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ABSTRACT

There is a growing body of work in HCI on the design of communication technologies to help support lovers in long distance relationships. We build upon this work by presenting an exploratory study of hand-holding prototypes. Our work distinguishes itself by basing distance communication metaphors on elements of familiar, simple co-located behaviours. We argue that the combined evocative power of unique co-created physical representations of the absent other can be used by separated lovers to generate powerful and positive experiences, in turn sustaining romantic connections at a distance.

Author Keywords

Hand Holding, Design, Communication Systems, Intimate Communication.

ACM Classification Keywords

H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.
H.4.3. Communications Applications: Miscellaneous

INTRODUCTION

Physical separation can pose many problems for those in romantic relationships. Feelings of dislocation and 'lostness' beset their efforts to construct new routines without diminishing a vital sense of connection with their loved one. People must strive to find a sustainable way to share moment-to-moment experiences. They may be able to preserve an enduring and personally meaningful sense of the absent other using mechanisms they can recruit to somehow be together whilst apart. In these circumstances, communication technologies cease to be tools of convenience but assume a new meaning; they are social lifelines for sustaining personally important relationships.

The exact number of people in long distance relationships (LDRs) is hard to ascertain; what we do know is that they are relatively prevalent. Within our target population, (University students), estimates suggest that between 25% -

50% of students are in an LDR at any one time with around 75% of students being in an LDR at some point [2].

Whilst one might assume that LDRs are somehow inferior to the relationships of co-located couples, the literature suggests otherwise. People in LDRs, on average, report the same or higher levels of relational stability and satisfaction than co-located couples [16]. One reason for this is the way that people in LDRs communicate. LDRs are characterised by a limitation of the amount of face-to-face communication that can take place; additionally there is no evidence that such couples use mediated technologies more than co-located ones. The difference is in what is focussed on during the communicative act; namely that LDRs focus more upon intimacy [16]. Our aim is to understand which design factors are most significant for communication technologies that create such intimacy.

In this paper we consider what a communication system directly aimed at supporting LDRs could be like if based upon a co-located experience. The experience we focus on is hand holding. Our research challenge is to explore what participants think of our prototype devices in terms of the design concepts they embody and then to reflect upon how these concepts could be realised in other interactive systems concerned with intimacy. We examine meaningful qualities of interactivity and communication in romantic personal relationships through several design parameters drawn from the physical act of hand holding. To this end, we report an exploratory qualitative evaluation of three prototype devices. Each device is intended for in-the-moment use by distant couples but is related to enduring values in the relationship. Our immediate aim is to establish the value of hand-holding as the basis of interactive designs. However, we wish to provoke a deeper consideration of paradigmatic approaches to interaction design in the arena of romantic relationships. In particular, we argue that the power of design approaches to communication technologies based on tangible, behavioural metaphors rests on their potential to exploit qualities of 'personalization' and to evoke personal memories.

Designing for Long-Distance Romantic Relationships

We see existing communication systems designed for distance couples falling into three broad categories, based on their design paradigm. These categories are *abstract-*, *object-augmentation-* and *behaviour-based* systems.

Abstract systems are those which in essence have no metaphor behind their use. The Vio system [7] is a good example of this, whereby a simple coloured circle is placed in the taskbar of a person's computer. The colour of the circle changes based on how frequently the person's partner clicked on their own circle. The systems presented by Strong and Gaver in [17] are also abstract, demonstrating how ambiguous movement and scent could be used to create a bond between a couple at a distance.

Object-augmentation systems are those that transfigure existing objects into communication tools. Dodge started this trend back in 1997 (along with an interest in tangible communication systems) when he presented his augmented bed [4]. By integrating heat pads, sound, and moving curtains, the idea was to connect couples that, for whatever reason, were sleeping in separate beds. ComSlipper, [3], is a personal artefact (namely, a pair of slippers) which have been supplemented with technology to develop a rather delightful communication medium. Pressure points on either pair of slippers are connected to an LED and heat pad in the other pair. Various interactions (such as foot tapping) then lead to different outputs. Looking beyond instantaneous experience, Thieme et al. [18] augmented the interior of a lockable antique box with messaging technologies. Their insight was to create a treasured private space, framing messages as intimate to the people who exchange them. In this way, they generated rich emotional experiences by fostering individual reflection on the content of personal messages [18].

