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CONNECTING COUPLES IN LONG-DISTANCE RELATIONSHIPS

Towards Unconventional Computer-Mediated
Emotional Communication Systems

Hong Li
李竑

HONG LI

**Connecting Couples in Long-Distance Relationships:
Towards Unconventional Computer-Mediated
Emotional Communication Systems**

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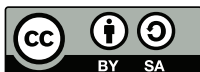
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Abstract

The number of couples who find themselves in a long-distance relationship (LDR) is increasing for a wide range of reasons, such as overseas employment, academic pursuits, military duty, and similar circumstances. With the myriad of communication channels enabled by the low cost and ubiquity of computer-mediated communication technologies, couples in LDRs are able to stay in touch with each other around the globe. However, recent studies have revealed that the mainstream communication tools are inadequate to support the full spectrum of communication needed in intimate relationships. Emotional communication is one of the fundamental needs in close relationships, as it forms an important part of intimacy. This dissertation argues that there is a gap between what is known about LDR couples' needs in research and what has been implemented for them in practice. The aim of this work is to bridge this gap by mediating emotional communication through unconventional user interfaces that use interaction solutions outside of the scope of their conventional use, with a particular focus on couples who sustain a committed LDR.

Here, taking *research through design* as a core approach, a variety of qualitative methods were employed to seek answers to the research questions. This dissertation includes eight case studies, each of which is dedicated to answering its corresponding research question(s). Study I presents a systematic literature review which explored the current state of the art and identified the design opportunities. Study II introduces a series of co-design activities with five couples in LDRs to reveal the needs and challenges of users in an LDR. Studies III and IV propose two functional prototypes for unconventional communication systems to connect couples in LDRs. Study V showcases 12 design concepts of wearables created by the participants to support their own LDR. Study VI describes how four low-resolution prototypes created for mediating LDRs by the participants in the workshop would be used in real-world contexts. Studies VII and VIII each present a novel design tool to be used as a scaffold when designing communication systems for supporting LDRs: specifically, a conceptual design framework and a card-based design toolkit.

This dissertation contributes new knowledge to the field of human-computer interaction through design interventions. It showcases a spectrum of practices which can be seen as a first step towards mediating emotional communication for couples in LDRs using unconventional communication systems. The findings comprise theoretical and empirical insights—derived from the eight case studies in which the

author identified design opportunities and design considerations—relating to how couples in LDRs can be better supported by unconventional computer-mediated emotional communication systems.

Keywords: Long-distance relationship, emotional communication, customisation, user studies, participatory design, human-computer interaction.

*To my distant loved ones who support me in all things great and small.
Also, in memory of my beloved grandparents who did not live to see me earn my PhD.*

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Pursuing a doctoral journey is undoubtedly challenging, particularly while working on it in a city that is situated right on the Arctic Circle, where the winters are very long, dark, and extremely cold. The path towards this dissertation has been a strenuous climb of resilience and perseverance. There were challenging situations that forced me to strive beyond my abilities and go beyond boundaries. It would never have been possible for me to take this work to completion without the incredible people who guided, supported, challenged, encouraged, and stuck with me along the way.

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Hong Li
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Abbreviations

3D	Three-Dimensional
CMC	Computer-Mediated Communication
ECD	Electrochromic Display
GCR	Geographically Close Relationship
HCI	Human-Computer Interaction
LED	Light-Emitting Diode
LDR	Long-Distance Relationship
PC	Personal Computer
PD	Participatory Design
PRC	Product Reaction Cards
UCD	User-Centred Design
UI	User Interface
UX	User Experience

List of Original Publications

- I. Li, H., Häkkinen, J., Väänänen, K. (2018). Review of Unconventional User Interfaces for Emotional Communication between Long-Distance Partners. In *Proceedings of the 20th International Conference on Human-Computer Interaction with Mobile Devices and Services* (MobileHCI'18, Article No.: 18, pp. 1-10). New York, NY: ACM.
- II. Li, H. (2018). Understanding Design as a Catalyst to Engage Remote Couples in Designing for Long-Distance Relationships. In *Proceedings of the DRS 2018 International Conference: Catalyst* (Vol 6., pp. 2265-2279). London, UK: Design Research Society.
- III. Häkkinen, J., Li, H., Koskinen, S., Colley, A. (2018). Connected Candles as Peripheral Emotional User Interface. In *Proceedings of the 17th International Conference on Mobile and Ubiquitous Multimedia* (MUM'18, pp. 327-333). New York, NY: ACM.
- IV. Li, H., Müller, H., Häkkinen, J. (2019). Our Little Secret: Design and User Study on an Electrochromic Ambient Display for Supporting Long-Distance Relationships. In *Interactivity, Game Creation, Design, Learning, and Innovation* (pp. 611-622). Cham, Switzerland: Springer.
- V. Li, H., Jarusriboonchai, P., Häkkinen, J. (2020). Exploring Wearable Technology for Supporting Couples in Long-Distance Relationships. In *Proceedings of the DRS 2020 International Conference: Synergy* (Vol 5. pp. 2083-2097). London, UK: Design Research Society.
- VI. Li, H., Jarusriboonchai, P., Müller, H., Harjuniemi, E., Häkkinen, J. (2020). Emotional Communication between Remote Couples: Exploring the Design of Wearable Ambient Displays. In *Proceedings of the 11th Nordic Conference on Human-Computer Interaction: Shaping Experiences, Shaping Society* (NordiCHI'20, Article No.: 34, pp. 1-5). New York, NY: ACM.

- VII. Li, H., Häkkinen, J., Väänänen, K. (2019). Towards a Conceptual Design Framework for Emotional Communication Systems for Long-Distance Relationships. In *Interactivity, Game Creation, Design, Learning, and Innovation* (pp. 103-123). Springer, Cham.
- VII. Li, H., Khan, A. H., Hurtig, K., Jarusriboonchai, P., Häkkinen, J. (in press). Flexi Card Game: A Design Toolkit for Unconventional Communication Systems for Long-Distance Relationships. In *Proceedings of the 15th ACM International Conference on Tangible, Embedded and Embodied Interaction* (TEI'21). New York, NY: ACM.

Rights to include the above publications in the printed version of this dissertation have been granted by the respective publishers. Original publications are not included in the electronic version of the dissertation.

Author's Contributions

This dissertation is based on eight original publications. The author's contribution to the publications and studies behind them are described as follows:

Publication I, *Review of Unconventional User Interfaces for Emotional Communication between Long-Distance Partners*. The author was the principal author and was in charge of producing this publication. Most of the data analysis was carried out by the author. The second author (Häkkinen) and the third author (Väänänen) helped produce a codebook for conducting the data analysis as well as providing guidance to the positioning of the work to ensure its novelty and contributing to the writing phase.

Publication II, *Understanding Design as a Catalyst to Engage Remote Couples in Designing for Long-Distance Relationships*. The author was the sole author in this publication. She alone planned the study, conducted the user study, analysed the data, and wrote the publication.

Publication III, *Connected Candles as Peripheral Emotional User Interface*. In this publication, the author and publication first author (Häkkinen) contributed equally to the work. The first author (Häkkinen) created the initial concept, gave guidance during the study planning phase, and was a co-writer of the publication with the author. The author designed the detail of the user studies, performed the analysis of the study results, and played the main role in writing the publication. The third author (Koskinen) manufactured the prototype. The fourth author (Colley) created the technical setups for the working prototype.

Publication IV, *Our Little Secret: Design and User Study on an Electrochromic Ambient Display for Supporting Long-Distance Relationships*. The author was responsible for the overall concept design and execution of the studies reported in the publication. The user studies and data analysis were conducted by the author. She also took the lead in writing the publication. The second author (Müller) created the prototypes and enabled the technology setups. The third author (Häkkinen) gave guidance during the study planning phase and contributed to the writing of the publication.

Publication V, *Exploring Wearable Technology for Supporting Couples in Long-Distance Relationships*. The author planned the study and conducted the data analysis in collaboration with the second author (Jarusriboonchai). The user study was run by the author, who was also the principal author and was in charge of producing the publication. The third author (Häkkinen) provided guidance on the positioning of the work to ensure its novelty and contributed to the writing of the publication.

Publication VI, *Emotional Communication between Remote Couples: Exploring the Design of Wearable Ambient Displays*. The author planned the study in collaboration with the second author (Jarusriboonchai). The author conducted the user studies and analysed most of the produced data. Additionally, she took the lead in writing the paper. The third author (Müller) manufactured the prototype and implemented the prototype application. The fourth author (Harjuniemi) helped in conducting the user study. The last author (Häkkinen) gave guidance during the study planning phase. While all authors contributed some text to the publication, the author was the main writer of the paper.

Publication VII, *Towards a Conceptual Design Framework for Emotional Communication Systems for Long-Distance Relationships*. The author planned the study in collaboration with the second author (Häkkinen) and the third author (Väänänen). The author conducted all the data analysis. The remaining authors (Häkkinen and Väänänen) helped identify key dimensions of the framework, gave guidance during the study planning phase and contributed to the writing of the publication.

Publication VIII, *Flexi Card Game: A Design Toolkit for Unconventional Communication Systems for Long-Distance Relationships*. The author designed the four versions of the card set and manufactured the first two versions in collaboration with the fourth author (Jarusriboonchai). The author also conducted the first three user studies. The second author (Khan) carried out the last user study, gave suggestions to improve the last version of the card set, and participated in the writing of the paper. The third author (Hurtig) was responsible for manufacturing the third and fourth versions of the card set. The fifth author (Häkkinen) provided essential guidance on the related work in the subject area, ensuring the novel direction of the work, and contributed to the writing of the publication.

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1 Introduction

1.1 The Big Picture

‘We have no choice but to be in an LDR, it is damn hard, but we finally have become the experts [...] Distance starts to mean nothing when someone means the whole world to you.’ — A married couple, who had been in a long-distance relationship (hereafter referred to as LDR) on and off for about 14 years, in this research.

LDRs have become increasingly prevalent in today’s society due to educational demands, career pursuits, military duty, emigration, and similar circumstances (Stafford, 2004). Exceptionally, global pandemics, such as the current outbreak of Coronavirus disease, can also keep numerous loved ones apart through travel bans, cancelled flights, closed borders, and so on. According to the latest available data provided by *The Center for the Study of Long Distance Relationships*, in excess of 7 million couples (i.e., 14–15 million individuals) in the US considered themselves to be in an LDR in 2005 (The Center for the Study of Long Distance Relationships, 2018). Moreover, the number of individuals that face geographical separation, including but not limited to those in romantic relationships, continues to increase (Stafford, 2004). Although the phenomenon of LDRs has increased, the discourse surrounding LDRs remains relatively understudied compared to the research on geographically close relationships (GCRs). The growing interest in this realm began when Rohlfsing (1995) claimed that the LDR was an understudied phenomenon. Apart from the various research challenges resulting from geographical distance, one core reason for making LDRs marginalised is that physical proximity and frequent face-to-face interaction are culturally deemed to be necessary to maintain healthy intimate relationships (Stafford, 2004). However, it has been demonstrated that couples in LDRs are equally or more intimate and satisfied than geographically close couples (Crystal Jiang & Hancock, 2013).

Advancements in mainstream communication technologies have made it easy for couples to connect over large geographic distances. Couples maintain LDRs by using myriad media: for example, phone calls, video chats, texting, instant messaging, email, and so on (Crystal Jiang & Hancock, 2013). Since these communication channels intend to serve a wide range of end-users, the focus has been placed on functionality. It has been noted that most available technologies currently focus on the transmission of explicit information, which neglects the emotional communication needed in close relationships (Hassenzahl, Heidecker, Eckoldt, Diefenbach, & Hillmann, 2012). Several negative impacts of this have

been noted. For instance, the ‘message seen’ feature provided by some mainstream communication channels (e.g., Facebook Messenger, WhatsApp, Line, etc.) could make the sender feel upset or angry at the recipient when the message was read but not responded to (Hoyle et al., 2017). Text messaging cannot accurately convey tone, emotion, facial expressions, gestures, body language, eye contact, and so on, and hence it is likely to cause misinterpretation and misunderstanding. In close relationships, the point of frequent exchange of messages should be emotional communication rather than just sharing explicit information, as emotional communication can create a positive experience via technology to make a relationship flourish (Hassenzahl et al., 2012).

Having acknowledged the above-mentioned problem, there has been a growing body of work on designing unconventional communication systems aimed at mediating emotional communication in LDRs in the field of human-computer interaction (HCI) over the past decade (Li, Häkkinen, & Väänänen, 2018). Wearable technologies (Singhal, Neustaedter, Ooi, Antle, & Matkin, 2017), ambient media (Chang, Resner, Koerner, Wang, & Ishii, 2001), biosignals (Werner, Wettach, & Hornecker, 2008), haptic sensations (Kontaris, Harrison, Patsoule, Zhuang, & Slade, 2012), hybrid interactions (Kowalski, Loehmann, & Hausen, 2013), and so on are widely employed to create a relatedness experience for remote couples. The purpose is to mimic the core components of every close relationship, which are being able to see, listen to, smell, and touch each other. However, research has indicated that the majority of the systems lack customisability (Li, 2018; Li et al., 2018). Every couple in an LDR has subjective love languages (e.g., for a certain couple, the ‘slice of pizza’ emoji could mean ‘I love you’ [Wiseman & Gould, 2018]). Customisation offers opportunities for the couples to adjust, specify, and modify an object, thus enabling it to better support their subjective love languages and serve their diverse needs in various contexts. Furthermore, through efforts in the form of customisation, a lifeless object becomes meaningful and symbolic to users, and as such, the object becomes a one-of-a-kind object to which users become emotionally attached. On the contrary, lifeless machines and standardised tools may fail to build the emotional connection needed by LDR couples. As a result, the author argues that there is a gap between what is known about LDR couples’ needs in research and what has been implemented for them in practice, potentially with their collaboration.

1.2 Research Questions, Scope, Approach, and Process

Coming from a design background, the author has been motivated to investigate how design can serve to translate an understanding of LDR couples’ needs in research to the design of technologies for them in practice, with their potential collaboration. The research questions of this dissertation are as follows:

- What are the design opportunities for designing unconventional communication systems for mediating couples in LDRs?
- What are the users' needs and challenges when being separated by a geographical distance that restricts physical contact and face-to-face communication?
- How can technology be unobtrusively integrated into the users' everyday lives and serve as a minimal communication channel between couples in LDRs?
- How can design play a role in supporting the process of designing unconventional communication systems for LDRs?

This work is positioned in the field of HCI. The scope is to mediate emotional communication (Gaelick et al., 1985) through unconventional user interfaces (UIs), with a particular focus on couples who sustain a committed LDR. It offers a topical outlook into a relatively understudied yet practically very important facet of interpersonal communication. In the context, 'unconventional' is considered to describe interaction solutions beyond conventional use and thus differing from existing mainstream communication. Unconventionality in this work was inspired by the notion of critical design, a term coined by Dunne and Raby (2001). As Dunne and Raby (2013) articulated, *'It was more of an attitude than anything else, a position rather than a methodology. Its opposite is affirmative design: design that reinforces the status quo.'* Bardzell and Bardzell (2013) encouraged that critical design be actively and creatively developed, as it has a high potential for the HCI design community. Even though HCI research is centred on problem-solving capacity (Oulasvirta & Hornbæk, 2016), this work also involves problem finding: that is, by proposing potential communication solutions for the future in the context of LDRs, the ultimate goal of this dissertation is to question and challenge the narrow assumptions of how technology is conventionally used. The prototypes presented in this dissertation might not be as bold as speculative design (Malpass, 2013) and design fiction (Bleecker, 2009), but the author hopes to evoke new assumptions in people about the way they communicate with each other and how they can interact with technology differently, as well as encouraging the imagination of the possibilities of future communication.

