

Review of Unconventional User Interfaces for Emotional Communication between Long-Distance Partners

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ABSTRACT

New form factors and user interfaces for computer-mediated communication are emerging. The possibilities to use these systems for emotional communication are interesting, and recent years have witnessed the appearance of a versatile range of prototypes. In this paper, we present the results of a systematic literature review on research addressing the design of systems with unconventional user interfaces for emotional communication, focusing on the use case of facilitating long-distance relationships. We reviewed a body of 150 papers resulting from a systematic search, further analysis scoping the body to 47 papers, containing altogether 52 prototypes that were relevant for our focus. We then analysed the characteristics affecting the interaction mediated by these systems and their user interfaces. We present the results related to the design attributes, e.g., form factors, modalities, and message types of the systems, as well as to the evaluation approaches. As salient findings, touch input and visual output are the most common interaction modalities in these systems, and their evaluations lack in-the-wild studies, especially on long-term usage.

Author Keywords

Literature review; romantic; emotional communication; intimate communication; remote presence; presence-in-absence; romantic communication; long-distance relationship; communication of emotions.

ACM Classification Keywords

H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION

Means for remote communication are emerging beyond conventional smart phones and video calls. Tangible and multimodal interfaces, and new form factors for computer mediated communication have been proposed for emotional

communication and mediating remote presence with loved ones (e.g. [26, 27, 42, 43, 47]). Today's *de facto* audio-video and text communication channels, e.g. phone and video calls, chats and messages, lack versatility, and there is a need for richer ways to communicate and express the feelings of caring, longing and intimacy.

The topic of communication in long-distance relationships (LDRs) in which the partners are living apart, separated by a substantial geographical distance, has been addressed by HCI research from many angles. The phenomenon has been investigated from the viewpoint of communication channel switching [45], video communications [34], conflict resolution strategies [29], and cultural point of view [1]. It has been suggested that communication technology design can be used to support long-distance relationships. Hassenzahl et al. [20] identified six strategies that are used to create a relatedness experience between the communicating parties: *awareness*, *expressivity*, *physicalness*, *gift giving*, *joint action*, and *memories*. Research has proposed new types of devices and user interfaces, which aim to better support the partners in LDR.

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 work by Hassenzahl et al. [20], which presents a literature review of works published prior to the end of 2009. Since that date however, tools e.g. for 3D fabrication and functional prototyping (e.g. Arduino kits) have greatly developed, making creation and trials of novel systems easier. Another paper by Gooch and Watts [13] 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 are exemplified by one system design. To form a more solid basis for this research and design theme, we argue it is timely to revisit the space, and conduct an analysis of emotional communication systems for partners in remote relationships.

In this paper, we present the results of a systematic literature review of system designs which support emotional communication between partners, focusing especially on long-distance relationships. Timewise, we continue from

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Hassenzahl’s literature review [20] ending to 2009, and analyse research published by ACM in 2010-2017. Whilst Hassenzahl et al. [20] focused on the connectedness *strategies*, our primary interest is in analyzing the characteristics of the systems with *unconventional user interfaces* (UI), i.e. UIs that use interaction solutions beyond visual mobile device applications. We analyse the systems through a broad set of design attributes, including the strategies identified in [20]. As a contribution, we present

- a systematic overview of design attributes and their appearance in systems for emotional connectedness between couples,
- analysis of user evaluation methods applied in the evaluations of the systems.

Our paper aims to reveal the emphasis and gaps in the current research on designing systems for emotional communication between partners. By understanding the current state of research, we can identify new opportunities for future work.

SCOPE AND METHOD

In our research, we are interested in how long-distance relationships can be supported by computer mediated emotional communication which uses unconventional user interfaces. For our systematic literature review on unconventional user interfaces for intimate relationships, we used the ACM Digital Library (DL) database, articles dated between the years 2010 and September 2017. The ACM DL was chosen to form the scope for the analysis as it covers 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, intimate communication*. This set of search terms was built on the search terms in Hassenzahl et al. [20]. The search was complemented with terms *long-distance relationship* and *communication of emotions*, which supported our focus on computer-mediated emotional communication in long-distance relationships. We searched the keywords in 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 out of the scope of the study were excluded manually. In order to be relevant for our analysis, the paper had to present a prototype or system for interpersonal communication, whose UI went beyond conventional mobile phone, PC and social media use. Thus, papers introducing theoretical frameworks, studies of current practices (e.g. phone, video chat), or conventional mobile phone apps only, were excluded. Focusing our research on

communication between partners, we also excluded work that was clearly targeted to different user groups, e.g. communication between grandparents-grandchildren, or office workers, and focused on designs that aimed to support intimate communication and relationship between couples. Duplicates presenting the same system design, e.g. 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, describing altogether 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 according to the criteria independently by three researchers, and then discussed in detail. Design attributes and their characteristics were added and iterated, resulting the final codebook consisting the following main attributes for analysis: *form factors, interaction types, nature of messages* and *strategies for expressing relatedness*. The analyses of these attributes and their characteristics are presented in the next section. Following this, we present the analysis of the user evaluation methods applied in the reviewed studies, in order to provide understanding of the validity of the evaluations.

