships. An autobiographical design exploration [41])

Figure 2.7 Furfur

Weak Joint Action

Furfur focuses on a rather weak yet playful joint caring without entailing strong behavior a linter dependence between LDRR couples. It eludes from imitating physiological needs of pets such as hunger or thirst that would require superfluous tasks such as feeding that are less conducive to enhancing the sense of togetherness. This can be explained by considering the importance of embodiment for pets, which is considered part of their identity and help pet owners establish connection with them. Although the simple mechanism of Furfur, to a robot perspective,requires only minimal interruption of daily lives, it is powerful on creating experience able impacts on LDRR couples through particular appropriation in everyday life. Specifically, in the final version, Furfur is able to learn sounds such as music and speech from the environment and reproduce them when interacting with partners. Throughout the process, Furfur builds a repertoire of sounds and movements by both partners which resembles the relationship structure between parents and new borns. Furfur provides couples with complex, meaningful and positive shared experiences of nurturing.

2.5.2 SyncDecor

Fundamentally, SyncDecor [42] is an effort to create a virtual experience of cohabitation through the synchronization of pairs of daily appliances that are deployed over distance between LDRR couples. There are several components of the SyncDecor System:

(1)SyncLamp: light can reflect the presence, status, and feelings of people while also serving an essential part of modern life. The prototype system of SyncLamp allows the lighting system in one's home keep in sync with that in his/her partner's home.

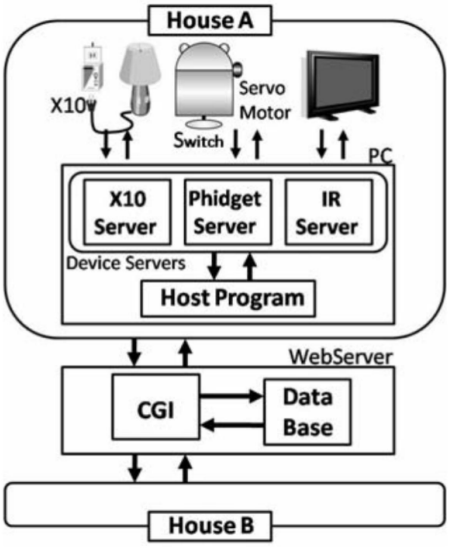
(2)SyncTrash: waste disposal is also a meaningful experience in people's daily life as it indicates the presence of an individual as well as the status of his/her activities. With the SyncTrash system, the lids of one's trash box opens as the other opens the lid of his/her trash box.

(3)SyncAroma: the SyncAroma system focuses on creating similar living environment between LDRR couples by synchronizing smells between them, while also conveying implicit information about the feelings, states, and tastes.

(4)SyncTV: it is a system that allows one to share the TV channel he/she is watching automatically to his/her loved one. In this sense, it helps LDRR couples to identify common topics for subsequent communication such as phone or video call.

Synchronization

The system is built on the principle of synchronization through which geographically separated couples can formulate a feeling of "living together" as one's daily applications are bonded to that in his/her partner's home. The system achieves the synchronization without requiring additional efforts such as sending an email or making a phone call. Hence, it is able to naturalize and sustain people's usage of the system, thus creating an environment where an long-distance romantic relationships are maintained and enhanced by the robust awareness of the presence of their partners, as well as a sense of cohabitation.



(Source:SyncDecor: Communication Appliances for Virtual Cohabitation [42])

Figure 2.8 SyncDecor

The system is built based on a pair of PCs with SyncDecor system that is installed in the home of each partner respectively. Each PC contains a middleware software operating on Ruby that controls the X10, Phidgets and IR servers. These two PCs are connected over distance wirelessly via a central web based server that

controls connection management, filtering and logging. The X10 controller serves to manage the SyncLamp and SyncAroma device; the SyncTrash system comprises of a pair of trash boxes with servo motors and foot switches that are connected to the Phidgets controller; Furthermore, the SyncTV system is controlled by the IR transciever based on USB.

2.6. Memory Support

The value of reminiscence has compelled HCI community to explore the ways in which people's sense of togetherness and connectedness can be reproduced when they are geographically separated. Relevant designs are associated the psychological principles and key requirements of memorabilia, commitment, tangibility. Mols et al [43] summarizes this design space as everyday life reflection. Whittaker et al. [44] continues by providing four principles for memory design, which include (1) selecting lightweight content; (2) integrating digital mementos better into everyday life; (3) supporting reminiscence and reflection; and (4) working in synergy with unaided memory.

2.6.1 MemoryReel

In this design research, Wei [45] tries to provide LDRR couples with distinctive recording and recollection of special moments shared with each other. The designers prototype a system that involves a desktop device to display memory cues and an accompanying mobile application to capture, organize and export contents.

Embodying Digital Memorabilia in Physical Objects

MemoryReel follows Whittaker et al's [46] principle of embodying digital memorabilia in physical objects to support the affective experience of meaningful relationships. The mobile application allows LDRR couples to capture and recollect special moments from video calls and collect messages in the form of animated GIFs. A user can group and organize these memory cues that will be uploaded to cloud storage and displayed by the desk device. The system supports three viewing modes, namely test messages on the E Ink display, audio messages, as well as animated GIFs of recorded videos.

(Source:Memoryreel: A purpose-designed device for recording digitally connected special moments for later recall and reminiscence [45])

Figure 2.9 MemoryReel

2.7. Summary

In light of the above reviews of strategies and designs, four models for presence-in-absence can be summarized as follows:

To reiterate, most of the existing designs to mediate intimacy for LDRR couples adopt more than one of the six strategies discussed in the first chapter. Quantitatively, as highlighted in Hassenzahl et al's research [6], physicalness is the most understudied area in this design space, with only 13 out of 143 designs working on physical technologies for enabling haptic experiences and building intimacy between LDRR couples. Despite the rapidly growing interest in the design of haptic communication devices such as Kissenger and Flex-N-Feel, there are missing dimensions of mimicking affective touches with current remote communication technology to facilitate interpersonal interactions between partners who are physically separated.

Specifically, designs such as Kissenger fit more into the domestic domain as the intimate interactions, i.e.kiss, and the messages they stimulate to convey are more private and restricted to specific locations. In other words, these designs are less

Enduring

Asynchronous Tele-copresence	**Presence through Objects**
Expressive Design(AmBird)	Gift-giving(e.g.Lovebox)
Physical Technology(Kissenger)	Awareness System (Forget Me Not)
Joint Action (SyncDeco)	
Routine	**Special**
Synchronous Tele-copresence	**Presence through Experience**
Physical Technology(Flex-N-Feel)	Joint Action (e.g., Furfur)
Awareness System (CoupleVIBE)	Memory Support (MemoryReel)

Ephemeral

viable in many public spaces. While there are technologies such as Flex-N-Feel that have addressed the mobility problem to some degree, they are nevertheless less mobile in specific settings. For instance, the emotive glove might be noticeable in the workplace, which may restrict usage. In this sense, the problem of mobility is of concern for this project to explore a more portable device for LDRR couples. It seeks to contribute to the HCI community by developing a physical technology that can be resorted to in most public settings to convey lightweight messages for LDRR couples.