This work takes *research through design* as a core approach (Zimmerman et al., 2007) to achieve a better understanding of how design can be utilised to create technology that is able to support new and positive user experience (UX). As shown in Figure 1, a double-diamond model (Ball, 2019) is formed by the eight case studies included in this dissertation. The research process was not linear but iterative: specifically, each case study went through a double-diamond process and was then integrated into a combined double diamond (see Figure 1). A variety of qualitative methods were employed to address the research questions. Systematic literature review techniques were applied to investigate the prior state of the art and explore

the design space. A number of participatory workshops were conducted in order to build empathy with the users and uncover the needs and challenges in LDRs. Design thinking tools such as persona, storytelling, and prototyping were utilised to engage the users in the study. Throughout the research process, two functional prototypes, one conceptual design framework, and one novel design toolkit were created, along with four low-fidelity prototypes co-created with the research participants. All of these research outcomes have been evaluated either in a laboratory setting or in the wild by the users or domain experts. Semi-structured interviews, questionnaires,

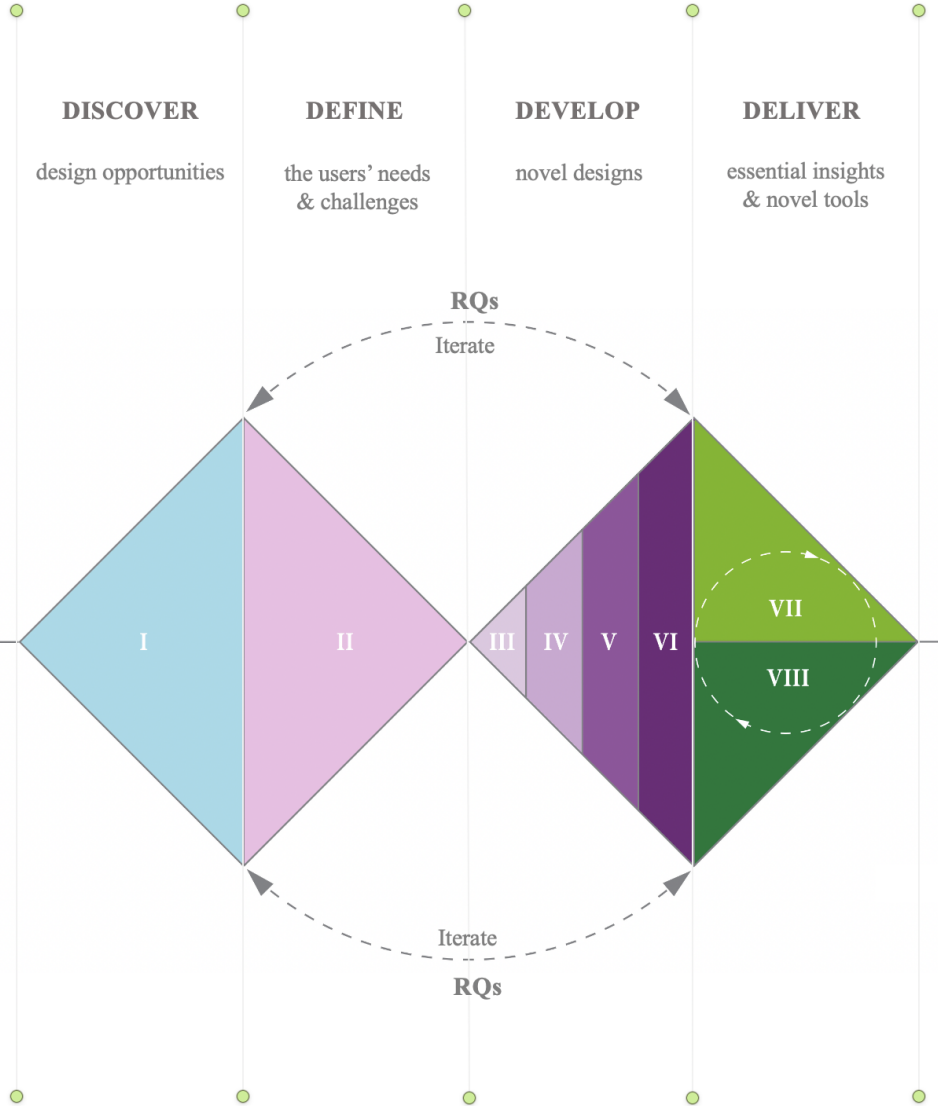


Figure 1: The research process of this dissertation outlined in a double-diamond model.

focus group were used as different means to obtain perceptions, report UX, and obtain feedback from research participants. Chapter 5 further describes the methods used in each case study.

1.3 Contributions of the Dissertation

The contribution of this dissertation is three-fold. First, it provides designers and researchers with essential insights and novel tools to help them in the design thinking process to create improved emotional-communication-mediated systems to support LDRs. Second, it delivers new knowledge relating to how communication technologies could be embedded in unconventional forms and humanised with higher levels of emotional communication for supporting LDRs, thus contributing to the advance of user-centred design (UCD) knowledge at the intersection of HCI and interpersonal communication. Third, it presents functional systems, design concepts, and examples of how to engage LDR users in a study, as well as findings derived from this dissertation, which not only identifies design opportunities in this specific domain but also provides practical knowledge for inspiring future design in this particular context. The novelty of each publication is described in detail as follows:

Publication I, *Review of Unconventional User Interfaces for Emotional Communication between Long-Distance Partners* presents a systematic overview of design attributes and their appearance in systems for emotional connectedness between LDR couples, as well as an analysis of user evaluation methods applied in the evaluations of the systems. In HCI research, different types of solutions for interpersonal emotional communication have been demonstrated in abundance. However, the research articles in the area typically introduce single design cases, and systematic overviews for the field are largely missing. The novelty of this study is that it reveals the emphasis and gaps in the current research on designing systems for emotional communication between partners in an LDR. By understanding the current state of research, new opportunities for future work can be identified.

Publication II, *Understanding Design as a Catalyst to Engage Remote Couples in Designing for Long-Distance Relationships* seeks an answer to how design can be utilised to translate an understanding of LDR couples' needs in research to the design of technologies for them in practice, with their potential collaboration. It has been noted that most of the research participants in the related studies were actually not remote couples in real life; rather, substitute participants were used (Li et al., 2018). The novelty of this study lies in presenting new insights into the experience of how current remote couples cope with LDRs; their challenges, needs and perspectives on existing LDR-oriented artefacts; as well as design considerations

for designing technologies to mediate emotional communication between LDR partners. The findings highlight the need to take the strategy of customisation—which is neglected in most system designs (Li et al., 2018)—into account when designing technologies for LDRs.

Publication III, *Connected Candles as Peripheral Emotional User Interface* proposes a novel concept which uses a pair of connected candles to bring a subtle and poetic cue of the presence of a distant loved one. Differing from the prior literature, the novelty of this research lies in presenting a working prototype which utilised a peripheral emotional UI that includes an authentic candle and an electronic one. The focus is on creating aesthetic experiences by lighting a candle, which intertwines seamlessly with existing traditions.

Publication IV, *Our Little Secret: Design and User Study on an Electrochromic Ambient Display for Supporting Long-Distance Relationships* presents a non-light-emitting electrochromic display (ECD), in the form of an ambient picture frame, for mediating emotional communication in LDRs. The novelty of this work is that it presents the first user study of ECDs as an ambient device implemented in the wild for connecting remote couples.

Publication V, *Exploring Wearable Technology for Supporting Couples in Long-Distance Relationships* explores the possibilities of wearable technology in supporting couples in LDRs. A hands-on design workshop was held in which 12 participants living in an LDR were engaged in creating concepts and low-fidelity physical prototypes of wearables to support their own LDRs. This work contributes to a better understanding of the communication needs of couples in LDRs and provides design considerations that support researchers, designers, and developers of communication technologies.

Publication VI, *Emotional Communication between Remote Couples: Exploring the Design of Wearable Ambient Displays* discusses how wearable ambient displays can be co-designed by the potential users to support communication and awareness between couples at a distance. The contribution of this work is three-fold: 1) revealing social, public, and private aspects related to wearable ambient displays for intimate and unobtrusive communication between couples; 2) formulating recommendations for the design; 3) providing a concept in-the-wild user study in the domain of computer-mediated emotional communication between couples, which has been noted to lack such research.

Publication VII, *Towards a Conceptual Design Framework for Emotional Communication Systems for Long-Distance Relationships* outlines a conceptual framework of the different aspects that designers should consider when designing technology-mediated communication systems for LDRs. The motivation is to synthesise a holistic set of design dimensions of LDR systems into the framework. The novelty of this work lies in the integration of the essential dimensions and their related key attributes, which should be taken into account when designing

communication systems to support emotional and subtle communication for remote couples. Furthermore, it also provides a more formalised and comprehensive framework for helping to recognise and consider different issues during the design process.

Publication VIII, *Flexi Card Game: A Design Toolkit for Unconventional Communication Systems for Long-Distance Relationships* presents a card-based generative design tool for supporting both designers and non-designers in participatory structures when designing unconventional communication devices for mediating LDRs. The development process of the toolkit underwent four iterations, each of which was implemented and improved based on the feedback. The contribution of this work is three-fold. First, it presents a novel card-based design toolkit to help develop unconventional communication systems in a participatory design context to support LDRs. Second, it provides insights and findings derived from five workshop deployments with a total of 56 participants and shows how the toolkit evolved during the iterative development process based on the user feedback. Third, it offers lessons learned for the creation of card-based design tools in supporting domain-specific designs.

1.4 Structure of the Dissertation

There are seven chapters in this dissertation, and they are organised as follows:

- i. Chapter 1, which is the current chapter, presents an introduction by providing an overview of the topic area to demonstrate the relevance and importance of this dissertation. This chapter introduces the topic and context and defines the research questions, scope, methodology, and contributions.
- ii. Chapter 2 describes the background of long-distance communication by unpacking how it has evolved and how people in LDRs have been communicating and interacting with each other in various ways in different eras. This chapter ends by giving an account of the problems and challenges in the topic area.
- iii. Chapter 3 reviews the theoretical background of this research, which includes a discussion of the impact of emotional communication and the definition and measurement of LDRs, as well as a summary of the related work on the solutions that have been developed in the field of HCI to support LDRs. The research gap is revealed at the end of the chapter.
- iv. Chapter 4 elaborates on the research approach taken, as well as the user study methods used in this work. Additionally, this chapter describes how the data set was collected and analysed and how ethical considerations were accounted for during the research.

- v. Chapter 5 summarises the case studies conducted in this dissertation. The summary includes motivation and positioning, scope, study design, methodology, and the main findings of each case study.
- vi. Chapter 6 revisits the research questions; considers the meaning, importance, and relevance of the findings; and discusses how they answer the research questions. This chapter shows the overall contribution of the presented work and highlights its strengths and weaknesses. It also includes a discussion of the design considerations and methodological notes.
- vii. Chapter 7 concludes this dissertation by summarising and reflecting on the presented work and notes possible future directions of this research area.

2 Background

2.1 Long-Distance Communication in a Previous Era

Communication plays a vital part in human life and exists in a variety of forms. For instance, ancient civilisations used drumbeats to exchange information between far-flung points. History has also seen a long use of smoke signals for communicating: in times of war, smoke was used to send a visual signal of danger to warn allies who were hundreds of miles away. Homing pigeons were used as a means of distance communication to deliver written forms of secret messages. Until the early 19th century, the development of electrical telegraphy revolutionised how information was transmitted across vast distances. At the end of the 19th century, new technologies began to emerge, and the invention of the telephone and the mobile phone made communication become easier and more efficient. Handwritten letters and occasional phone calls used to be the main forms of communication for LDRs. The individuals involved in an LDR would take time and effort to write letters to their distant loved ones, or to wait for a call from a distant loved one to come to a landline phone.

2.2 Present-Day Communication Technologies

Advances in technology changed the way people interact, enabling myriad communication channels for couples in LDRs to communicate and interact over vast distances. People have built a bond and attachment with their mobile phones (Ventä, Isomursu, Ahtinen, & Ramiah, 2008). In the smartphone era, video chat, voice call, phone call, instant messaging, text messaging, emails, and so on are available communication channels to help a couple to stay connected. While these channels could offer efficient communication, they are considered one-size-fits-all solutions and lacking in emotional and intimate experience (Gaver, 2002; Strong & Gaver, 1996), as they were originally developed for collaboration and goal-oriented activities which are optimised for efficient exchange of information that is often explicit and informative. Furthermore, they demand attention and can be distracting from other ongoing activities at hand (Yoon et al., 2014). It has been found that there are risks of problematic or addictive smartphone use with extended screen times and constant checking behaviour (Shin & Dey, 2013). Technology can be a double-edged sword. It may shape a hyper-connected lifestyle which makes one spend hours

staring at the screens of mobile devices, send mindless text messages, and suffer from anxiety which comes from waiting for a reply from a loved one. Such a noisy digital world is not able to fulfil one of the crucial human needs—connectedness—which is regarded primarily as a positive experience that technology can create to make a relationship flourish (Hassenzahl et al., 2012). It has been noted that most available technologies, such as text messaging and email, are not designed to provide a sense of relatedness (Hassenzahl et al., 2012); rather, the focus is placed on functionality (e.g., exchanging explicit information). Indeed, interacting with a significant other may not necessarily require explicit communication. Intimacy can be created by interacting through nonverbal communication which involves a variety of visual, auditory, tactile, and olfactory links (Strong & Gaver, 1996). Such a subtle and delicate manner of implicit communication may enable the expression of positive emotions that lead to a feeling of warm companionship beneficial for maintaining a relationship at a distance.

3 Review of Theoretical Background

3.1 Emotional Communication in Romantic Relationships

Emotional communication is predominant in everyday interaction, as Planalp (2009) highlights: *'In a sense, all communication is emotional, though by varying degrees.'* According to Planalp (2009), emotional communication can be defined as the process of using messages, which may be verbal and nonverbal, to exchange information about and to influence each other's emotional states. Emotions, either positive, such as love and affection, or negative, such as anger and jealousy, are intensively experienced in close relationships (Berscheid & Ammazalorso, 2001). Emotions can be communicated either explicitly through facial or verbal cues (e.g., laughing out loud and saying: 'I am having so much fun!'), or in a subtle way (e.g., through tactile cues). Hertenstein et al. (2009) demonstrated that humans are able to communicate at least eight emotions through touch: specifically, anger, fear, happiness, sadness, disgust, love, gratitude, and sympathy.

Emotions are central to a romantic relationship. It is crucial to be aware of a significant other's show of emotion in order to provide care and support when needed and in a timely manner. Based on a review of the theories of a wide range of emotions, including love and affection, loneliness, anger, jealousy, hurt feelings, shame, guilt, and embarrassment, Planalp and Rosenberg (2014) revealed that emotions are deeply embedded in the communication process and are able to play the roles of antecedent, mediator, moderator, or consequence in interpersonal interaction. Guerrero et al. (2009) conducted a questionnaire study involving 581 couples and identified that emotional communication can mediate couples' attachment and relational satisfaction. One of the key results showed that constructive emotional communication can bring higher relational satisfaction. Specifically, behaviours such as communicating positive emotions on a regular basis, expressing anger using assertive rather than aggressive or passive-aggressive means, and expressing sadness using positive activity and social support seeking can help maintain a healthy and satisfactory romantic relationship. In contrast, Gaelick et al. (1985) carried out a study in which 29 couples were engaged in a videotaped discussion of a problem that they were having in their relationship. Later, they were asked to reciprocate both the positive and negative feelings that they perceived their partner to express towards them. Surprisingly, the results showed that the couples were inaccurate in perceiving their partners' expressions of positive feelings such as love, whereas only negative feelings such as hostility were actually reciprocated. This was due mainly to the

couples being sensitive to the differences in the negative feelings expressed by their partner and hence tending to reciprocate them. As a result, such miscommunication and misunderstanding may consequently influence relational satisfaction. What and how emotions are communicated is influential in romantic relationships. In this light, this dissertation is motivated to explore implicit and subtle means to convey positive emotions (e.g., love, affection, care, etc.) in the communication systems with the goal of mediating emotional communication between couples in LDRs.

3.2 Defining and Measuring LDRs

A broad definition of LDR would be a close relationship in which the individuals are separated by a geographical distance that restricts physical contact and face-to-face communication. One may naturally consider LDRs to be intimate partners who live apart from each other for a variety of reasons (Aylor, 2003; Stafford, 2004). However, LDRs consist of myriad types of relationships other than romantic types: for example, the multiple generations of a family, including grandparents with grandchildren, ageing parents with adult children, or parents with children who live apart and are unable to interact often; people who are separated by educational demands, career pursuits, military duty, emigration, or prison; and couples who date online. In general, LDRs can be categorised into three main types: specifically, long-distance friendship, long-distance family relationship, and long-distance romantic relationship. A romantic LDR can be further divided into: 1) online dating; 2) steady dating (e.g., couples who are exclusive with one another); and 3) married couples who may or may not have children living with them. As Stafford (2004) has identified, each of the myriad types of LDRs has its own challenges and helps to raise research questions specific to those contexts. This dissertation focuses particularly on the last two groups. The reason behind this selected focus is the universality, stability, and valuableness of this user group.

Related work in this area has taken different approaches to measure LDRs, which can be summarised as two-fold. One line of research measures an LDR based on researchers' subjective criteria: for example, living apart, ranging from 50 (Schwebel et al., 1992), 100 (Carpenter & Knox, 1986), to 200 miles or more (Lydon, Pierce, & O'Regan, 1997); geographical boundaries, from state (Stephen, 1986), county (Helgeson, 1994), to town lines (Canary, Stafford, Hause, & Wallace, 1993); or nights spent apart during the workweek, ranging from at least two (Holmes, 2004), three (Bergen, Kirby, & McBride, 2007) to four nights apart per week (Rabe, 2001). Similarly, telephone area codes (Cameron & Ross, 2007) and names of residential city (Helgeson, 1994) were also used to verify LDR status. The other line of research determines an LDR by allowing participants to self-define in an LDR or GCR (Aylor, 2003) by asking for a forced-choice response (Pistole & Roberts, 2011). For instance,

‘Do you consider this a long-distance relationship?’ (Van Horn et al., 1997), ‘My partner lives far enough away from me that it would be very difficult or impossible for me to see him or her every day’ (Guldner & Swensen, 1995), or ‘able/unable to see each other, face to face, frequently due to geographical separation’ (Dellmann-Jenkins, Bernard-Paolucci, & Rushing, 1994). Given that these approaches are all subjective, either defined by researchers or participants, such vulnerability may result in potential inexactness and misclassification. LDRs are diverse in terms of relationship stage (Aylor, 2003), reasons for separation (Stafford, 2004), geographic distance (Dellmann-Jenkins et al., 1994), and communication patterns (Dainton & Aylor, 2002). In order to achieve a diverse sample in this dissertation, these criteria were used as the basis for recruiting research participants.

3.3 Computer-Mediated Emotional Communication for LDRs

There has been a fruitful investigation into developing computer-mediated communication (CMC) technologies to support LDRs in the field of HCI. Prior work has examined the use of mainstream communication technologies, such as video chat (Neustaedter & Greenberg, 2012) and mobile phones (Pettigrew, 2009; Shirazi et al., 2009). In addition to such conventional communication tools, a variety of unconventional solutions have been designed to connect couples at a distance. For instance, *MyEyes* (Pan et al., 2017b) allows LDR couples to see through the eyes of a distant loved one to share daily activities and experiences together. Similarly, *BeWithMe* (Singhal & Neustaedter, 2017) presents a 360-degree view of a partner’s location through a smartphone as a way for a couple to share a sense of presence and understanding of their physical environment.