RESULTS OF THE ANALYSIS OF SYSTEM DESIGN ATTRIBUTES

Form Factors

The form factors used in mediating emotional communication between LDR couples by using unconventional UIs are summarised in Table 1. Here, phone, tablet, and PC/laptop were included in the analysis if they were part of a user interface, which included elements that were beyond the conventional textual or voice/video communication applications. Note that the total number shown in the Table 1 is larger than the number of analysed systems (i.e. 52), as some devices utilize a hybrid approach, i.e., combining multiple form factors. Example systems of selected categories are illustrated in Figure 1.

Form factor	No. of systems
Movable/Semi-fixed objects	24
Phone or tablet	18
Carried object	9
PC or laptop	5
Wearable – accessories	4
Wearable – clothes	3
Fixed Object	2
Other	1

Table 1. Form factors of the analysed systems (N=52).



Figure 1. Examples of different form factors that can support communication between partners in long-distance relationships.

The most common form factors turned out to be movable or semi-fixed objects, e.g., a pair of furry robotic pets that can be summoned by knocking on the lid of a closed box [6]. Smartphones and tablets were also popular form factors applied in designs that went beyond conventional communication applications. Some form factors took a hybrid approach, e.g., a dedicated object combined with a mobile smartphone [27]. Wearable devices in the form of clothes or accessories were also used, such as a smart garment that enables intimate, remote communication for a couple [23]. There were also some other form factors, e.g., a telepresence robot that allows users seamlessly move within the space and engage in real-time [56].

Interaction Types

This section presents the input and output modalities, and symmetry of the interaction between couples.

Input Modalities

The most common input modalities related to touching in different forms, see Table 2.

Input modalities	No. of systems
Touch	21
Non-typing touch via phone/tablet	15
Speech	11
PC controlled	9
Physiological	6
Typing	5
Object manipulation or object movement	3
Gestures, non-touching	2
Audio, non-speech	1

Table 2. Input modalities of the analysed systems.

Most commonly this was about touching an object, or utilising touch input over a mobile phone or tablet (typing excluded). Numerous devices in our analysis were designed to enable users to communicate by touching over a distance, e.g. allowing partners to feel the other person’s touch [26]. Input through a PC was mainly applied at video conferencing (for an example, see [56]). Physiological input modalities used were pulse, facial expressions and breath signals.

Output Modalities

Most commonly, the systems utilized graphics for output, see Table 3. This means was followed by haptics, vibration and speech. Lights and colours were also common in mediating emotional communication between remote partners.

Output modalities	No. of systems
Graphics visual	22
Haptic, vibration	16
Speech	14
Lights, colours	10
Text	8
Sound, non-speech	6
Temperature, heat	6
Shape changing	4
Object movement	2
Taste	1
Smell	0

Table 3. Output modalities of the analysed systems.

Symmetry of Interaction

Out of the total of 52 systems for mediating emotional communication between remote partners, 34 used the same device for both directions, e.g., a set of two bathroom mirrors that can be placed in each partner’s apartment, which enable leaving a message on a steamy bathroom mirror over a distance [44]. Altogether, 40/52 systems were designed for

two-way communication, e.g., a pair of stuffed bears that allow exchange of tangible expressions of emotions, such as hugs, in real-time [11]. Only 12 of the devices were designed for asymmetric communication, e.g., a pair of gloves that one sends finger movement through a flex glove and the other receives the vibrotactile sensations on their skin through a feel glove [47].

Nature of Messages

Explicit Messages vs. Messages Open to Interpretation

In our analysis, we divided the types of messages being sent or received from the devices into two types, messages that were open for interpretation and messages that were explicit. The results indicated that in 35 cases, the messages were open for interpretation. Examples in this category were, e.g., a remotely paired set of communicating chairs sensing the bodyprint of a distant loved one and mapping it to its paired device through colour and light [38]; or a multi-touch screen and vibrotactile display to enable bidirectional touch on a remote partner's cheek in real-time during a call [40]. On the other hand, 17 of the cases supported explicit messages, e.g., a pair of pillows that allowed couples, who did not see each other due to mismatches in daily routines, to leave messages for each other [5].

Noticeability of Communication by Others

Although privacy has been one of the targeted experiences for mediating emotional communication between remote partners, interestingly, the results revealed that in almost half of the cases (24/52), other people in the vicinity were able to notice the communication. Communication was made known through lights, colours, digital screens, sound, etc. For instance, a distributed tangible jigsaw puzzle that allowed remote partners to play remotely and synchronously through a table surface display, could also be seen by other people in proximity [36]. On the contrary, communication was more private through heat, haptics and vibrations, e.g., when sending heat to a distant loved one through a unique imprint of the his/her hands [14].

