Sense you in TeleTouch

Designing mediated social touch in asynchronous communication

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To all of you: touch inspires me, let us keep in touch.

Abstract

Social distancing during the pandemic deprives our social touch. This led us to look for solutions from technology. As a promising channel for affective mediated communication, our work anchored mediated social touch. By applying this novel mediated communication method, we aim at enhancing the social connectedness for remote loved ones. Investigating this study, we deconstructed the grounded knowledge in social connectedness, computer mediated communication, and mediated social touch technology as our starting points. Inspired by personal experience, asynchronous channels in mediated communication generate the sparks of social connectedness, catching our attention. An observation study based on messaging tools was produced to understand this situation in the daily context. We found that asynchronous communication may cause tension for remote loved ones under time difference but offer design opportunities for a calm mediated communication channel. Thus, we proposed a communication system applying mediated social touch in asynchronous communication. Interested in the pleasant tactile sensation, two creative technology design cycles were produced. We implemented a communication system that enables remote loved ones to convey affective messages through touch sensation in a flexible timing space. The final evaluation was deployed at participants' homes over a few days of usage. We employed the auto-ethnographic design method as the participant in this work, efficiently supporting the creative technology design process. Tinkering in the design process aided us in thinking and reflecting practically. As the results of this work, we discuss the effects of our implementation on social connectedness. Our implementation succeeded at giving a calm and pleasant mediated affective communication that enhanced social connectedness. We share the discussion of our design practice by highlighting several opportunities and giving insights for future work, including applying warmth and softness for physical composition, opening spaces for diverse relationships, richer variables for touch messages, consideration for embodied information, limitation and future improvement.

Contents

1

Introduction

Distance has been a challenge in building and maintaining social relationships, particularly for the people who live apart from loved ones. While technology mediated communication helped to minimise this physical barrier, making communication possible even in the long distance.

In the technology mediated communication field, efficiency has obtained significant attention in developing the mediated communication tool. Real-time is not a problem anymore under the advanced internet technology. Communicating anywhere and anytime is possible as long as the internet/technology is available, through verbal or nonverbal communication, by text, voice call, video call and other novel channels. Not only literal information but emotion and affection can also be exchanged aided by various novel media that enhance the communication quality.

Due to discrepancies between actual and mediated social interactions, some common phenomenons emerge under massive use of real-time technology mediated communication. Users may resist real-time mediated communication because of the high demand of mental workload, particularly for video conferences that "zoom fatigue" commonly generated from working from home during the pandemic. However, the social norm nudges users to pretend to be present in mediated interaction although under the resistant feelings, so that "absence of presence" emerged that users seem to be online interaction. Still, their mind is wandering somewhere else in physical life. These may negatively impact communication quality that influences the social connection during mediated communication.

As HCI researchers, we start to question these mediated communication channels, seeming efficient for communication, but is it efficient for social interaction? Instead of concerning the speed of transferring messages, we may consider the effectiveness and meaningfulness of mediated communication. Thus, creating a meaningful communication experience becomes a challenge for HCI researchers.

However, we find a starting point from mediated social touch. Touch, one of the most intuitive ways to interact with the physical world, is an essential nonverbal language in social interaction. And it could convey the affection between close relationships. Due to the importance of social touch for individuals and society, mediated social touch technology has been developed to break the spatial limitation. It is explained that social touch could be mediated over a distance by employing technology offering tactile or kinesthetic feedback. Previous studies have shown that mediated social touch technology support affective communication, enabling to exchange affections that enhances social presence and connectedness.

Particularly for remote loved ones, they are dependent on technology mediated communication to share personal experiences and feelings and convey affection. Moreover, intimacy built in these relationships makes mediated social touch possible to apply because actual touch is acceptable in real-life settings. Thus, we anchored our work in mediated social touch, serving as a promising option for affective communication for

people in a close relationship but live apart, including romantic relationships, families, close friends.

Mediated communication among these people involves hundreds of informal conversations with spontaneous interaction and response, causing significant asynchronous communication, meaning communicators respond to the interaction with delay. According to the researcher's personal experiences, asynchronous communication is likely to generate a misunderstanding under time difference, but it may leave a flexible personal space in mediated communication for a pleasant communication experience. Besides, asynchronous communication is commonly seen in old-fashioned communication, such as writing letters or leaving messages in voice mail. It seems slow and inconvenient but enriches the communication experience in a temporal dimension. Therefore, we posited another interest in asynchronous communication. Applying mediated social touch in asynchronous communication, we expected to generate a fruitful communication experience and enhance the feeling of connection.

1.1. Aim of project and research question

Given the context in which technology mediated communication is pervasive in our daily life, we invite designers and HCI researchers to reflect on the relations between mediated communication tools and users, and contribute to the real human connection by mediated communication technology. This project is expected to design a mediated social touch device applied in asynchronous communication, aiming at enhancing social connectedness. With tangible interaction, mediated social touch allows remote loved ones to feel each other remotely, supporting affective communication. Applying asynchronous communication is expected to create a calm and pleasant communication space in given channels. Hopefully, by putting the old-fashioned style on the novel mediated communication channel, we could generate the sparks for remote communication that improves affective feelings and enhance social connection for remote loved ones.

The central research question therefore is:

- **RQ1:** How can a **mediated social touch technology** with the **asynchronous channel** enhance **social connectedness** for remote loved ones?

The central outcome of this project is the development of such a communicative tool that could be used for remote loved ones in real-life settings. We attempt to understand the asynchronous communication for remote loved ones in mediated communication settings, then implement the mediated social touch on asynchronous channels. Additionally, we are interested in what features given by artefact can improve the mediated touch experience. Eventually, we situate this communication tool in real-life settings to evaluate the social connectedness given by the communication experience. This brings us the following sub-questions:

SQ1: How does **asynchronous communication** impact the experience of technology mediated communication for loved ones?

SQ2: How to design a **mediated social touch tool with an asynchronous channel** for remote loved ones?

SQ3: How can **tactile experience** affect the mediated social touch experience?

