

Towards a Conceptual Design Framework for Emotional Communication Systems for Long-Distance Relationships

Omitted for review

Abstract. Couples living in long-distance relationships (LDR) may lack ways to keep emotionally connected. Previous research has presented a wealth of systems and user studies that offer insights of individual systems and their user interface designs. These studies have revealed a multitude of design attributes of the relatedness strategies of LDRs and the user interfaces used in computer-mediated communication (CMC) systems for LDRs. In this paper, we synthesise the multitude of different design attributes, and present a design framework that addresses the five main areas of LDR systems: users (the remote couple), the LDR itself, the used technology, the design of the device, interaction, nature of messages and supported connectedness strategies, and the context of use. We validate the framework by analysing and presenting a set of six existing systems and prototypes in light of this framework, and show how they take into account the central design attributes. As a conclusion, we propose that this framework can be used for design and evaluation of user interfaces of CMC systems for emotional communication to support LDRs.

Keywords: Design framework · Emotional communication · Computer-mediated communication (CMC) · Long-distance relationships · Long-distance romantic relationships.

1 Introduction

Emotional communication is fundamental and crucial to everyday interaction in close relationships, as emotional sharing and concern for each others emotional needs builds an important part of the intimacy [42]. Being aware of our loved ones emotions is essential to interacting and relating with them efficiently. However, emotional communication can be challenging for couples who live apart, due to the absence of a number of important cues, e.g. facial expression, tone of voice, or gestures.

Long-distance relationships (LDRs) thrive in the contemporary life. As an example of the prevalence of LDR couples, there are over seven million couples who self-define themselves as being in an LDR in the US [21]. Furthermore, there is a tendency indicating that the number of LDRs has been steadily increasing over the past few years [21]. Despite the fact that today there is a variety of media available for people to enhance and extend communication with their

loved ones at a distance, the majority of remote couples rely on the low-cost and ubiquity of computer-mediated communication (CMC) tools to communicate. Since the interactions through mainstream communication technologies are mostly screen-to-screen, it inevitably leads to miscommunication and misunderstanding without adequate multimodal cues. Moreover, it has been found out that most available technologies focus on the transmission of explicit information, which neglects the emotional communication needed for close relationships [24].

Luckily, HCI researchers have started to take a broad perspective by exploring different communication devices that can be used to support emotional communication in LDRs. Different types of unconventional communication concepts and prototypes have been developed, and research has proposed systems such as paired, interactive picture frames [7], or connection through sharing music and background sounds [35]. Despite the growing number of solutions for supporting emotional communication in LDRs, the works are still scattered in their approach [34], and systematic studies looking the big picture are scarce. Also, 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 [19], 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 pointed out [19], the framework is only provisional, and it only covers a limited number of design-relevant attributes for intimate relationships. Thus, it is relevant to develop a more holistic framework focusing on LDRs.

In this paper, we present 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 aim of our paper is to (a) 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 established a committed romantic relationship for a substantial amount of time, as opposed to casually dating, and (b) provide a more formalised and comprehensive framework for helping to recognise and consider different issues during the design process. The framework we have developed is based on 1) the literature reviews presented by Hassenzahl et al. [24] and Li et al. [34], 2) our user studies on LDR couples revealing design challenges, and 3) our own designs and prototypes, as presented in Section 4.1 and Figure 8.

The remainder of this paper is organised as follows. Section 2 presents the related work in mediating emotional communication to support LDRs. Section 3 describes the framework in detail. Section 4 analyses a number of example systems using our framework. Section 5 discusses the highlights of our findings towards the framework. Finally, Section 6 draws conclusions of our work and suggests directions for future work.

2 Related Work

In this section we first introduce the study of emotional communication and how it has been defined. We then briefly review concepts that aim to support LDRs through mediating emotional communication.

2.1 Emotional Communication

Communication is one of the basic human needs. The intention behind communication is not only to exchange information, but also to mediate emotions. Emotional communication has been conceptualised as a process of mutual influence between the emotions of communication partners [2]. Emotional communication happens every day of our lives, either being more conscious through facial or vocal channels, or being unconscious through tactile channel. It has been found out that humans are able to communicate at least eight emotions through touch, i.e. anger, fear, happiness, sadness, disgust, love, gratitude, and sympathy [26].

The study of emotions has flourished in different fields. Based on neuroscience models of emotion, appraisal theories of emotion, prototype approach, and social constructivist theories of emotion, Bartsch and Hbner [3] have outlined a theoretical framework that introduces four working definitions for emotional communication, which can be defined as *1) a process of reciprocal activation of emotional brain systems; 2) a process of information exchange about cognitive appraisals; 3) a process of reciprocal activation of emotional scripts; and 4) a process of symbolic negotiation of emotions.*

There has been substantial research investigating the implications of emotional communication in clinical context [6], musical performance [28], and mother-child relationships [13]. Emotional communication also plays an important role in romantic relationships, its impact has been demonstrated in a number of studies. Findings from a questionnaire study involving 581 couples highlighted that relational satisfaction and partners attachment style are partially mediated by the emotional communication between the partners [20]. Another qualitative research which engaged 29 couples in discussing a problem that they had been having in their relationship showed that emotional communication may both influence and be influenced by relationship satisfaction and partners' general beliefs about close relationships [18].

