Warmth and Affection: Exploring Thermal Sensation in the Design of Parent-Child Distant Interaction

Sunmin Lee(✉) and Thecla Schiphorst

School of Interactive Arts and Technology, Simon Fraser University,
Suite 250-13450 102 Ave., Surrey, British Columbia V3T 0A3, Canada
{sla38,thecla}@sfu.ca

Abstract. Within HCI there is a history of investigating how wearable technologies provide the promise of creating intimate experiences in distant interactions. Through an iterative design process, we developed a wearable prototype for parent-child remote communication that explored warmth as a metaphor for affection. In our field study, we discovered that children interpreted thermal messages in several ways, constructing their own meanings of messages which support thoughtful interaction with design artifacts. Our findings suggest multiple uses of thermal interaction can arise by engaging the parents in reconsidering the roles of meaning-making in their everyday environment. We discuss how these findings exemplify an emerging design space akin to *non-finito products* underlying user values and creativity. Furthermore, our findings show how parents and children in different families practicing with the same prototype co-created a set of distinct and unique meaning based on their own creative application of their values surrounding warmth and affection.

Keywords: Somaesthetics · Parent-child distant communication · Thermal sensation · Affection · Ambiguity · Non-finito products

1 Introduction

Current video chat systems such as Skype or Apple's FaceTime afford high quality of auditory and visual cues by allowing users to communicate with others anytime and anywhere. However, it is still a challenge for parents and their young children to maintain and develop an intimate relationship as physical intimacy that plays a vital role in social-emotional development for the children is filtered out of the process in the video conversation. Considerable research studies [4, 6, 7, 19] on infant development have revealed that a lack of touch from caregivers causes emotional, behavioral and social problems for children.

To address this problem, we consider an alternate way to provide interpersonal touch in remote communication between parents and their children. We developed a wearable system to augment physical intimacy for parent-child remote communication. Concerning the issues carried by the absence of physical contact in remote communication, we focused on one-way form of communication, from a parent to a child, to understand the child experiences and perspectives of warm messages. Through several

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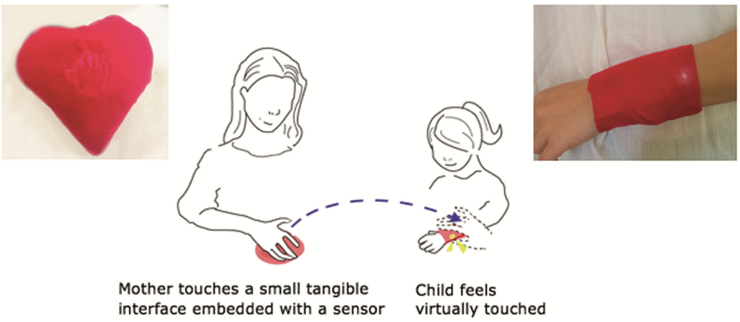

Fig. 1. The overview of final prototype system that generates thermal sensation as a metaphor for physical intimacy

design iterations with various tactile feedback, we investigated thermal sensation in the design of parent-child distant interaction. Based on a somaesthetic design framework underlining the aesthetics of somatic experience, our design prototype allows parents to send children heat messages as a poetic metaphor for interpersonal touch (see Fig. 1). Through a qualitatively focused methodological approach, we conducted a field study of working families in which parents in the work-force spent time away from their children. Our findings reveal each user group in the field study developed different strategies of using the same device with their own meanings and contexts of interaction.

In this paper, we discuss the process of designing our design prototype, *TouchMe*, and present the methodology used to understand its emerging usages and interpretations in user personal experiences. We then show our findings and how these findings reveal an emerging design space, *non-finito products*, which highlights user values and creativity in the practical cases of deploying the system as a resources for design [12].