One line of research has been dedicated to utilising everyday objects to connect people at distance through implicit interaction. For instance, early work introduced a pair of remotely located beds as a shared virtual environment augmented with aural, visual, and tactile elements for bridging the distance between two remote individuals (Dodge, 1997). *LumiTouch* (Chang et al., 2001) is a pair of picture frames for emotional communication. The picture frame illuminates when the remote partner touches the paired one. *Lover’s Cups* (Chung et al., 2006) are two paired cups that enable remote drinking-together interactions by showing the liquid level of the paired cup and illuminating when the paired user is drinking. *Connected Candles* (Häkkinen et al., 2018) are a pair of candle stands, each including an authentic candle and an electronic one. The system is designed to promote emotional connections using the electronic candle to mimic the light in the connected partner’s authentic candle. Several designs come in a form of a fixed object: for example, *Touch Trace Mirror* (Schmeer & Baffi, 2010) contains a pair of bathroom mirrors that allow remote couples to leave asynchronous messages on

a steamy bathroom mirror over a distance. Other designs are based on semi-fixed objects or mobile devices. For instance, *SleepyWhispers* allows distant lovers to share goodnight messages through a pillow and a picture frame (Gooch & Watts, 2012). Wearable form factors can also be seen, as the nature of being worn directly on the body provides a potential communication channel for intimate and affective communication. For instance, *Flex-N-Feel* is a glove which can imitate a feeling of touch by capturing the flex actions of fingers and transmitting them to the other partner as vibrotactile sensations (Singhal et al., 2017). Furthermore, jewellery-like wearables (Silina & Haddadi, 2015b) are considered to have novel potential as they convey symbolic meanings related to identity and memories, creating a multi-layered experience which is often considered lacking in technology-driven wearable gadgets (Wallace & Dearden, 2005). As a case in point, *United-Pulse* is a pair of rings which can measure the wearer's heartbeat and send it to the partner's ring to share remote intimacy (Werner et al., 2008).

A second line of research has focused on communicating intimacy through subtle and implicit actions to indicate the presence of a distant loved one and express affection (e.g., 'I love you' or 'I'm thinking of you'). The pioneering study by Strong and Gaver (1996) developed three prototypical systems: specifically, *Feather*, *Scent* and *Shaker*, which were built on the notion of awareness and aimed at supporting implicit, personal, and expressive communication by providing ambient representation of the distant loved one. Kaye (2006) built *Virtual Intimate Objects* enabling LDR couples to click on a circle which fades over time on the computer screen to create a sense of abstracted presence over a low bandwidth connection. Lottridge et al. (2009) designed the *MissU* system, which enables emotional support between remote couples by sharing music and background sounds to feel the virtual presence and signify the thinking of the remote partner. Tsetserukou and Neviarouskaya (2010) proposed a wearable humanoid robot which consists of a set of haptic devices allowing the user to emotionally enhance the immersive experience of real-time messaging with the distant loved one but also emotionally and physically feel the presence of the remote partner.

A third line of research has developed numerous embodied and tangible interfaces to mediate LDRs. *Cubble* (Kowalski et al., 2013) is a hybrid communication concept that consists of a cube-like object and a mobile application. A couple could remotely share their digital presence through the change of colour of the cube augmented with haptic tap patterns and thermal feedback to imply emotions and simulate a feeling of holding hands. *Puzzle Space* is a distributed tangible jigsaw puzzle which can be played on a table surface where movements are shown on the remote partner's screen synchronously (Pan, Neustaedter, Antle, & Matkin, 2017a). *Kissenger* is a mobile device with a lip-like interface through which a remote couple send and receive a kiss from one another (Samani et al., 2012).

3.4 Identifying the Research Gap

Although many studies have been done to explore a variety of unconventional systems for new types of communication practices to connect people at a distance (Hassenzahl et al., 2012), it has been suggested that a deeper understanding of how LDRs can be best supported by technology-mediated intimacy and the corresponding practices is still needed (Saadatian, Samani, Toudeshki, & Nakatsu, 2013). Participatory design (PD) has been found to be a powerful approach in bringing together different perspectives, which are needed to understand different aspects of the service or product that is under development (Steen, Manschot, & De Koning, 2011) and establish a common understanding of people with different world views (Sanders & Stappers, 2008). Although benefits of user involvement have been identified (Steen, Kuijt-Evers, & Klok, 2007), a recent systematic literature review study on unconventional communication systems for LDRs (Li et al., 2018) showed a striking lack of authentic user participation: specifically, most of the recruited participants in the reviewed lab studies were not remote couples in real life, but substitute participants were used instead. In addition, most of the reviewed systems typically introduce single design cases and lack customisability, which is believed to be one of the most essential aspects to be considered when designing computer-mediated emotional communication systems for LDRs (Li, Häkkinen, & Väänänen, 2019a). In contrast to prior work, this dissertation work promotes a participatory approach (Spinuzzi, 2005) by engaging the users (i.e., individuals who maintain a committed LDR) in designing for LDRs throughout the design process as co-designers, not just in the evaluation stage. Furthermore, customisability is valued in the development of each prototype, with a view to enabling a user-tailored approach (Sundar & Marathe, 2010) to support subjective love languages.

4 Methodology and Ethics

4.1 Research Approach

This dissertation belongs to the field of HCI, specifically to UX research in this community. There is not yet a unified definition of UX, as it can be associated with a broad range of dynamic concepts (Forlizzi & Battarbee, 2004), including emotional, affective, experiential, hedonic, and aesthetic variables (Law et al., 2008). The focus of the HCI community has shifted towards UX. Vermeeren et al. (2016) investigated how design-inclusive UX research can support and advance designing for UX. Through a designer's lens, the author takes *research through design* (Zimmerman et al., 2007) as the core approach to address the research questions by achieving a better understanding of how design can be utilised to create technology in order to support new and positive UX. Zimmerman et al. (2007) argued that: *'The artifacts produced in this type of research become design exemplars, providing an appropriate conduit for research findings to easily transfer to the HCI research and practice communities'* (p.493). The *'design exemplars'* presented in this dissertation are a spectrum of design practices (e.g., working prototypes, low-fidelity prototypes, frameworks, design tools, etc.) that provide concrete embodiments of theory and design opportunities to the HCI community. The new knowledge this dissertation presents was generated by iteratively understanding the current state of the art, the users, their needs and challenges, and different contexts with regards to the topic of mediating emotional communication for LDRs.

This dissertation involves qualitative research which investigates human relationships—namely, LDR couples—with a view to designing unconventional computer-mediated emotional communication systems for, and, or with them. The author has striven to explore the aspects of what, why, and how of certain phenomena—the research questions—rather than how often it occurs (Berg & Lune, 2004). Therefore, the emphasis is placed on meaning-making (Krauss, 2005): that is, understating the meaning behind users' behaviours, motivations, expectations, experience, and practices. Olsson (2014) highlighted that user expectations, including both positive and negative sides, are a factor affecting the UX design in HCI. He constituted a four-layered framework of user expectations to guide and inspire the design of future technology that consists of *desires*, *experience-based assumptions*, *social & societal norms*, and *must-be expectations*; each dimension describes different origins where user expectations can stem from (Olsson, 2014).

It is important to understand the expectation components holistically, instead of blindly following the expectations mentioned by users.

4.2 Data Collection and Analysis Methods

A total of 72 participants with diverse nationalities and different backgrounds participated in the cases studies. All of the case studies in this dissertation are semi-structured qualitative studies (Blandford, 2013) which produce and collect qualitative data using qualitative research methods (e.g., semi-structured interview, focus group, open-end survey, field study, etc.). The collected data was analysed with the conventional content analysis technique (Hsieh & Shannon, 2005). The coding in the qualitative data analytic process followed general qualitative coding principles (Saldaña, 2015). Data was organised with an affinity mapping (Scupin, 1997) to generate a data-driven and bottom-up hierarchy of themes. Table 1 presents the methodological breakdown of this dissertation work in detail.

Table 1: Methodological breakdown of the dissertation work.

Study	Sample	Method	Data Collection
I	47 research papers	Systematic literature review	Document analysis
II	5 LDR couples	Semi-structured interviews Co-design workshops Prototyping Focus group	Audio recording Survey Observation
III	6 individuals who had an LDR	Prototyping Focus group	Audio recording Survey Observation
IV	10 individuals who had an LDR 1 GCR couple	Semi-structured interviews Wizard-of-Oz simulation Field study	Audio recording Survey Diary study
V	12 individuals who had an LDR	Co-design workshops Prototyping Semi-structured interviews	Audio and video recording Survey Observation
VI	11 individuals who had an LDR 5 individuals who had a GCR	Co-design workshop Prototyping Focus group Role-playing Field study	Audio and video recording Survey Diary study Observation
VII	4 existing products 2 research prototypes	Case Study	Document analysis
VIII	22 non-designers 18 designers 16 researchers & practitioners	Participatory workshop Focus group	Audio and video recording Survey Observation

4.3 User Study Methods in the Case Studies

4.3.1 Co-design Workshop

Sanders and Stappers (2008) refer to ‘co-design’ in a broader sense as ‘the creativity of designers and people not trained in design working together in the design development process’. The term is often used interchangeably with PD, which is an approach pioneered in the Nordic countries in the 1970s with a strong political emphasis (Muller & Kuhn, 1993; Schuler & Namioka, 1993). Current design attitude has shifted from designing *for* users to designing *with* users (Sanders, 2002). In UCD, users are passively involved in the design process, while in co-design, users are given the role of *expert of their experience* (Visser, Stappers, Van, & Sanders, 2005), becoming designers of their own with the design tools provided by researchers and designers. This shift leads to the hybrid experiences in HCI, as Muller (2007) articulates, ‘practices that take place neither in the users’ domain, nor in the technology developers’ domain, but in an “in-between” region that shares attributes of both spaces.’

Taking the participatory approach, a number of co-design workshops were conducted in case studies II, V, VI, and VIII. Specifically, case studies II, V, and VI engaged the users (i.e., individuals who sustained a committed LDR) in co-designing unconventional communication systems for LDRs with researchers and designers. The users were respectfully treated as *experts of their own LDR experience* throughout the design process, to encourage them to take the role of *co-designer* to identify their needs, define the problems, share empirical insights, contribute new ideas, and evaluate the proposed solutions. Case study VIII included not only the users but also technology developers, researchers, and designers throughout the entire design process from research to implementation. Co-design inclusively allows the users, even those without a design background, to become an active part of the design process but also utilises different stakeholders’ skills and perspectives to make a creative contribution in the formulation of better solutions for mediating emotional communication for couples in LDRs through collaboration.

4.3.2 Prototyping

Prototyping is a widely used approach in HCI to build an early and experimental model of a proposed solution. It provides a quick and inexpensive way to make ideas become tangible and evaluate ideas. Beaudouin-Lafon and Mackay (2009) define a prototype as ‘a concrete representation of part or all of an interactive system’ and distinguish two basic representations of prototypes: specifically, *offline prototypes* that do not require a computer and *online prototypes* that run on a computer. Offline prototypes take many forms which can be made by a wide range of stakeholders quickly and cheaply (e.g., paper or cardboard mock-ups, paper sketches, illustrated storyboards, videos, etc.). In contrast, online prototypes are usually made by programmers familiar with a programming language.

Offline prototyping was employed in case studies II, V, and VI, where the users were encouraged to make low-fidelity paper prototypes to visualise their design concepts in a tangible way. In case study VI, in particular, the users formed four groups to create the paper prototypes. During the collaboration, the prototypes were iteratively refined by different perspectives from the team members. Due to the nature of the paper, the prototypes were flexible and easy to adapt to changes, albeit low-fidelity. Case studies III and IV both adopted online prototyping to produce functional prototypes, with which the users were given a chance to interact with high-fidelity prototypes. This method was greatly beneficial to case study IV, as the evaluation of the prototype was conducted outside of the laboratory environment. The high and realistic interactivity of online prototypes provide can help to discover usability problems efficiently (Virzi, Sokolov, & Karis, 1996).

4.3.3 Semi-structured Interviews

In general, interviews can be broadly divided into three types: structured, semi-structured, and unstructured. Longhurst (2003) defines semi-structured interviews as follows:

A semi-structured interview is a verbal interchange where one person, the interviewer, attempts to elicit information from another person by asking questions. Although the interviewer prepares a list of predetermined questions, semi-structured interviews unfold in a conversational manner offering participants the chance to explore issues they feel are important.

Most of the questions asked in the case studies were open-ended questions which explored the users and their experience: for example, a number of semi-structured interviews were carried out in case study II to investigate the users' needs, challenges, and skills in maintaining an LDR. Semi-structured interviews are conversational and informal in tone. Compared with structured interviews, semi-structured interviews do not strictly follow a rigorous set of questions, and hence such flexibility allows for an open response to an open-ended question which is broad and can be answered in detail, instead of a limited set of possible answers (e.g., yes or no). Similarly, unstructured interviews can provide participants with increased freedom to answer questions however they see fit in a relatively relaxed atmosphere. In contrast, unstructured interviews are time-consuming and produce large amounts of text which is difficult to analyse. In order to elicit the participants' empirical experience and encourage them to describe their experience in their own words, semi-structured interviews were employed in case studies II, IV, and V, as this method would provide the necessary structure without compromising the informal atmosphere. It was an efficient technique to collect user data, obtain user feedback, and gather preliminary data before designing a survey.

4.3.4 Focus Group

Focus groups are a research method devoted to data collection from a group discussion in which the researcher plays an active role in creating the group discussion for data collection purposes (Morgan, 1996). Focus groups were used in case studies II, III, VI, and VIII, where the research participants were engaged in an informal setting to discuss specific topics with the goal to understand their perceptions, attitudes, motivations, needs, and so on. Although the author acted as a moderator in the focus groups, the discussion was still non-directive in order to allow the participants to explore the subject from as many angles as they wished. This is an efficient and quick method to gather information from a relatively wide range of participants in a relatively short time.

4.3.5 Laboratory and Field Evaluation

The two most discussed evaluation methods in HCI are laboratory and field evaluations (Kjeldskov & Skov, 2014; Kjeldskov, Skov, Als, & Høegh, 2004; Nielsen, Overgaard, Pedersen, Stage, & Stenild, 2006). The results of a review based on examining 102 publications in the field of mobile HCI show that 41% of the papers involved evaluation, of which 71% were performed in laboratory settings, 19% through field study, and the remaining 10% through surveys (Kjeldskov & Graham, 2003). Rogers et al. (2007) discussed the advantages and disadvantages of these two evaluation methods:

While lab studies are good at sensing aspects of human behavior and revealing usability problems, they are poor at capturing context of use. In-situ studies are good at demonstrating how people appropriate technologies in their intended setting, but are expensive and difficult to conduct.

Nielsen et al. (2006) added the following:

It is worthwhile conducting user-based usability evaluations in the field, even though it is more complex and time-consuming. The added value is a more complete list of usability problems that include issues not detected in the laboratory setting.

In contrast, Kjeldskov et al. (2004) questioned whether conducting usability evaluations in real-world settings is ‘worth the hassle’, since it provides little added value, as well as being difficult and more expensive to conduct than in laboratory settings. However, Kjeldskov and Skov (2014) revisited this question after a decade and argued that ‘there is still no definite answer to the lab versus field question’ and suggested engaging with field studies that are truly in-the-wild and longitudinal in nature, in order to fully experience and explore real-world use.

In this dissertation work, case studies IV and VI were deployed in the wild, even though the durations were relatively short and the samples were small. The users were engaged in diary studies, recording their UX with the prototype via an online logbook, as in case study IV, or by taking photos, as in case study VI. There were many constraints in conducting evaluations in the wild, particularly with couples who were in an LDR. As a result, it was challenging to involve both sides of LDR couples in participating in the research due to geographical barriers, cost, and the time-consuming nature of such involvement. Nevertheless, the approach of engaging the users in controlled settings also functioned as a feasible method to gain insight and feedback from them in case studies II, III, and V.

4.3.6 Wizard-of-Oz

The Wizard-of-Oz method is widely used in the field of HCI, which enables designers to explore and evaluate designs before investing the considerable development time needed to build a complete prototype (Dow et al., 2005). In the early phase of case study IV, Wizard-of-Oz simulation was taken as a cost-effective approach to allow the users to interact with the prototype, which was partially functional in a laboratory setting, without revealing that the moderator was in fact controlling it. This approach enabled the author to observe how the users would interact with the prototype even before it was fully functional and more importantly, to uncover potential usability problems before it was fully developed and deployed in the wild.

4.3.7 Role-playing

Embodied design is rooted in embodied cognition in which the body plays a central role in interacting with a real-world situation to serve the mind (M. Wilson, 2002). Role-playing is one of the embodied design techniques and has similarity with other embodied design techniques: for example, bodystorming (Schleicher, Jones, & Kachur, 2010) or experience prototyping (Buchenau & Suri, 2000), that is, using a physical body to inspire creativity in the design process, as well as to evaluate designs.

Role-playing refers to ‘the practice of group physical and spatial pretend where individuals deliberately assume a character role in a constructed scene with, or without, props’ (Simsarian, 2003). It can be used at every stage of the design process where the body serves as an agent to make the design process more experiential and explore various contexts to develop new ideas and uses. The role-playing method was used in case study VI in which the participants presented the design concept made in their group by role-playing. Each group came up with a context demonstrating the use of their design concept, as shown in Figure 2.



Figure 2: Participants demonstrating two scenarios by role-playing (i.e., in a bus on the left and in a rainy day on the right).

4.4 Ethical Considerations

This research abides by the guidelines of the Finish Advisory Board on Research Integrity.¹ All of the studies carried out in this dissertation work started by providing an explanation of the nature of the research to the research participants. Following this, a written consent form was given to the participants and signed by them. The consent form 1) informed the participants that they had the right to stop any interaction or engagement in the research at any time as the participation is truly voluntary; 2) stated how the data was to be collected; 3) described how the confidentiality or anonymity was to be maintained; and 4) listed researchers who would have access to the data. Additionally, in order to make the researcher-participant relationship reciprocal, the author was a good listener to anything that the participants were open to sharing, as well as providing the participants with feedback, coffee, refreshments, and gifts in appreciation of their time and effort that they spent on participating in the studies. Finally, the author ensured the authenticity of the data by not failing to present negative results.