2.2 Prior Art for Mediating Emotional Communication in the LDR Context

To bridge the gap between people living apart, there has been a growing interest in exploring ways to utilise CMC technology for supporting the mediation of emotional communication in LDRs among HCI researchers. One line of research has dedicated to utilising everyday objects in connecting people over distance through implicit interaction. Early work introduced a pair of remotely located bed environments where each uses pillows and curtain as tangible interfaces and ambient display to support intimate communication over distance through

aural, visual, and tactile manifestations of subtle emotional qualities [16]. Chang et al. proposed a pair of interactive picture frames as a semi-ambient display for remote couples to develop their personal emotional language and enhance emotional communication between them [7]. Chung et al. used two paired cups as communication interfaces to promote emotional interaction by enabling two remotely located individuals to share feelings of drinking [8].

Another line of research has focused on communicating intimacy for couples in LDRs through subtle and implicit actions to indicate the presence of the distant loved one and express the affection for the remote partner, e.g. "I love you" or "I'm thinking of you". Kaye et al. [31] built a virtual system which enables LDR couples to click a circle which fades over time on the computer screen to indicate the remote presence and convey a subtle message of "thinking of you". Lottridge et al. [35] designed MissU system, which enables emotional support between remote couples by sharing music and background sounds to feel the presence of and signify thinking of the remote partner. Tsetserukou et al. [47] proposed a wearable humanoid robot which consists of a set of haptic devices allowing 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.

Li et al. [34] conducted a systematic analysis of 52 LDR systems and using a synthesis of four main design-relevant attributes. They used attribute categories of form factors, modalities, and message types of the systems, as well as to the evaluation approaches. As a conclusion, they came up with key design implications that highlight the emphasis and gaps in the current research, which gives a comprehensive overview of the HCI research on different emotional communication systems for LDRs.

3 The Framework

Prior frameworks have emerged in the area of intimacy and computer-mediated communication (CMC). Vetere et al. [49] present a framework distinguishing themes that emerge between, before, during interaction, and as a consequence of the intimate interaction. Before the interaction, the conditions for intimate interaction require trust, commitment and self-disclosure. During the interaction, the constituents of the intimate acts include themes of emotional, physical, expressive, reciprocity and public and private. The consequences of intimate interaction can result the feeling of presence-in-absence. However, Vetere et al. point out that intimate relationships are strong but vulnerable, and intimate interactions can result also misunderstandings. Gooch and Watts [19] proposed a design framework for social presence that consists of six factors, i.e. *personalisation*, *sensory medium*, *effort*, *openness of the system*, *metaphor of use* and *fleeting vs realised output*. They also point out that there exist extraneous factors which are related to, but not directly incorporated into, the communication medium, and which have an impact on social presence and important for sup-

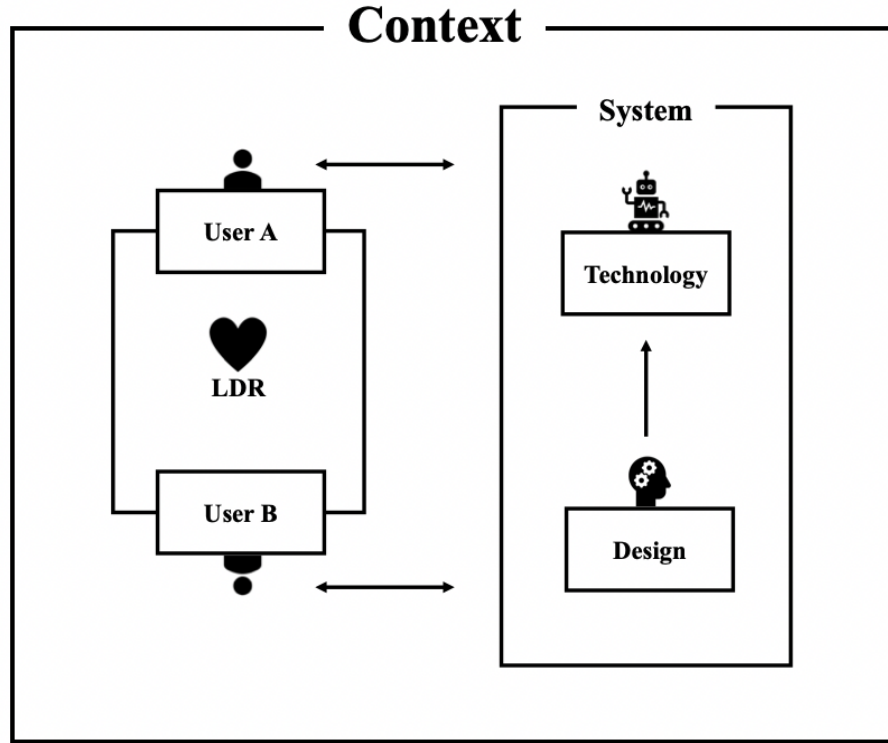


Fig. 1. The key concepts of Computer-Mediated Communication (CMC) between couples in Long-Distance Relationships (LDRs).

porting intimate relationships over distance. In our research, we focus especially on LDRs, and address the design space of CMC systems from this viewpoint.

