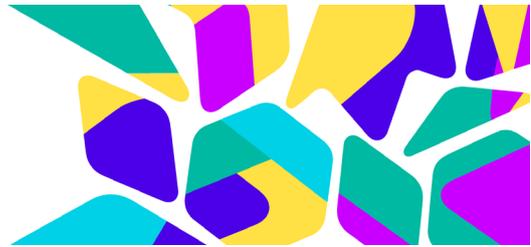


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Exploring wearable technology for supporting couples in long-distance relationships

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Abstract: In this paper, we explore the possibilities of wearable technology in supporting couples in long-distance relationships (LDRs) to achieve better insights on how wearables could be designed to fit the real needs of this user group. We approach the topic with a hands-on design workshop, where twelve participants living in an LDR created concepts and low-fidelity physical prototypes of wearables, and presented the video-recorded concepts to their remote partners to get their feedback. We thoroughly documented and analysed the workshop, and, based on the findings, we propose design considerations for designing wearable communication devices to support LDRs, including supporting secret communication modes, effortless awareness, and asynchronous lifestyle of the couples. It is also important that technology, particularly wearables, is designed so that it can be seamlessly integrated as part of everyday life and fits to different contexts.

Keywords: co-design; participatory workshop; wearable technology; long-distance relationships

1. Introduction

Fulfilling one of the most crucial human needs – relatedness – is regarded primarily as a positive experience that technology can create to make a relationship flourish (Hassenzahl, Heidecker, Eckoldt, Diefenbach, & Hillmann, 2012). There are increasingly many couples in long-distance relationships (LDRs) who cannot interact physically or talk to each other face-to-face on a daily basis. Their interaction and communication depends on different computer-mediated communication (CMC) tools, such as phone, email, instant messaging and video chat (Neustaedter & Greenberg, 2012), to mediate intimacy at a distance (Jiang & Hancock, 2013). Despite that CMC tools provide a wide variety of communication channels, evidence suggests that the current mainstream technologies are unable to support the full spectrum of communication needed in intimate relationships (Hassenzahl et al., 2012). Commonly used CMC tools, e.g. text messaging and email, are not designed to support



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sharing activities together (Pan, Neustaedter, Antle, & Matkin, 2017) or to provide a sense of remote presence (Tollmar & Persson, 2002), and they are unable to fulfil the need of relatedness (Sahlstein, 2004; Hassenzahl et al., 2012).

Recently, LDRs have become more common than ever and the number continues to increase due to various reasons such as the growing acceptance of international education and overseas employment (Stafford, 2004). This drives a need to create new communication technologies that can better support the needs for connectedness and communication of couples in LDRs. Wearable technology has been shown to have potential to change the way people interact with one another. Wearable devices can be embedded in clothing, worn close to the body as accessories, implanted in the body, or even as temporary tattoos on the skin (Liu, Vega, Maes, & Paradiso, 2016). A growing body of research has set out to explore the use of wearable technology in enriching communication over distance. However, there is still less understanding from the users' perspectives in terms of the content and interaction that should be communicated or mediated through wearable technology. In this paper, we further explore the communication needs of couples in LDRs through a co-design and low-fi prototyping methodology. This paper contributes to better understanding of the communication needs of couples in LDRs, and provides design considerations that support researchers, designers, and developers working on the topic.

2. Related work

In addition to the conventional communication tools, a variety of novel solutions have been designed to connect couples at a distance (Li, Häkkinen & Väänänen, 2018). For example, MyEyes (Pan et al., 2017) allows LDR couples to see through the eyes of a distant loved one to share daily activities and experiences together. Also, numerous embodied and tangible interfaces have been developed. For instance, Cubble (Kowalski, Loehmann, & Hausen, 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 the feeling of holding hands.

Wearable devices, different from most computing form factors, 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 for other forms of technology. This has made wearable technology a highly potential candidate for facilitating communication between remote couples, and prior art has presented examples such as HugShirt (CuteCircuit, 2002), ComSlipper (Chen, Forlizzi, & Jennings, 2006), and United-pulse ring (Werner, Wettach, & Hornecker, 2008).