Ephemerality of Messages

Ephemeral UIs are temporal in nature, and disappear with time [8]. In terms of the ephemerality of messages, we divided messages into three types: messages that disappeared 1) by themselves, 2) when a new action (e.g. a message) was initiated by the sender, or 3) with an action by the receiver. Our results show that these different behaviours were found in 30, 5 and 17 systems, respectively. Thus, disappearing, ephemeral messages were clearly the most dominant type in the analysed systems.

Synchronicity of Communication

We also analysed whether the systems required synchronicity or not, that is, if both parties were required to be active for exchanging the messages in real-time. This was utilized e.g., at a dining table system that augmented and transported the experience of dining in order to create a sense of coexistence [55]. Our results show that 24/52 of the systems required synchronicity from the remote couples.

One the other hand, 28 of the systems were asynchronous. An example of this was a communication system that sent digital handwriting notes as personalised "gifts" to surprise a distant loved one, who would find those love notes automatically printed out [12].

Strategies for Experiencing Relatedness and Target Experiences

Table 4 presents the analysis of the systems based on Hassenzahl et al.'s categorisation of different strategies used to create a relatedness and mediate intimate relationship over distance with the support of technology [20].

Strategy	No. of systems
Awareness	22
Expressivity	18
Physicalness	13
Gift giving	2
Joint action	20
Memories	5

Table 4. Strategies for creating relatedness and mediating intimate relationships over distance (categories according to Hassenzahl et al [20]).

Additionally, we considered it interesting if the authors explicitly mentioned that the system was targeting to a certain experience, that is, aimed at eliciting a specific type of experience. These specifically articulated target experiences are presented in the following, with an example for each:

- Unobtrusiveness: a haptic virtual touch application enabling a feeling of a remote partner's touch simultaneously via vibrotactile cues [31]
- Playfulness and joyfulness: a wearable humanoid robot that reproduced hugging with a hugging animation [51]
- Personalisation: a system that sent drawn or typed symbolic digital love notes to a beloved remote person [12]
- Coincidences: notifying the user when similar actions by the remote partner happen simultaneously [53]
- Reassurance: automatically pushing the user's location information to the partner's mobile phone [3]
- Effortlessness: automatically sending a "smile" or a "handprint" to the twin device when sensing a touch and movement [48]
- Effortful investment: a pair of heavyweight boxes designed to enhance the visibility of effort when permitting the recipient to play back the sender's music composition [24]

EVALUATION METHODS APPLIED

To achieve a better understanding of the validity of the evaluation methods applied in the reviewed studies, we analysed the applied user study methods, number of participants, and the duration of the evaluation studies, see

Tables 5, 6, and 7. The analysis revealed that most of the studies were conducted in laboratory conditions, over a very short time frame, and with 2-20 test participants. Additionally, in many cases the participants were not remote couples in real life.

The biggest size of the sample involved in the evaluations was more than 300, with the wearable humanoid robot *iFeel_IM!* which was demonstrated at a number of conferences for people to experience [51]. By contrast, the smallest size of evaluation involved only one couple: The *SleepyWhispers* prototype was used for 8 weeks by a couple who lived at 120 miles from each other [15]. The longest duration of the user study was a period of 200 days: Different versions of the robotic pet *Furfur* were developed and applied to the paper author’s LDR as an autobiographical design exploration [6].

There were also 12 cases in our corpus that did not carry out any evaluation, while three of the studies had only one system but carried out multiple user studies. For instance, the authors conducted a two-month field test in a laboratory setting, and a three-month field test in an actual home with the *InPhase* system [53].

Study Types	Number of systems
Lab, controlled	16
Lab, uncontrolled	15
In-the-wild	12
No user study	12

Table 5. Evaluation methods used in the studies. (Some systems were studied in several studies.)

Number of participants	Number of systems
0	12
2-5	10
6-20	20
Over 20	11

Table 6. Numbers of participants involved in the user studies.

Duration of the user study	Number of systems
=0	12
<2h	3
<= 1 day	23
<= 1 week	4
> 1 week	10

Table 7. Duration of the user studies.

DISCUSSION

Our findings give a comprehensive overview of the HCI research on different emotional communication systems for long-distance relationships, and lead to several findings that can be further discussed.