Finally, *behaviour-based systems* are designed to selectively mimic one or more elements of intimate behaviour over a distance. Interaction with the system is thus intended to resemble an encounter that is already romantically meaningful to those in a relationship. Appearance is deprecated in favour of feel and action. This is an area that thus far has received a little attention. Mueller et al., [11] presented a device that used air pressure to create an enveloping hug sensation when activated. Participants were positive about the concept but were concerned about the practicalities of using such a system. Tsetserukou created the HaptiHug system based on the idea of a full embrace, combining mechanical and thermal emitters into an upper torso harness [19]. Gooch & Watts [5] designed a belt interaction mimicking the idea of an arm around the waist. They showed that using Peltier heat pumps to create an impression of a loved-one's arm increased feelings of Social Presence [5]. The characteristic feature of this third group is the creation of a metaphor around a limited set of physical attributes that are rooted in a familiar intimate act. Our description of these systems as the third grouping should not be confused with the "third paradigm" of HCI [21], where design is emphasized as a process of situated and constructive activity of making meaning rather than as a problem solving activity. Many of the communication systems we have described here fit into this third category of behavioural mimicry.

Before proceeding, it is important to note that there is some overlap between the groups. For example, we could characterize Strong and Gaver's system [17] as augmenting objects; we could also characterize Dodge's bed under behaviour. However, what we have tried to do is classify objects based not on their actual use, but rather, the underlying motivation behind the designs, Strong and Gaver's systems are based around constructing meaning from subtle movements and smells, essentially using abstractness as a resource for design. Likewise, Dodge's bed is not concerned with what occurs in a bed (which would be behaviour-oriented) but is focused heavily upon adaptation of the object itself.

Hand-Holding: Into the Valley
To further elaborate behaviour-based intimate design, we now turn to hand-holding. Within the HCI literature, there is a small amount work based around investigating this specific behaviour. O'Brien and Mueller carried out a technology probe investigating hand-holding [13]. The only similar device of which we are aware is the handshaking system presented in [1]. However, there are some significant differences between their device and our aims. First, a handshake is fundamentally different from holding hands – it is a different action with different emotional overtones. One is a greeting, the other of emotional significance. It is a rare business meeting which would involve the participants holding hands together. Second, the work in [1] uses a force-feedback joystick. Our aim was to build custom communication systems to better understand the factors that would contribute to a good design.

In addition, there are at least two different focus groups that have suggested the building of hand holding devices [8, 20]. Although these designs did not go on to be built, the fact that participants requested such a device makes this area a compelling one to investigate. We build on this work by presenting three prototype devices that are based on the metaphor of hand holding.

Robotics researchers have struggled to find ways of realizing acceptable appearance and behaviour. This is the well-known uncanny valley phenomenon, where high-fidelity androids can provoke feelings of revulsion [10]. Whilst increasing android fidelity initially results in more favourable human reactions, this trend becomes dramatically reversed as the ungainliness of robots ceases to look cute and instead is perceived as 'creepy' or 'weird'. Given that our devices are based around the behaviour of human hands, there is a possibility that they could fall within the valley. Thus one of our considerations for designing three distinct prototypes was to deliberately limit realism, to clearly establish which of a limited set of behavioural and appearance cues we would leverage. In this way we wished to gain insights into how far the metaphor could be developed before the device is rejected as being uncanny.

Our perspective is also semiotic: that the physical signals are only meaningful when embedded in elements of the relationship. We conceptualize the interpretation of signals within a close personal relationship as a matter of establishing it as a personification of the remote loved one. This is akin to Thieme et al.'s specialness of an intimate place [18] but more particularly concerned with the uniqueness of the individual, perhaps best thought of as the 'finger print' of the absent other.

THE HAND-HOLDING PROTOTYPES

The three prototypes we present are titled *YourGlove*, *HotHands* and *HotMits*. They use different physical channels (e.g. movement or heat) to communicate intimate signals and thus present the same behavioural metaphor of hand-holding in three distinctive ways. Movement was selected as the tangible signal most like hand-holding. Heat was used as an alternative metaphor as it has been previously associated with emotional communication [9].

Figure 1. The YourGlove system.

YourGlove is based around the movement of hand-holding (see Figure 1). The device is made up of a robotic hand controlled by strings which, when pulled, cause the hand to contract. YourGlove is mounted onto a tube, approximating the dimensions of a human forearm, and is controlled via a Phidget interface board. The device has the appearance of a limb that can be used to reciprocate hand-holding. Hidden within the back of the glove is a switch that, when pressed, causes an additional paired hand to close. The position of the switch is such that it is activated when someone holds their YourGlove. YourGlove is used by placing the hand within the glove, pressing the aforementioned switch. This sends a signal to the partnered hand making it contract gently around the partner's hand.