¹ <https://www.tenk.fi/en>

5 Case Studies

This chapter articulates the eight case studies conducted in this dissertation, each of which provides clues to answer its corresponding research question(s). Figure 3 illustrates the connections between the case studies and the research questions.

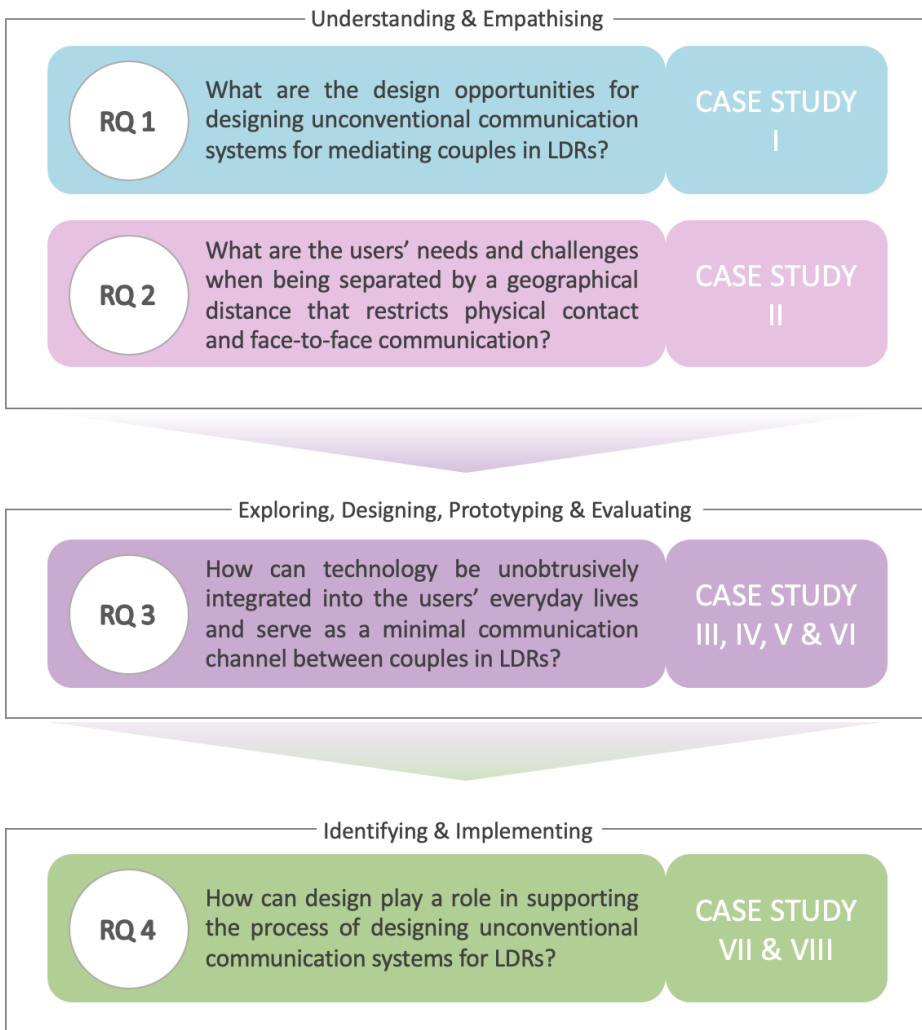


Figure 3: The outline of how the case studies are intertwined with the research questions.

5.1 Investigating the Design Opportunities

Case study I presents a systematic literature review on research addressing the design of systems with unconventional UIs for emotional communication, focusing on the use case of facilitating LDRs.

5.1.1 Motivation and Positioning

Among HCI research, different types of solutions for interpersonal emotional communication have been demonstrated in abundance. However, the research articles in the area typically introduce single design cases, and systematic overviews for the field are largely missing. An exception here is the work by Hassenzahl et al. (Hassenzahl et al., 2012), which presents a literature review of work published prior to the end of 2009. Since that date, however, tools—for example, for 3D fabrication and functional prototyping (e.g., Arduino kits)—have been extensively developed, making creation and trials of novel systems easier. Another paper by Gooch and Watts (Gooch & Watts, 2011) proposes six factors for designing intimate communication devices: *personalisation*, *sensory medium*, *effort*, *openness of the system*, *metaphor of use*, and *fleeting vs. realised output*. These dimensions were based on the authors' insights of the field, and they were exemplified by one system design. To form a more solid basis for this research and design theme, it was timely to revisit the space and conduct an analysis of emotional communication systems for remote partners.

5.1.2 Scope and Method

The ACM Digital Library was used as the database, including articles dated between the years 2010 and September 2017. The ACM Digital Library was chosen to form the scope for the analysis as it includes a wide set of high-quality research forums focusing on HCI research. The purpose of the analysis was to form a categorisation of systems and an overview of design attributes, not to gain absolute numbers of all published papers. The search terms used were *romantic*, *emotional communication*, *remote presence*, *presence-in-absence*, *romantic communication*, and *intimate communication*. This set of search terms was constructed after the search terms in (Hassenzahl et al., 2012). The search was complemented with the terms *long-distance relationship* and *communication of emotions*, which supported the focus on computer-mediated emotional communication in LDRs. The keywords were searched in the database fields 'abstract' or (Boolean OR) 'author keyword'. These results formed the corpus for the analysis.

Altogether, the search criteria resulted in 150 articles for further analysis, which were manually analysed. As the next step, papers that were beyond scope of the study were manually excluded. In order to be relevant for the analysis, the paper had to present a prototype or system for interpersonal communication whose UI went beyond conventional mobile phone, personal computer (PC), and social media use.

Thus, papers introducing theoretical frameworks, studies of current practices (e.g., phone, video chat), or conventional mobile phone applications only were excluded. In addition, work that was clearly targeted to different user groups—for example, communication between grandparents-grandchildren, or office workers—was excluded. Duplicates presenting the same system design—for example, a work-in-progress paper about a later published long paper—were removed. For papers describing several alternatives, each communication system was analysed separately.

The resulting papers, together describing 52 system prototypes, were then analysed in detail using a codebook developed for the purpose. This codebook was tested and iterated two times with ten sample publications, which were coded independently by three researchers according to the criteria and then discussed in detail. Design attributes and their characteristics were added and iterated, resulting in the final codebook consisting of the following main attributes for analysis: *form factors*, *interaction types*, *nature of messages*, and *strategies for expressing relatedness*. In order to provide an understanding of the validity of the evaluations, the user evaluation methods applied in the reviewed studies were also analysed.

5.1.3 Main Findings

The findings give a comprehensive overview of the HCI research on different emotional communication systems for LDRs. Table 2 illustrates the most common design attributes found in the 52 analysed systems. Apart from movable or semi-fixed objects as the dominant form factor, smartphones and tablets were also popular form factors applied in designs that went beyond conventional communication applications. Some form factors took a hybrid approach. Wearable devices in the form of clothes or accessories were also used. Regarding modalities, the importance of touch as an input modality aligns with the literature, where touch is highlighted for social communication and affection (Haans & IJsselsteijn, 2006). Studies have shown that people are able to communicate emotions through mediated touch, and can also encode a number of emotions when using an input device (Huisman, 2012). Combinations of haptic sensations, wearable technologies, ambient media, biosignals, and so on are widely employed to create a feeling of emotional connection for LDRs. Multisensory devices have enabled users to see, hear and feel their distant loved ones. However, there has been little work to date aiming to understand how LDR couples could maintain an emotional connection through taste and smell. Many designs aim at mediating feelings of connectedness and togetherness through synchronised emotional communication. However, in geographically distant relationships, the time zone difference is one of the main challenges in an LDR, which leads to unsynchronised daily life and schedules. Therefore, the synchrony required in such designs might be difficult for users. Consequently, transferring affect asynchronously is an important challenge in designing future systems.

Table 2: The most common design attributes of the analysed systems.

Design Attributes	Most Common
Form Factor	Movable/Semi-fixed objects
Input Modality	Touch
Output Modality	Graphics
Symmetry of Interaction	Same device for both ends and two-way communication
Openness of Communication	Messages that are open for interpretation
Noticeability of Communication	Noticeable by other people in the vicinity
Ephemerality of Messages	Messages disappear by themselves
Synchronicity of Communication	Real-time
Target Experiences	Awareness

Another key finding was that many reviewed works show a lack of user participation, and strikingly, most of the recruited participants in the lab studies were not authentic remote couples in real life; rather, substitute participants were used instead. This weakens the validity of the results of the studies. Although a number of studies did engage authentic participants who were involved in LDRs when the studies were conducted, in most cases the participants were only engaged in the evaluation stage. Shortcomings of the evaluations also include that the evaluations were mostly conducted in the lab, either in controlled or uncontrolled settings and over a short time period. Overall, the related work indicates that mediating emotional communication through digital devices has a positive impact on LDR couples. However, a lack of real-life prototyping over time may not be sufficient for assessing the value of the system. To gain more reliable insight, the device should be tested in many different contexts over a longer period of time. Further investigation is needed to see if the systems do or do not have a longer-term impact on the relationship as a whole.

5.2 Understanding Couples in LDRs

Case study II is a user study which thoroughly engaged five remote couples in a series of design activities with a view to build empathy with them, explore their experiences and skills for coping with LDRs, identify their main challenges and needs, and understand their perspectives on existing artefacts that mediate intimacy between remote partners. The intention of this study was not to present a finalised solution to LDRs but to discuss how design can act as a catalyst to elicit empirical insights

around the experiences, challenges, and needs of LDRs and how these can act as a foundation for future technology design so as to close the gap between research and practice.

5.2.1 Motivation and Positioning

There has been budding interest within the field of HCI around the design of technologies that aim to enhance emotional and intimate communication for LDR couples. In contrast, there has been little work setting out to understand how LDR couples could maintain an emotional connection without the support of technology. It is suggested that users should be engaged in the design process as co-designers and experts of their experiences so that they can provide valuable insights on how technology can be designed to enhance the quality of their lives (Sanders & Stappers, 2008). Prior studies have involved couples in the process of designing technologies to mediate intimacy and closeness over distance. For instance, a telepresence robot was evaluated by two LDR couples in real-world settings in a 4-week field test (Yang et al., 2017). Chien developed different versions of a robotic pet, *Furfur*, and applied it to his own LDR in the sense of an autobiographical design exploration (Chien et al., 2016). The deployment of *sleepyWhispers*, a prototype device which allows distant lovers to share goodnight messages, involved a single couple who lived around 120 miles from each other for an 8-week evaluation (Gooch & Watts, 2012). However, a recent systematic literature review has revealed that in many cases the participants were not remote couples in real life but that substitute participants were used instead (Li et al., 2018). Therefore, much room remains for engaging real users (i.e., couples in LDRs) in the design process such that they can contribute their insights and experiences to help designers improve their creations. LDR couples who have sustained a long-term commitment in their relationships are experts in LDR experiences. Such authentic participants should be engaged as co-designers throughout the design process—not merely in the evaluation stage—so as to design desirable LDR-oriented products that can integrate into the lives of the end-users. Moreover, authentic participants should be encouraged to feel that they are seriously regarded as experts in the LDR experiences. In doing so, they will feel that they need to respond as experts in their experience domains (Visser et al., 2005), thus allowing their contributions to provide valuable insights into how technology can be designed to enhance the users' experience in LDR-oriented artefacts.

5.2.2 Participants

This study engaged a total of ten participants—specifically, five LDR couples (M = 5, F = 5) ranging in age from 23 to 45—who were involved in different stages of LDRs. The most experienced LDR couple in the study was a married couple who had been in an LDR on and off around 14 years, while the most inexperienced one was a couple who had been dating for 2 years but were forced to live apart from

each other for 5 months due to study-related obligation. Every couple selected for this study had remained committed to each other in a serious LDR, as opposed to a casual dating relationship. They had been in steady romantic relationships for at least two years, and varied significantly in terms of nationality, age, occupation, location, marital status, and personality.

Given that the participants were currently involved in LDRs, they were divided into two groups. The local group included five participants (M = 1, F = 4) recruited from Rovaniemi, Finland, where the study was conducted, whereas the remote group consisted of their remote partners, who had to participate remotely from China, the US, Poland, Russia, and Helsinki. The participants volunteered for the study. Consent forms were provided so as to ensure that the participants fully understood the potential risks and benefits of participating as well as their right to privacy. The participants were treated as experts on their own LDR experiences and were intensively engaged as co-designers throughout the design process, where they had a chance to express their knowledge and insights on designing desirable LDR-oriented products that could better integrate into the lives of the end-users.

5.2.3 Study Design

This study consisted of three stages, which followed an iterative five-step design-thinking process which consisted of *empathising*, *defining*, *ideating*, *prototyping*, and *testing* (Hasso Plattner Institute of Design, 2010). It was comprised of three activities:

1. A set of semi-structured interviews via Skype with each remote couple to gain an empathic understanding of their challenges, needs, and skills to cope with LDRs.
2. A co-design workshop with the five local participants to ideate possible solutions for mediating emotional communication to support LDRs.
3. A prototyping workshop with the same local participants to test the feasibility of the solution for supporting LDRs (see Figure 4).



Figure 4: Participants making prototypes in one of the design activities (from Publication II).

The interviews and the workshops were audio recorded. The audio recordings were transcribed verbatim. Then, the audio transcripts were analysed using qualitative content analysis (Hsieh & Shannon, 2005), particularly with an affinity mapping (Scupin, 1997) to generate a data-driven and bottom-up hierarchy of themes.

5.2.4 Main Findings

A deepened understanding of current LDR couples' perspectives regarding existing LDR- oriented artefacts, as well as their challenges, needs, and skills in LDRs were uncovered. Every LDR couple faced their own challenges, had diverse needs, and used different skills to maintain and nurture an LDR. The findings indicate that most LDR-oriented artefacts provide a traditional one-size-fits-all solution, including the same package for every user, which might not be appealing and sufficient to meet every user's needs. Thus, there is a need to account for the customisation strategy when designing technologies for LDRs, where customisation can play a subsidiary yet important role: that is, empowering LDR couples as skilled practitioners to use technologies in their own creative ways to meet their diverse needs. There is no doubt that technologies can provide immediate access to talk to, see, or even to feel a remote partner in real-time. However, it is questionable whether the technology-based one-size-fits-all solutions for LDR are still useful when there is no Internet connection or technology to support such communication and interaction between LDR couples. In this light, customisation makes a lifeless object become meaningful and symbolic to users, and as such, the object becomes a one-of-a-kind object, which thereby enables an emotional connection with it. Although it may not seem surprising that customisation was seen positively by the participants, given that it has been well-known for engendering value for an object that cannot be obtained through mass production, customisation adds to the positive impact of what technology is able to bring to LDRs, as customisation supports users in an LDR as skilled practitioners in utilising technology to meet their diverse needs in their own creative ways.

5.3 Utilising Candles to Mediate Emotional Communication

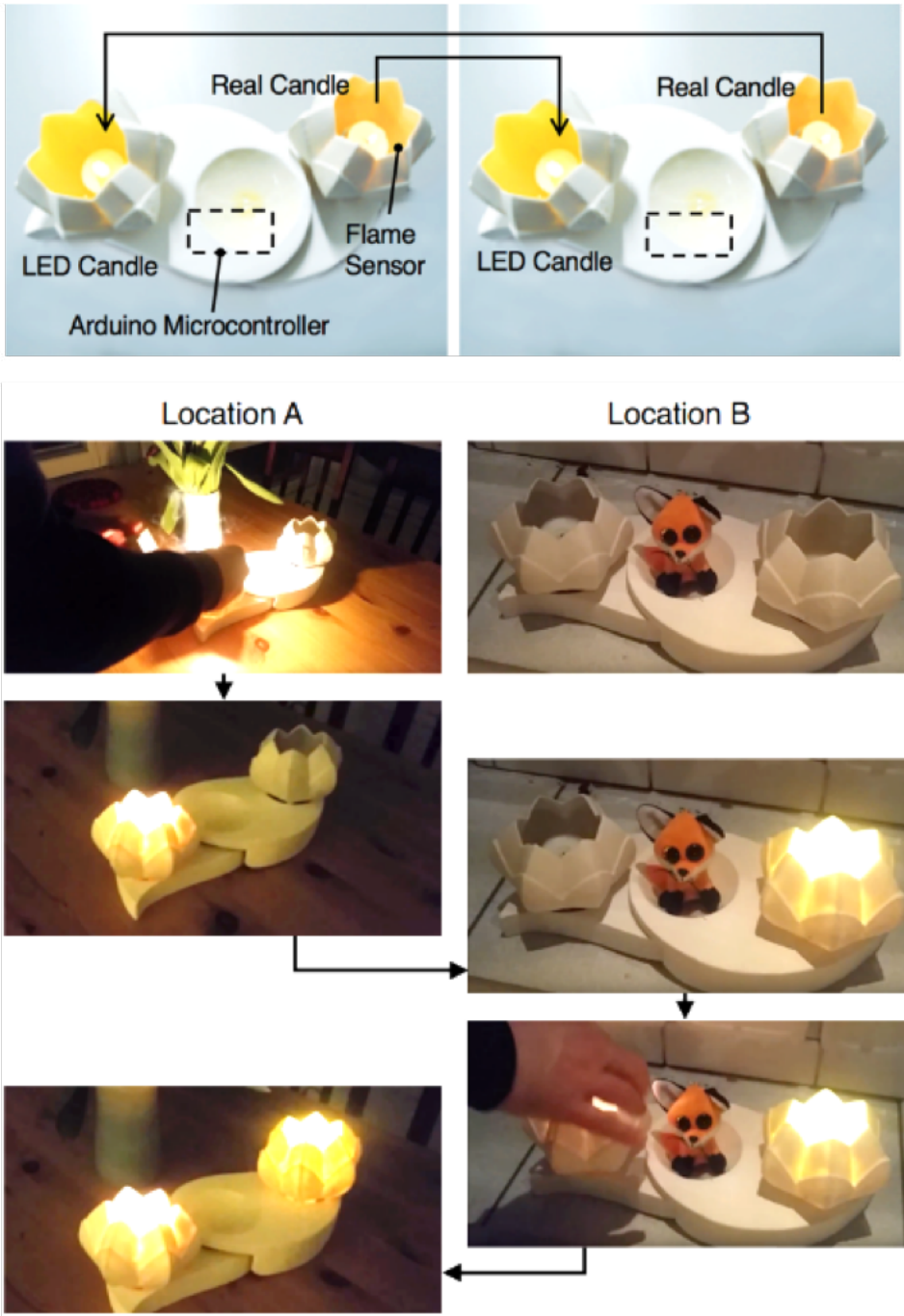


Figure 5: The working prototype of Connected Candles (from Publication III).