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 (see Figure 1). Both design and technology influence on the overall user experience (UX), and play a role in its success. In addition, there are other aspects that need to be taken into account when designing for this specific user group. As a well-established tradition of user-centric design emphasises, the user, his/her needs, skills and preferences should be taken into account when designing any systems for them [41]. 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 taken into account. 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 [15].

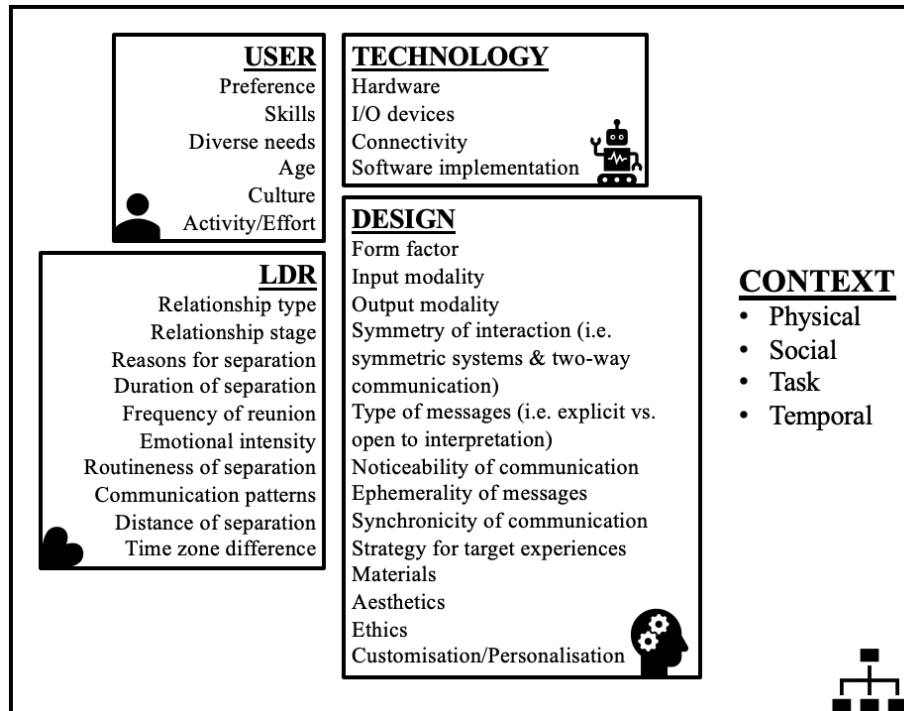


Fig. 2. The framework for designing CMC systems for LDRs.

The presented concepts form the main dimensions of our conceptual framework for designing CMC systems for LDRs (see Figure 2), and are explained in detail in the following five subsections.

3.1 User

As can be argued for any HCI concept, user is in the centrum when designing an interactive system. There is a vast amount of research on how individuals use the technology differently, as well as numerous design methods that focus on how to take into account the users the system is designed for. For instance, personas, i.e. archetypes of users [9], is a well-known method to guide the designer in his/her decisions. The diverse needs and the preferences of the target user are essential in formulating the design concept, and addressed through different user research methods collecting data of the practices and preferences of the people. Related to the preferences, the willingness to put in effort/activity that is required from the users behalf, may vary between users. Considering the skill levels of the target users is important factor to take into account, especially the distinction between novice and expert users has gained much attention when designing interactive systems [39]. Also, the users age plays a role when consid-

ering the technical solutions, especially when designing technology for elderly. In the context of LDR, it is important to remember that the couples can be in a long-term relationship, even lasting for the lifetime, and the age spectrum can be wide. Cultural background is also an interesting aspect to take into account, and may affect e.g. on how the user perceives different design solutions [46]. Thus, as the main attributes related to the user dimension the framework, we define *Preference, Skills, Diverse needs, Age, Culture, Activity / Effort*.

3.2 LDR

A human-centred design thinking process starts from empathising with the user, i.e. the LDR couples. It is essential to understand the relationship type, relationship stage, and reasons for separation, in order to gain a deep and empathic understanding of the target user. LDR can be narrowly defined as an intimate relationship in which the couple is separated by a geographical distance that restricts physical contact and face-to-face communication [33], yet LDR is not limited to romantic relationships. A significant number of individuals have to live apart from their loved ones due to educational demands, career pursuits, military duty, emigration and such circumstances [1] [36] [45]. These reasons for separation have formed three main types of LDRs, i.e. LD friendships [43], LD family relationships [37], and LD romantic relationships [22] which can be further categorised into a series of stages, that is, casually dating, seriously dating, engagement or married [1]. Every case is significantly different when it comes to an LDR. Duration of separation, frequency of reunion, emotional intensity, routineness of separation have been highlighted as important differences in LDRs [36]. Another important difference in LDRs is communication patterns. It has been noted that the communication patterns vary dramatically in LDR couples, as they use various communication channels to enhance intimacy [10], and use different strategies in different communication channels to maintain their relationships over distance [12]. Distance of separation pose all kinds of barriers to LDR couples. Maintaining an LDR in a different time zone could make it even more challenging. Time zone difference leads to unsynchronised daily life and schedules, which has been pointed out as one of the main challenges in LDRs [33]. However, there has been little effort made to address this issue for LDR couples who have to live in large different time zones. Thus, we define *Relationship type, Relationship stage, Reasons for separation, Duration of separation, Frequency of reunion, Emotional intensity, Routineness of separation, Communication patterns, Distance of separation, and Time zone difference* as the main attributes related to the LDR dimension of the framework.