Meanwhile, a majority of the existing tactile technologies focus exclusively on a specific type of nonverbal cues, such as the physical gesture of kiss by Kissenger or the flex actions of fingers by Flex-N-Feel. This research explores the possibility of integrating different types of nonverbal cues, namely the affective touch and visual cues, into a single design that enables the tele-copresence of LDRR couples in meaningful and diverse ways.

Chapter 3
Design Concept

3.1. Design Process

The project aims to contribute to the HCI community by creating a physical technology to augment implicit intimate communication and enable haptic experience between LDRR couples. It is based upon a human-centered design process, as illustrated in Figure 3.1, with the purpose of addressing the unmet demands of couples in long-distance relationships. It started with a brainstorming session where people who were in long-distance romantic relationships were invited to share their experiences and discuss the challenges they encountered in maintaining their relationships. This step aimed to identify participants' needs, especially those left unchecked by existing technologies. The project then proceeded to build up its core design concepts in accordance with the need analysis and implement these proposed concepts through prototyping. Upon the prototype was developed, field tests and user study were conducted to examine the potential problems. The concept development and prototyping process will be repeated until the design achieved the intended goals.

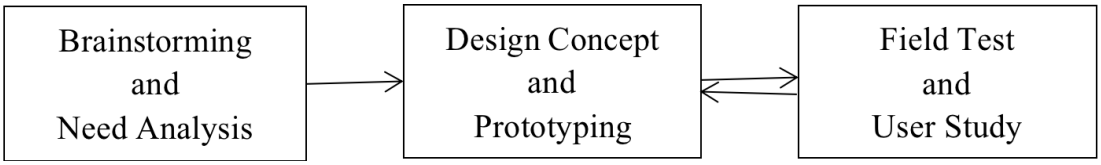


Figure 3.1 Design Process

3.1.1 Brainstorming and Need Analysis

The first step is conducted in the form of focus group interview. The participants were featured by the following characteristics:
(1)between the age of 20 and 35;
(2)living in long distance from their partners during the course of study;
(3)having been in a relationship with their partners for at least a year;
(4)not having a child.
In the brainstorming session, they were asked several questions to identify the unmet needs of LDRR couples:
(1)what do you feel that were lacked and needed in a long-distance romantic relationship?
(2)what are the internal or external factors that caused your breakups?
(3)what are the problems of existing technologies you have adopted? According to the discussion, the unmet needs of LDRR couples can be summarized asImplicit Communication and Communicating Touch Over Distance.

3.1.2 Implicit Communication

According to the discussion, one of the most frequently mentioned aspects regarding what was lost in long-distance relationships is an effective channel for implicit communication:

"Just imagine that you wake up in the morning and have nothing explicit to say to your girlfriend but a simple message of "being with you" or "missing you"…. of course it is possible to make a phone call to express my feeling, but it might be "too much" if I do so. In the worst case, my girlfriend might feel interrupted and overwhelmed." (Li, 22, male)

"Sometimes all I need is knowing his presence and a feeling of relatedness. This feeling of relatedness does not necessarily result from some kinds of direct communication that might disturb his current activity. I have no intention to distract him so I always give up contacting him while really missing him ." (Nancy, 29, female)

In romantic relationships, people always want to connect regularly with their "significant other" to disclose their feelings sense and emotions, which helps create

a feeling of closeness and intimacy. In keeping with the notion that communication is pivotal for a romantic relationship, Provoost and Dewit [47] continued that nonverbal communication is the easiest way to achieve the communication goal of increasing relatedness between partners, especially when partners do not have any stories to tell. In real-world practices, although communication technologies such as social media have compensated verbal and visual elements for LDRR couples to maintain their relationships, these prevailing technologies are far from capable of providing and conveying subtle, emotional cues when needed. As such, this project is inspired to explore an implicit messaging channel that fits into the daily routines without causing much disruption to both sides in a long-distance romantic relationship.

3.1.3 Communicating Touch Over Distance

Admittedly, there are a burgeoning presence of awareness systems such as CoupleVIBE and Forget Me Not, as discussed in the previous chapter, that have enabled LDRR couples to build up personalized, nonverbal communication in recent years. These designs, however, left some significant problems unchecked. One of the issues in maintaining long-distance romantic relationships, as reflected in the brainstorming session, is associated with how to ensure the physical contacts between partners when they are geographically separated.

Xu, in his 30, reported that, *"we are in the verge of break up because we rarely have opportunity to have any touch experiences. I often feel that she only exists virtually". "me too", agreed Karl when considering his relationship with his remote partner, "I don't want to think about how he (his partner) manages to overcome this problem, otherwise I may end up suspecting that he has already betrayed me".*

The problem of lack of presence feeling and physical interactions has in fact been repeatedly revealed in relationship research. It is also a dominant source of unpleasantness between couples living apart, according to the focus group discussion of this project. Although designs such as CoupleVIBE and Forget Me Not are capable of bringing the significant other in mind, they fail to provide the experience of affective touch that are essential in romantic relationships. Furthermore, limited physical contact also can cause a wide range of issues such as loyalty and commitment. The ability to experience the other's physical presence,

as Kontaris et al. [48] concluded, constitutes an important foundation of intimacy between LDRR couples that helps them overcome the challenges posed by geographical distance. In this sense, this research, while exploring an implicit messaging channel, also attempts to creatively engage with the emerging field of physical telepresence, exploiting tactile systems to supplement the traditional communication mediums for affective interaction.

Notwithstanding that there are attempts including the Kissenger and Flex-N-Feel to enrich haptic experiences between LDRR couples, they are constrained in the eyes of participants.

"It seems to be gross if you kiss a mouth made of silicon... it does not create any sense of togetherness at all." (Zhang, 24, female).

"people might think that you are weird when you wear a glove in the workplace or in a warm day..there might also be the case where you would like to initiate an affective interaction but your lover does not take their glove" (Steven, 33, male).

To sum up, the needs and requirements of long-distance romantic relationship couples mainly include an implicit messaging channel through which partners can share haptic experiences. In other word, the requests of LDRR couples are multifold, thus making it imperative to integrate different types of relation maintenance strategy into a single design to better serve the LDRR couples.

3.2. Design Concepts

Based on the feedback from the brainstorming session, I decided to augment a LDRR experience by addressing the problem of lack of implicit and haptic communication channel. The design is therefore developed and evolved into a lightweight system through which LDRR couples are able to have intimate sensory communication.