Case study III presents a functional prototype which uses a pair of connected candles as a peripheral UI for creating an implicit communication channel to support emotional awareness in LDRs. As illustrated in Figure 5, each partner has an identical setup which consists of an authentic candle and an electronic candle. When the local partner lights the authentic candle, the light-emitting diode (LED) candle of the paired system at his or her remote partner's location will illuminate. Additionally, there is a space between the candles for the users to customise their candle setup by placing a small token or memento, reminding them of the connected partner. The aim was to bring a subtle and poetic cue of the presence of a distant loved one by lighting up a candle. The evaluation was conducted in a focus-group-based user study.

5.3.1 Motivation and Positioning

Prior work has introduced a wide range of modalities for presence indication and emotional message exchange to mediate LDRs (Hassenzahl et al., 2012; Li et al., 2018). Candles, either electronic or real, have been employed in different contexts as interactive media. Due to the temporal nature of candles, systems in which the interaction is mediated with candles can be regarded as ephemeral UIs, which are deemed to be of aesthetic value (Döring et al., 2013). Being perceived as warm and emotional, candles have been found to have the potential to serve as an aesthetic channel for emotional communication (Häkkinen et al., 2016). However, relatively scant research has been conducted to investigate candles as a medium for enabling emotional connection in the context of LDRs. Differing from the prior literature, the focus was placed on creating aesthetic experiences to enable emotional connection between remote couples. This design seamlessly intertwines with existing traditions by utilising fire in the form of a natural flame. As it was discovered in the prior user study that people prefer an authentic candle to an electronic one, and that the action of lighting a physical flame was an important part of the experience (Häkkinen et al., 2016), the use of a real candle was taken as a design requirement for the prototype.

5.3.2 Participants

The study involved six participants (M = 2, F = 4) from diverse cultural backgrounds (i.e., Finland, China, Australia, the United Kingdom, Vietnam, and Nigeria). The participants were students and staff at the University of Lapland and had a median age of 32 years, with 4 out of 6 from a non-design background. The participants were recruited according to the criterion of being involved in a steady LDR. All of them lived in a time zone different from their remote partner to varying degrees, the largest time difference being 7 hours.

5.3.3 Study Design

A focus group (N = 6) was organised in order to evaluate the concept of *Connected Candles*. It was facilitated by one moderator and observed by one researcher, who took notes. The participants were given an introductory explanation about the aim of the demo of *Connected Candles*, the purpose of the study, and their role. Three candle UI concepts were presented to the participants:

1. A commercial smart candle product with a real flame that can be lit remotely using a smartphone application (LuDela PBC, 2016). This was presented to the participants by showing a video of the product.
2. A digital candle mobile application running on a tablet device that can be lit by touching the screen (iHandy Inc., 2013). Participants were tasked to imagine that the digital candle was decorated as if a picture frame at their remote partners' home, which they were able to light remotely to send a message of 'I am thinking of you'.
3. The working prototype of the *Connected Candles*. Firstly, a short video showing the concept functionality in a home environment was shown to participants. Then participants were able to try out the prototype by lighting one of the real candles with matches or a lighter. One set of the *Connected Candles* was placed at the front of the room and the other at the rear.

The participants were tasked to evaluate the experience of using each concept to support their own LDR using the product reaction cards (PRC) method (Benedek & Miner, 2002) by selecting the five terms from the PRC which best described the concepts. They were informed that the discussion was recorded and assured that it would be used confidentially for the sole purpose of evaluating and improving our prototype.

The focus group lasted approximately two hours and was audio recorded. The audio recordings were transcribed verbatim. The audio transcripts were analysed by taking qualitative content analysis approach (Hsieh & Shannon, 2005), particularly with an affinity mapping (Scupin, 1997) to generate a data-driven and bottom-up hierarchy of themes.

5.3.4 Main Findings

The findings from the evaluation revealed that the concept of *Connected Candles* was generally positively received. The concept of using the *Connected Candles* to enable subtle communication between remote couples was well understood by the participants, who were able to reflect on its potential usage in everyday contexts. From the PRC responses and discussions, it was clear that the participants most preferred the concept of *Connected Candles*. The design of the prototype appealed to most of the participants' aesthetic preferences (5 out of 6). Positive feedback was

also given to its novelty, creativity, and the warm atmosphere created by the candles. The majority of the participants (4 out of 6) perceived lighting candles as a pleasant gesture. On the other hand, two participants highlighted the possible cultural differences related to the meaning of lighting candles.

Criticism of the *Connected Candles* concept was due to its lack of the richer vocabulary present in technology-mediated communication and impracticality when used across different time zones in LDRs. Moreover, the cultural meaning of lighting candles may vary, creating associations not relevant to the concept (e.g., about remembering the dead). These aspects illustrate that the concept may not fit all and should be designed with a specific target user group in mind. Enabling customisation could help create a desirable product according to users' preferences and diverse needs. Furthermore, the issues with authentic candles (e.g., safety and lifetime) need to be addressed further, although safety aspects were already considered in the conducted design process.

5.4 Customising Ambient Displays to Support Secretive Love Languages

Case study IV introduces the design and manufacturing of a non-illuminating electrochromic ambient display called *Our Little Secret*. The system contains a pair of ambient ECDs that are designed to support emotional communication through secrecy, customisation, subtleness, and simpleness for couples in LDRs, particularly those with large time zone differences. The unobtrusive display technology was prototyped with an interactive picture frame, as it is a fairly familiar object and suited for the daily environment (see Figure 6). However, the concept of *Our Little Secret* is that the form factor can be customised to fit the users' preference (see Figure 7 for an alternative form factor).

Our Little Secret presents a city landscape and colourful spiral hearts (see Figure 6), but the graphical contents can also be customised by the users, as ECDs allow customisation of graphics, which can be printed with conventional techniques. The prototype comprised of three functions:

- The city landscape switches between day and night display according to the time of the paired user's location;
- The hearts switch colours when receiving a secret code from the paired user;
- The display stops switching when the interaction between the LDR couple is low.



Figure 6: The working prototype of *Our Little Secret* in different modes (from Publication IV).

The design of *Our Little Secret* followed the framework derived from the work by Li et al. (2018), which articulates different aspects for systems designed for computer-mediated emotional communication in LDRs. The aim was to explore the potential use of ECDs in the context of supporting emotional communication in LDRs. The user study was two-fold, including interviews of people living in LDR ($N = 12$) and a 1-week in-the-wild deployment with one couple in a commuter marriage (Gerstel & Gross, 1982).



Figure 7: The ECD technology prototyped in the form of a bracelet and was worn in different real-life contexts (which is currently a work in progress).

5.4.1 Motivation and Positioning

Ambient displays are often used in a discreet way such as an unobtrusive reminder (Müller, Kazakova, Pielot, Heuten, & Boll, 2013). They have been employed as an aesthetically pleasing form of information visualisation in mediating emotions or creating the feeling of remote presence. Prior work has proposed a number of everyday objects as unconventional UIs to facilitate emotional communication in order to connect couples in LDRs (Li et al., 2018). In contrast to prior work on ambient displays using LED light (Chang et al., 2001), biosignals (Kim et al., 2015), heat (Dodge, 1997), or tactile sensation (Chen et al., 2006) to create a feeling of remote presence and relatedness, an ECD was employed in this study as a new manner of mediating emotional communication for couples in LDRs. While numerous emotional-communication-mediated systems aim to support LDRs, it has been remarked that the availability of customisation is lacking in the design of many systems (Li, 2018; Li et al., 2018). Differing from those systems, customisation was enabled in the design of *Our Little Secret* as a user-tailored approach (Sundar & Marathe, 2010) and one of the key design requirements in the concept thanks to the flexibility of the ECDs.

5.4.2 Participants

Twelve participants (M = 6, F = 6), with a median age of 34 years, were recruited according to the criterion of being involved in a steady LDR. The longest relationship length in this study was 17 years and the shortest was 2 years. In terms of the relationship stage, 7 out of the 12 participants were married. Among the rest of the participants, two were engaged to their remote partner and three were in serious dating stages. Education or work purposes were the reasons why the participants lived apart from their partners, which are common reasons for separation in LDRs. Mainstream communication media (e.g., WhatsApp, Skype, Wechat, Messenger, etc.) were the CMC tools most used by the participants to communicate with their remote partners. Among the 12 participants, 10 were living in an international LDR with varied time zone differences, while two participants were a married couple who were in a domestic distant relationship within the same time zone. This remote couple was recruited for the in-the-wild study of the proposed design.

5.4.3 Study Design

The two-fold evaluation was started with a Wizard-of-Oz study (N = 12, M = 6, F = 6) given that the prototype was not yet fully functional in this phase of the evaluation. The goal was to explore user perceptions of the non-illuminating ECD, comparing to an illuminating tablet screen which was form as a conventional digital picture frame containing similar graphical contents as presented in *Our Little Secret*. The functions of the digital picture frame worked the same as the concept of *Our Little Secret*, the graphical contents shown in both displays were customisable. The

differences were that the user interface of the digital picture frame was illuminating, while *Our Little Secret*'s user interface was nonilluminating. In addition, the form factor of *Our Little Secret* could be customised by the users, while the form factor of the digital picture frame was fixed as what it was, namely, an iPad. The participants were tasked to learn and familiarise with both concepts, then they were asked to select five terms from PRC (Benedek & Miner, 2002) to describe each concept, and the final task was to compare the two concepts in the use case of LDRs using the AttrakDiffTM (Hassenzahl et al., 2003) seven-point scale. Each session took approximately 45 minutes per participant and was audio recorded.

Following this, a 1-week in-the-wild study was conducted in order to explore whether the design decisions made were appreciated by the potential users. The remote couple involved in the field study was heterosexual, married, and did not have children. They had been living apart from each other for about two years before the study due to the maintenance of dual-career, and they reunited as often as every weekend. The couple used *Our Little Secret* for 1 week and filled out a daily logbook reporting their experience. The switching of colourful hearts was able to be controlled by sending a digital number—namely, 2—to the paired user's phone. The couples were asked to convey secret languages with which they could associate when the hearts were switching colours. To avoid any ethical issues and protect participants' privacy, the app did not track any conversation so the research moderator had no access to the couple's private conversations. Following the field study, a separate interview was conducted with each participant. The interviews were audio-recorded and then transcribed for analysis.

The data was transcribed verbatim and analysed following the general qualitative coding principles (Saldaña, 2015). Affinity mapping (Scupin, 1997) was used to organise the data. The process started from developing a number of codes based on the collected data, then the emerging similarly coded data was organised into categories.

5.4.4 Main Findings

Overall, the concept of *Our Little Secret* was positively received, with all of the test participants preferring it over the conventional digital picture frame. Specifically, on a scale of 1 (would strongly prefer the concept of the digital picture frame) to 5 (would strongly prefer the concept of *Our Little Secret*), 9 out of 12 of the participants strongly preferred the concept of *Our Little Secret*. This high level of positive valence was apparent not only in the positive adjective selected to describe the presented concept—for example, *creative* (9), *customisable* (7), *meaningful* (7), *personal* (7), *calm* (5)—but also in the wealth of ideas that the participants provided to iterate the concept. Examining the participants' qualitative comments in regard to enhance the presented concept, 5 out of 12 of the participants considered that the switching of the display was too subtle and hence desired to increase the

contrast of the display or to enable more colours in it. The feature of customisation was considered as beneficial. However, instead of a semi-fixed picture frame, 4 out of 12 of the participants would like the concept to be smaller, more portable, or wearable. Furthermore, 3 out of 12 of the participants desired to enrich the display by customising more meanings to the display (e.g., enabling a weather forecast for the remote partner's location).

Given that it has been pointed out that ambient displays are difficult to be evaluated in real-world settings (Hazlewood et al., 2011), the goal of the in-the-wild study was not to evaluate or measure the awareness of significant changes in *Our Little Secret*; rather, the focus was to investigate if the concept could work for a random remote couple and how they would use it in real life. The salient findings from the in-the-wild study highlighted positive responses especially relating to the non-light-emitting nature of the display. Moreover, the presented concept added a new communication channel between the remote couple in real-life settings, which supported their communication and relationship through a pair of private, meaningful, and always-on yet calm displays. ECDs support the making of customisable, thin, and bendable displays. Its cost-efficient and easy manufacturing process affords do-it-yourself use.

5.5 Exploring the Potential of Wearable Technology with Users

Case study V explores the potential of wearable technology in supporting couples in LDRs. A hands-on design workshop was conducted in which 12 participants living in an LDR created concepts and low-fidelity physical prototypes of wearables which could better support their own LDR. The concepts were later presented to their remote partners through video recordings to obtain their feedback. The aim was to achieve better insights into the design decisions and how they were justified, as well as the types of messages and forms of communication that remote couples wish to communicate with their significant other.

5.5.1 Motivation and Positioning

Wearable devices, different from the form factors of most computing devices, are typically worn directly on the body. This allows the technology to always be with the user. Being close to the body also offers an intimate communication channel which is more challenging to achieve for other forms of technology. This has made wearable technology a candidate with high potential for facilitating communication between remote couples. A growing body of research has set out to explore the use of wearable technology in enriching distance communication. However, the majority of previous studies in this area have focused on presenting novel concepts of wearable devices to mediate LDRs (Li et al., 2018), addressing a single idea at

a time and creating proof-of-concept level prototypes (Joi et al., 2015; Pan et al., 2017b; Singhal et al., 2017; Werner et al., 2008). There is even less understanding from the users' perspectives in terms of the content and interaction that should be communicated or mediated through wearable technology. Thus, this study further explored the communication needs of couples in LDRs and the ways for wearable technology to help them overcome the challenges and sustain a healthy relationship at a distance.

5.5.2 Participants

Twelve participants (M = 3, F = 9), with different backgrounds at the University of Lapland, Finland, were recruited from the university's mailing list. The intention was to recruit a group of participants with diverse ages, longer LDR lengths, and mature LDR stages. The participants described their own LDR stages as 'married', 'engaged', or 'dating' according to their marital statuses. The participants were aged between 19 and 45 years old with a median age of 29 years old. One of the participants was involved in a same-sex relationship while the rest of the participants were involved in opposite-sex relationships. All participants had experience of using wearable devices, such as Apple Watch. Each participant received two movie tickets (worth approximately 20 euros) in appreciation of their participation.

5.5.3 Study Design

The workshop was divided into three sessions (with four, three, and five participants) for compatibility with time slots that were convenient for the participants. Each co-design workshop session took approximately 2.5 hours. The activities and given tasks were the same in each session. Each session started with the participants reflecting on the problems they were facing in existing communication channels and ideal communication that supported their LDRs. Then, the participants designed their ideal form of wearable device and desired input and output modalities. During the design activity, the participants were provided with a deck of design cards which includes essential aspects to be considered when designing communication devices to mediate LDRs. The design cards were created based on two systematic literature reviews of communication devices for mediating intimate relationships at a distance (Hassenzahl et al., 2012; Li et al., 2018) and a framework for designing emotional communication systems for LDRs (Li et al., 2019a). The design cards were introduced to the participants as a design tool to help them to develop ideas. Additionally, different materials and tools (e.g., white fabric, coloured ribbons, yarns) were provided to the participants to build low-fidelity prototypes to communicate their design idea. After that, they reflected on how their design could work as a medium for their long-distance communication with an individual semi-structured interview and an open-ended questionnaire. The interview questions and the questionnaire focused on the participants' reasons for choosing a certain

form factor and input and output modalities for their wearable design and the target experience they intended to create using the design.

After the co-design workshop sessions, the participants' remote partners were invited to take part in the study as remote participants. Video recordings of each local participant explaining their design were taken and were later sent to the remote participants for their feedback. An online questionnaire was provided for the remote participants to provide comments on the designs, and also to rate their partner's design on a five-point scale ranging from 'bad' to 'excellent'. The questionnaire was intended to understand the remote participants' perspectives on the design made by their partner, to investigate whether and how the design could support their own LDR, and to seek their suggestions for improving on the design.

Data was collected during the workshop sessions through questionnaires, photographs, videos, and audio recordings. The audio recordings were transcribed verbatim. The answers from both the participant's questionnaire and their partner's online questionnaire were all qualitative data. The data analysis followed general qualitative coding principles (Saldaña, 2015). The data was collaboratively analysed by two researchers so as to form a common understanding of the findings as well as commonly agreed categories. The process of our data analysis was iterative, involving reviewing questionnaires and media and adapting themes through continued discussions. A number of themes were identified and similar codes emerged as categories. These themes and categories were visualised using affinity mapping (Scupin, 1997).

5.5.4 Main Findings

The participants remarked on different challenges they had been facing in their LDRs, including an absence of tangible support, unsynchronised daily life that might result from time zone differences, a lack of physical intimacy, and an unstable communication environment. The participants revealed that a lack of constant and intimate interaction was the main problem in their LDRs. As shown in Figure 8, the participants presented different concepts and designs that they believed to address challenges they were facing in their own LDR. The participants' designs varied from a blanket to a t-shirt, bracelets, and headbands. Their choice of form factor varied depend on various factors, including relationship experience, lifestyle and context, and culture. These factors are also associated and influence each other.