2 Related Work

Several HCI researchers [1, 3] attempt to support physical interaction for remote communication by exploring wearable technologies. Lee and Lim fabricated a heat application as a pair of wearable devices to enhance social connectedness in remote communication [9]. They recruited two groups of participants who are in intimate relationships and asked them to report the situation and purpose of using the prototype within the context of everyday routines for a day. The findings from their study suggested that heat expression has its own unique attributes such as abstract degrees of thermal perception, positive preconceptions on warmth and unobtrusiveness in sending and receiving the thermo-messages. Similarly, YourGlove, HotHands and HotMits designed by Gooch and Watts [5] involve a wearable technology that simulates tangible presence such as a physical representation of hand-holding, interaction. Gooch and Watts conducted a semi-structured interview to understand the qualities of individual design factors on the systems. Most participants found that all three prototypes assisted them to share a connection with their partners, evoking personal memories. Nonetheless, the participants stated that the representation of hand-holding with thermal cues was more compelling.

Although the researchers suggested wearable technology could illustrate physical metaphors of interpersonal touch using thermal sensation in order to reinforce affective communication and contribute to sustain close social relationship, they heavily focused on long distance romantic relationships instead of parents and their children. Few researchers including Teh et al. [15] sought for a more effective method to foster physical interaction in interpersonal communication between parents and child. However, most of their prototypes were not evaluated to get insight into the users' expectations and experiences.

3 System Design

In a research through design process, we iterated our design with two artifacts. Addressing the issues carried by the absence of physical contact from a caregiver in remote interaction, we designed a wearable and tangible system that supports one-way form of communication, from a parent to a child.

3.1 First Prototype with Various Tactile Feedback

To illustrate physical intimacy, we first explored three types of tangible information; vibrotactile cues, thermal feedback, and combination of both vibrotactile and thermal feedback. The system was designed to simulate tactile sensation in particularly the forearm which is sensitive to light touch [16].

We designed a wearable technology that can evoke the sensation of subtle movements next to our skin [11, 15, 18]. The system comprises a pair of devices; one (tangible input device) is for a parent to send tactile information to a child, and the other (wearable output device) is for the child to receive the messages (see Fig. 2).

When a parent touches the tangible interface worn on his or her arm, it detects the tactile movement and transfers the data wirelessly to the child for up to 10 km. The child then receives the information from the wearable system. Both input and output feedbacks are accompanied by light cues to indicate the real-time state of sending or receiving intimate information at a glance. The prototype was built with soft circuits using conductive thread and small mobile programmable computers (see Fig. 3).

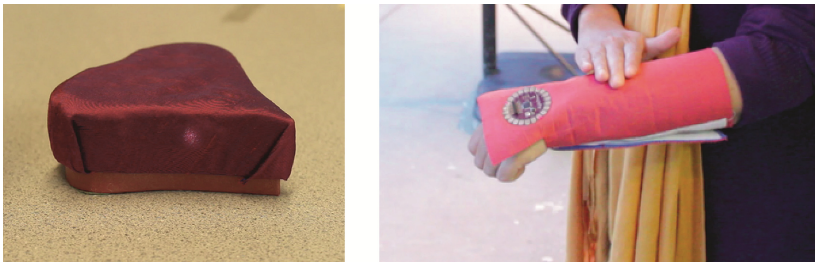

Fig. 2. The initial prototype comprises a tangible input device (left) and a wearable output device (right).

Fig. 3. The system is composed of soft circuits (left) with LilyPad Arduino (right)

Therefore, target users for the wearable communication system are (1) either a full or part time working parent who tends to spend less time with his or her child, and (2) a child in the age group of 7 to 11 years. The system was geared specifically towards school-aged children experiencing rapid progress in all areas of development and skills [2]. She claimed that in this stage, the child begins to have activities outside the family and explore independence, yet they still need "warm, supportive, and engaged parents" to develop "secure emotional attachments, healthy peer relationships, high self esteem, and a strong sense of morality."