YourGlove is designed to be personalized to the absent other by being dressed in a familiar glove, the sleeve of a top and jewellery according to its significance for the particular couple. This means it could gain a familiar and treasured feel (fabric), aroma, and appearance.

Figure 2. The HotHands system.

HotHands (see Figure 2) uses heat rather than movement as the key physical signal in the medium of the hand. The system consists of two model hands, each with containing a Peltier heat pump. Under each heat pump, a push switch is embedded into the hand. Using a Phidget control board, the heat pump can be controlled in software. When a person places their hand onto their model hand, the other person's model hand warms up. HotHands is personalized to each partner because it is their own unique casting. We envision a co-creation process – making the castings whilst on a visit or before moving away, and including the decoration or embellishment of the device as users see fit.

Figure 3. The HotMits system.

HotMits (see Figure 3) again uses heat as the sensory medium, driven by a Phidget-controlled Peltier pump. Instead of casting a hand, HotMits is based around a hand imprint. The device is used by placing one's hand into the imprint. If the partner's hand is within their imprint, both devices warm up. Personalization is again achieved by co-creating the devices but this time as unique imprints of the each person's hand.

METHODOLOGY

The prototypes were intended to explore the design potential around what it could mean to create a communication system based on behavioural qualities of holding hands. We wanted to gather data that would contribute to an understanding of the meaningful qualities of each prototype. To this end, we used a three-phase semi-structured interview process: (1) Introducing the design idea, together with a narrative scenario, (2) a hands-on demonstration of the prototypes device, and (3), a discussion to compare and relate their experience with each device in the context of their own romantic relationship (see Table 1).

The scenarios were used to gather information about the differences in how people viewed the design concept and the actual prototypes. We wanted our participants to engage with the underlying design concept rather than any shortcomings in the way the prototypes had been realized. Along with our design variations on the hand-holding theme, we wanted to better understand the influence of partner uniqueness on the basic design ideas. Scenarios were thus devised in two forms of vignette: device- and person-centred alternatives. Device-centred vignettes were based around giving and receiving a gift in the form of a new remote hand-holding device. Person-centred vignettes described the co-creation of a remote hand-holding device. The YourGlove system was personalised by making it clear that the glove used was that of the person's partner, not just a standard glove. The system could also include other personal items such as bracelets or rings. The HotHands system was personalised by making it clear that the moulds were of the couples' hands rather than a standard meld. It was also made clear that the moulded hands could be painted or decorated. Similarly, the HotMits were personalised by emphasizing that they were imprints of the couples' hands rather than a standardized imprint. HotHands and HotMits also included painting and decoration by the lovers.

12 people in long-term distant relationships took part in the study, 6 male and 6 female. These were 12 individuals, not 6 couples – we interviewed one person from 12 different couples. People were recruited using online noticeboards and posters at a UK university. Participants were paid £10 for taking part. The presentation of the 3 devices was counterbalanced for order. For each order condition, 1 male and 1 female took part. Of these two, one got the person-focused vignettes and the other the device-centred vignettes, counterbalancing for gender. All Device participants were finally introduced to the Person-centred concept in the final phase of the interviews, only after forming impressions based on the relevant device-cantered vignettes.

First Phase – Concept and Scenario
First thoughts on hand holding… do you miss holding hands while you are apart or not?
Do you think you would or wouldn't use a system which represented holding hands?
End of Scenario
What are your first thoughts about the [x] system?
Do you think this is a system you might or might not use? Why/why not?
What do you like about the concepts behind the [x] system? Why?
What do you dislike about the concepts behind the [x] system? Why?
Second Phase - Using the Device
So having used the prototype, has your opinion of the system changed or stayed the same?
Are there any features you thought you would like/dislike which having used you now disliked/liked?
What, if anything, would you change about the device?
If we changed the device by making is more/less personal [by doing Y] would you change your opinion of the device? Or do you think it would stay the same?
What do you think about the way the device is activated? Do you think it would be better if it was activated together? Or do you think separate is better?
Third Phase – Comparison and Discussion
Which of the devices is your favourite? Why? Why don't you like the others as much?
What do you think about the overall idea of trying to support hand holding at a distance? Do or do you not miss holding hands while you're apart? How well do you think the devices I've shown you meet that goal?
Are there other things that you miss more? Do you think those could be supported while you're apart?
These systems are all content free and intended to be used in conjunction with something like IM or Skype, almost like an accessory. Do you use anything like that already? Do you think you would use such a system or not?
Anything else you'd like to add?