SQ4: How to evaluate the effect of mediated communication tools on **social connectedness**?

Moreover, we apply the auto-ethnography design method where the researcher plays multiple roles as the participant, the designer, the maker. There is the opportunity to explore the design implication and reflect on the technology and human relations by switching between multiple perspectives in the creative technology design process. This brings us to our second research question:

- **RQ2:** How can switching between **multiple perspectives** for one researcher be used to enlighten the research through design practice?

1.2. Report structure

Report is structured as follows:

Methodology: Applied methodology is described in this chapter, including research through design, creative technology design process, auto-ethnographic design method, and user research employed in observation and evaluation.

Prior knowledge[1] including **understanding social connectedness**: introduction of social connection with a look at the intersection of social presence and awareness underlying computer mediated communication domain; **understanding computer mediated communication CMC**: introduction of computer mediated communication with theoretical background and discussion of challenge of CMC, and eliciting the solution of "embrace the old and articulate the new".

Mediated social touch: Introduction of mediated social touch and look at the mediated social touch prototype from previous studies to refine the elements for a mediated social touch device and define the requirement for design and making process. General aspects of mediated social touch and aspects focused on communication systems will be discussed.

Observation study: The observation on interpersonal communication through instant communication tools was conducted before the design process. We will describe the reason and purpose for studying instant messaging tools, and executive of observation study. The quantitative result helps understand the behaviour and subjective feelings about asynchronicity in mediated communication between remote loved ones.

Designer and Maker Cycle I: The outcome of this cycle is the usable prototype for in-lab evaluation. Starting from the divergence process involves discovering the inspiration, materials, actuators, electronic components. Several hands-on experiments were conducted with self-test. Results of each discovery proceed the development. Underlying the specialisation, a practical concept is formed for realisation. Usable prototypes had been evaluated in the lab, and the result formed the requirement for the next development cycle. This cycle is reported into two chapters: **ideation and specialisation** and **realisation and evaluation**.

Designer and Maker Cycle II: Pre-inLife evaluation was conducted to look for potential unreliability of the prototype. Integrating warmth sensation and minimised information related communication process, we redesigned the previous prototype. The outcome of cycle II is a robust prototype that can be placed in the participants' homes for final evaluation.

Evaluation and results: Final evaluation is executed in real-life settings; executive and result will be shown in this chapter. Qualitative results from the questionnaire, informative results from the interview and diary will be organised and summarised.

Discussion and conclusion: A discussion of the current implementation on mediated social touch in asynchronous communication will be described, followed by reflection on the auto-ethnographic study and creative technology process. Eventually, we will conclude our work with closing thoughts.

[1] prior knowledge is primarily reframed from research topic reports

2

Methodology

This project globally applied research through design, auto-ethnographic design method and creative design process as guidance for research journey. And we conducted user research in observation study and evaluation.

2.1. Research through design

Research through design(RtD) is an approach that links research and design to explore new knowledge by applying design practises and processes. Instead of driving to create new things or commercial products, it focuses on exploring new and valuable knowledge by design action, and the knowledge includes novel perspectives, insights and implications, new design methods, and artefacts that inspire speculation. It lends design strength which continually reflects practises underlying reinterpret and reframe a problematic situation through making and critiquing artefacts. RtD stands at the speculative future, probing on what and how the world could be and should be. The generated knowledge is regarded as a proposal rather than a predication[1]. RtD generally suggested the five simple steps to conduct the RtD research project: select(which is done in the researching topics), design, evaluate, reflect and disseminate and repeat. As exploratory research in the early stage, repeat is not engaged in this study but will be the future work. More specifically, the design process followed the creative technology design process introduced in the following section.

2.2. Creative technology design process

RtD guides to formulate the construct for the overall research project, and the design process has referred to a design method underlying creative technology design practice[2]. It is a divergence-convergence and spiral model consisting of four major phases, so-called ideation, specification, realisation and evaluation, introducing explicit design guidance for creative technology apprentices.

Divergence phase embraces openness in design space fostering creativity for an unexpected view of solutions; convergence ***phase*** is expected to reduce the design space to determine the final solution. The designer's experience shapes the solution space, preferences and openness to take risks. The idea of ***spiral model*** argued variations of the design process, which is not restricted to a logical order. All components of models are interconnected and could go over in any order fitting the actual design practice. Besides, it pointed out interwovenness between design questions and knowledge questions, which to answer one of the questions will be dependent on the other one in creative design practice.

Ideation phase refers to the starting point of creative technology with many sources, which could be user needs or stakeholder requests, product ideas, or flash of inspiration resulting from lateral thinking or

related work. The result of this phase is to elaborate the project idea with problem requirements and then drive to seek the solution in the specification phase.

Specification phase is the process of seeking and determining the solution involving many prototypes with quick evaluation and feedback loop, and early prototypes are generated by experience specification and functional specification. And prototypes could be reframed and developed by a small evaluation loop until the final design is generated. ***Realisation phase*** includes "decomposition of specification, the realisation of the components integration of components and evaluation" to meet the end product.

Evaluation phase could be included in the realisation phase, which concerns the validity of whether the output of realisation fits the subsequent specification, typically as functional testing. However, evaluation is worth having a place in the overall design process. To evaluate if requirements determined by the ideation phase has been met, and compared with the related work, reflecting about implicit decisions during the design process to offer the implication for further research. Given the convergence-divergence concept and spiral concept with explicit design phases, this design method provides a framework for exploration and exploitation in creative design space concerning technological realisation.

2.3. Auto-ethnographic design method

This research follows the auto-ethnographic design method. Auto-ethnography is a form of qualitative research to apply researchers' personal experience to understand the broader experience in the social and cultural[3]. Unlike the traditional ethnography, where researchers focus on a certain group of people as outsiders. Auto-ethnography practitioners start from self-observation as insiders. Specifically, in the auto-ethnographic design method, designers look for the valuable factors to themselves from personal experiences, then analyse and reflect what has been found, consequently using these thoughts to make design decisions.