In order to understand which form of tactile information is more emotive and convincing on users, we pursued a preliminary pilot user study with eight participants having various careers such as a housewife and an electrical engineer. In the study, we simply asked the participants to interact with both input and output devices and report their experiences including feelings on three different tactile feedbacks. Interestingly, all participants responded that they only felt vibrotactile cue when it was given with heat feedback. On the other hand, when either vibrotactile or heat reaction was separately occurred, every participant could identify the information. Although vibrotactile cue illustrated in our prototype was more prevailing in stimulating the users' sensory experiences compared with heat feedbacks, the participants perceived it as an alarming or notifying message instead of physical intimacy. Suhonen et al. confirmed this result by arguing that thermal signal may be more suitable in the contexts of communicating emotional information such as interpersonal touch [14]. Therefore, our new prototype focused on only thermal sensation.

3.2 Final Prototype

Focusing on thermal sensation, we modified the wearable communication system framed within the context of somaesthetics for more expressive tactile interaction in remote communication between parent and child. By adopting a somaesthetic design framework of tactile interaction proposed by Schiphorst et al. [10], the wearable communication device explores four underlying themes; *experience, poetics of interaction, materiality and semantics.*

It focuses on *somatic sensory experience* of the wearer to evoke positive interpersonal reactions for remote communication between parents and child. The tangible feedback exhibited by the Peltier thermoelectric heat pump in the system not only induces thermal sensibility but also brings physical comfort, which is essential to the

formation of social bonds as well as psychological development of the child [Harlow]. The *poetic concepts* of embodied communication form the foundation of designing fundamental features and functionality of wearable systems. The output device conveys thermal feedbacks as a metaphor of interpersonal warmth accompanied by skin-to-skin interaction. The system expresses two interaction modes with symbolic displays of visual aesthetics. A pulsating LED light pattern in a non-interaction mode symbolizes the pulse of other wearer to signify his or her physical presence at a distance. In interaction mode when the wearer interacts with the interface, LED emits the brightest sparks which visualizes the meaning of lighting up social relationship. The device emphasizes its *physical material properties* including textile, shape and color that engrosses emotive experience of interaction between the wearer and the system. The heart shape (see Fig. 1) underlines a metaphorical sense as the center of a child's emotions and affection towards the child, offering more meaningful interaction. It formulates *semantics* of thermal sensory qualities in interpersonal touch, exploring the meaning of heat feedbacks in remote communication. Thermal sensation simulated by the system highlights connotative values derived from our social experience. The patterns of thermal information bring up new interpretations of remote interaction and reflect the values of physical presence in intimate relationship.

4 Methodology

4.1 Participants

Through snowball sampling, we recruited seven families with young children responded to participate in the study. Table 1 provides an overview of the participant demographics including employment status, working/school hours, and the amount of time they spend interacting with children using communication devices per day. Adult participants were 1 male and 6 female parents between the ages of 32 and 41, whereas child participants were 4 male and 3 female elementary students.

4.2 Methods

Our research involves an exploratory approach where researchers observe how people use and adopt a new technology to gain an in-depth understanding of its use patterns and key problems [8]. Consequently, qualitative research methodology was applied in a user study to understand how parents and child utilize the thermal wearable application to share a feeling of connection. The evaluation methods were composed of semi-structured interviews, field trial, diary study, and survey. The two-week field trial study was designed with diary studies to collect empirical data in a natural setting. The survey study was planned with paper-based questionnaires to measure a participant's general experiences in using the prototype. All methods took place at participants' houses or any other locations convenient to the participants.