Table 1. Three-Phase Exploratory Process.

Vignette Centred on	YourGlove	HotHands	HotMits
Person	2	0	4
Device	0	4	2
Total	2	4	6

Table 2. The favourite device of each participant

Vignette Cantered on	YourGlove	HotHands	HotMits
Person	3	6	5
Device	0	5	4
Total	3 (25%)	11 (91%)	9 (75%)

Table 3. Devices participants 'would use again'

RESULTS AND ANLYSIS

All participant interviews took approximately one hour. The three-phases of the interviews were continuously audio recorded and then transcribed for analysis. Our data are primarily qualitative and are presented as direct quotations from our participants in the form [Px – yz] where x indicates their participant number, y whether they read the Person-centred or Device-cantered scenario and z whether they were male (M) or female (F).

In addition to open-ended questions; we asked each participant to state which device was their favourite (see Table 2) and whether they could imagine using any of the devices, if commercially available (see Table 3). We will discuss these preferences before moving on to consider the specific issues that were raised in response to our prompts.

The first thing to note is that all the prototypes were well received by at least some of our participants but the two casting-based prototypes were much preferred. This indicates that the design concepts behind these devices have a role to play in long-distance relationships. Participants did feel that hand holding was something they missed:

"*Yeah, I think the holding hands is one part of it… if you're away every week for a long period of time… it's that intimacy, the subtle things, just holding hands is something you do miss*" [P10 - DM]

Furthermore, participants felt that these prototypes went some way to helping deal with the distance:

"*if these had been available at the start of my uni life knowing I had 5 years of long distance then I possibly would have considered one*" [P9 - DM]

We now consider these preferences in detail.

Thematic Results

The transcripts were subjected to a three-reading thematic analysis (familiarization, annotation, and consolidation) to form a viewpoint on the interaction factors that were most salient to our participants. Two general themes are used to make sense of our participants experiences: **emotional closeness**, and **practicality**. Our main concern for supporting long-distance romantic relationships is directly addressed though the **emotional significance** of the designs for our participants. **Practical** issues apply across the devices and to communication systems more generally and have an important bearing on situations of use.

Along with describing the themes while using quotes from our interview transcripts to illustrate each, we also indicate how many of our participants raised that particular theme. This in itself provides a guideline as to how significant the theme was. However, we should bear in mind that other participants could agree with the theme but not have thought about it or mentioned it.

Emotional Closeness

Making Connections

The subtle and phatic nature of touch was commended by our participants for helping to "bridge the gap" between them and their partner:

"*its just the little physical thing and something like this wouldn't replace it but help bridge the gap…*" [P11 - PM]

This links to the value that participants saw in the devices. Instead of traditional communication, exchanging news about the day, the devices were liked for "connecting" the couple. Eleven of our 12 participants talked about how the devices would help them to connect to their partner:

"*I'm not sure why but for me there would be more of a connection there because rather than holding something which is fake (YourGlove), you're more putting your hand on a model of something which is creating a reaction on theirs is more like holding your hands together*" [P12 - DF]

People are used to touching their partners; living at a distance prevents this. Couples can still talk to one another but they cannot touch – this is perhaps the most salient thing that changes when a couple start living apart. The tangible interfaces helped to support this change:

"*You just feel the feeling of someone's hand so you feel safe and connected…so you'd associate that more than talking to someone or seeing them on skype*" [P7 - DM]

There was even a view that it didn't even matter what the device did – that it simply has to form a connection:

"*its more about forming that personal connection than the specific action*" [P10 - DM]

One of the things that we wanted to explore in the interviews is what was the best interaction model for the devices. They were configured as synchronous devices in our study – as one put their hand into a device, the partner's device is activated. There was some variation in opinion on whether it might be better to use this synchronicity differently so that *both* hands have to be in their device before they are activated. This was of significance to our participants because it changed the type of connection that was being formed between them and their partner.