Design considerations and possibilities for how wearable technology could better support couples in LDRs from potential users' perspectives were identified as follows:

- Design for expressing the emotions;
- Seek possibilities to support physical connection;
- Enable the use of secret communication codes;

- Cope with the asynchronised life of the couple;
- Support effortless interaction to establish awareness between the partners;
- Design solutions that can be entwined with everyday life.



Figure 8: The low-fidelity prototypes made by the workshop participants (from Publication V).

The findings highlight the importance of practical aspects of how the concept should integrate into the user's everyday life, and could be worn, or used, in the long term. Methodologically, involving remote partners in the study through videos on the concepts and interviews was found to be a feasible and fruitful solution to engage authentic LDR couples in the study. This can be used as an example of how to conduct a co-design workshop with geographically divided people. The findings were derived from the co-design workshop sessions for wearable computing, but they may be generalised to help develop wearable technology to support other types of LDRs and other types of couples. Future research could include involving both partners in co-designing a wearable communication device concept and creating functional prototypes.

5.6 Concepts of Wearable Ambient Displays in Real-World Contexts

Case study VI explores the potential of low-resolution wearable ambient displays and their preferable characters in communicating intimacy between couples at a distance. It comprises two studies: a co-design workshop and a field study of the design concepts generated from the co-design workshops using low-resolution prototypes. The aim was to explore the potential of wearable ambient displays to support remote couples in communicating intimacy.

5.6.1 Motivation and Positioning

Wearables have been suggested as a candidate with high potential for facilitating communication between remote couples (Li et al., 2020a). Wearable technologies have been employed in various forms—for example, glove (Singhal et al., 2017), vest (Tsetserukou & Neviarouskaya, 2010), ring (Pradana et al., 2014; Werner et al., 2008), wristband (Joi et al., 2015), necklace (Silina & Haddadi, 2015a; Wallace et al., 2007), glasses (Pan et al., 2017b), and watch (Liu et al., 2019)—to connect remote couples. This suggests that wearable form factors can become a vehicle for new types of communication practices. Taking a different angle, the focus of this study was placed on wearable designs that are customisable (Jarusriboonchai & Häkkinen, 2019), aesthetic, and ambient such that they do not distract or be visually obtrusive. Minimal communication has been found to promote awareness between remote couples. Kaye (2006) demonstrated that the change of colour on a small circle located on a small corner of a computer screen that is triggered by a simple click from a remote partner could efficiently maintain intimacy between a couple in an LDR.

Wearable displays are an interesting communication channel for connecting distant couples as they provide means for unobtrusive, easily glanceable messages for emotional connections. At the same time, they are publicly visible. Wearable displays have been investigated for presenting sports and wellness data (Mauriello et al., 2014; Schneegass et al., 2016), notifications (Fortmann et al., 2014; Xu & Lyons, 2015), and as public information displays (Pearson et al., 2015). It was interesting to explore how remote couples perceive this contrast and explore the experience of using wearable displays as an intimate communication channel between them, which is a lesser investigated context (Li et al., 2018). ECDs were selected as the main display technology in this study. ECDs are graphical segment-based displays. Unlike pixel-based displays that can display anything within their resolution, the dynamic graphics of ECDs are fixed at the time of their creation. ECDs undergo an opacity and/or colour change when a small voltage is applied to them (Jensen et al., 2019). This constraint helps in framing and encourages the participants to develop a design that provides minimal communication but is still meaningful to them. ECDs are non-light-emitting (Meunier et al., 2011), which better suits wearable items for daily wear (Devendorf et al., 2016). As ECDs are free-form and flexible, this gives freedom for the participants to design wearable devices of any form factor. Given that the prior literature showed a lack of user participation (Li et al., 2018), a co-design approach (Sanders & Stappers, 2008) was taken to develop concepts with potential users, which has been reported positively in the prior literature for prototyping for different design domains, including activity trackers (Pateman et al., 2018), interactive tools used in the classroom (Holstein et al., 2018; Kazemitabaar et al., 2017), and the user group of deaf women (Wilde & Marti, 2018).

5.6.2 Participants

A total of 16 participants ($M = 8$, $F = 8$) were recruited, all of whom were in a romantic relationship at the time of the study, with 11 participants being in an LDR. One of the participants was involved in a same-sex relationship, while other participants were involved in opposite-sex relationships. All participants had experience in using wearable devices (e.g., a smart watch, activity tracker, or wireless headphones). Four participants were aware of ECDs.

5.6.3 Study Design

This study took two main approaches: co-design (Sanders & Stappers, 2008) and research through design (Zimmerman et al., 2007). It consisted of two parts: a co-design workshop with role-playing and low-resolution prototyping, and a concept evaluation in-the-wild.

The objective of the co-design workshop ($N = 16$) was to explore different ways that wearable ambient displays could be used for remote couples to communicate intimacy and affection. Two sessions of co-design workshop were organised to explore the design of wearable ambient displays for couples to communicate intimacy when in different locations. Each session lasted approximately two hours with eight participants (four males and four females) respectively. Each session had the same activities, including creating a design concept and making a low-resolution prototype with the group members, presenting the design concept by role-playing in a group, and reflecting on each other's design concepts. The participants reflected on their design concepts through an open-ended questionnaire and discussion. Conversations during each session were recorded in audio and the role-playing part in video. Each participant was compensated with one cinema ticket.

As shown in Figure 9, four concepts of wearable devices were developed as the outcomes of the co-design workshop. After this, four polished non-functional prototypes of each concept were constructed and evaluated in-the-wild. Eight participants ($M = 4$, $F = 4$) from the co-design workshop participated in the evaluation. The participants were tasked to wear the specific polished prototype, which was their group design concept, for 2 days. The field study focused on evaluating the concepts created by the participants themselves and how the workshop concepts would still work in different contexts in real life. The methodology sought to take advantage of in-the-wild studies (Rogers et al., 2007) while avoiding their common weaknesses (e.g., unreliability in prototype functionality and bulkiness of the implementation). In the prior literature, imaginary device functionality in a field user study has been used: for example, for location-awareness (Barkhuus & Dey, 2003), user control with context-awareness (Barkhuus & Dey, 2003), and pico projectors (M. L. Wilson et al., 2012). During the study, three triggers were sent to the participants at different times of each day (i.e., in the morning, in the afternoon, and at night).

WhatsApp was used as the channel to send triggers (i.e., messages) to the participants as if they sent or received a message on their prototype. The same channel was also used by the participants to submit their answers. The same tasks were sent to the participants on both days. However, on the first day, the participants were asked to imagine using the prototypes to send a message to their remote partner. On the second day, they were asked to imagine receiving a message sent by their remote partner the moment they received the triggers. They were also asked to describe what would happen to the prototype when they received their partner's message and how long it would take until they noticed it. At the end of each day, the participants were asked to complete an online survey to share their overall experience with the prototype. Lastly, one-to-one semi-structured interviews were carried out with the participant after the study. Each interview took around 15–20 minutes and was audio recorded. Each participant received a movie ticket in appreciation of their contribution to the study.

Data were collected through questionnaires, online surveys, photographs, videos and audio recordings in the study. As this study was both qualitative and exploratory, the thematic analysis method (Braun & Clarke, 2006) was adopted. The data analysis was conducted by two researchers to ensure accurate interpretation of data and outcomes.



Figure 9: 1) bracelet, 2) ring, 3) multi-wear pin, 4) necklace. Upper row: low-resolution prototypes made by the participants. Bottom row: polished prototypes made by an industrial designer.

5.6.4 Main Findings

A total of four concepts of wearable devices were generated from the co-design workshop (see Figure 9). This includes a bracelet, a ring, a multi-wear pin, and a necklace which can display customised meaningful visual elements which would be activated by different input modalities. Half of the participants envisioned that ambient displays could be used to share their emotional state with their partners. Others considered their design to provide a subtle way to send an open-ended message to their partner. Each concept is described in detail below.

The bracelet featured an ECD that shows four different visual symbols that convey intimate and personal sentiments. The participants would prefer these symbols to be bespoke just for them. The changing from one symbol to another could be activated by direct touch on the display. The change of the display would be accompanied with haptic feedback to also simulate touch sensation from their partner (Figure 9-1a).

The ring has an ambient display that shows a symbol visualising their partner's emotion. The ring represents two emotion states using different colours, which the couple themselves would agree on. The motion status was shared by pressing the ring. This triggers a change in the partner's ring display (Figure 9-2a).

The multi-wear pin would allow a user to wear the device on different body locations according to their preference. The design comprises an ambient display, a dial, and a choker. The display shows an abstract pattern as a representation of the partner's emotional state. The choker has a component at the back of the neck that will produce heat to notify the user when getting a message. Sending the emotional state message required dialling a pin code, and in addition, the user needed to find a deliberately quiet moment to be able to send the message. This was to create a thoughtful form of communication, cherished due to the effort, instead of an easy throwaway message (Figure 9-3a).

The necklace has an ECD as a pendant. The display can show different colours and patterns that are customised by the couple to convey intimate and personal sentiments. The pendant has a small lever which the wearer could use to communicate with their partner. Lifting the lever would change the colour and pattern on the display along with subtle vibration (Figure 9-4a).

Figure 10 illustrates a number of examples of how the participants wore and interacted with the prototypes in real life. Altogether, participants reported using the prototypes in 48 contexts (six contexts per participant). The common contexts were watching TV, eating, working on in front of a computer, lying in bed, walking outside, on public transportation, hanging out with friends, and shopping at a store. Overall, the participants appreciated the low-resolution and abstract communication the ambient displays and the prototype would have to offer. They highlighted that there are already numerous existing means to communicate with words, voice, and images; the prototypes could offer a compelling intimate communication

channel. The participants found that the prototypes would be useful in a variety of contexts, particularly when using mainstream communication tools (e.g., calling and texting) might not be possible or appropriate. Thus, wearable ambient displays can be considered as complement devices to smartphones, which could allow a couple to stay connected even when they are busy or when it is inappropriate to use a smartphone in a certain situation.



Figure 10: Polished prototypes worn on the participants in different real-world contexts during the in-the-wild study.

As the participants wore the prototypes and engaged in their activities, the way they imagined themselves using the prototypes as an intimate communication with their partner changed depending on different contexts. They considered that they would be more comfortable using the prototypes to send messages when they were alone. Receiving messages would be considered acceptable in most contexts, even when participants were engaged in other social situations, such as a church service or chatting with friends.

After using the prototypes they designed for 2 days, the participants became more aware of the interaction with their wearable devices. Using the prototypes in the wild raised the participants' concerns related to the form factor and interactions with

the prototypes. Low-bandwidth communication has the potential to communicate intimacy between a couple, but the participants would prefer to have a broad variety of messaging options to express their feelings and emotions, not merely an on/off display. Among the four prototypes, the participants with the necklace raised concerns related to not noticing a message their partner sent. For instance, the necklace would not be easily accessed or visible if used outside in winter. This could potentially decrease the feeling of being passively connected, which would make the wearable less distinctive from a smartphone. Usability issues with the ring were related to its interactions. While intuitive interactions are important and may be preferred, the issues raised in using the ring show that it should be different and specific enough that the interactions could be identified as intended.

The participants further commented that relying uniquely on themselves to notice the change of visual elements on the display could be problematic. They did not always pay attention to the devices. Although the participants considered this channel of communication to be passive and less stressful, they did not want to miss knowing that their partner had recently sent them something. Furthermore, the participants reported that they would appreciate seeing changes that happen on the display as well as all previous messages their partner had sent. Additional notifications, such as vibration or heat, were considered beneficial.

5.7 Towards a Conceptual Design Framework for LDRs

Case study VII presents a conceptual framework of the different aspects that designers should consider when designing technology-mediated communication systems for LDRs. The framework is based on the following:

- The literature reviews presented by the author (Li et al., 2018) and Hassenzahl et al. (2012);
- The author's own user studies on LDR couples, revealing design challenges (Li, 2018);
- The designs and prototypes developed by the author and her colleagues (Häkkinen et al., 2018; Li et al., 2019b).

5.7.1 Motivation and Positioning

LDRs thrive in contemporary life. Despite the growing number of solutions for supporting emotional communication in LDRs, the studies are still scattered in their approach (Li et al., 2018), and systematic studies looking at the big picture of this realm are scarce. Furthermore, limited research has been done to develop a comprehensive framework which can help to create better communication devices to support remote couples. An exception here is the work by Gooch and Watts

(2011), who proposed a design framework to explore how intimate communication devices can be designed to convey social presence, which is believed to be essential for supporting close relationships at a distance. However, as it was noted, the framework is only provisional, and it only covers a limited number of design-relevant attributes for intimate relationships (Gooch & Watts, 2011). Thus, it is relevant to develop a more holistic framework focusing on LDRs. The motivation is to synthesise a holistic set of design dimensions of LDR systems into the framework. The aim was to 1) highlight a number of important aspects that should be taken into account when designing communication devices to support emotional and subtle communication for remote couples, particularly for those who have been in a committed romantic relationship for a substantial amount of time, as opposed to casually dating, and 2) provide a more formalised and comprehensive framework for helping to recognise and consider different issues during the design process.

5.7.2 The Framework

In CMC between couples in LDRs, the users interact with each other through a technical system, which mediates the communication through its input and output channels. Both design and technology influence the overall UX and play a role in its success. In addition, other aspects need to be considered when designing for this specific user group. As a well-established tradition of UCD emphasises, the user and their needs, skills and preferences should be considered when designing any systems for them (Rogers et al., 2011). The setting of LDR itself sets special requirements for the design, as the setting of the relationship as well as the characteristics related to the physical distance need to be considered. Context also influences the use of technology and can affect not only the habits of use but also the system behaviour, which is adapted according to the context. The influence of the use context has been actively investigated in the research theme of context-awareness (Dey, 2001). In the thorough work of Häkkinä (2006), she further demonstrates the importance of the use context, which can influence users' preferences on how to use their devices and how the device should behave. The presented concepts form the main dimensions of the conceptual framework for designing CMC systems for LDRs. As shown in Figure 11, the framework includes the key characteristics of users, the LDR itself, technology, design, and context of use as the areas that define what aspects need to be considered when such systems are designed or evaluated.

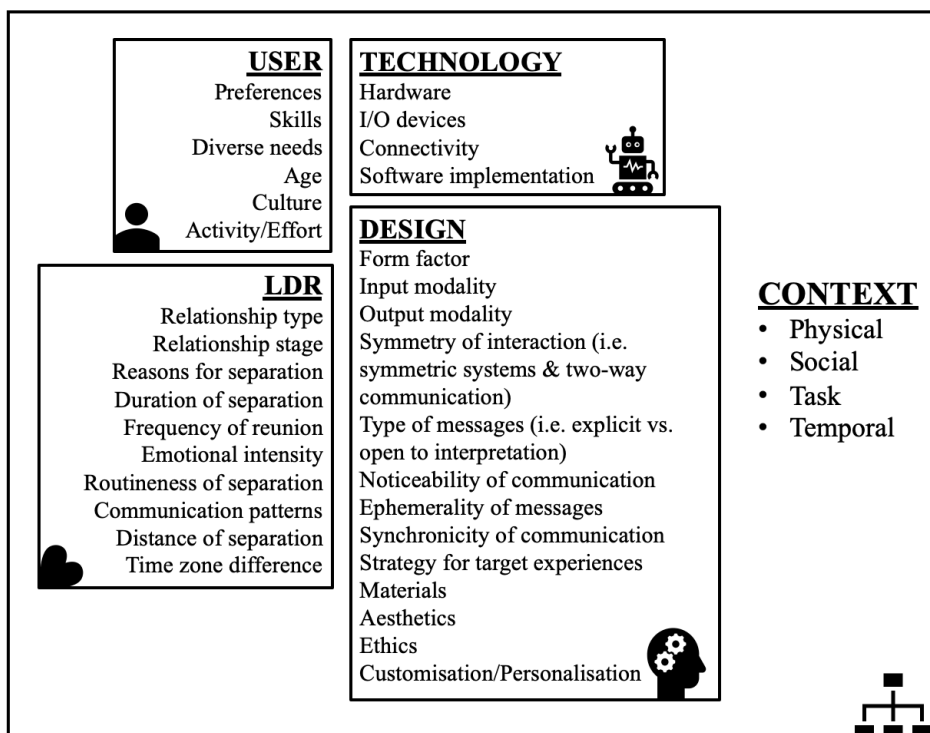


Figure 11: The framework for designing unconventional communication systems for LDRs (from Publication VII).

5.7.3 Main Findings

To validate the conceptual framework, six existing products and examples of research designed for emotional communication between LDR couples were analysed. The example systems analysed with the framework were the following:

- Beam® (Yang et al., 2017)
- Kissenger (Samani et al., 2012)
- Hug Shirt™ (CuteCircuit, 2002)
- Frebble (Vansant, Amy, 2014)
- Connected Candles (Häkkinä et al., 2018)
- Our Little Secret (Li et al., 2019b)

These example systems were chosen to represent a wide variety of CMC systems with a wealth of different attribute choices. The analysis of the six example systems shows that the framework can be applied in practice for categorising and investigating their different aspects in a systematic way. The analysed examples do not represent widely adopted or known communication tools, such as mobile

phones and video chats. The framework thus provides a practical means for gaining a systematic overview of the concepts. It helps in attending to different details and makes a comparable presentation of different systems and system versions easier.

5.8 Developing a Design Toolkit for LDR-Oriented Communication Systems

Case study VIII presents the design and development of the *Flexi Card Game* (FCG), a card-based, generative design toolkit for supporting both designers and non-designers in the PD process of designing unconventional communication systems for LDRs (see Figure 12).² The aim of FCG was to make domain-specific design knowledge—specifically, the design framework (Li et al., 2019a)—accessible to designers and practitioners, even individuals who have no design background or are not familiar with the domain-specific topic.