The reasons why we chose this method are explained below. First, the relevant interests of our research highly involve personal context. The observation phase involves interpersonal communication in private settings, and the design phase focuses on touch experience, which is highly personal. Self-observation could generate authentic views and overcome the difficulties of studying others, and self-reflexivity could obtain subtlety from self-observation and may reveal significant effects.

Second, auto-ethnography has been noted as a quick method in HCI that shortens the time frame[4]. Ourselves as the target users for the mediated social touch device, it could collect first-hand information with the concentration of research questions, which will be efficient and effective. Thus, self-evaluation during the design process could be quickly applied for the iteration.

Third, emphasising and understanding is an important skill for a designer, while our understanding and emphasising to others is based on our personal experience. We hope this method could help researchers recognise this impact and utilise it, re-centring the researcher's experience as vital in and to the research process. Meanwhile, training ourselves to reflect from different views is expected to develop our skill of understanding and emphasising.

In this research, we start with self-observation to understand the scenario of technology mediated communication, and run the self-test through the design practice to improve our prototype. In the observation phase, we conducted a self-diary to record our acts and feelings of interpersonal communication through instant messaging tools, subsequently interpreting and reflecting the diary. In the design phase, we develop the prototype concept according to our own context, and produce a self-test after each experiment. The following improvements are according to our own reflection and experience, eventually, forming the final design.

However, the auto-ethnographical design method has risks converting scientific research into art, with a less analytic view and less sufficient validity from "others". Therefore, we recruit users to join the study after self-study in the observation and evaluation phase. It is essential to note that the self-test is just the first

step, evaluation by a large group of users is always needed in the design practice.

2.4. User research

As a design project, inviting users to involve research is necessary, particularly for evaluation. We conducted the user research in the observation and evaluation phases by applying the following methods.

2.4.1 Diary studies

Diary study is a research method to collect qualitative information, asking participants to record activities, experiences and thoughts in everyday life entries in a period. It is suitable for the study to observe behaviour over time in a natural environment[5]. It allows us to collect longitudinal and temporal information, report the experience in the context, and minimise the potential post-rationalisation. However, it may involve inaccurate recall and result in disturbing the actions. Besides, it is potentially low control and low participation.

This method is applied in the observation and final evaluation sessions. We organised the logbook with semi-structured questions to point out the focused interest of our study for participants. Considering the low participation issue, we ask for permission from participants to send a reminder to write the diary during the study. To reduce the potential disturbance, researchers will not involve the diary study except the reminder, and collect the logbook when the study is over. After the diary study, we produce a posterior interview.

2.4.2 Survey

The survey is often applied to assess opinions, feelings and thoughts, and could focus on specific questions or have global and widespread goals. We employed this method to evaluate both in lab-session and inLife-session to collect general feedback about users' feelings. Our survey is primarily built up by linear scale and multiple-choice. It provides quantitative information as an effective and representative evaluation tool.

2.4.3 Posterior interview

We conducted semi-structured interviews after the diary study and survey. It allows researchers to bring up new ideas during the interview according to the conversation with the interviewee. Posterior interviews aim to get more insightful information from participants' opinions. Specifically, the interview after the diary study is to help with understanding the diary content. Moreover, it could uncover more details about subjective feelings, which may not be easily expressed in the diary. Moreover, the interview after the survey aims at looking for open thoughts and opinions, collecting qualitative information. Combining our survey that focuses on quantitative data, interviews provide a comprehensive view to evaluate our design.

2.5. Research journey

Applied to the auto-ethnographic design method and the creative technology design method, we play several roles as the observer, participant, designer, maker, and researcher in the complete research. The figure below2.1 illustrates the research journey based on the major role in the different phases. Diamond shape illustrates the divergence and convergence process, and the spiral design process is conducted in the designer and maker cycle; both are inspired by the creative technology process[2]. Overall, research is followed but not strictly the chronological order.