Our participants overwhelming preferred to have both people's hands on the device before it was activated because it formed a more personal connection:

"*Making the link… the trouble is, if you put your hand in it and they haven't and it warms up, they cant really get anything from it… so when you're both in it, it probably works better…yeah, I think if you both put it in to form that connection…*" [P8 - DF]

"*Both of you would have to have your hand on because I think that's where the personal connection comes…*" [P10 - DM]

However, it was acknowledged that doing so meant that an element of spontaneity was lost, that arranging the connection did devalue it:

"*I was just thinking that and I don't think that would be as nice as then you'd have to arrange it… cause its not like you'd both spend your evenings sat with your hands in it waiting just waiting for that split second featuring heat and holding his hand… whereas I suppose if you were just sitting there and it warmed up it would be nice… maybe… are you thinking that you just have to sense its warmed up by feeling or you could maybe put a light on it or something…*" [P4 - PF]

The suggestion, then, is that having to use a hand from each partner formed a stronger connection, but if people choose to be spontaneous, some kind of secondary signal would assist this.

We also postulated the option of turning the system into an asynchronous one, a kind of tangible voicemail. We suggested that the system would either consist of recording a short video message with a tangible signal or recording part of a video chat along with the tangible signal. Participants generally disliked this thought as it removed the connection aspect of the experience:

"*I think that's, it is a good idea because as you say then it means you don't have to be there all the time although part of me thinks its slightly impersonal in a way because yes you've recorded the video for them and yes you've triggered the device to respond for them but you're not directly talking to them in a way, I think this sort of device would work better if you were actually in your skype conversation at the time rather than pre-recorded in a way…*" [P9 - DM]

Clearly the asynchronous nature was appealing but the cost of sacrificing the connection with their partner was too high for many participants.

Metaphor

Generally, our participants were able to understand the devices as pointers to hand-holding experiences to form a connection between the couple while they are apart.

"*this is just like feeling closer to someone by almost using holding hands as an inspiration but not trying to imitate the same concept of holding hands but what holding hands represents*" [P3 - PF]

Nine of our participants talked about the different metaphors that the devices were based around. The stronger the metaphor, the more problematic it was for our participants to differentiate the sentiment of the behaviour from the realization of the device. More people would use, and favoured, the devices with the weaker model of hand-holding, the HotMits and HotHands systems. The YourGlove was repeatedly described as being "creepy" and even the HotHands were less accepted than the HotMits:

"*the unfamiliarity people have with just seeing a limb lying around… and I think it's very familiar to see a hand print, and I suppose it's more common and less innovative for people to either dip their hands in paint and put it on the wall or whatever…*" [P5 - PM]

"*just because the imprint it's not something that would be attached to a body whereas these you expect them more to be attached or it's weird to take a part of the body off and have like a dismembered hand or arm or whatever…*" [P3 - PF]

"*I think it's good because [HotHands] was trying to be a hand which it clearly wasn't but this acknowledges that its not a hand, its just an imprint so in a way it's not like trying to trick you into thinking about it… other than that, same as the other one I guess… it doesn't look as nice but it doesn't really matter what it looks like*" [P11 - PM]

The strength of the metaphor helped to determine how "creepy" people found the particular device. Additionally, there was also a practical strand to this thinking. As one participant said:

"*I think I prefer the warmth over the movement because whatever you do, it's never quite going to be the same as an actual movement of your hand… whereas that you can more stimulate something…*" [P8 - DF]

This clearly relates back to the uncanny valley we were discussing earlier. Those devices which tried to copy the behaviour most closely (in this case, the YourGloves) most directly violate expectations of fidelity. Alternative ways of presenting the essence of a behaviour are likely to be successful.

That said, in one particular case, the weak metaphor was seen as a weakness:

"*maybe that seems a bit less personal, its nice again that it's controlled by your partner, but… on the other hand it's sort of, you could just be sat there thinking oh this is warming my hand up rather than thinking im sitting there holding my partners hand…*" [P9 - DM]

It may be enough to convey the envisionment of a behavioural design through a compelling narrative, based on a familiar behavioural experience, as long as it has a simple, direct connection to a tangible facet of that experience. In this instance, our participant points out that heat is inherently less like hand-holding than movement. What keeps it within the realms of believability is the fact that the devices are physically modelled on lovers' hands.

The acceptance or not of a particular metaphor is a difficult thing to design for. Simply going for the lowest common denominator, that which would be acceptable to everyone, runs the risk of forming a weaker connection between the users of the device. Relating that to our own designs, as the process for creating HotHands and HotMits is essentially the same, simply a different cast, any deployment could

easily see participants choosing themselves which metaphor they themselves wish to use. As we will discuss, memories played a significant part in people's treatment of the different devices. Allowing users to select which cast they make would have the additional advantage that if people had significant memories based on either of these designs, they could opt for that particular system.