Table 1. Overview of participant demographics

User group	Partici-pants	gender	age	Employment status	Working/ school schedule	Average time spent on remote communication
Family 1	Parent 1	Female	41	Full time	10 a.m. ~ 7 p.m.	15 min
	Child 1	Male	9	Student	8 a.m. ~ 3 p.m.	
Family 2	Parent 2	Female	33	Full time	9 a.m.~ 5 p.m.	Less than 15 min
	Child 2	Female	8	Student	8 a.m. ~ 2 p.m.	
Family 3	Parent 3	Female	34	Full time	12 p.m.~ 8 p.m.	50 min
	Child 3	Female	9	Student	8 a.m. ~ 3 p.m.	
Family 4	Parent 4	Female	40	Part time	4 p.m.~ 8 p.m.	40 min
	Child 4	Male	7	Student	8 a.m. ~ 1:45 p.m.	
Family 5	Parent 5	Male	35	Full time	9 a.m.~ 5 p.m.	10 ~ 15 min
	Child 5	Female	8	Student	8 a.m. ~ 2 p.m.	
Family 6	Parent 6	Female	32	Full time	10 a.m. ~ 7 p.m.	15 ~ 20 min
	Child 6	Male	8	Student	8 a.m. ~ 2 p.m.	
Family 7	Parent 7	Female	36	Full time	4 p.m.~ 12 p.m.	30 min
	Child 7	Male	9	Student	8 a.m. ~ 2 p.m.	

4.3 Procedure

The study began with semi-structured interviews asking current experiences in communication devices and general concept of thermal sensation. We then conducted a short prototype trial session where both parent and child were asked to experience thermal messages on their forearm and describe the first impression of thermal information. Additionally, the adult participants were requested to thermally interact with children using the prototype for 30 min (see Fig. 4). After the trial session, they were given a series of questionnaires with two open-ended questions to understand their overall experience in the first prototype use.

Due to the limited range of wireless communication in the prototype, we considered the distances between the participants' houses and work/school and their daily activity routine. With that in mind we carefully designated four families (Family 1, 2, 6 and 7) from the user groups to pursue a field trial and diary studies. A prototype was provided to each selected user group and they were asked to use it as an interpersonal

Fig. 4. A short prototype trial session

communication device in their daily lives for two weeks. The participants were also inquired to report their experiences or context of prototype usage including intention, duration, feeling or reaction in a diary format. For the reporting method, they wrote a diary on a study web page (called Online Diary). The parents were requested to record the children's experiences of thermal messages by asking them if they encounter any challenges to access or achieve the tasks. After the field trial periods, we revisited the participants and conducted a debriefing interview to gain additional information about use experiences and values that we were not able to extract from the diary study.

5 Results

5.1 Usage Patterns of Thermal Wearable System

During a two-week period of the field trial, four parents in the user groups reported that they sent a total of 151 thermal messages to their children; this indicated on average, 2.69 thermal messages were conveyed to children by an individual parent each day. Each user group showed different patterns on the daily usage of prototype. However, most parents sent fewer thermal messages during the weekend. They sent the thermal information at diverse locations such as home, a coffee shop and grocery store as there was no limitation on the time and manner of use.

The thermal messages were delivered for a variety of purposes. Each parent in the user groups showed her own distinct patterns of using the prototype. Parent 1 sent the thermal information at a specified time including lunchtime as a greeting message. Another participant, Parent 2, used it to encourage her child for special occasions such as when he took an exam. The participants, Parent 6 and Child 6, predefined system use cases so the parent used it accordingly. On the other hand, Parent 7 sent the messages with physical affectionate expressions to her child.

Based on the above usage patterns, our analysis revealed that users accessed the thermal wearable system as a method to (1) express affection towards their children and (2) notify the children.

As a way to convey affection

The results of diary study showed parents in the field study groups predominantly used the thermal wearable system in order to express affection which refers to a feeling of loving and caring for children. During the debriefing interview, Parent 1 mentioned that thermal message is another "loving expression" that she was able to share with her child. She explained warmth that the messages contained reminded her child a feeling of love. The parent and child in Family 6 came up with their own values of thermal messages. For instance, they defined two short signals of thermal information as "I am so proud of you" and one long signal as "I love you." When the child was at school and slept over at his friend's house, these interpersonal expressions were delivered to him through the thermal wearable system. She stated that the way of sending thermal messages was much more comfortable for her to communicate how much she loves and cares about him than verbally saying the phrases.