A recent systematic literature review on 52 communication systems for LDRs shows that the majority of previous research in this area has focused on presenting novel concepts to mediate LDRs, addressing a single idea at a time and creating proof-of-concept level prototypes (Li, et al., 2018). Most of the recruited participants in the reviewed lab studies

were not remote couples in real life, but instead used substitute participants (Li, et al., 2018). Although a number of studies have involved remote couples in the design process (e.g., Kaye & Goulding, 2004), the subjects have been mostly involved in evaluating the proposed systems (e.g., Saadatian et al., 2014; Silina & Haddadi, 2015). It has been pointed out that there is a gap between understanding the needs of LDR couples in research and designing technologies for them in practice (Li, 2018). Remote couples who have sustained a long-term commitment in their relationships are experts by virtue of their personal experiences (Visser, Stappers, Lugt, & Sanders, 2005). In our study, we listened to LDR couples by engaging them in a number of co-design workshop sessions to create desired communication devices that could better support their relationship.

3. The wearable co-design workshop sessions

Co-design workshops (Sanders & Stappers, 2008) have been found to provide rich insight into an exploratory research topic in the design aspects of HCI (Devendorf et al., 2016; Pakanen, Lappalainen, Roinesalo, & Häkkinen, 2016). We organised three co-design workshop sessions (see Figure 1) with potential users of wearable technology aiming to support LDRs. We were particularly interested in getting insights about 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. We divided the workshop into three sessions (with four, three, and five participants) so they would fit into the time slots that were convenient for the participants. The activities and given tasks were the same in each session.



Figure 1 Participants making wearable prototypes in the co-design workshop sessions.

3.1 Participants

We recruited twelve participants (3 males, 9 females), with the age of 19-45 (mean 29) years, with different backgrounds at the University of Lapland, Finland, from the university's emailing list. All participants had been in a stable LDR, see Table 1. Participants described their own LDR stages as "married", "engaged", or "dating" according to their marital status. 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, e.g., Apple Watch. Each participant received two movie tickets (worth of appr. 20 euros) as gratitude for their participation.

Table 1 Summary of the workshop participants and their remote partner.

	Gender	Age	Partner's gender	Partner's age	Partner's location	Length (years)	Stage	Duration of separation (months)
P1	F	38	M	38	UK	14	Married	7
P2	F	19	F	18	China	3	Dating	7
P3	M	40	F	33	Estonia	10	Married	48
P4	F	26	M	29	Belgium	1	Engaged	12
P5	F	20	M	22	Netherlands	4.5	Dating	48
P6	F	21	M	21	France	5	Dating	8
P7	M	23	F	23	Japan	3	Engaged	12
P8	M	45	F	52	Germany	12	Married	108
P9	F	24	M	23	Finland	3.5	Dating	24
P10	F	25	M	21	Russia	3	Married	6
P11	F	26	M	41	Russia	7	Married	24
P12	F	35	M	57	Chile	9	Dating	24

3.2 Set-up, Procedure and Data Analysis

Each co-design workshop session took approximately 2.5 hours. In the beginning, we explained the nature of research activities and filled in the consent forms with the participants. All the sessions 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, we provided the participants with a deck of design cards which includes essential aspects needed to be taken into account 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, Häkkinen, & Väinänen., 2019). We introduced the design cards to the participants as a design tool to help them develop ideas. We also provided the participants with different materials and tools, e.g., white fabrics, coloured ribbons, yarns, 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 through 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, we invited the participants' remote partners to take part in the

study as remote participants, as explained later.

Data was collected during the workshop sessions through questionnaires, photographs, videos and audio recordings. We transcribed the audio recordings in verbatim. 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. A number of themes were identified, and similar codes were emerged into categories.

4. Co-creation workshop outcomes

Each participant created different designs that they believed would help address the challenges they were facing in their own LDR. Figure 2 shows the outcomes of the co-design workshop sessions, with a detailed description in Table 2.

Table 2 Details of the design outcomes.