Conceptually, the design is based upon the idea of elf out of the long-standing nature-culture dialectic that has endowed non-human creatures like elves with spiritual and magical power. In his review of animal archeology, Jerolmack [49] provided vivid accounts of the ways in which animals are imagined and symbolized that reflect the cultural context where they emanate, suggesting that animals are repositories for social meaning.The aforementioned project of AmBird that takes

the shape of a pigeon served as an illustrative example of employing the symbolic meaning of animals in media design. It is built on the universally accepted meaning of pigeon as a gentle and loving symbol. This project, instead of pitching to a particular animal and operating on the socially constructed meaning of that animal, adopts the image of elves whose meanings are more fluid, subject to individual interpretation with limited social construction. It also rejected the idea of stuffed, furry animal as it is less flexible to take them out of the house or put them in the workplace. Furthermore, the project also received inspiration from the posthuman theory and historical discourses of monstrosity [50] to challenge the anthropocentric humanism of romantic relationships with the idea of elf. Specifically, by highlighting the elf, this project seeks to stimulate people to reimagine themselves as being enmeshed into a broader web of human and nonhuman agencies shaped by communal relationships, which indicates forward-looking ideas of science and technology in human relationships.

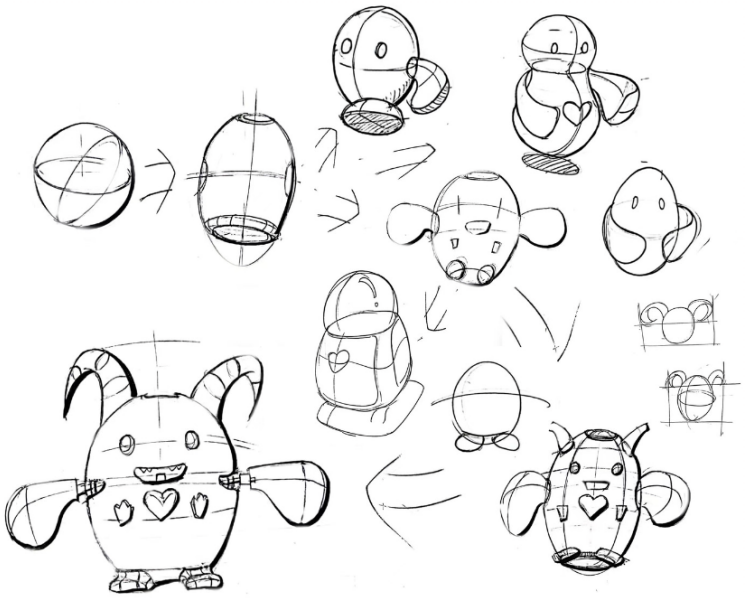


Figure 3.2 Morphological conception and evolution of love guardian

3.2.1 Initial Formation: An Elf Guardian for Lightweight Link

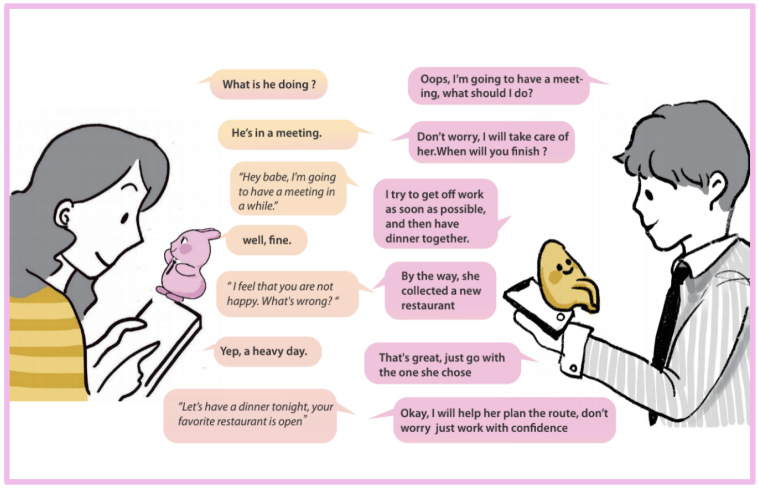


Figure 3.3 An Elf Guardian - Initial Imaginary Scenarios

One of the critical elements of the design is summarized as a lightweight link that demands less attention from both sides in a long-distance romantic relationship, since most of the participants in the focus group discussion believed that "too much awareness" could adversely impact romantic relationships, especially in terms of invading the other person's privacy.

The lightweight link between LDRR couples can be formed through an elf bot. Figure 3.2 sketched out the initial idea of the system. Specifically, when Miss Liu and Mr.Wang experience an emotional breakdown, two elves that feed on love will play a proactive role in helping the couples build intimacy. The affective interactions mediated by the elf system are basically ambient and implicit.

The initial design presents a lightweight awareness system to transmit the significant other into one's emotional world digitally, allowing one to feel the social presence of his/her loved one. As is illustrated in 3.4, everyone is able to have a digital elf as his/her representative that will be displayed on the screens of his/her partner to create a sense of togetherness between the couple. The appearance of the elf can be adjusted according to the user's preference. The elf employs algorithms such as an autonomous reply algorithm to interact with a person's partner

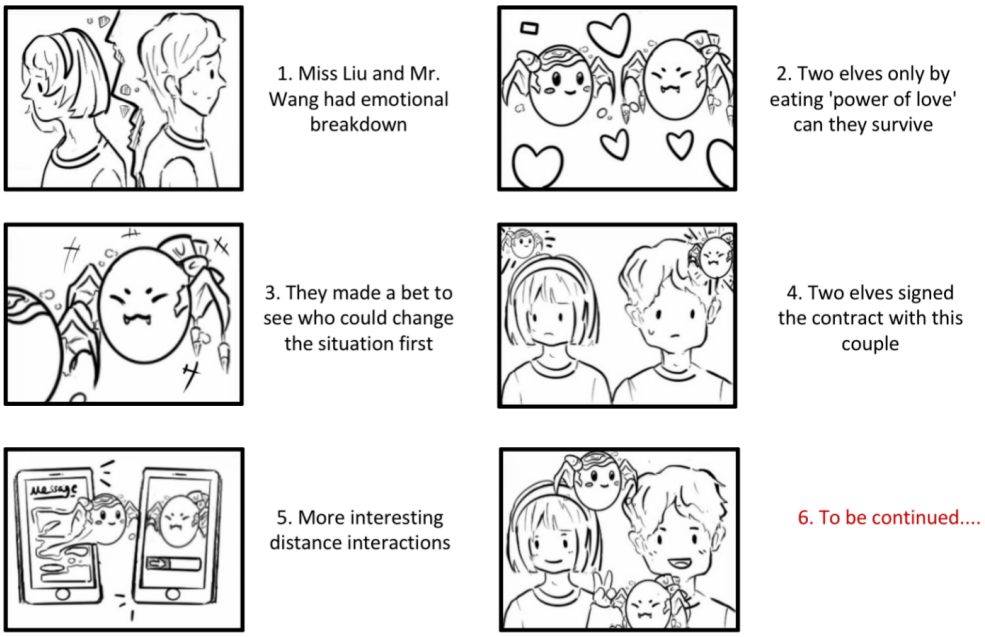


Figure 3.4 Elf Storyboard

on his/her behalf. The design can make intimate communication more personalized, given that everyone can create a distinct elf with unique communication patterns.