As a way to notify children

The quality of current message in the system merely involves thermal display and light indication which amplifies the feature of heat cue. In addition, there is no difference in the degree of temperature. However, the participants in the field trial group reported that they utilized the system to deliver distinct information in different contexts. Parent 2 presented their ideas on particular topics within specific time frames. For example, Parent 2 sent the messages to her child playing with friends in the playground at dinner time in order to let him know "it is time for dinner." Parent 6 gave a disciplinary notice to her child to limit his certain actions by sending the thermal messages. Though she shares a physical space with her child, she sent the thermal messages to her child to distract or redirect his attention by restricting his behaviors.

Children's perceptions and experiences of thermal messages

Each group of parents and children provided different responses when they were verbally given a term "warmth" in the first semi-structured interview. Most children came up with objects or materials that contain or convey physical sensation of being warm; for example, they answered, "heater", "jacket", "sun", "fire" and "mom and baby." Nonetheless, a majority of child participants positively assessed thermal feedbacks generated in the wearable device (see Fig. 5), and recalled feelings of interpersonal warmth.

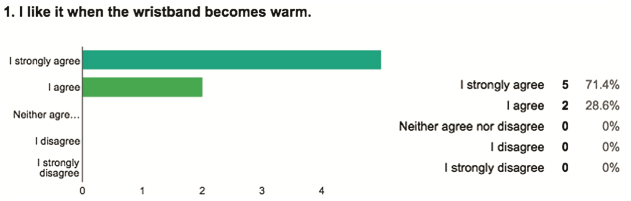

Fig. 5. The results of survey questionnaire in the first semi-structured interview indicate most of child participants positively reacted to thermal cues in the system.

As a loving attention

In particular, children perceived the quality of heat messages with its metaphorical meanings involving parents' presence and attention. For instance, Child 1 and Child 6 experienced the physical presence of mother at a distance with thermal messages. In the beginning of field study, Child 1 considered the message notified him that his mother was physically close to him when he received it. On the other hand, Child 6 explained the first impression of warmth in the system reminded him "mom's cuddles." He said warm temperature of message suggested him a feeling of comfort which he experienced in cuddling with his mom, even though the warmth was simulated on his wrist. In addition, Child 2 referred to the thermal messages as physical protection from her mother. She expressed that when she was anxious about her test or scared of thunderstorm, she felt more secure and confident after getting the messages from her parent. Child 7 elicited the parent's loving attention from the thermal information. He believed the fact of getting a heat message indicated his mother attempted to physically interact with him regardless of the fact that she was located at a different place.

Playfulness
The results of the field study presented that the prototype also encouraged children to have playful and explorative experiences. The system embraced some degree of inherent playfulness not only for adults who interact with the prototype, but also for children who experience the feedback. The feature of playful interaction was characterized by unique tangible values of thermal information. By way of illustration, Child 1 said, "It's not like a text message I can read, so I have to guess what she is trying to say (through the heat)." Child 6 experienced thermal interaction in a playful and affectionate manner. Unlike Child 1 speculating the connotations of message, Child 6 designated its values as affectionate verbal expressions with his parent, by employing the relative length of thermal signals. He described the thermal messages sent by his parent was unique information which can be only decrypted by him.

As a disciplinary note
The thermal wearable system fostered intimate atmosphere in parent-child communication, but it also allowed children to have unfriendly experiences. On the whole, child user groups reported they perceived thermal messages as moderate and sympathetic sensory information. However, the perceived quality of thermal stimulus was interpreted in a negative way according to the context of situation in which the child received the message. The children tended to feel that the tone of thermal interaction was fierce and intense when they confronted unsupportive communication climates. For instance, as Parent 6 gave the disciplinary notification to her child in order to limit the time he spent playing video games, he discerned her furious feelings through the message. He mentioned in the interview, "She didn't tell me stop playing game, but I could feel she was pretty angry at me (through the message)." He also added that the intensity of thermal expression was higher at that moment.