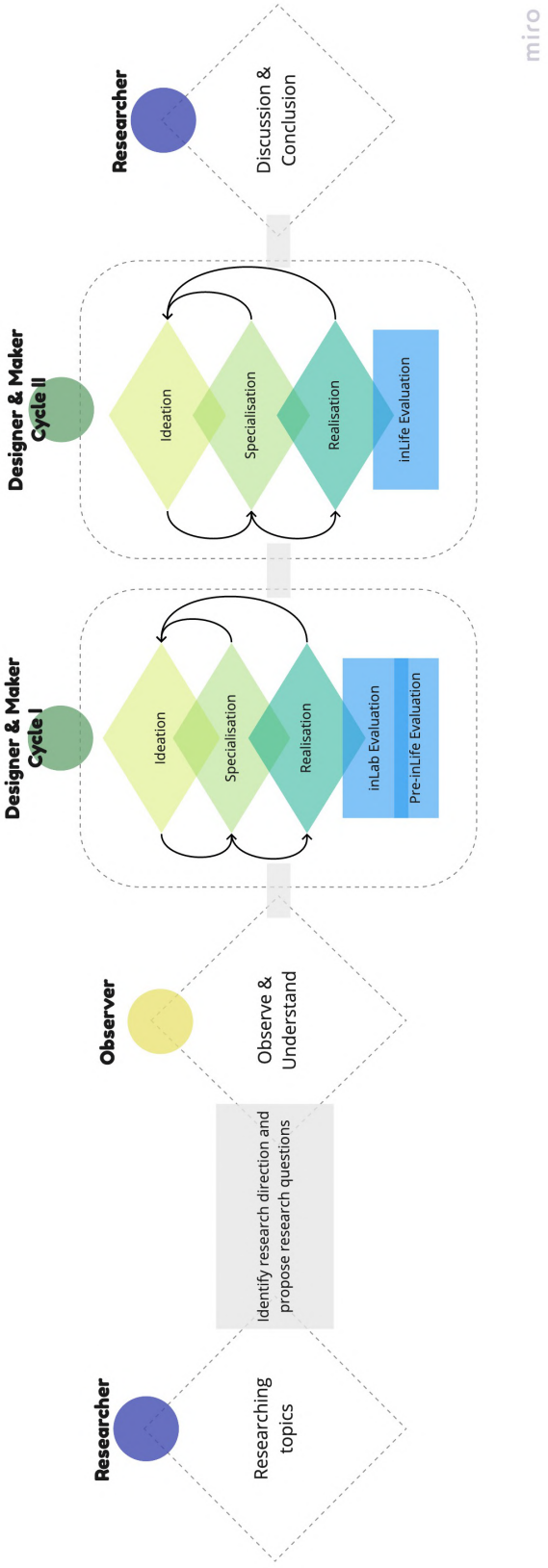

Figure 2.1: Research journey

3

Understanding social connectedness

3.1. Social connectedness

Social connectedness is regarded as the most fundamental aspect of human life, defined as the feeling of belonging and bonding that people feel having a relation with individuals or groups of others. If the needs of belongingness are not satisfied, individuals will have difficulty forming the sense of SC in adulthood [6]. Lee and colleagues [6] conceptualised the construct of SC in a comprehensive aspect from self-reflection about the beliefs and attitudes towards other individuals and social relationships, linked to the ability to understand others, to participate in social activities, to feel related to other people with empathy. These abilities are relevant to generate a feeling of acceptance, pleasant experience of friendship, and recognition in the forms of close and reciprocal relationships, notably impacting the meaning of human life as human is the social animal. "Universal need to belong" has been argued by a study [7], the failures to be valued in a social network strongly negatively influence people's emotions, self-reviews, social behaviour, psychological well-being, and physical health [8].

In addition to belonging, loneliness is the consequence of insufficient social interaction and stable social relationships[9]. The others' responsiveness creates the sense of security, enabling the relationship to protect against loneliness, and satisfactory social interaction with a feeling of social connectedness could maintain the healthy relationship [10].

Specifically, in the design domain, Rettis [11] described social connectedness as "the ongoing momentary affective experience of belonging", strongly related to, but different from belongingness and loneliness, which describe the long-term affective states and are not likely to be changed by a single social interaction [12]. The temporal experience of connectedness has been argued by the concept [13], which assumes that single interaction can influence the feeling of connectedness.

Furthermore, ranging from subtle experiences to the experiences where richer interactions are possible to support social connectedness, van Bel et al. [13] described these ideas along five dimensions and summarised by Visser and colleagues [14], providing the design directions for social connectedness: 1) *Relationship saliency* refers to the importance of the relationship in one's mind, which is the outcome of thinking or another person or being aware of another person; 2)*Closeness* refers to the experience of feeling close to another, emphasised the social presence in one's mind rather than physical proximity; 3)*Contact quality* refers to the perceived quality of social contact with another person; 4)*Knowing each other's experiences* refers to the awareness of each other experiences, both in subjective experience and of things that happen in one's life; 5) Shared understanding refers to having a similar view on the world, both for similar opinions and being on the same page. These five dimensions are valued as the guideline both for design and evaluation in the project.

3.2. Social connectedness and computer mediated communication

Communication is promising to generate a sense of connectedness or feeling of being linked, and social connectedness is potentially regarded as the core in the assessment of communication and the development of communication technology [15]. By providing accessible and handy communication channels, technology-mediated communication improves the efficiency of communication and has dramatically changed our social patterns in this digital age. These pervasive and open communicative channels make us share and know each other's experiences that support the social connection. Particularly during the pandemic under social distancing circumstances, it helps alleviate social isolation and loneliness. Thus technology mediated communication is essential to enhance and maintain social connectedness.

While massive mediated communication use also has caused dysfunction of communication impact on social interaction, mainly due to the lack of social proximity. Reducing the dysfunction in communicating and promoting the competence of technology-mediated communication is a challenge for HCI researchers. Beyond the efficiency of communication, this project invites designers and researchers to look for the far-reaching effect of technology-mediated communication to enhance social connection. More discussion about technology mediated communication will be described in the next chapter.

3.3. An intersection with social presence, awareness for mediated communication

Social connectedness is closely related to social presence and awareness, and these notions are commonly discussed in technology mediated communication domain as possible analysis of communication tools. They are intersected but differ from each other; understanding awareness and social presence will help to understand social connectedness. In this section, concepts will be introduced, respectively, along with a discussion about their intersection.

- Social presence

Social presence was conceptualised by Short et al. [16] as the "degree of salience of the other person in a mediated communication and the consequent salience of their interpersonal interactions", and the notion of intimacy and immediacy have been related as the core of social presence. 'Immediacy' refers to a measure of psychological distance, such as nodding and smiling, the behaviour of immediacy, "enhance closeness to and nonverbal interaction with another" [17]. 'Intimacy' is associated with the feeling of connectedness that occurs in an interaction [17]. Immediacy can create and maintain intimacy and also enhance social presence. Social presence is regarded as the 'sense of being with another' [18] and related to the ease with which one can perceive that another's intelligence, intentions, and sensory impressions is accessible[19].

- Awareness

Awareness has been defined as "an understanding of the activities of others, which provides a context for your own activity" by Dourish and Bly [20]. The perception is not derived from "heard of", nor "thinking of", rather from "the sense of experience" and believed as an external perception; thus it requires to be perceived to be synchronous or near-synchronous [15]. Retti explained that its meaning derived from the object of awareness, as an almost simile of consciousness.

- Intersection for awareness, presence and connectedness

Related to social presence, social connectedness can be formed by, but not depends on the other's presence. Ijsselstein et al. [21] stated that social presence and connectedness are complementary, arguing that a sense

of connectedness can be strongly perceived even with a low level of social presence. Lee and colleague [22], described social connectedness as one's subjective awareness of others and how interpersonal relation is close, being felt more prominent to the individual self than the actual presence of other people. Retti[11] presented a logical relationship between awareness, social presence and connectedness 3.1. It argued that awareness could be generated without social presence or connectedness, and social presence and connectedness can occur together, and occur independently, e.g., telemarketing creating social presence but without experience of connectedness, and text messages with little or no social presence but creating connectedness. Awareness of presence can create the experience of connectedness, but it is unclear whether connectedness can be generated without awareness or whether connectedness leads to awareness of the other individual. For example, receiving a postcard can create the experience of connectedness but no direct awareness of the sender. An alternative description of the relation between awareness and connectedness is that the experience of connectedness is mediated by the object instead of the real person. However, the embodied meaning is derived from the person who actuated the objects. For example, text messages received on the mobile phone evoke the feeling of connectedness but without the receiver's awareness of the sender. Rettie argued that this concept might enhance connectedness without imitating face-to-face communication, allowing devices to facilitate intimate experience while minimising intrusiveness, which is an insight for developing novel mediated communication tools.