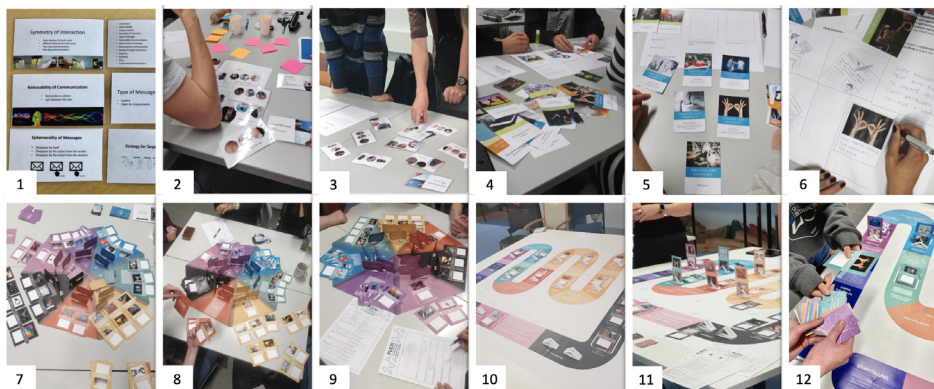


Figure 12: The overview of the iterative development of the *Flexi Card Game*.

5.8.1 Motivation and Positioning

There has been increasing interest in designing unconventional communication systems to mediate LDRs within participatory contexts (Li et al., 2018). However, developing design tools that facilitate both designers and non-designers to explore LDRs in a PD process remains under-researched. Inspired by Hornecker's (Hornecker, 2010) treatment of design cards as a means of mobilising the *Tangible User Interface* framework (Hornecker & Buur, 2006) to facilitate creative dialogue, this study applied that work to the context of designing unconventional communication technologies for LDRs using the design framework (Li et al.,

² A video that demonstrates the latest version of FCG is available on: <https://youtu.be/9vSzLuNUKVo>

2019a), a previously under-explored domain for PD game-based tools. Card-based design tools have been a popular approach as a design method, as summarised by Roy and Warren (2019), who analysed 155 card decks for designers and noted several weaknesses, such as that the information being presented on the cards may be overwhelming or oversimplifying, may be complicated to understand and apply, and is often difficult to change and update. FCG was designed to enable flexibility, hence it was named *Flexi*. FCG was envisioned to be flexible enough in order to avoid card-based design tools' common weaknesses, such as the information presented on cards can be overwhelming if too much, or in contrast overtly simplified and hence not useful enough (Roy & Warren, 2019).

5.8.2 Participants

The development of FCG went through four iterations over 12 months, each of which was implemented and improved based on the participants' feedback. FCG was deployed to generate concepts for addressing technology-mediated communication for LDRs over five workshop deployments, with a total of 56 participants across the sessions (see Table 3).

Table 3: Brief overview of the development of FCG.

Version	Workshop	Participants	Place
V1	WS1 (2.5h)	10 non-designers and 2 designers	University of Lapland, Finland
V1	WS2 (2h)	12 non-designers and 4 designers	University of Lapland, Finland
V2	WS3 (2h)	12 design students	University of Lapland, Finland
V3	WS4 (2.5h)	7 practitioners	University of Lapland, Finland
V4	WS5 (1)	9 design researchers	The University of Queensland, Australia

5.8.3 Study Design

Study I. V1 was a deck of 18 rectangle-shaped cards that were laminated with round edges (see Figure 12-1). The cards were single-sided and the visual layout was simple. The front side of each card had a bold title of its category and the textual examples as well as copyright-free images found on the Internet that were easy for users to relate to. The categories included form factors, input and output modalities, types of interaction, types of messages, types of communications, and targeted experience.

V1 was implemented in two workshops in which the participants were engaged in designing wearable devices to support remote couples. The participants in the WS1 (N = 12) conceived the concept individually (see Figure 12-2), while the WS2 (N = 16) was a collaborative design setting (see Figure 12-3).

Study II. V2 consisted of three decks of cards each containing 27 cards. The cards remained single-sided, and the layout was divided into three parts (see Figure 12-5). The top part of each card had an abstract image which represented the meaning of the term. All the images were copyright free. The middle part was colour-coded textual information of the card categories, including user needs, targeted user experience, the behaviour of messages, technology, and customisation. The category of user needs was new in V2, which included diverse LDR user needs identified by Stafford, (2004), Li (2018), and Jarusriboonchai et al. (2020). The bottom part was the term of the card, where academic jargon was with relatively simple language to make the textual information easier to understand and apply. A black-and-white board (17 x 23 inches), which was inspired by the *PLEX scenario* (Lucero & Arrasvuori, 2010), was introduced as one of the accompanying tools in this version. The board was divided into five sections corresponding to the five card categories. Selected cards were to be placed on the corresponding sections. There were a number of supporting questions under each section to guide the card users to select the cards that were relevant and that could help participants develop their concept. The other accompanying tools included an A4-sized design challenge statement with which the card users were tasked to use the cards as a support to create a tangible unconventional design concept to connect people in LDRs. The design challenge statement covered three types of LDRs as user groups for card users to choose which one to design for. The user groups include the following: 1) long-distance romantic couples including couples who are married with kids and couples who are stably dating; 2) long-distance family including child-parent, adult child with ageing parent, grandchild with grandparent, and siblings; and 3) long-distance friends. The three decks of cards were meant for three user groups: each deck was varied in the 'user needs' category. For instance, the 'check healthy state' card was placed in the deck of cards for designing for LD family but not in the other two decks.

V2 was tested with 12 first-year industrial design students. The participants were equally divided into three groups. WS3 consisted of two rounds of design activities. In the first round of design, each group was asked to choose a user group as their design challenge. In the second round of design, all groups were tasked to use the cards to help them redesign another group's design concept for the user group they had chosen at the beginning.

Study III. V3 comprised of a deck of 58 cards. The category of problems and challenges was added in addition to the following categories: *user needs, targeted user experience, form factor, behaviour of messages, technology, and customisation*. Regarding visual presentation and layout, the cards were changed to double-sided. Both the front and back were colour coded. The front side of each card had four colour-coded edges with textual information of the card category on the top middle area, followed by a copyright-free image which implied the meaning of the term on the card. The middle part was colour-coded textual information of the 58 terms, each

accompanied by a pullable information strip which contained a short definition or examples of the term. The bottom part was an empty window where another image could be inserted if the card users did not relate to the existing image on the card or wished to seek more inspiration. An image bank found online which contained 150 copyright-free labelled images with varying levels of abstraction was provided for the card users to select more images if needed. The backs of the cards were also colour-coded and showed the name of the cards: namely, *Flexi Cards*. The accompanying tools were: 1) a heptagon-shaped board (approximately 31 x 30 inches) which was divided into seven colour-coded sections as the card categories; 2) a user profile template for building up a specific user; 3) an A4-sized idea card for describing what the concept is and how it functions, and; 4) a storyboard template for illustrating how, when, and why the user would interact with the created concept.

V3 was implemented in WS4, which involved seven participants with expertise. Each participant was assigned to lead the discussion of a card category which was their specific area of expertise.

Study IV. V4 is comprised of 1) the same deck of 58 cards since no critical feedback was received in WS4; 2) a serpentine-shaped, colourful game board (63 x 53 inches) which guides the players throughout the process (see Figure 12-7); 3) a new image bank (copyright-free) which contains 58 explicit images describing various contexts including positive and negative emotions, social situations, weathers, as well as different environments; and 4) two user archetypes. The user archetypes used in this design case were based on two discrete types of LDRs: specifically, a steady dating couple in an international LDR and an ageing parent with an adult child in a domestic LDR. The navy sections in Figure 12-12 are the add-on tools which have been integrated into the game process. The card categories are presented by seven colour codes: purple represents *user needs*, blue represents *problems and challenges*, green represents *targeted user experience*, orange represents *form factor*, yellow represents *behaviour of messages*, black represents *technology*, and pink represents *customisation*.

WS5 was conducted with nine design researchers to critically appraise the V4 (see Figure 12-11), commenting on what the setup did well and identifying potential challenges and opportunities for improvement. All participants had significant experience in both the teaching and practice of design methods, with six participants having prior experience in creating card-based generative tools and methods in their work.

5.8.4 Main Findings

FCG can be regarded as a first step towards an LDR-oriented card-based design game toolkit. It was based not only on empirical evidence, but also on a theoretical understanding of LDRs and card-based design toolkits. FCG has been demonstrated to be a versatile and useful design toolkit which can serve as a collaboration mediator,

storytelling stimulus, and tangible knowledge carrier in a PD context. FCG was found useful at different design stages. The positiveness of the cards was beneficial in helping establish the design process as a good starting point to engage individuals in discussing the topic and various use cases in a group setting when designing for people in LDRs. At the beginning of the design process, FCG was used as an ideation tool with which the participants *'did not have to start from a complete zero'* (P3-12, i.e., WS3, participant 12) when building their concept. During the design process, when proper design ideas started to take form, FCG was used as a tool to document the main features of their design. With the help of FCG, all participants were able to take the key design aspects identified by Li et al. (2019a) into account during the design process. The most repeated feedback received from the participants without a design or technology background was that the cards introduced important knowledge about certain aspects that needed to be considered when designing communication systems to mediate LDRs, which they would not have known if not using the cards. As P1-8 stated: *'I wouldn't have thought about how the message arrives to the receiver and how it disappears [...] Those pointers wouldn't have come to my mind without the cards'*. In addition to using the cards to help create ideas, FCG could also be used as a tool at the end of the design process to evaluate if the concept had included the key aspects needed to be considered. More importantly, FCG had a strong positive impact in engaging experts and users with various backgrounds in a PD activity. The game nature of FCG helped to keep the PD process advancing and keep the participants excited. By making the design process game-like, it was easier and more efficient to engage the individuals, who did not have domain-specific knowledge, in a PD context where people with different backgrounds worked collaboratively. As P4-22 described, *'designers can draw the concept and non-designers can give their unbiased perspective, while tech-savvy people can explain how the product can be made'*.

6 Discussion

6.1 Revisiting the Research Questions

In answer to the research questions, this dissertation work aimed to explore and investigate a variety of solutions through an iterative process in which any case study could generate new insights that constitute a discovery and cause the process to oscillate between different stages according to the double diamond model (see Figure 1). In doing so, it has helped to ultimately develop a profound understanding of the research topic and to iteratively improve the answers to the research questions.

RQ1: What are the design opportunities for designing unconventional communication systems for mediating couples in LDRs? A systematic literature review (Li et al., 2018) was conducted to examine the current state of the art and identify the design opportunities with which a comprehensive overview of the HCI research on different emotional communication systems for LDRs was uncovered. The analysis revealed that haptics was the dominant input modality in the UI design for LDRs; for the output modality, visuals were dominant. Taste and smell were very rarely used modalities in mediating emotional communication for LDRs, revealing a design space for future researchers. Furthermore, the evaluation of the reviewed systems lacked in-the-wild studies, especially concerning long-term usage. One of the salient findings reveals that many reviewed works show a lack of user participation, and strikingly, most of the recruited participants in the lab studies were not authentic remote couples in real life, but substitute participants were used instead. Even though a number of studies did engage authentic participants who were involved in LDRs when the studies were conducted, in most cases the participants were only engaged in the evaluation stage.

RQ2: What are the users' needs and challenges when being separated by a geographical distance that restricts physical contact and face-to-face communication? The work then progressed to address the shortcoming of lacking real user participation by intensively engaging five authentic LDR couples who had sustained a long-term commitment in their LDRs in a number of design activities (Li, 2018). The findings provided an empathic and deeper understanding of the LDR couples' needs, underlying problems, and challenges and skills used to maintain a healthy LDR. Some common challenges that couples face in an LDR are identified: for example, a lack of physical intimacy, an unstable communication environment, and unsynchronised daily lives. On the contrary, every couple's needs are different concerning LDRs. This sheds light on a need to take the strategy of

customisation as a user-tailored approach to enable creativity, where LDR couples who are the experts in their own LDR experiences can feel empowered to become designers on their own, having space to adapt, modify, specify, and create a desirable product according to their own preferences and needs, which is thereby able to meet their diverse needs.

RQ3: How can technology be unobtrusively integrated into the users' everyday lives and serve as a minimal communication channel between couples in LDRs? Followed by the discovery of the need of customisation, a set of *Connected Candles* (Häkkinen et al., 2018), a pair of ambient picture frames (Li et al., 2019b), 12 low-fidelity wearable design concepts (Li et al., 2020a), and four wearable display concepts (Li, Jarusriboonchai, Müller, Harjuniemi, & Häkkinen, 2020b) were developed and proposed as unconventional communication channels for couples in LDRs to mediate emotional communication and customise secretive love languages. These practices demonstrated how technology can be unobtrusively integrated into the users' everyday lives by integrating unobtrusive technologies (e.g., non-illuminating ECD, haptic feedback, wearable technology, etc.) into the form of everyday objects that can be easily found in the users' life (e.g., candles, picture frames, jewellery, etc.). These practices can be regarded as a first step towards connecting couples in LDRs through unconventional UIs, by serving as a complementary and minimal channel for remote couples to communicate intimacy, rather than replacing the mainstream communication channels which they are currently using.

RQ4: How can design play a role in supporting the process of designing unconventional communication systems for LDRs? The intention of this dissertation is not to present a finalised solution to address LDRs but rather to explore how design can be utilised to elicit empirical insights around the experiences, challenges, and needs of LDRs and how these can act as a foundation for future technology design, so as to bridge the gap between research and practice. Ultimately, the aim is to question and challenge the narrow assumptions of how technology is conventionally used, evoking new assumptions in people about the way they communicate with each other and how they can interact with technology differently, as well as encouraging the imagination of the possibilities of future communication. In addition to the essential insights and novel design concepts, a conceptual design framework (Li et al., 2019a) and a card-based design toolkit (Li, Khan, Hurtig, Jarusriboonchai, & Häkkinen, in press) were created and delivered to the HCI field as new knowledge for designers, users, and practitioners to use when designing unconventional communication systems for connecting couples in LDRs. The design framework identified five essential dimensions—namely, users (the remote couple), the LDR itself, the used technology, the design, and the context of the use—as well as their related key attributes that should be considered when designing computer-mediated emotional communication systems for LDRs (see Figure 11). In order to make this domain-specific design knowledge accessible to

designers and practitioners—even individuals who have no design background or are not familiar with the domain-specific topic—the card-based design toolkit *FCG* was created as a first step towards an LDR-oriented design game tool.

6.2 Design Considerations

The following design considerations were redacted based on the main findings of this dissertation for the design of unconventional communication systems to support couples in LDRs:

Offering an additional channel for mediating emotional communication. In line with pioneering work (Strong & Gaver, 1996) in the area of technology-mediated emotional communication and the reviews done to survey the current state of the art (Hassenzahl et al., 2012; Li et al., 2018; Saadatian et al., 2013), the case studies have underlined the need for expressing affection and emotion, creating relatedness, and mediating physical intimacy between couples in LDRs. Even though explicit communication is dominant in current communication systems, love can be expressed implicitly in the absence of speech: for example, by sharing life moments (Olsson et al., 2009; Olsson, Soronen, & Väänänen-Vainio-Mattila, 2008) and using music and background sounds (Lottridge et al., 2009). Currently, couples are able to easily share mundane details in life by sending photos via smartphones regardless of their distance apart. The mainstream communication channels have provided an efficient, cheap, and convenient channel for couples in LDRs to stay connected, and they have formed different patterns in using the communication channels to maintain LDRs (Dainton & Aylor, 2002). The field study of case study VI identified that in most cases, the participants tended to use the prototypes when direct communication via mainstream communication tools would not be an ideal option (e.g., answering a call from a remote partner). The prototypes were used as an additional channel for emotional communication in a subtle way. Instead of interrupting the user's communication ecology by replacing the mainstream communication tools they are using, the communication systems for LDRs should be added on to their existing communication means and dedicated to communication with a distant loved one.

Utilising the haptic modality to mediate physical intimacy. The mainstream communication tools such as smartphones and PC have a digital screen as a conventional UI, which can make interaction difficult. A digital screen shows various limitations—for example, small space, eyes heavily used when mobile, requiring too much visual attention, which may be dangerous—to name a few. The haptic modality has the potential to improve mobile interaction in varied contexts where visual interaction is limited. Brewster and Brown (2004) have developed *Tactons* (i.e., tactile icons) which are vibrotactile messages that can be used to present

multidimensional information non-visually in computer interfaces. The haptic modality has benefits not only over a visual display, as it is *eyes-free*, but also over an audio display as it is *invisible* like the sense of touch. In case study I, touch was found to be the most-used modality in unconventional communication systems designed for mediating emotional communication between couples in LDRs (Li et al., 2018). Haptics can be utilised in emotive communication situations to convey emotional expression and binary information (Heikkinen, Olsson, & Väänänen-Vainio-Mattila, 2009). Such a modality can provide a means for richer emotional communication between couples over distance to allow expressive ways of communicating: as indicated in case study V, haptic modality was utilised to simulate ‘a warm hug’, give ‘a nice massage’ and create a feeling of ‘holding hands’. Couples in LDRs lack physical intimacy, and this fact makes the haptic modality an appropriate and fitting candidate for strengthening the physical connection. Thanks to its nature of tactile reception, the haptics modality is a private medium that allows the users to communicate subtly and intimately in the vicinity of others. On the other hand, the implicit messages mediated by touch might be ambiguous and vague to the users due to the low-informative nature of the haptic modality. Boll et al. (2008) envisioned a multimedia future, where the next generation of UI will involve senses and emotions (e.g., touch and smell, joy, and excitement). In light of this speculation, the haptic modality could be used more versatily by integrating with other modalities so as to enrich the interaction between couples in LDRs.