3.3 Technology

LDR systems employ a vast array of technological hardware and input-output devices embedded or attached to them. Hardware can either be off-the shelf (e.g. a commercial smart device) or custom made (e.g. a decorative household item embedded with new technology construct built with an electronics toolkit

[23]). Input devices can be traditional ones such as joysticks and microphones, or they can be more novel ones with advanced computational capabilities such as cameras with gesture recognitions or touch-sensitive displays. All LDR systems utilise some kind of connectivity solutions, based on e.g. Bluetooth, cellular network or WIFI. LDR solutions are programmed to include the necessary software implementation, and the exact implementations are highly dependent on the requirements of the system. Thus, we define *Hardware*, *I/O devices*, *Connectivity*, and *Software implementation* as the main attributes related to the technology dimension of the framework. It is however not the focus of our framework to describe the technical details of the LDR systems.

3.4 Design

With the rapid development of technologies, the means of remote communication for LDR couples have transformed from the old communication platforms which consisted of handwritten letters and phone calls to numerous newer communication channels enabled by CMC technology. New form factors and user interfaces are emerging beyond conventional screens. Li et al. [34] identified a number of design attributes through a systematic literature review of the design of systems which support emotional communication between LDR couples. The main design attributes are form factors, interaction types, nature of messages and strategies for expressing relatedness. Specifically, input modality, output modality and symmetry of interaction (whether the systems used by both ends are symmetric and whether the communication is two-way) are further analysed under interaction types. Type of messages (i.e. explicit vs. open to interpretation), noticeability of communication, ephemerality of messages, and synchronicity of communication are further analysed under nature of messages. Hassenzahl et al. [24] identified current six strategies used in published artefacts to mediate a relatedness experience for intimate relationships, which are: *awareness*, *expressivity*, *physicalness*, *gift giving*, *joint action*, and *memories*. These strategies support the design of technology-mediated relatedness which is important for humans psychological well-being, and therefore should be taken into account when designing experience-oriented technology for LDR. In addition to the attributes that have been identified in [34], we also consider materials, aesthetics, customisation/personalisation, and ethics should be taken into account in the design process. It has been found out that interacting with different types of materials can evoke particular practice in which materials serve a role in carrying certain design intentions and creating a unique UX [29]. Aesthetics is a well-known design attribute which satisfies peoples senses and gives a feeling of pleasure that results from sensory perception [25]. Another two well-known design attributes that have been suggested that should be taken into account when designing for LDRs are customisation and personalisation [19] [33]. Customisation plays a subsidiary yet important role in design, it can empower LDR couples as skilled practitioners to use technologies in their own creative ways to meet their diverse needs [33]. Similarly, personalisation makes an object become meaningful and symbolic to users [19]. Enabling customisation/personalisation in design makes

a standard object becomes a one-of-a-kind, which thereby forms an emotional bond to users. Last but not least, it is worth noting that ethical issues could arise while mediating intimate feelings or actions through technology. Privacy has been viewed as significant to individuals. Despite that users may raise concerns about experiencing intimacy through technology [33], it has been revealed that ethics considerations were largely not addressed [34]. Thus, we define *Form factor*, *Input modality*, *Output modality*, *Symmetry of interaction*, *Type of messages* (i.e. *explicit vs. open to interpretation*), *Noticeability of communication*, *Ephemerality of messages*, *Synchronicity of communication*, *Strategy for target experiences*, *Materials*, *Aesthetics*, *Customisation/Personalisation* and *Ethics* as the main attributes related to the Design dimension of the framework.

3.5 Context

Context of use is an important factor when investigating human-computer interaction. It has given rise to an entire sector of research among computer science, context-awareness, which can be tracked back to the Mark Weisers vision of ubiquitous computing [50]. He visioned that computers of the 21st century would be able to capture context information and adapt their behaviour to support users tasks. The adapted behaviour of the system can vary between different levels of automation, allowing the user a chance to initiate or confirm the device actions [2]. It has been pointed out that the level of automation should inversely correlate with the uncertainties in context recognition to avoid misplaced device actions [14]. A widely used definition for context states that "context is any information that can be used to characterise the situation of an entity" [15]. However, when designing or evaluating interactive systems, it is meaningful to structure the context in more detail, as for instance suggested by Bradley and Dunlop [5], who distinguish between physical, social, task, and temporal contexts. The physical context of technology use can be determined through different environmental sensors, and can influence e.g. the volume, brightness of the display lights. Social context defines much of the norms the user is expected to behave with technology, and e.g. smart glasses in the company with others [32], and influences on the acceptability of the technology. Task context relates to the goals the user has, and what are the resources and constraints influencing it [5]. Temporal context relates to the time of, e.g., a month or day [30], or the duration and frequency of interaction [40]. Thus, similarly to [5], in our framework we see it fit to distinguish between the *physical*, *social*, *task* and *temporal* contexts.