6 Discussion

The results from the study revealed fundamental values of thermal messages and system usages by highlighting two underlying themes; 1) Unobtrusive way to express a feeling of affection towards a child and 2) Thermal message as action trigger. We also discovered unexpected system usage patterns of parents and children's multiple interpretations on thermal information.

According to Sengers and Gaver [13], "People appropriate and reinterpret systems to produce their own uses and meanings, and these are frequently incompatible with design expectations and inconsistent within and across groups." Complexity in advancing technologies has shifted a fundamental practice of designing interaction in a more meaningful and interpretable way [17]. Seok et al. suggested an emerging design space, *non-finito products*, by highlighting user's own values and creativity in the practical cases of using the system as interaction design resources [12]. They argued that purposefully incomplete design artifacts stimulate users to complete the interaction based on their own contexts and choices.

From the findings, we found that our prototype, *TouchMe* manifestly encompasses the properties of *non-finito products* by allowing the parents and children to manipulate

thermal interaction and interpret the metaphorical meanings of thermal expression in their own manner. *TouchMe* is designed to support parents and children to share a feeling of connectedness using thermal sensation as a metaphor for physical intimacy. Nevertheless, the system let the users build their own usages to achieve the specific goals. A majority of the parent participants used the system to express affectionate feelings towards their children by recalling their experiences and the children's reactions in the first field trial.

Furthermore, the thermal wearable communication system was used to convey non-emotional information to children. For instance, some parents sent thermal messages non-verbally to persuade the children into performing certain actions such as stop playing video games and return home for dinner. Thermal sensation triggers the children's creativity and imagination to create their own meaning of messages, and it simultaneously provokes their intuitions to understand the intentions of thermal interaction. The thermal message was occasionally perceived as multiple degrees of temperature based on the situational contexts in which the child experienced the message.

TouchMe was not intended to foster a *non-finito product.* However, with the ambiguous quality of sensory information, *TouchMe* evolving through several processes of a user study and somaesthetic design framework may spontaneously fit into the new design space that provokes user's creativity and values in the actual contexts of deploying the systems.

As pointed out by Seok et al., the old paradigm of designing finished and closed systems based on designer's single interpretation hardly satisfies user's individual needs. Consequently, researchers should consider to develop the systems to be more open, interpretable and customizable through multiple design processes by focusing on users' somatic experiences, like *TouchMe*.

7 Conclusion

Our prototype, *TouchMe* opens a space for interpretation and functionality in metaphors of warmth and affection through thermal communication between parents and children. The ambiguous information of thermal sensation provides a creative space that initiates the children's imagination enabling them to construct their own meaning for the messages. Thoughtfully designed artifacts suggests multiple uses by engaging the parents in reconsidering the roles of system in their daily environment.

Thermal feedback in distance interaction system was employed in an unobtrusive way to express affection towards a parent's child. It was also used as an action trigger in certain contexts. For instance, in one case the thermal feedback non-verbally persuaded the children to stop playing video games and returned home to have dinner. While the physical sensation of warmth in the messages supported the children's feeling of emotional warmth, the act of sending the messages to the children and expecting them to experience not only the sensation of warmth but also the feeling of warmth allowed parents to maintain connection in simple yet 'anytime' moments while in the workplace. Lastly, despite the stability of the thermal temperature, a child's emotional response was affected by their perceived interpretation of the meaning of the thermal sensation.

This explores the proposition of Seok et al. [12] which focuses on a user's value-creating approach in the design process. The dynamic feedbacks of *TouchMe* discloses users' needs and values in thermal communication and allows them to have continuous experiences within their everyday contexts. Our research affords insight for a more effective and flexible design in thermal interfaces to provoke user's values and creativity.

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