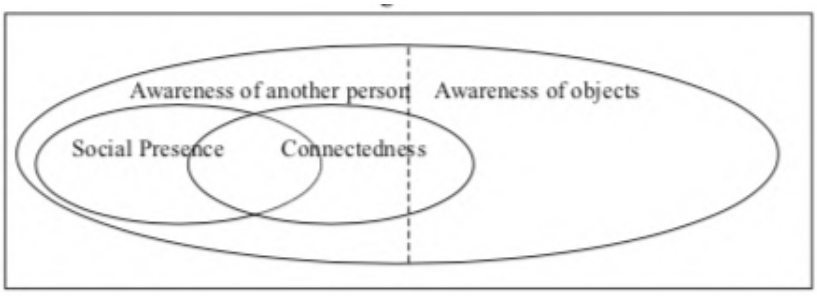

Figure 3.1: Relation of SP, SA and SC
[11]

In summary, awareness, social presence and social connectedness are strongly related to each other. Awareness is considered as an external perception and can evoke both social presence and connectedness; social presence emphasises the "sense of being together", it can create connectedness where the sense of presence is perceived for the people who have involved a particular level of closeness. Whereas awareness of presence facilitates the experience of connectedness. In terms of temporal dimension, they all can be perceived in a single interaction, whereas senses of connectedness are more likely to be prolonged; importantly, with its higher level of affective state, social connectedness has a profound impact on support belongingness, and in the long run, resulting in social well-being.

4

Understanding computer-mediated communication(CMC)

In the past decades, information and communication technologies have been rapidly developed and associated with computer-mediated communication (CMC). It potentially altered how human beings share information and communicate with one another, referring to human communication through computer networks. In the early age when the Internet was underdeveloped, a distinction made between synchronous CMC and asynchronous CMC, the former interaction takes place in real-time, includes type text-based online chat, computer, audio, and video conferencing, whereas the latter does not necessarily co-occur, consists of email, discussion forums, and mailing lists. Today, more complex and crowd-based systems have been generated to provide new ways for remote collaboration and online sharing. Social media technologies, such as Facebook, Instagram, allow people to share the content online as a highly accessible means of CMC. In addition to advanced functions and accessibility, the integration of offline and online channels has a substantial impact on our interpersonal communication [23]. Although CMC provides various channels with multimodal, richer sensations through photos, videos, and immersive environments, text-based communication keeps the prisumary use for exchanging information. Therefore, the previous research based on text-based forms of CMC is still valuable to be learned, which will be introduced in the following sections, and the problems of CMC focused on by this project will be stated afterward.

4.1. Cues-Filtered-Out theories: lack of nonverbal cues

A basic model of communication [24], as central components is made up of the sender, receivers, messages, feedback and communication channels, aids the development of CMC. As numerous discussions reflected on CMC, the term cues-filtered-out has been coined by Culnan, and Markus [25] stated that CMC's lack of nonverbal cues limited the social functions involving those cues. Based on this theory, social presence theory [16] claims that limited cues correspond to reduce social presence for communicators. Without nonverbal cues, information related to an individual's personality, character, interpersonal warmth and ease will be ineffectively conveyed.

However, media richness theory [26] suggests that the media without nonverbal cues may be more efficient. Instead of focusing on the cues provided by CMC, the best communication result occurs as the information channel matches the equivocality of the communication context. For example, CMC may suffice when one person asks about the date of an event, such as email, but when an individual wants to know another person's personality or character, which is conveyed efficiently by nonverbal cues, the quality of information will be degraded via CMC.

4.2. Theories of interpersonal adaptation and exploitation of media

The theories of interpersonal adaptation and exploitation of media try to cover all components of the communication model, including the sender's role and the sender's active reactiveness of message and channels.

Social information process (SIP) theory [27] presented that communicators will integrate the available cues to encode and decode information, it is supposed that CMC requires more effort than those in FtF communication to develop the same level of relationship, as CMC channel change the efficiency of social information exchange. Taking a step beyond the SIP theory, the hyperpersonal model [24] argued the potential advantage of CMC that is likely to aid in developing interpersonal relationships and even exceed the desirability and intimacy occurring in FtF. Four components of the communication process encompass this model: 1) effects due to the receiver process; 2) effect by encoding messages from the sender, 3) attributes of the communication channel, and 4) feedback. These components stated a dynamic of communication and show the possibility that over time effort of CMC might exceed the FtF communication. While certain aspects of this model remain under-researched, for example, the integrity of its subcomponents and the reciprocal effects of feedback. SIP theory and hyperpersonal models both involve the limitations of cue-filter-out approaches.

Furthermore, several efficiency frameworks have been developed trying to resolve the previously contradictory finding from satisfaction with, and the effectiveness of, CMC collaboration [28, 29, 30]

Media synchronicity theory extends beyond media richness theory, defined as an "ability to support individuals working together at the same time with a shared pattern of coordinated behaviour" [31], conceptualising the communication into two processes, that is, conveyance and convergence. Convergence processes involve coming to a shared understanding of information with high levels of co-create and ambiguous information. To make the communication successful, individuals must engage in both transmission and processing activities, promoting more behavioural coordination (e.g., face-to-face, video-chat). Conveyance processes involve sharing large amounts of diverse and unambiguous information, which is new information. Due to a large amount of information, the sender may have to get more time to prepare, and the receiver has more time to process and integrate the information into his/her mind. This process corresponds with communication channels with a lower level of behavioural coordination, e.g., email and Short Message Service(SMS).