3.2.2 First Design: A Pair of Physical Elf for Lightweight-Sensory Communication

As mentioned earlier, while the digital elf, similar to CoupleVIBE and Forget Me Not, is suited to promote implicit communication between couples by increasing awareness, it fails to tackle the problem of lack of sensorial experiences or and augment the feeling of physical presence. For LDRR couples, geographical separation has significantly reduced the opportunity of for physical togetherness and haptic experiences from sensory communication, a problem insufficiently addressed by prevailing technologies. The initial design focused on brainstorming and refining the meaning behind the elves story and giving imagination to the stage while also serving as a solid prelude to the second design.

According to Field [51], affective touches play a critical role in ensuring physical and mental well-being, as well as building and maintaining intimacy. Dziabiola et al. [52] also revealed similar findings in their latest survey in 2022: that most people in long-distance romantic relationships reported a strong wish for the feeling of the physical presence of their partners who are geographically remote and put a particular emphasis on sensorial experiences, such as smell and touch, in their relationship. Therefore, mediating lightweight sensory communication through physical technology can be a viable solution to allow for the "presence-in-absence" and the exchanges of emotional cues between LDRR couples.

Findings and Redefinition

During the previous brainstorming sessions, participants also repeatedly mentioned some strong desires to help them fill or smooth out particular moments in their lives, such as empty, busy, or tired moments. Conversely, it would be inappropriate to communicate during such moments based on text messages or video calls. The vast majority of people in such moments do not have any desire to communicate explicitly, but simply want to fill the void inside from the stimulation of another person. The main requirements can be summarized in 3 points: (1) asymmetric use, (2) lightweight interaction, (3) not too much direct information (information explosion).

Therefore, this study redefines **special moments**: *moments when a long-distance couple (he or she) cannot or does not want to exchange too much communication with each other through SNS in their daily activities but only wants to convey a sense of presence and connection to each other to bring the feeling of security and love.*

Design Function

The final design decides upon a pair of devices that could recognize hand touch and eye contact before sending the touching signals wirelessly to a corresponding device. It is named Knotting, which is inspired by a decorative handicraft art in China with affluent symbolic meaning. For lovers, it is seen as a token of love. The An elf-shaped Knotting device could translate identify the input of affective touch on its head or eye contact and translate it into the outputs in the corresponding Knotting elf. of lighted LED that will recreate the patterns. The proposed design considers two types of interaction: (1) the number of strokes

changes to light, the input sensor in a pixie-shaped device can send signals to the corresponding device receiver based on stroking the head, the LED light on the heart of the corresponding device pairing elf will have the effect of incremental brightening; (2) sight gaze to physical changes, face-to-face gaze at the elf, the corresponding device pairing pixie will open and close to stir the wings, which also has the meaning of hugs.

3.3. Prototyping Knotting

This research designed Knotting in three major iterations that progressed from defining the physical shape of the device, then the materials and size of the device, and finally to improve the usability for the field study.

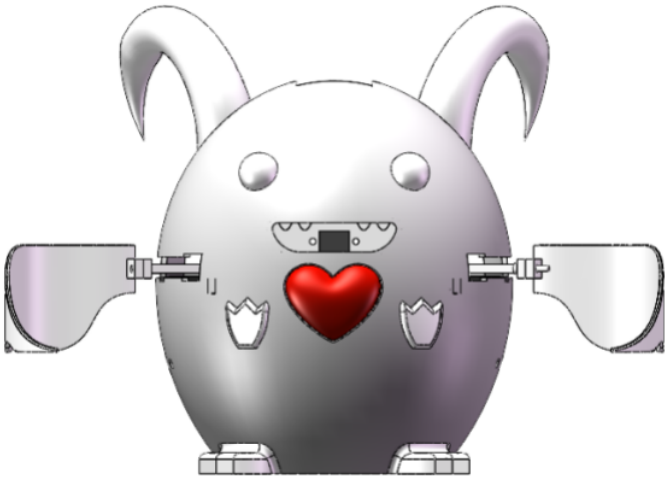


Figure 3.5 Proposed Shape of Knotting

Figure 3.5 demonstrates the proposed shape of Knotting. Armed with the data from the brainstorming session, I focused on making the shape of the elf device more aesthetically pleasing and welcoming and targeted a cute design similar to those cute monsters in Pokemon to elude people from an uncanny feeling of a realistic design. The prototype presented a short, chubby, rodent representation with a red heart at the center of its front side and a pair of leaf-like wings. It is

smelling as it seeks to transmit a positive vibe between couples.

Concept Selection	Not a particular animal	Something with wings	Animal Type
Selection Criteria	Rating	Rating	Rating
Fluid	4	4	3
Universally accepted symbol	4	3	4
Fashion Trend	4	4	4
Socially construction	3	3	3
More Imagination	4	4	3
Total Score	3.8	3.6	3.4
Continue ?	☑	☑	×

Figure 3.6 Score and evaluation form from interviewers

The exterior prototypes were developed with the help of 3D printing technology. Initially, I modeled the exterior as a whole and failed to print the proposed design. Because the shape has both angles and rounded parts, there is a misalignment when printed in a whole form. By segmenting and assembling, the exterior prototypes were successfully manufactured. Tactile interaction through the sensor is the affirmed method, and we hope to achieve the effect of visualizing the sense of touch, respectively, in the top of the elf's head and the mouth designed the installation location. The elf's chest is also designed to install a heart-shaped light that can change color brightness.

3.3.1 The First Version of Prototype

Materials and Size

The first version of prototype, made of acrylonitrile butadiene styrene, had a length of 40 cm and a height of 20 cm. The prototype was more suitable to be