Touch for Input, Visuals for Output

The analysis revealed that touch, either touching an object, phone or tablet, was the dominant input modality in the UI design. The importance of this modality aligns with the literature, where touch is highlighted for social communication and affection (e.g. [18]). Studies have shown that people are able to communicate emotions through mediated touch, and could also encode a number of emotions when using an input device [22]. For output modalities, visual feedback (graphics, lights) was dominant. Studies have shown that colour stimuli can invoke positive valence and as such they have more effect to convey positive emotional communication [41]. The difference between input and output modalities can be explained with several factors. For instance, touch output is a challenging channel to implement reliably and easily.

Combinations of haptic sensations, wearable technologies, ambient media, bio-signals, etc. 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, to date there has been little work setting out to understand how LDR couples could maintain an emotional connection through taste and smell.

There are many designs that 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 design challenge in future system design.

Towards Personalisation in Intimate Messaging

Messaging in the current commercial communication tools is often fairly “standardised”. Adding a personalised symbolic emotional communication feature is suggested [42]. Previous research has proven the merits of personalisation in designing technologies for LDRs [12, 14]. Customisation and personalisation both refer to tailored contents. The difference between these two terms is that customisation is user-tailored while personalisation is system-tailored [49]. It has been reported that the stronger the metaphor of the device – i.e. the more fixed it is – the less users seemed to enjoy using it [14]. LDR couples are a special user group with diverse needs, which not only reveals the potential of employing the strategy of personalisation, but also a need of taking customisation as a user-tailored approach when designing technologies for them.

It is worth noting the ethical issues that could arise while mediating intimate feelings or actions through technology. Ethics considerations were largely not addressed in depth in the analysed papers, although users raise concerns about experiencing intimacy through technology.

Weaknesses in Evaluations

Many related works show a lack of user participation, even though engaging users in the design process is a well-known requirement in HCI. As Gooch & Watts [14] argue, co-construction of the designed artefact, whether by casting or decoration, and the traces of loved ones that thereby embed some aspect of the person, are powerful contributors to the user experience of connectedness. Generally speaking, the size of the conducted evaluations in the reviewed papers was small, and strikingly, most of the recruited participants in the lab studies were actually not remote couples in real life. This naturally weakens the validity of the results of the studies.

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 works have indicated that mediating emotional communication through digital devices have 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.

Comparison to the Relatedness Strategies Ten Years Ago

In comparison with Hassenzahl et al.'s 2012 publication [20] (covering works to the end of 2009), the most common strategies both then and now were 'awareness' and 'expressivity'. The biggest change was with 'joint action', which now appeared in 38% of the systems, compared to the 8% reported by Hassenzahl. One reason for this development may be the better availability of prototyping kits today, enabling researchers to more easily construct systems utilizing unconventional interfaces.

Future Directions

In comparison to creating completely new devices, augmenting current technologies and integrating them into users' communication ecology could be more easy and beneficial than introducing totally new devices. Some devices were based on dedicated objects, while it turned out that users tended to prefer the hybrid approach of using e.g. a mobile phone and perceived it enriching [27]. New design concepts for emotional communication could be developed utilising culture and tradition [17].

Authentic LDR users should be more involved in the future research, where they could be engaged in the design process as co-designers. In contrast to substitute participants who are

not truly LDR couples in real life, authentic LDR participants are the experts of their own LDR experience, who deeply understand their needs, challenges and problems. Hence, they are able to provide valuable insights on how technology could be designed to enhance the users' experience in LDR-oriented artefacts. Additionally, in order to achieve better evaluation and scientific assessment, more long-term studies in-the-wild are needed. So far, the reviewed studies have mostly focused on young adults, or the age of the participants was not reported. Given that the aging of the population has become a global phenomenon, elderly remote couples would be an interesting user group in the future studies.

Limitations

We acknowledge that our research is limited by the search on ACM DL database only. However, as this is a primary publication database for HCI research and includes a wide set of publication forums (such as CHI, TEI, UbiComp, and AH conferences), we believe that our corpus of data provides a very representative overview of the field.

CONCLUSION

Based on a systematic literature review and analysis of 52 systems aiming to support emotional communication between partners, we highlight the following emphasis and gaps in the current research. The modalities dominating in the design are touch based input and visual or haptic output. Object manipulation, movements and shape changing appear less, and the modalities of smell and taste are very rarely used, revealing a research gap for future researchers. The communication style used in the system designs is predominantly symmetric, and the exchanged messages typically ephemeral. The validation of prototypes has been mostly done with short duration studies and in lab conditions, which calls for longer duration studies in real-life use contexts in the future.

ANALYSED PAPERS

In the initial body of 150 papers, we found 47 papers to be in the scope of our focus. These papers included 52 system prototypes, as 3 of the papers presented multiple systems [14][24][31]. The papers that formed our final corpus are the following:

[2][3][4][5][6][7][9][10][11][12][14][15][16][17]
[19][21][22][23][24][25][26][27][28][30][31][32][33][35]
[36][37][38][39][40][41][42][44][46][47][48][50][51][52]
[53] [54][55][56][57]

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