Most communication tasks in CMC integrate conveyance and convergence processes so that individuals should suitably convey information and converge the meaning of information. Adequate conveyance of information helps to reach the correct conclusion of information, whereas adequate convergence on meaning helps to obtain shared understanding and subsequently move forward to other activities [32]. Synchronicity is an additional component, which improves the convergence process but weakens the conveyance process. The convergence process requires individuals to exchange information rapidly and respond to questions and misunderstandings immediately, involving more interaction and shared focus. Whereas in the conveyance process, synchronicity shortens the time for the sender to think about and craft the proper message as well as for the receiver to reprocess the information [33].

4.3. Update the term

Standing at a macroscopic view for CMC, the above discussion provides prior knowledge of CMC for further design projects. Moreover, as it has been argued, the term "computer" seems not ideal to join with mediated communication [34], and the traditional characteristics of computer will be weakened for the further design stage, for example, the digital screen will be excluded, the cues of communication are expected to convey less sense of digitalization for users. Therefore, computer-mediated communication will be replaced by technology-mediated communication in the reset of the report, although the core of the communication process may still rely on computer systems. Additionally, this project will focus on one-to-one interaction experience of technology mediated communication instead of technological development. Moreover, problems from desk research will be stated in the next sections.

4.4. Problem statement for TMC

4.4.1 Cues overload

Zoom fatigue is the phenomenon that occurred during a pandemic, as part of the extensive experience with CMC exhaustion, explained as "a common experience through prolonged use of CMC platforms"[35]. The audio-visual channel exchanges information by capturing nuances, such as body language and tone. Intensive communication in this way (intense degree can be referred to as duration and frequency of communication) requires a heavier cognitive load than FtF communication. Compared to physical interaction, it is less natural that users need to pay extra effort to be present in the communication settings, consequently causing physical and mental exhaustion. While in physical interaction settings, face-to-face leaves the space for social coordination and social resilience. This finding states that rich nonverbal cues in CMC may minimise the communication quality, particularly in the case of running a long-session communication, which argues with Cues-Filtered-Out theories that limitation of nonverbal results in diminished communicative experiences and socially lean interactions. However, exchanging nonverbal cues facilitates sharing affective feelings and symbolic meaning, which is vital for interpersonal communication concerning the social connection. Nowadays, advanced technology can exchange nonverbal cues through multiple channels efficiently and effectively, providing the immersive and compelling experience of CMC. The accessibility of these technologies benefits users, particularly for distant relations. Therefore, designers and researchers should consider how to employ channels that facilitates exchanging nonverbal cues and shared meanings, but reduce the cognitive workload, to create a light but fruitful mediated communication experience.

4.4.2 Resistance for the immediacy

Real-time is not the difficulty for CMC underlying the development of technology, but resistance for real-time communication in interpersonal communication has emerged, even with the loved one. Objectively, being online all the time is impossible, so asynchronous communication is more common for interpersonal communication on TMC. Moreover, the real-time response on TMC channels may not be as easy as we think. Unlike FtF communication, verbal and nonverbal feedback could be conveyed immediately and directly in the physical settings. Response on TMC channels through the mediated tools asks users to be present in a virtual environment. Like physical being somewhere for FtF communication, a meaningful TMC requires equal or more cognitive workload. Additionally, the high availability of real-time communication nudges users to value or get used to synchronous communication. While considering the cognitive workload as discussed before, the resistance of real-time response is generated reasonably. Besides, TMC opens the broad space for remote interpersonal communication but also narrows the boundary of personal space and social space. The intrusiveness of personal space made from TMC also results in resistance to immediacy.

However, the initiator starts the interaction with the expectation of feedback, sooner or later, the resistance of real-time response for the recipient may impact the communication quality negatively, subsequently affecting the social relations and connection. Therefore, the development of TMC tools, beyond being instant, should be attuned to embrace moderately asynchronous under this context. The challenge for designers emerges: how to design the mediated communication experience to embrace the flexible synchronicity that relieves the pressure of real-time response from social norms but does not impact the communication quality?

4.4.3 Absence of presence

"Presence of absence" is one of the advantages of technology mediated communication, meaning that communicators can perceive the social presence of each other in the process even with the physical absence. However, Zoom fatigue presents a new phenomenon of technology mediated communication: absence of presence, which means people are being present in the video conference but being tired of online presence;

moreover, under this fatigue without sufficient energy and intention, they may can not spontaneously respond to the interaction from another, standing at an absent state. Besides, absence of presence is also common in text-based communication. In the case that the responder is busy but feels obligated to reply, a simple response may be given to show the mediated presence, but mental presence is insufficient. For the response-recipient, although the response is delivered but missing the connection. Therefore, absence of presence can be described as "disconnect of connection". While similar situations may occur during face-to-face interaction. People may be lost in thought during the conversation, but co-located setting grants the FtF communication more space for social coordination when this zone-out occurs. Therefore, designers should reflect on the communication process to learn the possible causes of this phenomenon and think about how to design to reduce the "disconnected state" during connection. Another direction is to design the space for users to relieve their fatigue and attune their states when they encounter disconnected issues, offering buffer zones for resilience during social interaction.

4.5. Embrace the old, articulate the new

The importance of synchronicity for mediated communication has been emphasised in the social presence theory, media richness theory and media synchronicity theory. Among these theories, media synchronicity theory [32] defined five media capabilities related to synchronicity: 1) transmission velocity, referring to the speed of transmitting a message by medium; 2)parallelism refers to the capability of medium to convey two or more messages at the same time; 3)reversibility refers to the extent to which a medium offers the sender to rehearse a message before sending it; 4)reprocessability refers to the extent to which the receiver can reprocess a message once or more times; 5)symbol sets refers to the number of ways to convey the message through a medium. Both faster transmission velocity and greater symbol sets lead to greater synchronicity; more parallelism, rehearsability and reprocessability lead to less synchronicity. Besides, a study [36] found evidence to support that asynchronous media are better for conveyance and synchronous media are better for convergence. Hassell and Limgayem [33] showed that the lower synchronous medium outperformed the higher synchronous medium for a conveyance-intensive task; they also suggested that a portfolio of media, both with lower synchronous and higher synchronous, is the best.