4 Example Systems Analysed with the Framework

To validate our conceptual framework, in the following we analysed six existing products and examples of research works, designed for emotional communication between LDR couples. The last example, Ambient Picture Frame Display, presents the authors own work, with the first design prototype presented here. These system examples were chosen to represent a wide variety of CMC systems with a wealth of different attribute choices.

4.1 The Analysis

We developed a template based on our framework for analysing the example systems. The results of the analysis are reported in Figure 1 to 8.







<p>Beam® Smart Presence™</p> <p>A telepresence robot that supports visual communication by allowing users to seamlessly move within the space and engage in real time across distance [50].</p> <p>Image source: https://www.suitabletech.com</p> 	
<p><u>User</u></p> <p>This product is mainly designed for business use, such as remote conference calls. But it can be adapted in the use case of LDRs [50]. It works similarly to a video chat system which provides visual communication but the robot is featured with the mobility to move around. It can be used as a multi-channel communication tool which would meet the users' diverse needs. On the other hand, it requires more skills and effort to control the robot.</p> 	<p><u>Technology</u></p> <ul style="list-style-type: none"> • Hardware: screen, video and audio devices, body • Connectivity: Internet • I/O devices: using the Beam® App and controlling the Beam® robot as input; the mobile video chat system supported by the Beam® robot as output • Software: Beam® App 
<p><u>LDR</u></p> <p>This product can be adapted in any types of LDRs at any stage. The emotional intensity is considered strong when having visual communication with a distant loved one. The communication pattern is explicit, intimate and can be both synchronous and asynchronous. With mobility and autonomy, the robot enables remote couples to be able to participate in the mundane parts of each other's everyday routines. The availability of being able to connect with each other both synchronously and asynchronously better supports LDRs.</p> 	<p><u>Design</u></p> <ul style="list-style-type: none"> • Form factor: movable or semi-autonomous object • Input modality: non-typing touch via smartphone or tablet, PC controlled, speech, visuals • Output modality: visuals, speech, object movement • Symmetry: can be symmetric or asymmetric, two-way • Type of messages: explicit • Noticeability: noticeable to others • Ephemerality: disappears with user actions (e.g. turning off the system) • Synchronicity: synchronous and asynchronous • Strategy: physicalness, awareness • Materials: reinforced polymer • Aesthetics: the appearance is suitable for business usage, but might be less pleasant in romantic settings. • Ethics: may raise privacy and hyper-connectivity issues due to the mobility and autonomy of the robot, particularly those still in the early stage of their relationships [50]. • Customisation/Personalisation: not available 
<p><u>Context</u></p> <ul style="list-style-type: none"> • Physical: at home • Social: can be used to connect with the remote partner's family and friends • Task: interacting with the Beam® App and controlling the Beam® robot • Temporal: it can be freely used at any time of the day, as the robot has mobility and autonomy which can be controlled by the paired user, so the user is not required to control the robot all the time. 	

Fig. 3. Beam® [51] analysed with the framework.


<p>Kissenger</p> <p>A smartphone accessory that provides a physical interface which can sense a kiss and transmit realistic kissing sensations to the paired user in real time [44].</p> <p>Image source: <i>Imagineering Institute</i>, http://imagineeringinstitute.org/kissenger/</p> <div style="text-align: right;">  <p>KISSENGER World's first mobile kiss messenger</p> </div>	
<p><u>User</u></p> <p>This product is designed to connect friends, families and couples who live apart (at any age from any culture). Interestingly, it can also connect idols and their fans. It is suitable for users who wish to strengthen intimacy over distance. It does not require much effort or skills to use it. However, the functions are limited with transmitting kisses and the gadget is not available for personalisation, which might not be sufficient to meet users' diverse needs.</p>	<p><u>Technology</u></p> <ul style="list-style-type: none"> • Hardware: Bluetooth, sensors and actuators, a scent tank, a vibration motor, and a smartphone connector • Connectivity: Bluetooth, Internet • I/O devices: using the Kissenger App and kissing the silicon lip on the Kissenger as input; the kissing back sensation coming from the Kissenger as output • Software: Kissenger App
<p><u>LDR</u></p> <p>This product is mainly designed for any types of LDRs at any stage, but it also supports the interaction between idols and their fans. The emotional intensity is considered strong when giving or receiving a kiss. The communication pattern is implicit, synchronous and intimate. Since the communication is in real time, it requires the users from both ends to be active at the same time. This might cause inconvenience for the users who have unsynchronised daily life due to large time zone differences.</p>	<p><u>Design</u></p> <ul style="list-style-type: none"> • Form factor: carried, portable object • Input modality: touch, non-typing touch via smartphone • Output modality: haptic, vibration • Symmetry: symmetric, two-way • Type of messages: open for interpretation • Noticeability: private • Ephemerality: disappears by itself • Synchronicity: synchronous • Strategy: physicalness, awareness, joint action • Materials: plastics and silicon • Aesthetics: it might be too big as a portable smartphone accessory. • Ethics: a number of ethical issues that may arise by using this device have been discussed in [44], e.g. failing to return a kiss. • Customisation/Personalisation: not available
<p><u>Context</u></p> <ul style="list-style-type: none"> • Physical: relaxing and private environment • Social: preferably no other people around and the user is feeling lonely or missing a distant loved one • Task: sending kisses to a distant loved one by interacting with the Kissenger APP first, and then kissing the silicon lip on the Kissenger device. • Temporal: it can be used at any time of the day when the user is not occupied, having a relaxing time and missing a distant loved one. Given both users need to be active for the communication, the user might need to schedule a convenient time with the paired user for the kiss, particularly in large time zone separation cases. 	