Supporting secretive love languages by providing customisability. A standardised form of communication is inadequate to meet the full spectrum of couples’ communication needs. For instance, typed letters on a digital screen look exactly the same no matter who the sender is. Every LDR is distinctive in various ways, particularly in the manner of expressing affection. Couples use secretive love languages to communicate: it was reported in a recent study that the typical use of emoji has been repurposed for personalised communication (Wiseman & Gould, 2018). The findings from case studies IV and VI also emphasised that couples wished to communicate in a secretive and intimate way that no-one else was able to understand (e.g., a shared memory or an inside joke.) In case study VI, the participants believed they were able to communicate intimacy, affection, and emotion with their remote partner via subtle, nonverbal means, which is different from conventional text-based explicit communication. The love languages were encoded using subjectively meaningful symbols, patterns and colours so that the communication was secretive and private. Customisability should be enabled in the communication systems for couples in LDRs in order to support their subjective and secretive love languages. The personal meanings that are ‘embedded’ and ‘encoded’ in the system can enrich the user experience (McCarthy & Wright, 2004). Additionally, by offering a high order of customisability in the design—including not only the appearance but also the type of communication—can make the device

itself more personal to the user (Fortmann, Root, Boll, & Heuten, 2016) and support the users in creating new symbolism or language during the communication (Heikkinen et al., 2009).

Coping with asynchronised lifestyles through a hybrid approach. Geographic separation poses many challenges to couples in LDRs, such as time-zone differences, different daily routines, and asynchronised lifestyles. However, the mainstream communication channels often require synchronicity: that is, both ends need to be active at the same in order to communicate in real time. Due the asynchronised lives of remote partners, they are more likely to face obstacles for real-time communication. While synchronous communication can create a feeling of being together, the findings from the user study of the *Connected Candles* (Häkkinen et al., 2018) and *Our Little Secret* (Li et al., 2019b) suggest that asynchronous communication could better support LDR couples who have to cope with a time-zone difference. The possibility of using both synchronous and asynchronous ways of communicating is appreciated (Heikkinen et al., 2009). As the interaction and communication contexts vary, synchronicity in the technology-mediated emotional-communication systems for LDRs should be balanced by enabling a hybrid approach of combining synchronous and asynchronous communication for the users to choose freely based on their preference and the context of communication. Additionally, even though some couples in an LDR might wish to have a feeling of being constantly connected, it is worth noting that social acceptability concerns (Koelle et al., 2018; Koelle et al., 2019) may arise with regard to the technology being used to enable such *always-on, always-connected* experience.

Enabling adaptability in various contexts. Schmidt et al. (1999) emphasised the importance of adapting the functionality of an artefact according to the context it is being used in, and Schmidt (2000) explored ways of implicit communication between the user and their environment with mobile devices. Abowd et al. (1999) define context as follows:

Context is any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves.

A sustainable system should be adaptive in myriad contexts in a mobile world. One of the important findings in case study VI, which is aligned with the findings in case study V, highlights that the participants desired their design concepts to be integrated into everyday contexts. The proof-of-concept in-the-wild study of case study VI vividly illustrates how a wearable ambient display could be integrated into a user's everyday life and how it would be used in different real-life contexts. This responds to one of the design guidelines for increasing the usability of context-aware

mobile applications proposed by Häkkinen (2006), suggesting that individual needs or preferences should be taken into account, as their preferences may change over the time, and hence the possibility to adjust the context attributes should be provided. Moreover, the user's cultural context is also influential. Through the lens of one's cultural background, things can be interpreted differently. For instance, as one of the lessons learned from case study III, the gesture of lighting a candle was intended to serve as a poetic cue of the presence of a distant loved. However, the meaning of lighting candles may vary in different cultural contexts, which might create associations not relevant to the concept (e.g., about remembering the dead). Consequently, cultural contexts need to be considered when designing unconventional communication systems for LDRs, in an effort to avoid miscommunication and misunderstanding. A sustainable solution for connecting couples in LDRs should consider the long-term use by unobtrusively integrating the communication system into the users' communication ecology and enabling adaptability in various contexts in their everyday life.

Aesthetically unobtrusive fashionable jewellery-like wearables have the potential to connect couples in LDRs. As highlighted in case study V and VI, wearable devices are worn close to the body, thus serving as an unconventional communication channel to connect couples in LDRs by naturally creating a feeling of intimacy. Although wearable devices have become vogue, the majority of today's wearable devices neglect aesthetics, as the focus is mainly placed on functionality. Indeed, it is suggested that the priority should be placed on the functionality, form factor, and interaction and display design concerning design wearables such as digital jewellery (Fortmann, Heuten, & Boll, 2015). Nevertheless, it is also important to consider aesthetics when designing wearable devices, as there are market needs for fashionable wearable devices which are able to address users' aesthetic and style needs (IBM Corporation, 2014). This market niche sheds light on the potential of fashionable jewellery-like wearables. As defined by Silina and Haddadi (2015b), jewellery-like devices refer to a subset of wearable devices that occupy traditional places on the body as jewellery but do not necessarily look like jewellery, with an exception of *smart watches* and *fitness watches*, which are considered as *watches*. For instance, prior work has introduced *Tangible Apps Bracelet* (Fortmann et al., 2016), an aesthetic jewellery-like wearable device that seamlessly integrates a number of applications and digital components. As noted in its user study, nonverbal communication applications were favoured by the participants and were suggested for future designs. This matches the users' needs for mediating emotional, nonverbal communication between couples in LDRs found in case studies II, III, IV, V, and VI. There are myriad forms of nonverbal communication, such as biosignals, which are widely used on today's wearable devices for wellbeing purposes (e.g., fitness tracking). Interestingly, *Heartefacts* utilises heart rate changes measured by wrist-worn sensors while watching videos to share video highlights. The author envisions

that integrating nonverbal communication with fashionable jewellery-like wearables will introduce new potential opportunities for connecting couples at a distance.

6.3 Methodological Discussion

User studies on LDRs are challenging to organise for many reasons resulting from geographical barriers—for example, time-zone differences may pose challenges to organising a study in which both sides of a couple are able to participate—thus, contributing to the low number of studies involving actual LDR couples (Li et al., 2018). Five cases studies in this dissertation engaged research participants who were in an LDR or had been in an LDR, in a number of PD settings. Case study II involved five couples in LDRs: namely, the local group of on-site participants and their remote partners who formed the remote group which participated in the study remotely. The semi-structured interviews were conducted in each local participant's residence where they usually had video chats with their remote partner. Skype was used as an aid for involving the remote-site participants in the interviews. In doing so, the purpose was to create a relaxing and familiar atmosphere in which the participants would feel comfortable enough to share thoughts, insights and personal experiences. The participants had been involved in a steady romantic relationship for at least two years and had remained committed in a serious LDR. This made them skilled practitioners of LDRs who were more likely to contribute valuable insights on how technology could be better designed for LDRs. However, the main drawback of this study is the lack of real-life prototyping over time, as a short-duration study may not be sufficient to assess and substantiate the value of a system that will operate in many different contexts and situations over a longer period of time. Having acknowledged this shortcoming, case studies III and IV developed a functional prototype: specifically, the *Connected Candles* (Häkkinen et al., 2016) and *Our Little Secret* (Li et al., 2019b), respectively. The evaluation of the two prototypes engaged participants, who had diverse cultural backgrounds and were living in a different time zone to their remote partner, to varying degrees when the studies occurred. Case study III involved a focus group discussion regarding the usability of the *Connected Candles* (Häkkinen et al., 2016). In addition, for 1 week, case study IV deployed the working prototype of *Our Little Secret* (Li et al., 2019b) in the wild with a couple who was in a commuter marriage. Although ECDs offer opportunities for customisable communication, the main flaw of this study is that the prototype of *Our Little Secret* used in the field study was fixed in a picture frame with defined graphic contents. Even though the couple fully understood the concept, given the limited extension of the in-the-wild study, it was less likely to demonstrate if the proposed design would be sustainable in terms of interest, involvement, and motivation in the longer term, as well as if it met the requirement of providing a

symbolic meaning and guaranteeing the sense of remote awareness underlying this type of communication with a limited ‘vocabulary’. In an attempt to minimise this shortcoming, case studies V and VI gave the participants the freedom to customise their own ideal design concepts. In case study V, the participants were asked to create low-resolution wearables prototypes that could support their own LDR. The evaluation was performed by their remote partner who watched a video of their partner explaining the design concept. However, the weakness here is that asking the remote participants to evaluate the design work made by their own partner may result in biases. More insights could have been generated by mixing the videos, sending them to others’ remote partners, and having them iterate and improve the designs, not uniquely judge them. Similarly, the participants in case study VI co-created low-resolution prototypes, which were further polished and returned to the participants to wear and interact in real-world contexts for 2 days. However, the study is limited by the fact that the duration of the concepts in-the-wild study was relatively short, and the prototypes were not functional in the field study.

Overall, the sample of this dissertation is representative of varying degrees of diversity. First, the research participants were involved in different stages of a steady LDR with a wide age range. Second, the sample consisted of individuals who came from the seven continents of the world so as to minimise cultural bias. Third, in order to achieve a wider diversity of the sample, a number of same-sex couples were also recruited for this research. In a participatory approach, the research participants were encouraged to feel that they were regarded as *experts in LDR experiences* (Visser et al., 2005) since the majority of the participants had been in or had experience of a typical LDR for a number of years. This made them feel more confident to contribute insights based on their empirical experiences to help design better communication systems to support LDRs, even if some of them did not come from a design background. In case studies II, IV, and VI, the research participants were engaged in multiple study sessions besides the co-design phase. Hence the sample should be representative given the intensity of involvement. Involving both sides of LDR couples in participating in the research has proven to be challenging due to geographical barriers. Nevertheless, the approach of engaging remote partners in interviews through Skype, as in case study II, and in giving comments and suggestions on the LDR-oriented design concepts through videos, as in case study V, functioned as a feasible and fruitful methodology to gain feedback from both sides of the LDR couples. With this compromise, it became possible to involve authentic LDR couples in this research. Although only one member of the LDR was able to participate in the on-site workshops, the method worked well as it enabled gathering insights and perspectives from both sides. This can be an example of how to conduct a co-design workshop with people who are geographically divided. Future research could include both sides of a couple in co-designing a concept then compare them—which may help the couple to understand each other’s needs—and design a suite of tools that best suits them.

7 Conclusion

7.1 Summary

Following a *research through design* approach (Zimmerman et al., 2007), this dissertation has presented eight design case studies for mediating emotional communication in LDRs through unconventional UIs that use interaction solutions beyond conventional use. Each of the case studies has provided answers to its corresponding research question(s). Case study I explored the current state of the art and identified the design opportunities. Case study II uncovered the users' needs and challenges in an LDR. Case studies III, IV, V, and VI proposed and evaluated a number of solutions as unconventional communication systems to connect couples in LDRs. The presented solutions are the outcome of co-creation practices with *the experts of LDRs* (i.e., couples and individuals who had been committed to an LDR). These practices contribute to the understanding of how technology can be unobtrusively integrated into the users' everyday life. Case studies VII and VIII developed a conceptual design framework and a card-based design toolkit which provide a scaffolding that can help designers and practitioners to consider the essential aspects when designing for LDRs.

The contribution of this dissertation is three-fold. First, it provides theoretical and empirical insights and findings derived from the eight case studies which have identified opportunities, design space, and design considerations of how couples in LDRs can be better supported by technology-mediated emotional communication systems. Second, it showcases a spectrum of practices which can be seen as a first step towards connecting couples in LDRs through unconventional communication systems. Third, it contributes two novel design tools as new knowledge to help develop unconventional communication systems to support LDRs.

The findings of this dissertation comprise subjective user experiences, objective observations of users' interactions with LDR-oriented prototypical communication systems, as well as reflections on the findings in light of existing literature. To conclude, the key findings of this dissertation are summarised as follows:

- User needs vary considerably in LDRs. Customisation can empower LDR couples as skilled practitioners to use technologies in their own creative ways to meet their diverse needs. Enabling customisability in the communication systems can make a lifeless, standardised object become meaningful and

symbolic to its user by allowing them to customise subjective and secretive love languages to express affection. As in case study VI, the research participants would convey intimate and personal sentiments by customising the visual contents into secret codes.

- Synchronicity in communication systems needs to be balanced. In current communication systems, creating a feeling of connectedness and togetherness is often mediated through synchronised emotional communication. The synchronicity required in such systems might be difficult for couples in LDRs, as time-zone difference is one of the main challenges which leads to asynchronised lifestyles and schedules.
- Ambient and unobtrusive technologies show potential in mediating emotional communication for LDRs. For instance, the candle stands as in case study III and the non-light-emitting ECDs as in case study IV were well-received for their pleasantness and calmness in the user studies.
- Five dimensions need to be considered when designing or evaluating computer-mediated emotional communication systems for LDRs: namely, the users, the LDR itself, technology, design, and context of use.
- The design concepts created by the research participants were based on daily objects that can be integrated into everyday life. This indicates that the solutions for mediating LDRs should support everyday contexts and be able to blend in multiple contexts when needed. The finding also sheds light on the potential of wearable technology, as it can be worn directly on different locations on the body, which opens a myriad of opportunities for intimate communication beyond what conventional mobile communication means could offer. For instance, the multi-wear design concept created in case study VI not only allows a user to wear the device on different body locations according to their preference for style and aesthetic purposes but also provides the possibility for multi-wear in different occasions and the ability to hide it for practicality.

7.2 Future Directions

LDRs contain different relationship types that are not limited to romantic ones (Stafford, 2004). In light of this, even though this dissertation work focused on couples who sustain a committed LDR, the findings may be generalised to help develop technology to support other types of LDRs and other types of couples. For future research, it will be interesting to further explore the following directions:

- Prior research has shown that olfactory interfaces have the potential to create personal and subtle notification (Dobbelstein, Herrdum, & Rukzio, 2017),

which matches well with the LDR design case. However, smell as an output modality appears to be rare in current technology-mediated communication systems. It would be interesting to study how smell could be applied to mediate LDRs as an interaction modality.

- Interpersonal conflict seems inevitable in every LDR. Looking into how technology can help couples in LDRs mediate negative emotions when having a conflict would be an interesting and timely topic.
- The LDR couples involved in this research tended to be young adults, ranging in age from their early 20s to mid-40s. As worldwide societies continue to age, it would be valuable to investigate elderly remote couples in future studies.
- Even though the scope of this dissertation is centred on the topic of designing unconventional communication systems for couples in LDRs, the author believes that the findings can be extended beyond the romantic context: for example, to grandparents who have trouble using conventional communication technology to connect with their grandchildren who live apart (Wallbaum, Matviienko, Ananthanarayan, Olsson, Heuten, & Boll, 2018) or patients whose illness hinders them in using conventional communication methods to interact with their distant loved ones (Wallbaum, Timmermann, Heuten, & Boll, 2015). In light of this, the author suggests an opportunity for future work to explore the extensibility of LDRs to develop unconventional artefacts to support other types of relationships.
- Emotional communication plays a significant role in LDRs and therefore sexual wellness. Although sex with robots (Scheutz & Arnold, 2016) is gaining a remarkable amount of attention, research with regard to how technology-mediated systems can promote sexual wellbeing in LDRs is still scarce due to ethical issues. This would be a bold and cutting-edge area to explore.
- Haptic modality shows great potential for mediating emotions and physicality (Obrist, Subramanian, Gatti, Long, & Carter, 2015). However, studies have criticised that current technologies still do not support the same natural sensation of real intimate communication (Saadatian et al., 2013), and the use of haptic modality is limited in the current HCI field (Heikkinen et al., 2009). Future research should develop new forms of haptic interaction to allow for more realistic sensation and richer interaction.

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Original Publications

Original publications are not included in the electronic version of the dissertation.

Publication I

Li, H., Häkkinen, J., & Väänänen, K. (2018). Review of Unconventional User Interfaces for Emotional Communication between Long-Distance Partners. In *Proceedings of the 20th International Conference on Human-Computer Interaction with Mobile Devices and Services* (MobileHCI'18, Article No.: 18, pp. 1-10). New York, NY: ACM.

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Publication II

Li, H. (2018). Understanding Design as a Catalyst to Engage Remote Couples in Designing for Long-Distance Relationships. In *Proceedings of the DRS 2018 International Conference: Catalyst* (Vol 6., pp. 2265-2279). London, UK: Design Research Society.

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Publication III

Häkkinen, J., Li, H., Koskinen, S., & Colley, A. (2018). Connected Candles as Peripheral Emotional User Interface. In *Proceedings of the 17th International Conference on Mobile and Ubiquitous Multimedia* (MUM'18, pp. 327-333). New York, NY: ACM.

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Publication IV

Li, H., Müller, H., & Häkkinen, J. (2019). Our Little Secret: Design and User Study on an Electrochromic Ambient Display for Supporting Long-Distance Relationships. In *Interactivity, Game Creation, Design, Learning, and Innovation* (pp. 611-622). Cham, Switzerland: Springer.

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Publication V

Li, H., Jarusriboonchai, P., & Häkkinen, J. (2020). Exploring Wearable Technology for Supporting Couples in Long-Distance Relationships. In *Proceedings of the DRS 2020 International Conference: Synergy* (Vol 5., pp. 2083-2097). London, UK: Design Research Society.

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Publication VI

Li, H., Jarusriboonchai, P., Müller, H., Harjuniemi, E., & Häkkinä, J. (2020). Emotional Communication between Remote Couples: Exploring the Design of Wearable Ambient Displays. In *Proceedings of the 11th Nordic Conference on Human-Computer Interaction: Shaping Experiences, Shaping Society* (NordiCHI'20, Article No.: 34, pp. 1-5). New York, NY: ACM.

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Publication VII

Li, H., Häkkinen, J., & Väänänen, K. (2019). Towards a Conceptual Design Framework for Emotional Communication Systems for Long-Distance Relationships. In *Interactivity, Game Creation, Design, Learning, and Innovation* (pp. 103-123). Cham, Switzerland: Springer.

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Publication VIII

Li, H., Khan, A. H., Hurtig, K., Jarusriboonchai, P., & Häkkinen, J. (in press). Flexi Card Game: A Design Tool for Unconventional Communication Systems for Long-Distance Relationships. In *Proceedings of the 15th ACM International Conference on Tangible, Embedded and Embodied Interaction* (TEI'21). New York, NY: ACM.

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