Although these studies based on the communication for specific tasks slightly differ from the communication occurring in the close relationship, they imply that lower synchronicity may enhance the communication in the specific settings primarily because asynchronous medium offers more space for rehearsability, reprocessability and parallelism, less pressure to quickly compose and send the messages. Recent studies have shown that asynchronous communication enhances the communication experience. A study stated that an asynchronous communication channel allows individuals to collect rich contextual information generating rich, flexible and creative expressions [37]. A synchronous storytelling system for families in different time zones, showing the value of slow, flexible and non-urgent asynchronous audio interfaces for family bonding [38]. Moreover, an asynchronous co-dining experience through audio recordings enhances the intimacy between users [39].

Regarding asynchronous communication in interpersonal communication, writing letters, postcards were common before the largely used CMC, and emailing and leaving messaging was the primary way in the early stage of CMC. Concerning efficiency and effectiveness, this old communication style does not fit the current scenario of mediated communication. Advanced CMC acquired prominence from old-style communication, instant messaging tools with video- and audio-based channels are functional and accessible, VR even makes mediated communication more immersive and multisensory.

However, these old-fashioned ways seem less efficient compared to advanced CMC channels but may notably impact affective experience. Firstly, the process of message preparation requires more effort for the sender than typing a text or sending a GIF; this makes mediated messages more precious. Second, the surprise of receiving a message could be generated by unknown message processing. People receive the message by self-checking, being less intrusive and more empowered. Besides, because of the low accessibility of remote communication back then, people would highly value communication time that may lead to a better quality of communication. Additionally, the postcards and letters are tangible so that people can "re-taste" the affection

in the messages. These features of old-fashioned communication build up the affective experience during the communication. Therefore, old-fashioned communication with slow and less synchronous characteristics may indicate a new direction for designers, in which learning from the affective experience offered by old-style communication to reproduce the positive experience by applying the novel CMC tools. In other words, "embrace the old, articulate the new." This project applies the mediated social touch as the novel channel, which will be introduced in the next chapter.

5

Articulate the new: mediated social touch

5.1. Understanding mediated social touch

Touch is essential in social interaction as the nonverbal language conveys the message both with near-semantic and affective meanings. Mediated social touch has been defined by [40] as "the ability of one after to touch another actor over a distance employing tactile or kinesthetic feedback technology". Mediated social touch technology requires detecting a touch at the sender's end and a form of touch at the receiver's end. Huisman [41] presented that the senders should be aware that their input generates a physical sensation at the receiver's end, and the receiver should believe the sensation of touch they perceive made by senders. As mediated social touch may occur without physical proximity, the difference between real social touch and mediated social touch should be considered, which provides implications for designing mediated social touch technology. Huisman [41] summarised by following: firstly, mediated touch could be non-reciprocal that sender and receiver can have different perceptions of touch sensations, for example, pressing a sensor by the sender can be conveyed through vibration to the receiver. Secondly, mediated touch can occur asynchronously, and the touch can be stored and received later than that being applied and sent. However, mediated touch provides a poorer sensory-rich experience than actual social touch, in terms of both cutaneous and kinesthetic feedback and feedback from other modalities that may not be present in the mediated social touch.

5.1.1 Mediated social touch and TMC

TMC technologies enable communication over distance, conveying information conveniently but with less affective components of communication, [13]. Besides, TMC is criticised for devaluing and impoverishing human communication [42], and may result in the prevalence of individualism and feelings of loneliness [43]. Applying mediated social touch for TMC is suggested to be a possible approach to overcome these issues or improve TMC encounters' satisfaction [40, 44, 41]. As non-social physical stimuli can elicit affective responses, the touch attributed by remote partners can be exploited in a TMC setting [45]. In addition, social touch impacts on perceiving satisfaction of co-located social context resulting in various effects; if mediated touch can elicit similar responses as real social touch, it will be beneficial for the intimate contact between partners, families members, friends who are geographically separated [45]. Social touch is ubiquitous in our daily interactions, and more possible TMC channels applied mediated touches are available nowadays, the possible application of mediated touch is likely to be promising. The effect of mediated social touch will be discussed in the following section. Followed by presenting various prototypes, discussion of design mediated social touch technology will be entailed afterwards.

5.1.2 Effect of mediated social touch

As a novelty for mediated communication, mediated social touch is beneficial for affective communication that supports conveying the affection and giving the affective response, consequently, enhances presence and connectedness. These aspects state mediated social touch as the promising channel to enrich mediated communication with affection.

Affection and discrete emotions can be conveyed by the different types of touch in actual social interaction [46], aligned by this notion, mediated social touch is investigated to communicate affection and emotions. Some studies have presented that discrete emotions can be expressed through mediated social touch, and the others could recognise it [47, 48, 49]. Actual social touch can attune the affective stimuli process and alter the affective state. Studies have investigated the similar effect of mediated social touch, and it shows that it helps with relieving the stress[50], and attune sad feelings [51, 52].

Mediated social touch can enhance the feeling of presence when it occurs at a distance [53], also in a collaborative shared virtual environment[54], and in this context, mediated social touch help with task performance and enhance the sense of togetherness for female participants [55]. Besides, a study in the storytelling setting [56] showed that haptic feedback makes the storyteller and audience closer.

Moreover, effect of enhancing presence has been explored in mediated social touch for interpersonal communication [57, 58, 59], game setting [60] and virtual life [61, 62]. And a study [57] showed mediated social touch can facilitate awareness, empathy and emotional influence. While awareness and presence are related to creating connectedness discussed in the section 3.3. In addition to presence, effect of social connectedness has been invested by many mediated social touch prototypes [58, 63, 64, 65, 66], especially aimed at long-distance relationships.