Fig. 4. Kissenger [44] analysed with the framework.





<p>Hug Shirt™</p> <p>A high-tech garment that captures the pressure, duration and location of the touch, the skin warmth, and the heartbeat rate of the user, and simulates the experience of being embraced by a distant loved one to the paired user synchronously [11].</p> <p>Image source: <i>CuteCircuit</i>, http://cutecircuit.com/the-hug-shirt/</p>		
<p><u>User</u></p> <p>This product is designed for people (at any age from any culture) who wish to connect with a distant loved one, such as friends, families and couples. It is suitable for users who prefer a mediated feeling of physical intimacy over distance. It does not require much effort or skills to use it. However, the functions are limited to hug sensations, and the garment is not available for personalisation, which might not be able to support users' diverse needs.</p>	<p><u>Technology</u></p> <ul style="list-style-type: none"> • Hardware: Bluetooth, sensors and actuators • Connectivity: Bluetooth, Internet • I/O devices: using the Hug Shirt™ App, hugging oneself while wearing the Hug Shirt™ as input; the mediated hug sensation coming from Hug Shirt™ as output • Software: Hug Shirt™ App 	
<p><u>LDR</u></p> <p>This product is designed for any types of LDRs at any stage. It mediates emotional communication between the two remote parties when giving or receiving a hug. The communication pattern is implicit, synchronous and intimate. However, receiving hugs when the user's attention is required for learning, working and such situations might be disturbing. As the hug is transmitted to the paired user synchronously, it might be insufficient for those who have unsynchronised daily life due to large time differences.</p>	<p><u>Design</u></p> <ul style="list-style-type: none"> • Form factor: wearable smart garment • Input modality: touch, non-typing touch via smartphone or tablet, physiological data • Output modality: haptic, temperature • Symmetry: symmetric, two-way • Type of messages: open for interpretation • Noticeability: private • Ephemerality: disappears by itself • Synchronicity: synchronous • Strategy: physicalness, awareness, expressivity • Materials: smart garments • Aesthetics: designed by an established fashion company and has received a number of awards. • Ethics: receiving hugs out of blue or when the user is occupied may be disturbing. • Customisation/Personalisation: not available 	
<p><u>Context</u></p> <ul style="list-style-type: none"> • Physical: relaxing and private environment • Social: preferably no other people around and the user is feeling lonely or missing a distant loved one • Task: sending hugs to a distant loved one by interacting with the Hug Shirt™ App first and then hugging the user himself/herself while wearing the Hug Shirt™ • Temporal: it can be used at any time of the day when the user is not occupied, having a relaxing time and missing a distant loved one. Given the synchronicity required in the communication, the user needs to consider if it is an appropriate time to send a hug to the paired user, particularly those who have to deal with large time zone differences. 		

Fig. 5. Hug Shirt™ [11] analysed with the framework.