	Functionality	Form factor
P1	Simulating an embrace of a distant loved one.	Wearable blanket
P2	Live streaming of a remote partner via hologram during a video call.	Wristwatch
P3	Sharing intimate voice messages between a remote couple.	Multi-wear pin
P4	Changing its colour to create a sense of remote presence.	Attachable multi-wear accessory
P5	Sharing agendas or making plans together with a remote partner.	Attachable notebook
P6	Changing its colour to cheer up the remote partner.	Bracelet
P7	Using eye-movements to generate visuals visible only to the remote partner.	Augmented glasses
P8	Thermal and haptic feedback to generate awareness and simulate hand-holding.	T-shirt and pendant compass
P9	Simulating head massage given by a remote partner.	Gloves and headset
P10	Playing music in real-time and sharing audio messages between the LDR couple.	Headband
P11	Sharing personal audio messages between the LDR couple.	Attachable stuffed toy
P12	Changing its colour to evoke a feeling of relatedness.	Bracelet



Figure 2 The design outcomes made by the workshop participants.

5. Findings

5.1 Designing for Inner Relationship Experience

The participants designed their wearable devices considering inner experience and feeling of being connected with their love one through the devices. Particularly, the participants' designs attempted to create and imitate experiences of themselves being more involved in each other's lives at a distance. The design concepts sought for warmth, caring and intimacy, and form factors that supported them. For example, P1 created a blanket and indicated that "it is comforting and warm like a loved one's embrace". Several participants design their devices with the intention to be "always connected". P6 chose to design a bracelet because it would always be with her and her partner, and P4, P6, and P12 explained that their designs were meant to deliver a message saying, "I am thinking of you" or "I am always with you", to their partner.

"If I am doing something and go like 'oh, I miss my partner', and I can kind of like fiddle with [my design], then, it would change the colour at my partner's end [...] Maybe he's also busy doing something, but it's kind of like 'Aww, she is thinking about me'." (P4)

The purpose of the messages, or the meanings encoded in them, could be clustered to the following categories:

- Enabling remote touch
- Expressing emotions
- Providing mental support
- Reliving shared memories

Haptic feedback was largely presented in the participants' designs. Haptic feedback was considered as a way to mimic natural touch experience, like "a warm hug" (P1) or "holding hands" (P8). The feeling of holding a distant loved one's hand was commented to be a way to comfort each other in difficult times, and the design could be used to "show support to the partner when it is a difficult time" (P6).

“If you are lost, you would like crumble the sleeve [of the T-shirt], something that you press out of despair basically, and then the partner could, for example, put the hand on the truck, basically on the heart, and send you some reassuring, maybe vibration or some thermal stimulus.” (P8)

Some participants designed their device with the intention to mediate a feeling of physical intimacy. “It’s already easy with today’s technology to share images, video, call, and keep in touch. But it’s not possible to feel physically close or being touched by the love one” (P1).

A number of designs were made to express affection and personal feelings and to show mental support in various ways. For example, emoji were used in highly personalised and purposefully secretive ways in P7’s wearable design to convey intimate and personal sentiments, i.e., inside jokes, between him and the partner. P3, P10, and P11 designed wearable devices that allow them to express intimacy by sharing audio messages. The voice of a loved one was said to be “unique” (P3), “reassuring” (P10) and “intimate” (P11). P11 found listening to her partner saying romantic words was more intimate than looking at those words typed on a screen. “We would [use the stuffed toy design concept to] send each other sweet messages to express our romantic feelings or our favourite music to remind us of some moments we shared together, or to just cheer each other up” (P11).