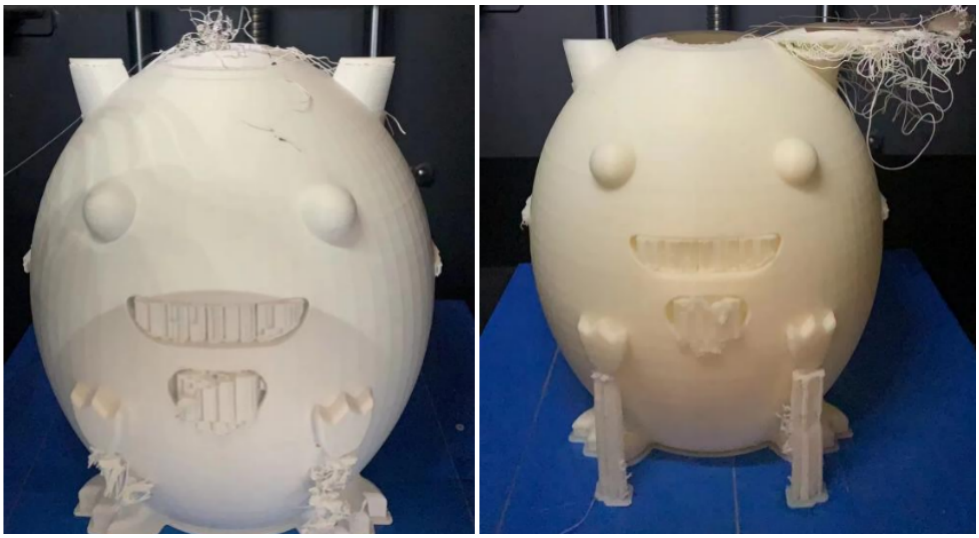


Figure 3.7 Failed Version of Knotting

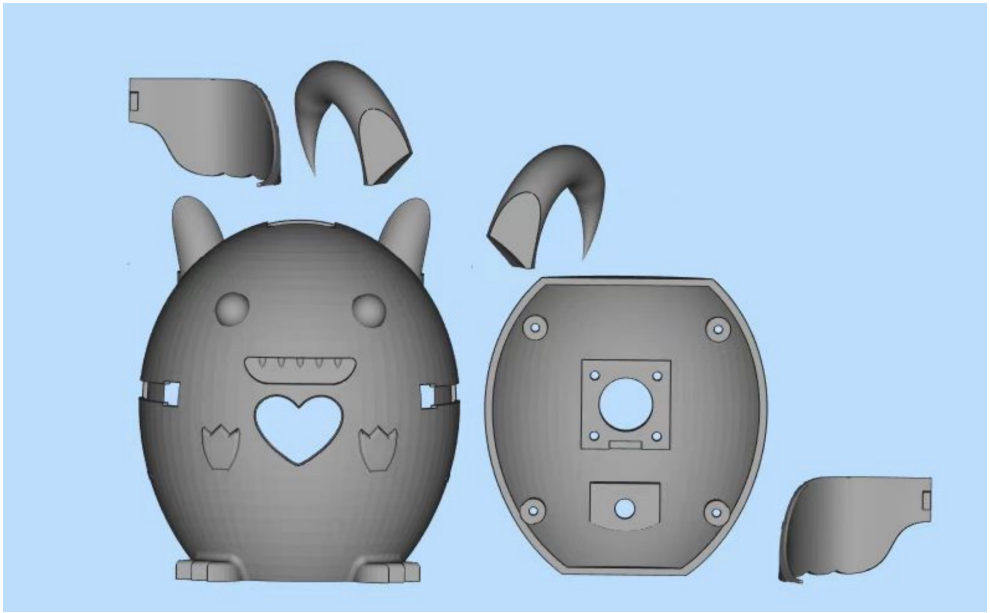


Figure 3.8 3D Segmentation of Proposed Prototype

placed at home and less portable for its large size. It was also less possible to bear it on the bed for due to its hardness.

Figure 3.9 The Fist Version of Prototype

Usability

It purported to detect the temperature change that stems from fingertip contact on the top of the device as an indicator of human emotion and transmit the signal wirelessly to the corresponding device. Once the signal of the temperature is received, the RBG LED lights in the corresponding device would light up in a preset color corresponding to a specific range of temperatures.to display the emotional status of the sender. However, the design was less practical for several reasons: 1) the input sensor was difficult to design as it was difficult to probe the temperature of fingertip; 2) the temperature of a fingertip is less affected by human emotion

than by the ambient temperature, which might cause misunderstandings in remote communication. For instance, people who feel happy in a chilly day would convey a message of "low temperature" that might suggest a sense of unpleasantness.

3.3.2 The Second Version of Prototype

Figure 3.10 The Second Version of Prototype

Materials and Size

The revised prototype was a critical reconsideration and modification of the first version. It is of the size of a palm and made of malleable TPU. In this sense, the prototype could be more mobile and flexible that can be carried out and kept easily.

Usability

It abandons the temperature change-to-light mechanism and instead adopts a visual-touch-eye contact integrated sensory communication mechanism through which LDRR couples can have different types of haptic experiences. Specifically, the system consists of the following features:

Input touch sensing: affective touch on head of the elf will be detected by the force sensitive resistor placed beneath the surface of the head and transmitted to the corresponding device;

Output light actuation: The heart-shaped actuator in the receiving elf will light up automatically once the signal is successfully transmitted;

Input Human body recognition and detection:there are also a pair of infrared line sensors in the mouth of each elf to detect body existence from a person; **Output wing actuation**: when one elf detects an human body and transmit the signal to the other elf, the Servo Motor will be actuated to enable the wings of the other elf to flap for ten seconds.

About the specific application of the main several sensors, respectively, the TTP223 touch sensor on the top of the head and the TOF Laser Range sensor in the middle of the teeth. Then through the wings on each side of a servo motor to drive the wings back and forth flapping. The size is about a palm for easy carrying. And both body and wings parts are printed with TPU, there is a lot of softness, user can press and pinch, while also avoiding the potential threat of wing flapping when used.

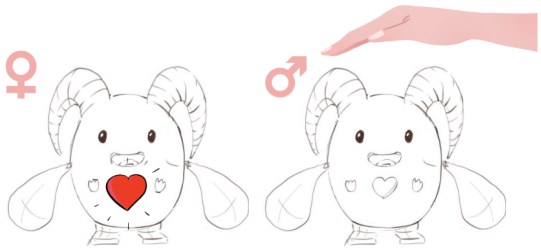


Figure 3.11 Key Feature 1

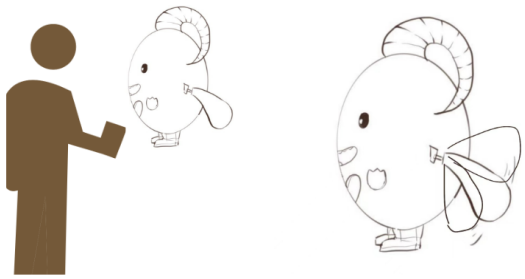


Figure 3.12 Key Feature 2

Figure 3.11 illustrate the first main function: Stroking the head, the heart of the opponent's elf will gradually become brighter with the number and degree of

strokes. And Figure 3.12 is the second main function: Standing in front of or stare at your elf, and the partner's elf flaps its wings.