<p>Frebble</p> <p>A mediated touch device that provides the tactile sense of holding hands with a loved one in real time over distance through the squeeze of a hand [17].</p> <p>Image source: <i>Holland Haptics</i> http://www.myfrebble.com</p>		
<p><u>User</u></p> <p>This product is designed to connect friends, families and couples remotely through simulating the feeling of hand-holding. However, it might not work for the users who do not like holding hands. It is more suitable for connecting children and parents, or grandchildren and grandparents. It does not require much effort or skills, but the function is limited within holding hands and the gadget is not available for personalisation, which might not be sufficient to meet users' diverse needs.</p>	<p><u>Technology</u></p> <ul style="list-style-type: none"> • Hardware: Bluetooth, pressure sensors, vibration motors, squeeze bar, multicolour LED light • Connectivity: Bluetooth, Internet • I/O devices: using the Frebble App and squeezing the Frebble as input; the mediated hand-holding sensation coming from the Frebble as output • Software: Frebble App 	
<p><u>LDR</u></p> <p>This product is designed to support any types of LDRs at any stage. However, it might be less useful for remote couples who are already in a more mature stage. It strengthens the emotional intensity when having visual communication while holding hands together with a distant loved one. The communication pattern is subtle, implicit, synchronous and intimate. Since the communication is in real time, it requires both to be active at the same time. This might be less considerate for those who have unsynchronised daily life with large time zone differences.</p>	<p><u>Design</u></p> <ul style="list-style-type: none"> • Form factor: carried, portable object • Input modality: touch, non-typing touch via smartphone or tablet • Output modality: haptic, vibration • Symmetry: symmetric, two-way • Type of messages: open for interpretation • Noticeability: private • Ephemerality: disappears with user actions (e.g. turning off the system) • Synchronicity: synchronous • Strategy: physicalness, awareness, joint action • Materials: plastic and rubberised pad • Aesthetics: negative feedback has been pointed out regarding the appearance of the device [48]. • Ethics: there might be digital ethics for young users, and may raise ethical concerns for inappropriate use of technology [48]. • Customisation/Personalisation: not available 	
<p><u>Context</u></p> <ul style="list-style-type: none"> • Physical: relaxing and private environment • Social: the user is feeling lonely or missing a distant loved one • Task: holding hands with a distant loved one by interacting with the Frebble first and then slightly squeezing the Frebble as if holding hands with a distant loved one. • Temporal: it can be used at any time of the day when the user is not occupied, having a relaxing time and missing a distant loved one. Given both users need to be active for the communication, the user might need to schedule a convenient time with the paired user for the hand-holding, particularly in large time zone separation cases. 		

Fig. 6. Frebble [17] analysed with the framework.





<p>Connected Candles</p> <p>A paired set of candle stands, each including a traditional and an electric candle. When the user lights the physical candle (with real fire), the electric candle of the paired candle stand in the remote location lights up [23].</p> <p>Image source: [23]</p>		
<p><u>User</u></p> <p>The (research) prototype has been designed for LDR couples, as recorded in the design process, but can also be used for affective communication between other people, e.g. a grandmother and the child's family. The concept utilises existing metaphors and familiar actions of lighting a candle (with a match stick), and is easy and simple to use. It is pleasant for the users who like burning candles, but the cultural meaning of burning candles may vary. The tangible UI does not require skills with computers or other technology.</p>	<p><u>Technology</u></p> <ul style="list-style-type: none"> • Hardware: Arduino HW, flame sensor • Connectivity: WIFI • I/O devices: a candle and matches input; electric candle as an ambient display output • Software: Arduino SW 	
<p><u>LDR</u></p> <p>Connected candles support any LDR couples at any level of their relationship. It is designed for moments where the user wants to create an emotional connection, e.g. for being lonely or feeling romantic. The communication pattern is subtle, implicit, and synchronous. Since the communication is in real time, and does not require actions in the remote end. The ambient light display can be on any time, but is preferred to be used in dim light conditions, e.g. in the evenings. Thus, time zone differences larger than a few hours do not fit well with the concept.</p>	<p><u>Design</u></p> <ul style="list-style-type: none"> • Form factor: Semi-fixed, movable object • Input modality: gestures (lighting the candle with a match stick or similar) • Output modality: visual, light turns on • Symmetry: symmetric, two-way • Type of messages: open for interpretation • Noticeability: public • Ephemerality: disappears with user action (turning of the candle) • Synchronicity: synchronous • Strategy: awareness • Materials: ceramics, candles, fire • Aesthetics: aesthetics driven concept with ceramics design and candle light. • Ethics: the user lighting the candle must remember to supervise it (in her/his end only) for the fire safety. Additionally, the cultural meaning of burning candles may vary. • Customisation/Personalisation: available 	
<p><u>Context</u></p> <ul style="list-style-type: none"> • Physical: relaxing and private environment, dim lighting conditions • Social: the user is feeling lonely or missing a distant loved one • Task: lighting a candle, enjoying the ambient light of a candle • Temporal: considering the dim light conditions, evening use preferred. Ambient illumination is long-lasting, and does not require actions. Big time zone differences hinder the use. 		

Fig. 7. Connected Candles [23] analysed with the framework.