Personalization: private and jointly crafted uniqueness
Personalisation was one of the themes than frequently came up in our interviews, 11 people mentioned it; those who read the person-centred scenarios delighted in it; those who read the device-centred enjoyed the concept more when the personalization idea was raised:

"*maybe because that's a bit more personal… if that were the case, and its made for each of us, it would be really nice to have and maybe id actually consider having it, yeah, I think it would really make a difference…*" [P6 - DF]

There seemed to be three distinct strands that caused personalization to be liked so much. The first is that by being able to personalize the device, it was associated more with their partner. This seemed to be important as it formed an additional connection to their partner as the device was customized to remind them of that individual:

"*it should represent him, so if he painted it boring colours that would be fine, that's what I'd have on my desk. But yeah, it should represent them*" [P2 - PF]

"*[while discussing YourGlove] I like the whole bracelet idea especially cause like I have this bracelet and my partner has the same one and we've had them for like four years so although it's like a pound and worthless to anyone else, there's some sentimental value that means we just don't take them off… so I think that's quite a powerful thing actually…*" [P5 - PM]

The second strand was that of uniqueness. Comparing analogue to digital communication technologies, we can see (arguably) a decrease in uniqueness – no one else has your handwriting but everyone (nearly) uses the same fonts for emails. You use the same phone to talk to your bank manager as you do to your lover. The unique element of these designs seemed to appeal to people:

"*Yeah definitely, because just like a mass produced hand has got nothing personal about it, there's nothing special for you or the person you're with, it's just something everyone else has, it's not unique*" [P11 - PM]

We found that the process of casting HotHands and HotMits was considerably liked. The casting would create something unique and that the effort invested in it would make the device more sentimental:

"*you wouldn't have any qualms about throwing it away… whereas if its someone whose made it, I always feel a bit, like cards and even letters, something someone's written or made or when little kids have painted you something, even*

though you cant keep it forever, you always feel really bad about throwing it away or getting rid of it… so even if you didn't use it, like you'd still have it on your desk" [P3 - PF]

The final strand that seemed to contribute to people's feelings of personalization was that of effort. Previous work has indicated that interfaces which require more effort can, sometimes, cause the receiver to value the communication act more [11]. Our participants seem to concur with this assessment but at a different level; the effort that had gone into the creation of the device was definitely appreciated. Whether this appreciation would continue when actually using the device is unknown:

"*its always nice when you have something handmade by someone else, that they put effort into it and you always appreciate that…*" [P3 - PF]

The fact that the personalization seemed so strong could, as one participant pointed out, actually be a downside. They argued that the personalization would remind them of their partner. Because the devices were modelled on a co-located behaviour, they thought that this would simply remind them that they couldn't actually hold hands:

"*Yeah I see, like customise it so it's more like your partner… I suppose that would definitely make it much more personal device so like then you would look at it; then on the other hand that could be quite creepy in a way; like sort of just the arm of your partner in your room… some people might find that a bit strange and actually they might find that a bit emotional in a way, especially if like being in an LDR, if you see things that remind you of your partner, that could be quite hard*" [P9 - DM]

Evocation of Memories
As well as being an act of personalisation, the process of casting the hands created a significant memory that connected the people within the relationship. As our participants said, this memory would subsequently be triggered each time the device was used, making the couple happier and imbuing a sense of attachment to the device:

"*the process of making is important because I imagine they'd be quite fun to make, because the activity is done together, it's a shared memory, so I think each time that you would go to use the system there would be a triggering of the memory of making the cast which I imagine would be a positive memory so that would then influence your mood in a positive way I think*" [P5 - PM]

This illustrates something we did not expect; the power that evoked memories brought to bear on people's attitudes towards the hand-holding devices. Five of our participants talked about memories and connected them to their use of the devices. These memories came in two types – personal memories that were associated with the device and broader cultural memories that made the devices seem less weird. One participant was particularly keen on the HotHands

system as it reminded her of an early, but significant, memory within her relationship:

"*it reminds me off a personal memory, just of being in the cinema, it's such a long time ago, I think it was on our second date and my hand was here and he put his hand on mine and I don't know just for me, perhaps not other people, that's why I liked it and when I saw it I thought "wow""* [P 6 - DF]

One participant recalled an activity they did on holiday, and related it back to the imprint in the HotMits system:

"*we kind of did it when we went on holiday in the sand, It might have been feet, and then like wrote our names in the sand and took a photo of that so that's kind of a similar concept I guess...*" [P3 - PF]

Others related the devices back to more clichéd cultural stereotypes including the imprints in concrete of celebrities' hands in Hollywood and finger painting as children:

"*you know like when you're a kid and you make hand print things and take them back to your parents...*" [P2 - PF]

The cultural memories were useful in so far as they demystified and helped people understand the aim behind the design concepts.