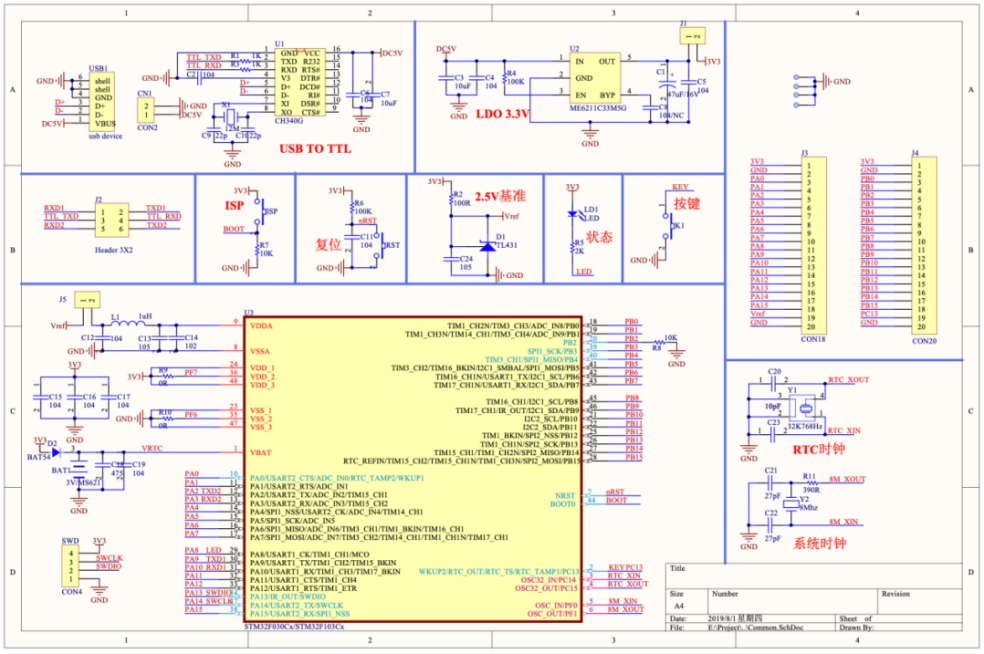


Figure 3.13 The System Design of Prototype

Chapter 4
Validation

Upon finishing the prototype design, we moved on to the validation process through which the design concepts and prototype can be assessed and validated by the targeted group, the LDRR couples. The validation processes purported to answer the following three questions:
(1)Does the current Knotting device enhance communication between LDRR couples?
(2)In what cases is the Knotting device more effective?
(3)What parts of Knotting device are better/less suited for supporting communication between LDRR couples?

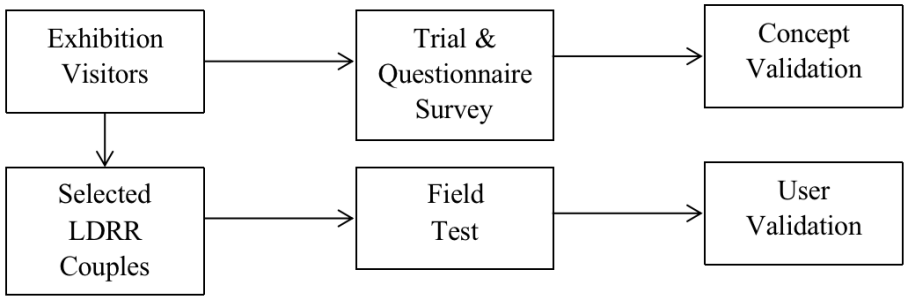


Figure 4.1 Road map of validation process

During this process, the tangible prototype of Knotting was evaluated twice. At an initial stage, opinions on the prototype were gathered from visitors to an exhibition where Knotting was displayed and introduced. These visitors were invited to respond to a questionnaire to indicate their attitudes and feelings towards the Knotting device. In doing so, this research was able to ensure the validity of the design concept of Knotting. Afterward, the field test was conducted with two LDRR couples for a week to examine the effectiveness of the prototype in

achieving intended goals. Figure 4.1 illustrates the road map of the validation process.

4.1. Concept Validation

The research has performed a preliminary concept validation with visitors of the exhibition held by the PLAY Project lab of Graduate School of Media Design, Keio University. Although some participants neither were nor had been in any long-distance romantic relationships, this research used the Knotting prototype as a trigger to obtain early feedback on the design concept. Figure 4.2 is the poster of the Knotting device displayed on the exhibition. It highlighted the key attributes of the prototype with two catchphrases: "mediating mutual intimacy and communication in long-distance relationships through surrogates" and "accurately seek for pain points of emotional communication in the current long-distance relationships". Clearly in the poster also included a yellowed invitation to the concept validation process read as "we'd love it if you volunteered to our special interactions".

Figure 4.2 The Poster of Knotting for Play Project Exhibition

4.1.1 Trial and Questionnaire Survey

As indicated by Figure 4.3, the guideline on Knotting distributed to the exhibition visitors, after being introduced to Knotting in terms of its goals and concepts, participants were asked to try designated moves with a friend or partner to experience the operating mechanism of Knotting. Specifically, a participant was requested to stroke the head of the elf-shaped device back and forth and stare at the face of the elf up close. His/her friend or partner would witness the reactions of the other elf paired to the experimented elf upon an action was initiated.

Figure 4.3 The Guideline on Knotting

Figure 4.4 Questionnaire Sample

Participants were then invited to fill out a questionnaire on the backside of the guideline (see Figure 4.4) based on their communication habits. The questionnaire did not require the respondents to reveal their personal information except for gender, age, and relationship status in case the investigation was obtrusive regarding their privacy. It also required every respondent to sign a consent form stating that he/she takes part in the test and survey out of his/her own free will and agrees to allow this research to use their survey data. The questionnaire mainly involved four questions:

(1)Have you ever had a long-distance relationship? (yes/no)
(2)If you're in a long-distance relationship, to what extent do you think this elf can make you feel connected? (a 5-point, negative-to-positive likert scale)
(3)Do you hope there will be any elves like this in the future? (yes/no/not sure)
(4)What do you think needs to be improved (optional)?

In total, 19 participants were involved in the conception validation test and spent an average of twenty minutes understanding and evaluating Knotting. After collecting the original data and initial analysis, all samples were confirmed to be valid and used for further analysis.

4.1.2 Findings

According to the survey data, 12 out of 19 participants had a partner over distance and, fortunately, the right user group reached as greatly as it was hoped for: despite that one respondent who never had a remote partner revealed an ambiguous attitude towards Knotting, the other 18 respondents, whether they had or had not been in long-distance romantic relationships, expressed their interest in having a Knotting elf to stay in contact with their partners.

Figure 4.5 Visitor Interaction Experiment

Figure 4.6 Interview in PLAY Exhibition

Meanwhile, the average score of the perceived effectiveness of the Knotting device in enhancing communication over distance and mediating intimacy, as statistics had it, was 3.68 out of 5, which suggested a generally optimistic attitude towards knotting. That attitude can also be captured by the fact that none of the respondents rated it below 2.5 that denotes a neutral stance. Furthermore, it was also indicated that participants who were once in a long-distance romantic relationship tended to give the effectiveness of Knotting a higher score, with all of them rating it over 3.5 with an average score of 4. In this sense, we can safely expect that the design concept of Knotting as a surrogate to mediate intimacy and enable haptic experiences would mostly be well-received by its potential users, namely the LDRR couples.