<p>Ambient Picture Frame Display</p> <p>A customisable ambient picture frame display that mediates couples who live apart with large time zone differences. The city landscape in the picture frame switches between day and night display synchronously with the time of the remote partner's location. The subtle switching of the hearts indicates receiving a secret code from the remote partner (e.g. I love you). When the interaction between the LDR couple is low, the content in the picture starts to fade away subtly and slowly.</p> <p>Image by the authors</p>		
<p><u>User</u></p> <p>This prototype is designed to support simpleness, light-weight communication, privacy, subtleness, customisation, and creation of secret codes or symbols for LDR couples. It does not require much effort or skills with computers or other technology. The picture frame display can be customised by the users, which is relatively able to fit diverse tastes appeal to different ages and cultures.</p>	<p><u>Technology</u></p> <ul style="list-style-type: none"> • Hardware: electrochromic display, Arduino HW • Connectivity: WIFI • I/O devices: real-time clock, touch sensors as input; electrochromic displays as output; • Software: Arduino SW 	
<p><u>LDR</u></p> <p>This concept is specifically designed for couples who have to deal with a large time zone difference in serious LDRs. But can be also adapted on other types of LDRs, e.g. elder parents with his/her adult children who live apart with time zone separation. It forms emotional bonds to a remote partner when noticing the subtle switching of the ambient display. The communication pattern is private, subtle, implicit, lightweight, and asynchronous. The concept works busy LDR couples with time zone differences.</p>	<p><u>Design</u></p> <ul style="list-style-type: none"> • Form factor: carried, portable object • Input modality: non-typing touch via smartphone or tablet • Output modality: graphics, visuals • Symmetry: symmetric, two-way • Type of messages: open for interpretation • Noticeability: private • Ephemerality: disappears by itself • Synchronicity: asynchronous • Strategy: awareness, expressivity • Materials: cardboard, plastics • Aesthetics: A simple concept with a customisable picture frame display could better fit varied tastes • Ethics: It may lead to negative emotions when the user notices the display is fading away due to having low interaction with a remote partner. • Customisation/Personalisation: available 	
<p><u>Context</u></p> <ul style="list-style-type: none"> • Physical: the picture frame can be placed anywhere • Social: the user is feeling lonely or missing a distant loved one • Task: noticing the subtle changes of the displays in the picture frame • Temporal: it can be used at any time of the day when the user feels relaxed 		

Fig. 8. Ambient Picture Frame Display analysed with the framework.

4.2 Summarising the Analysis Results

The analysis of the six example systems reveals that very different solutions are used for similar or at least overlapping purposes. For example, there are wearable (HugShirtTM [11]), portable (Kissinger [44]) and semi-autonomous (Beam[®] [51]) form factors to enable emotional communication. Further attributes related to users, LDRs, technology, design and context of use could be compared and contrasted to highlight the similarities and differences of the solutions. For example, in this sample of CMC systems, most systems were designed to support synchronous communication where the user and the paired user are required to be active at both ends. While in the cases with large time zone differences, this attribute hinders the use of the systems, as both parties have to agree on a convenient time for the synchronous communication, e.g. Kissenger [44], Hug ShirtTM [11], Frebble [17], Connected Candles [23]. Failing to find an appropriate time to initiate the synchronous communication might result in disturbing moments for the paired user, e.g. feeling hug sensations out of blue when the paired users attention is needed at work. Systems that enable both synchronous and asynchronous communication can better support LDRs with large time zone differences, e.g., Beam[®] [51]. Such analytic observations from the systematic analysis can help identify "design gaps" and help address them in further system designs.

5 Discussion

The commercial example systems are designed to fit a wider range of end users, which often aim to be used for all types of LDRs at any stage. However, the one-size-fits-all strategy does not work for every type of LDR, e.g. the design of Frebble might not fit LDR couples who are at a more mature stage of their relationship or people who do not like holding hands [48]. Customisation and personalisation are well-known design approaches that can make a product more appealing to users varied tastes and more likely to meet their diverse needs- Four out of the six reviewed example systems do not equip such feature in the design but we suggest this is an aspect that is worthwhile considering in all design efforts.

The novelty of our framework lies in the integration of five essential dimensions and their related key attributes that should to be taken into account when designing CMC systems for mediating emotional communication for LDRs. Previous work has proposed a provisional framework [19] that focused on identifying important factors when designing intimate communication devices which convey social presence at a distance so as to open up one of the possibilities to strengthen the feelings of presence in LDRs. Moreover, Benford et al. map different behaviours in sensing-based UIs and discuss how the expected, sensed, and desired interaction aspects do not always overlap perfectly [4]. Compared to us, they focus more on the conceptual aspects in the actual interaction event and system behaviour, and their framework can be seen as complementary to our approach. The focus of our framework has been primarily put on building a

formalised design framework with particular attention to identify the essential dimensions and their key characteristics needed for designing computer-mediated emotional communication systems for LDRs. We acknowledge, however, that more work is needed before it could function (e.g.) as a concrete tool for designers. We have now initially validated the framework by analysing the example systems and believe that the structured approach presented in this paper has value for researchers and designers addressing the CMC systems for LDRs. With the design has been conceived in more detail, it is then possible to conduct further evaluation with specific frameworks according to the domain, e.g. looking at the qualities for tangible interfaces [27] or musical interfaces [38].

The analysis of the six example systems show that our framework can be applied in practice for categorising and investigating their different aspects in a systematic way. The framework helps paying attention to different details, and makes a comparable presentation of different systems and system versions easier. We acknowledge that the sample of analysed systems is small, but we believe our findings provide indication and potential gaps in the overall design space. In the future, we aim to develop the framework further, and use it as a basis for a design tool to be used in brainstorming or participatory design sessions.

6 Conclusion

In this paper, we have presented a conceptual framework for defining different aspects for designing computer-mediated emotional communication systems for LDRs. 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. We have also validated the framework by analysing five existing products in the context of the framework, as well as one of our own research prototypes. The analysis indicates that our framework can help in identifying gaps in the system concept designs, and helps in systematic analysis of the concepts. As future work, we intend to apply our framework for different phases of a design and evaluation process for computer-mediated emotional communication systems for couples in LDRs, and develop the framework further towards a concrete design tool.

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