Another theme present in the designs was the idea of reliving shared memories through tokens that could evoke them. As P3 commented: “Memory is everything, either good or bad, they are usually cherished”. P8 designed a shape-changing T-shirt to relive shared memories and shared experiences with his remote partner in a playful way:

“Both of us like to travel a lot and we collect memories together in that way... If I’m thinking of a past trip, I could show my wife the gathered experiences by having some gears added to the top of the truck [of the T-shirt], and when she touches that, it starts an app on the screen of her phone and generates some photo slide shows or texts that we wrote down back then.” (P8)

5.2 Ambient Design and Openness for Interpretation

Several participants designed their devices to send messages that are ambiguous and open for interpretation. Ambiguous messages are usually non-verbal, such as haptic, temperature, colour, light, shape-changing, or music. This was considered to be a way for the participants to maintain intimacy over a distance without other people being aware. Furthermore, ambiguous messages were believed to add tones and emotion such as playfulness or a hug and warmth to their communication, which could not be easily done through verbal communication. The ambiguous form of messages was a way to maintain privacy when exposed to others. The participants believed that light, colours, or other forms of visuals in wearable devices would be considered as part of their outfit. P6 highlighted that ambiguous messages could help fill a communication gap: “sometimes it feels difficult to find the words to express a feeling of attachment to support the other”. Ambient designs could be used at work or during studying via subtle implicit messages without disturbing the other end, as P5 stated: “When he’s busy and can’t text or call me, he would still feel good to receive a

message from me and know that I'm thinking of him" (P5).

When choosing a form factor for their design, the participants considered also the appearance of the wearable device when used or worn in public. It was important to the participants that their design could function as an everyday object, e.g. to blend in well with any outfit, and be suitable to wear in everyday life. For example, P10 designed her wearable concept in the form of a headband because they both were usually wearing one on a daily basis. For example,

"At first I thought I'd make a scarf or something like that, but then I thought if it's summer or depending on the weather I might not wear it [...] It has to be something that I'd like to wear all the time, so I decided to make something that can be attached to anything or can be worn in many ways, then I can just attach it to my handbag or wear it in whatever way I want." (P4)

5.3 Messaging the Partner

Despite that the participants regarded their devices as a channel to send a message to their partner, a reply from the partner to acknowledge the message was not necessarily expected, as P12 stated: "I don't need him to answer to the change of colour, just to let him know that I'm thinking of him". Most of the participants preferred that their devices did not require both themselves and their partner to be active at the same time, as they believed that asynchronous communication would perform better when dealing with different schedules at both ends. For instance, P1 considered different time zones and different schedules herself and her partner had. Asynchronous communication was described as "less time consuming" (P6), "less demanding" (P5), and "less stressful" (P4) as there is no need to "wait for an answer or reply immediately" (P7).

The ephemerality of the messages divided opinions. Five participants wished the messages to disappear by themselves, but on the other hand, many designed their device concepts so that the message should be acknowledged by their partner before it disappeared. The arguments for ephemerality were partly in the nature of the message, e.g., "Touch cannot be stored" (P1). Furthermore, ephemeral messages were believed to be more "stress-free" (P3) and "convenient" (P11). Also, the concern of making the partner worry over nothing was a factor to take into account, if one happened to send a negative message when temporarily feeling sad. "I mean, everything is just horrible and then five minutes later it's fine again, so you don't need to keep on that 'I am lost' message, because that may worry the partner." (P8)

5.4 Paired Designs and Customisation

The majority of the participants designed their wearable device to be the same for both themselves and their partners. This represented a feeling of being a couple. The participants also considered that this would support "a better feeling of reciprocation and mutuality" (P4) between them. The designs, however, were not necessarily identical, but the paired devices could be subtly different to match different genders, preferences, and styles, as, for instance,

a pair of bracelets with different colours (P12).

When the participants discussed the material qualities they preferred to use in realising their design, comfortable materials were common as their devices were expected “to be worn all the time” (P6). P6 further explained: “Soft materials should be used so that [the wearable device] would be nice to touch. I could even take it to bed with me”. Organic and natural materials were the selected choices of many participants. They wished to create devices that looked like ordinary clothes and accessories, believing that such materials would make the devices “fit to many styles and occasions” (P4). However, P3 preferred “unique and rare” materials for his design, and would use “special wood that emits nice scents” in realising the multi-wear pin.