Simultaneously with the overall attitudes towards Knotting, this survey also attached great importance to the feedback from participants regarding how to improve the existing design and inspire future work. One of the most frequently mentioned aspect for further improvement was associated with the customization issue. Specifically, as one put it straightforwardly,

"(although) i think that a way, like this elf, to express simple feelings to your partner at a long distance will be part of our life in the future, I think that shape should be customisable, so that you can interact with something closer to your feelings" (respondent 3).

Likewise, another respondent prioritized the customized heart light on the Knotting device as what should be improved. By stressing customization, respondents expressed their hope for an expressiveness technology tailed to individual preference and interpretation. There were also respondents who prefer a furry look and touch that seemed to be more "real" as then-current design was based upon TPU that was comparably more machine-like.

An equally significant property that participants recommended Knotting to include was verbal cues aside from those nonverbal cues Knotting had enabled. For instance, respondent 6 advised Knotting to install the functionality of the alarm, thus allowing one to wake his/her partner who is geographically distant up by speaking to Knotting. While understanding that Knotting was pitched for conveying a lightweight message, some respondents expected to incorporate the conversation function into the design. Admittedly, it is impossible to develop a one-fits-all mode of communication technology that could fix all the problems faced by LDRR couples up. Any design is crafted through a difficult trade-off between different choices. Knotting also relinquished integrating verbal cues into the prototype since its inception as it centered around a lightweight connection between couples rather than content-rich communication that existing communication technologies such as social media have allowed for.

There was also a small group of respondents who looked forward to having more emotional interactions enabled by Knotting, through they remained open to what types of interactions they sought for.

4.2. User Validation

To ensure that Knotting achieves its intended goals of supporting implicit communication and communicating touch over distance, this research then proceeded to conduct a field test with two pairs of LDRR couples for detailed user validation. Meanwhile, a meaningful assessment of the design concept requires trials over short and long periods. Since the trailtrials performed at the exhibition could be regarded as short trailtrials that constructed key scenarios and situations for using Knotting, field tests could therefore be seen as long trailtrials to observe the unstructured use of Knotting and use patterns over a more extended period.

4.2.1 Field Test

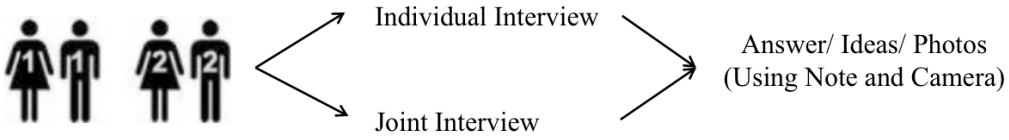


Figure 4.7 Field Test Flow

The participants of the field test were recruited from the questionnaire survey for two reasons: firstly, the data collected from the field test could be both an extension on and a comparison of what had been concluded from the trials at the exhibition of the Play Project. Participants who performed short trials at the exhibition would formulate an early impression about Knotting, especially concerning its effectiveness in supporting communication over the distance between romantic partners. The field test provided the opportunity to corroborate the findings on the short trials by tracking how Knotting was deployed in multiple real-life settings. Secondly, on account of the delivery control amid Covid-19, it was difficult to send the prototype to a larger group of participants such as those transborder LDRR partners. As such, this research performed the contextual inquiry with two pairs of LDRR couples residing in Japan:

Couple A: Male: 23 years old, Tokyo-based, student Female: 20 years old, Tokyo-based, student The partners, though both residing and studying in Tokyo, were unable to meet each other frequently on a weekly basis due to the geographic distance of their homes and different learning schedules.

Couple B: Male: 29 years old, Tokyo-based, employer Female: 25 years old, Shinagawa-based, employer The partners had been living in different prefectures and both busy working so that they were less likely to see each other quite often.

The two couples were provided with Knotting devices from June 8, 2022 to June 12, 2022 for five days. The field test included both working days (from Wednesday to Friday) and weekend (Saturday and Sunday) and recorded the usage of Knotting during the day and at night. Participants could take and use the device wherever and whenever they want without any third party intervention.

Data collection consisted of usage logs and post-test semi-structured interviews. We queried in-the-moment insight on usage, feelings, and reactions based on their real-life experiences.

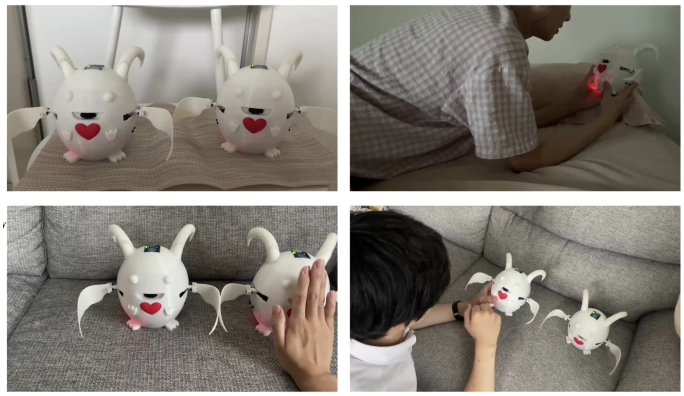


Figure 4.8 Application in field test

4.2.2 Results from Field Test

Usage at Special Moment

According to the usage logs of the participants, this research identified a dominant pattern of using Knotting by referring to the notion of "special Moment", namely at times when people "are not available for communication activities" . *Both couples lauded the mobility of Knotting and the minimal action it requires, which made it easy to use publicly even at the workplace without causing much influences to the surroundings. Notwithstanding their consensus, they applied Knotting in different settings.* For the couple A, they used Knotting most frequently in the morning before going out, at lunch times, and at night after back to home. Home was the main place for using Knotting, though there was one time they took Knotting when hanging out with friends. By contrast, the couple B resorted to Knotting mostly at workplace and midnight.

Lightweight Message for Implicit Expressiveness

The participating couples also agreed that Knotting was beneficial to communicate intimate messages without demanding immediate attention and response like

phone call. The male participant of Couple B expressed: *"(I always use it) when I am less available and exhausted, with no intention to having direct communication with my partner but the other one is waiting for my message.....the elf is rightly used in such a situation to enable my lover to know my presence in an unobtrusive manner". One of the participant of couple A also agreed: "it would be interrupting if I call her at the midnight when I missed her, so using Knotting is a more proper way to convey the message of 'I miss you'".*

Meanwhile, the participants considered on the nonverbal cues of the elf as *"something more real than a text". The female participant of couple A stressed that "you can better feel the presence of the other wholeheartedly with heart light and flapping wings of the elf than with SNS". Similarly, her partner indicated: "everything turns out to be spelled out with a test message, but the elf allows you to think more about the underlying tone and feeling than the content of the message".*

Most participants further claimed that the tangible metaphorical design of the elf tokens as a favourable feature of Knotting. The animated representation of oneself and close others effectively stimulated participants' empathy and meaning generation. Specifically, they would attach meanings to the elf and various types of actions relating the elf spontaneously based on the relationship experience.