However, what we are really trying to achieve is to tap into those deeper personal memories which were accompanied with a visceral attachment to a particular device. If we can find a way to access this visceral attachment within the communication act then the connection between the couple will be strengthened and hopefully better supported.

Practical Themes
In addition to the themes which had an emotional impact, there were a number of themes which revolved around the practical deployment of these devices, including biomechanical fit, mechanical noise, the possible abuse of the unique lover's channel and the viability of hand-holding devices alongside other media.

Biomechanical Compatibility
The first concern was to do with the simple fact that people have different sized hands. Eight people discussed how best they could actually use the cast hands:

"*well no, actually because this is odd, imagine if my hands were really big and my girlfriends hands are tiny, that still works in real life, but here it's like your putting your hand into a mould of a hand that's not yours so it wouldn't fit. So like that finger there doesn't feel comfortable because it's not resting in there. So even though it sounds odd, it might be better to have a cast of your own hand*" [P1 - PM]

As P1 correctly surmises, couples can have different sized hands and for the participant with larger hands, the device may be uncomfortable. That led to the concept of *not* swapping imprints. That concept had different concerns:

"*I think id find it weird if it was an imprint of my hand because im just holding my own hand*" [P8 - DF]

This suggests that this kind of decision should be left up to individual couples. Whether they choose to be more comfortable or to form a closer connection, it seems to be a personal decision for the couple.

There was also some debate as to the best way to deploy the heat within HotMits and HotHands. Some participants would like the whole device to warm up:

"*I'd say the whole hand, yeah*" [P10 - DM]

While others would have preferred the heat to be across the whole hand:

"*I think it might be weird if the whole thing heated up but actually I think it's good it's the bit in the middle cause if you're holding someones hand, that's the bit that kind of gets warm... but maybe a bigger area like the whole palm...*" [P3 - PF]

Again, these concerns seem to be something dependent upon an individual's own preferences.

Mechanical noise
Only one of the devices caused noise due to the motors in it – the YourGlove system. Four participants complained about the noise that the YourGloves made. As one said:

"*the mechanical noise is a bit odd as it reminds you, you couldn't like close your eyes and pretend it was them because im pretty sure [my partner's] hand doesn't go [buzzzzz] [giggles]...*" [P2 - PF]

And another:

"*I'm not to keen on the noise but obviously the noise has to be there, doesn't it... the noise makes it more robot-like which makes it less human-like...*" [P12 - DF]

Similar findings were reported by Mueller et al. when discussing their compressed air hug-belt [8]. It seems, perhaps unsurprisingly, that any kind of noise that distracts from the moment stands to ruin the communicative act. As tangible devices continue to be experimented with, this is something the design community needs to be aware of.

Channel Abuse
A concern that a two people shared was that somebody other than their partner might use the system, either deliberately or by accident:

"*one thing that stood out was, it is essentially, nothing stopping another person putting their hand in the device... if you're not currently having a conversation with your partner then they could potentially be under the false assumption that you're trying to communicate with them...*" [P5 - PM]

"*if you can see them and see that it's them using it rather than some other person who's hacked into the system and started holding your hand with a stranger...*" [P3 - PF]

The concern seems to be with the possibility that using the system could create issues with their partner by thinking that they were using the system with their partner when in fact they were using it with someone else. Additionally they thought they might use the system without their partner being there. The relationship problems that could stem from either of these situations are clear.