Customisation was seen as another relevant feature in the participants’ designs. The participants wished the appearance of their wearable device, such as colour, to be customisable to match with different tastes. A few participants mentioned about fine-tuning interactions to their preference, e.g. “adjusting the level of vibration and light” (P7), so that the user experience could be enhanced according to the user’s needs. The participants also mentioned that customisable appearance would allow the device to be used as different accessories, so it could be worn anywhere, attached to clothes, bags, or worn as a bracelet or in the hair (P4). Furthermore, customisation was regarded as an important aspect to enable meaningfulness of the design and to enrich shared memories.

6. Feedback from the remote partners

In this section, we report the feedback collected from the remote participants who commented on the concept designs created by their partner. We video recorded each local participant explaining their design, which was later sent to the remote participants for their feedback. We created an online questionnaire for the remote participants to give 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 making improvements on the design.

Even though the design concepts created by the local participants were merely low-fidelity prototypes, they were still appreciated by the remote partners, and overall, received positive responses to their partner’s design, rating *good* (1/12), *very good* (8/12), or *excellent* (3/12). The remote participants appreciated their partner’s thoughtfulness towards their preferences. For example, P5 stated that, “I think he would like [the attachable notebook], he appreciates simplicity [...] The notebook idea is something simple yet practical because it doesn’t attract the attention of others”. P5’s partner remarked that,

“It is an idea I could have expected from my partner [...] A very simple yet useful design for people in LDRs. It is a nice additional way of communication, that does not take much time when time is scarce, but it does make people feel closer.”

Furthermore, the remote participants considered the designs to be meaningful and well address problems they were facing in LDRs. For example, P1's partner appreciated the reminiscence of a meaningful experience when they were together:

"I miss those moments like at the end of the day when we sit close to each other on the sofa sharing a blanket while watching TV [...] we can talk as often as we like via WhatsApp but we can't reach out and touch or hug as we sometimes would."

All the remote participants found the design made by their partner was able to support their own LDRs in a variety of ways. Mimicking physical touch was believed to (virtually) lessen the distance by making remote couples enjoy a physical sensation together while being apart, if it "felt dynamically authentic enough" (P9's partner). Asynchronous communication was seen to better support couples in LDRs since it was often challenging to agree on a suitable time for both to be active at the same time while being apart.

"Sometimes it's quite annoying to wait for her reply because we have five hours' time differences between us [...] Knowing my partner's condition immediately can make me at ease, especially when she's too busy to inform me." (P2's partner).

The designs with unconventional form factors were deemed to "show support in a different way than typical communication means do" (P6's partner). The use of subtle cues, such as tactile, thermal, visuals, etc., to support non-verbal communication could enhance intimacy at a distance "by adding an extra dimension to the interaction" (P7's partner). The designs that enabled customisability were said to be meaningful, as it "builds a bond" and "creates a unique link" between couples.

There were suggestions given to adjust some details of the design so as to fit personal preferences, e.g., P4's partner suggested that: "A necklace or bracelet would be not as comfortable to wear as a man, a phone case or a phone accessory would be better". When asked about the potential ethical issues, P6's partner raised a concern about obtrusion with an illumination interference: "Having a bracelet emitting light in an important meeting or during class can be disturbing".

7. Discussion

In this section, we summarise and discuss the main findings and the design considerations derived from them.

7.1 Expressing the Emotions and Supporting Physical Connection

The design concepts and discussions in the study both emphasised, not surprisingly, the need for expressing emotions, creating awareness, and communicating the feeling of caring between the partners. The concepts were aimed for expressing affection rather than communicating more complex messages. Our study findings align with prior research, as awareness and expressivity have been found the most common relatedness strategies with emotional communication systems (Hassenzahl, et al., 2012; Li, et al., 2018). In general, the

designs were meant to serve as an additional interaction channel for mediating LDRs that add on to their existing communication channels, rather than replacing an existing one. The designers should thus consider how the unconventional communication device could support the idea of a physical connection and expressing emotions, and complement the conventional, explicit messaging channels. A wearable device could serve as a fast nudge that couples use to remind each other about their remote presence without using any explicit and verbal communication.