Haptic Experiences for Increased Feeling of Connectedness

The participants recognized that touch and staring could elicit the feeling of togetherness between LDRR couples and made them more cognizant of their partners. A participant responded, *"It put a smile on my face when I stroke the head of my elf to light up the heart of his elf or stare at the elf's eyes to make the wings of his elf flap.....It's meaningful because I feel I am physically interacting with him". Another participant in couple B shared his feeling, "the reactions of my elf make the abstract concepts more real, just as she is physically affecting me.... the emotion is attached to a more physical...". For the female of the couple A, "I made it a habit to interact with my elf every morning.....it seemed that I was saying "good morning" to him".*

Another welcoming attribute of Knotting, according to the participants, was its being noninvasive of personal privacy as they held that the levels of comfort in a romantic relationship was negatively correlated with the levels of detail in

sharing. The sutble yet affective touch and stares of Knotting were viewed as minimal invasion of personal spaces.

Limitations

Based on the field tests, this research believes that the communication between LDRR couples can be enhanced through the adoption of Knotting. Still, the interviews also disclosed the weakness of the design. First and foremost, the mood and demeanor of user affect the effectiveness of Knotting. When couple A and couple B experienced certain levels of conflicts, Knotting was applied by participants to ameliorate the tension. It was revealed that Knotting was more effective in minor tussles where a light message conveying the signal of "I care about you" via the elf could mend the relationship. In serious fight, however, Knotting was less instrumental, if not counterproductive. *"I was still in a bad mood and the situation went worse when I saw the elf", a participant recalled.*

Secondly, a participant also noted that there were always the cases where he neglected the signals of his elf unintentionally due to hectic schedules. In other worlds, Knotting, featured by ephemeral messaging and synchronous telecopresence, was less feasible when a person is unable to pay attention to his/her elf when the message of the other person arrives at the elf. The problem leaves further question for Knotting of whether to alter to or add an asynchronous design.

Thirdly, as the local device does not include any signaling components that confirms the successful delivery of the intimate messages of affective touch or eye contact, long-distance couples could face a situation where one side sends a message repeatedly without knowing whether the message has been received or not. A participant reported that, "I have to text another message via social media to inform him of my message". Such an action, however, betrayed the fundamental goal of Knotting to enhance intimate relationship in an unobtrusive manner. In this sense, future prototype should consider inserting a signaling component.

Lastly, due to the situational constraints at the time of Covid-19, it is less possible for this project to perform user tests with more LDRR couples with different demographic backgrounds such as age, location, culture, educational level, etc. For instance, the enhancing effects of Knotting on relationship might change with geographic distance and time zone differences, etc. Another parameter might be

age, as the Knotting device might be more effective for tech-savvy young couples who are more likely to consume popular culture and playful items. Meanwhile, an equally important factor that might affect the effectiveness of Knotting is the time period. The validation test failed to explore whether the effectiveness of Knotting change with time. It is possible that Knotting could be effective within a certain period of time yet less helpful when the separation time between long-distance couples becomes longer. As such, further investigation should include more diverse groups for experiment and set a comparison group with extended experiment periods.

Chapter 5
Conclusion

5.1. Summary

In modern contexts where relationships over distance are increasingly compensated by communication technologies, some of the communication needs of long-distance romantic relationship partners are untapped by existing technologies. This research demonstrates the design rational and concept development behind Knotting, which targets at the needs of LDRR couples that are not adequately addressed by explicit communication modalities. Knotting is a physical technology that ensures the synchronous tele-copresence and haptic communication of LDRR couples with the nonverbal cues of affective touch and eye contact. In a human-centered design process starting with a brainstorming session, I came up with the design concepts of an implicit messaging channel for haptic experience and implemented the prototypes in three major iterations that progressed from defining the physical shape of the device, then the materials and size of the device, and finally to improve the usability for the field study. After finalizing the prototype of Knotting, I then invited 19 participants to experience the Knotting device at an exhibition held by Play Project to receive early feedback. At a later stage, exploratory field test was performed to gain more insight on the usage and effectiveness of Knotting. It highlights the following properties of Knotting: (1)Implicit Communication, (2)Mobility and Feasibility, (3)Mediated Haptic Experience.

5.1.1 Implicit Communication

For LDRR couples, Knotting operates as a supplant of explicit communications by facilitating the exchange of subtle, nonverbal messages. A person could express

his/her feelings to the other person by simply stoking the head of his Knotting elf or staring at the elf's eyes, which would cause significant change of the corresponding elf kept by his/her partner without requiring a reciprocal act from the other side. The design contributes to existing implicit messaging channels through an emphasis on a lightweight link between couples, which proved to be essential for participants of the field test.

5.1.2 Mobility and Feasibility

As a handable, mobile device, Knotting can be taken with easily and therefore placed at the workplace and home depending on the communication habits of the users. Meanwhile, since the device only demands minimal action of users to communicate, it fits more into the daily routine of people compared to most of existing tactile technologies that are more bonded to fixed places and settings.

5.1.3 Mediated Haptic Experience

Knotting also enables the physical contacts between partners when they are geographically separated as it mediates lightweight sensorial communications through a physical design that integrates two sensory systems of human beings. People can touch and stare at the elf to express their feelings and emotions, which makes the "presence in absence" more real and increases the feeling of togetherness.

With these findings corroborated, we are able to envision a future of intimate social networks maintained by a broad set of communication tools, explicit and implicit, that help partners over distance feel more connected and coordinated.

5.2. Future Work

Based on the results from user study, this research also summarizes the following takeaways for further improvement on communication systems for long-distance romantic relationship:

(1)To Contextualize the Intimate Communication

According to the field test, the supporting effects of Knotting are pronounced in some cases while less salient in others. Future design therefore should take the

context of application into consideration as it plays a fundamental role in determining the real-world usability of a communication technology. For instance, a design can diversify its usage in multiple settings and scenarios to ensure it could mediate intimacy in as many contexts as possible. Likewise, a device may allow users to combine messages and environments to communicate with their partners over distance, which means a larger design space in future projects.

(2)To Increase the Flexibility of Design

For the participants of the user test, the digitally connected moments of intimate interactions were always transient and synchronous. The communication could be effortless for the initiator when the other party was away from the Knotting device. In fact, the hectic schedule in modern life always create breakdowns in communication that amplify the challenges of physical distance. In this regard, future work is supposed to integrate both synchronous and asynchronous telecopresence into a single installation.

(3)To integrate Artificial Intelligence Technology into Intimacy Communication

Although this project devised a physical technology, it does not deny the possibility of integrating artificial intelligence into a physical design for customization, as there were participants in the short trials who look forward to having a personalized elf that supports more types of interactions. Future attempts could try with the combination of AI technology and tactile technology into a single framework.

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