Channel Complementarity

Using the devices with an additional communication system was seen as a plus. Not only did it help overcome the concern of other people using the device, the ability to integrate the prototypes into people's existing communication practices was considered a major positive:

"*the way that you can combine the device with other communication devices is quite a nice idea... so the fact that you could be on skype or a phone, you don't have to be using a technical device; as long as the actual device is in the room with you, you could be using pretty much any method of communication... so I think that's quite a cool thing to have...*" [P5 - PM]

One participant travelled a great deal and as such was concerned about the portability of the devices:

"*the portability too I suppose... it doesn't seem too sort of cumbersome, something that you have to wear; you could potentially just carry it with you... so if you travel a lot, you could take this with you, it's nothing which is too restrictive in that sense... so I think its very convenient; it can be used with multiple communication tools*" [P5 - PM]

In that respect, HotHands and HotMits have a clear advantage over the rather bulky YourGloves.

Practical potential

What these practical concerns tell us is that creating designs based on a familiar intimate behaviour is not straightforward. Although the metaphor is extremely powerful, it is by its nature almost unique to individual relationships. Designing something that provides meaningful interpretation for all potential users is challenging, and thus an approach that leverages small, familiar behaviours could have wide applicability. One possibility for overcoming these concerns would be to modularize the system. This would allow users the opportunity to customize the system to their personal preferences without sacrificing any design innovation.

DISCUSSION

As well as a number of practical considerations, our data indicate that all three devices are valued, to different extents, for their ability to form connections between romantic partners at a distance. Our data suggests that the desirability and ability of our devices to bridge the distance gap is based on the interplay between a number of factors, including personalization, evocation and metaphor.

Some of our themes may seem somewhat unsurprising to designers (e.g. people preferred having both people's hands on the device to make it work) but others are more speculative (e.g. that holding a hand would make them feel more connected). However, we have discussed four key themes that could be of use to others who are designing intimate devices for LDRs.

The first of these concerns the way that co-creation invests special significance in the communication device. The casting process is a form of super-personalisation; not only is each participant customising the device for their own use, they are actually creating the device from scratch, creating a highly personal memory which is of significance to the relationship. As a design concept, it is possible to see how the embedding of memory in the creation or use of communication technologies could benefit LDRs.

We found that the stronger the metaphor of the device, the less participants seemed to enjoy using it. We've previously discussed how our devices relate to the Uncanny Valley phenomenon. Our data seems to indicate that people appreciate the use of underlying behaviours (in this case, handholding) as a starting point for design but that simply replicating the behaviour will not be successful. Given the large number of different behaviours and the different ways of representing such behaviours, this seems to be an area of untapped design potential.

A number of people discussed using our devices along with other communication technologies. People build up strong routines within their relationships, especially regarding the communication technologies they use. These become a necessary backdrop to significant communication activity. As such, designing to augment current technologies could be more successful than creating completely new devices. Although this limits the potential for new technologies, it increases the chance of a device being used. Evolutionary changes can be just as beneficial as revolutionary ones.

Finally, spontaneity was highlighted as a design factor worth considering. Several participants spoke of seeing things during their day which would encourage them to communicate, something which cannot be accomplished through a fixed desktop-based system. Spontaneity is something which can easily be lost within the routine of an LDR and as such, designing it into their communication ecology could be beneficial.

Through this work, our key insights centre on the design of devices based around small, tangible, intimate behaviours intended for long distance couples. We agree with the creators of 'Lovers' Box' that it is inherently hard for designers to direct interaction design for couples because it depends on elements of users' personal history [18]. We argue that 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. The memories created

through the process, and other memories that the simplicity of the behavioural paradigm can evoke, are both mechanisms created by designers that allow couples to direct their own experiences. Our study indicates that it is possible to inspire visceral attachments to particular devices and an appreciation of how these devices can be used to connect them to their distant partner. By no means do we suggest that these are the only design themes that are important; indeed we are working to expand the design space for these devices [6]. Our work here indicates that these key themes (co-creation, metaphor, channel complementarity and spontaneity) have demonstrable relevance for communication devices for LDRs.

FURTHER WORK
Our participants understood the value behind the 'unique physical' designs for tangible presence technologies we have presented here. However, there are two main challenges for the approach we have reported. The devices, especially the cast hands, were not actually made unique for our individual participants. Their responses were to the ideas behind our devices rather than to their individualized realization. It is unclear how much of a difference this made. Given that personalization was such a key theme running through participants' responses, the impact seems likely to have been minimal.

Our exploratory study indicates that devices based on co-located behaviour using tangible interfaces can be successful in supporting long distance romantic relationships. However, there is a substantial difference between understanding concepts and their realization in a design studio and incorporating them into everyday life. Although there are substantial practical barriers to real-world evaluation of relationship-centred technologies, it is clear that more work is required in this area.

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