7.2 Supporting Secret Communication

The findings also emphasised that couples wished to share intimate messages, which no-one else was able to understand, and through which they could mediate a private and intimate message, e.g. a memory or a shared joke. This aligns, with Crystal & Hancock (2013), who have stated that intimacy is derived from transactions of self-disclosure. Some similar communication strategies, such as repurposing an emoji in a secretive manner has been reported before (Wiseman & Gould, 2018). As a design consideration, we recommend supporting an exchange of private, or secret, messages in a way which is meaningful for the couple but ambiguous to others. This could be done e.g. with an ambient colour change of an object, or by repurposing commonly used symbols, e.g. emojis. Differing from the current standardised communication channels, wearables offer customisation possibilities with materials, form factors, integrated colour and light elements, and shape-changing.

7.3 Coping with Asynchronised Lifestyles

The study highlighted that LDR couples often had different daily schedules, resulting from geographic separation, time zone differences, and diverging daily routines. Due to the asynchronised life between the remote partners, they often faced obstacles to calling and chatting due to their different rhythms for day/night and work/leisure. As a design consideration, unobtrusive and ambient designs for output technologies should be preferred. When integrating such features with wearable form factors, the designer needs to consider that the device is suitable for different use contexts, and how the communication is placed in the periphery of the user's attention.

7.4 Supporting Effortless Interaction

The feedback gained in our study often emphasised the wish to easily and effortlessly send and receive short, affective messages. With current communication means, the actions for taking up the device and composing a message, as well as to open it, was perceived to require extra effort. The designer should consider how to support effortless interaction. With wearables, this could mean integrating inputs and outputs into the everyday garments or accessories.

7.5 Entwining with Everyday Life

As the final design consideration, the designer should take into account how to entwine the communication tool with everyday life. The findings emphasised that the technical solutions, as well as the design, should blend in with daily lifestyle. Subtle output, ambient design, and secret message encoding support this goal. Unobtrusive information delivery and aesthetic ambient displays that can be integrated into everyday wearable form factors and accessories, and, for instance, designs that can be worn with several outfits could be beneficial. Considering long-term use is also important in order to support the couples over lengthy time periods and to create sustainable design solutions.

7.6 Methodological Notes

Taking a participatory approach, we delivered three workshop sessions where each of our participants was given a chance to design wearable devices to support their own LDRs. We encouraged the participants to feel that they were regarded as experts in LDR experiences (Visser et al., 2005). In doing so, they felt more confident to contribute their insights for designing new wearables, even if some of them did not come from a design background. Overall, the participants embraced the participatory making environment and showed a sense of accomplishment and joy when presenting their works. The design cards were found to be useful for providing participants (mostly with no background in technology) ideas of different possibilities with technology.

As known from the prior art, user studies on LDRs are challenging to organise due to the long distances, contributing to the low number of studies involving actual LDR couples (Li et al., 2018). Our approach of engaging the remote partners in giving comments and suggestions on designs online functioned as a good methodology to gain feedback from both partners. With this compromise, we managed to involve true LDR partners, even though only one of them participated in the co-design workshop sessions. Based on our experience, the method worked well and provided insights into how both partners perceived the proposed design concepts. Naturally, note should be taken for the possible (positive) bias in assessing their partner's design. However, for discussing the wider design considerations, as well as generally, our experiences with the method were positive.

We acknowledge that our study is limited by the small sample size with an unbalanced gender sample. However, we believe our work utilising our participants' empirical experiences in LDR contributes useful insights on how wearables could be designed to support LDRs, and can help the designers and engineers working on the topic.

8. Conclusion

We have taken a participatory design approach to investigate the design of wearable communication devices for supporting couples in a long-distance relationship. Based on the findings of the three co-design sessions, we have identified design consideration and possibilities of how wearable technology could better support couples in LDRs from

potential users' perspectives. Especially, awareness between partners, expression of emotions, strengthening the physicality of the communication, and enabling the delivery of secret messages should be taken into account in the design. Our findings also highlight the importance of practical aspects of how the concept should fit into the user's everyday life, and could be worn, or used, long-term. Our study methodology involving the remote LDR partners through videos can be used as an example of how to conduct a co-design workshop with people who are geographically divided. We believe the findings 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.

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