Based on the effect as mentioned above, this project applies the mediated social touch to provide nonverbal cues and enrich affective experience of mediated communication. Eventually, integrating this novel channel with the old-fashioned communication way is expected to enhance the feelings of social connectedness.

5.2. General scope from previous prototype

Firstly we look at the mediated social touch prototype from previous studies, and form the general components for a mediated social touch device 5.1. Afterwards, design consideration for the further project is refined aiming for a communication system, see left part of the figure, mentioning direction and I/O mappings, giving and receiving touch, active and passive touch, the synchronicity of communication, contents of touch. Besides, reducing intrusiveness and tactile experience is discussed.

The prototypes of mediated social touch aim at different application areas and build upon different design principles, but they all have in common that they engage in socially affective communication through touch rather than task-oriented. To understand the design direction of mediated social touch, previous prototypes have been selected and listed in the tableA, which is developed underlying Huisman's work[41]. Selected prototypes are based on three criteria: 1) prototype should have a functioning haptic component, 2) be aimed at social interactions, 3) figure a form of input and output representing social touch.

5.2.1 Relationship

Touch can involve intimacy, and with a strong meaning of affection, the commonsense is that acceptance of mediated social touch is built upon the acceptance of social touch in real life. A recent online survey [67] on the perception of mediated social touch interaction offers users acceptance of types of interaction; respondents showed that communicating through mediated touch devices with loved ones, between partners,

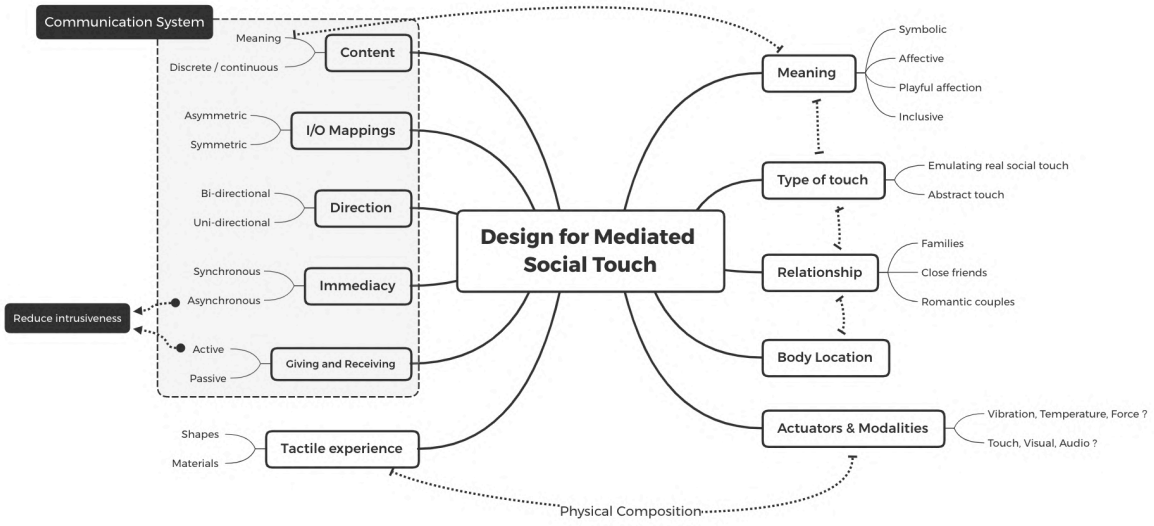

Figure 5.1: Design for mediated social touch

friends, and parents is comfortable. Another concern associated with the relationship specificity and social situatedness emphasised the importance of co-presence and believability.

Many prototypes were designed for interpersonal communication, particularly for people in intimate relationships, which usually employ touch to convey their affection to each other, and social touch is seen as essential for bonding and maintaining relationships. Long-distance relationships have been concerned the most among these intimate relationships, as this group of people have greater needs for affective communication and being touched by another loved one. While mediated social touch have contributed to affective communication between parent and children [68], grandparents and granddaughters [63], close friends [69], and between less intimate relationships, like game players [61, 60], storytellers and audience [56].

5.2.2 Meaning and types of touch

Different aims of mediated social touch apply different types of touch that generate distinct meanings, which could simulate the human social touch or generate abstract touch type with symbolic meaning. Emulated the familiar human touching actions has been designed like hug [63, 70, 68, 61, 64], stroke [65], kiss [71], squeeze [56], hand shaking [72, 73], hand holding [66], tickle [51], and merely contact [58]. These types of touch can be intuitively related to the meaning of affection as they can be found in real social touch interaction.

However, by enabling communication over distance, mediated social touch can generate a novel type of touch as an abstract form consisting of conveyance of one's physical signals, not necessarily existent in the real social touch. Playful affection as the meaning aims to arise the interactivity, can be provided by abstract forms of touch [69, 74], playful touches like tickling [75, 76, 62], and manipulating shared objects in the game [77, 60], which makes the mediated communication more fun.

Besides, the meaning of shared symbolism is a specialty of mediated social touch, that is not necessarily matched with actual social touch interaction. Huisman [41] categorised this type of meaning of touch into "symbolic". Underlying the symbolic meaning with abstract types or real social touch types, mediated social touch technology can augment the experience of traditional mediated communication and support interactors to develop a pattern of tactile language [78], which would be a meaningful direction to design for mediated social touch.

5.2.3 Actuation And Modalities

To design the mediated social touch, designers and researchers have to choose a set of actuation methods, specifically the physical composition consisting of physical qualities and parameters. Vibration and force are largely used for prototypes, which are easy and reliable actuation. However, vibrotactile does not stimulate CT afferents that present that CT stimulation is unnecessary for mediated social touch. As a natural perception of touch, several prototypes apply warmth to represent the mediated social touch [58, 63, 64].

Besides, due to the lack of sensory richness in mediated experience, some prototypes apply visual or audio, or both with mediated social touch conjointly enrich the mediated experience [58, 63, 61, 71]. Visual and auditory cues can create the context of expected touch [56, 57, 78, 59], but also enhance the feeling of touch. And several studies have shown that visual presentation of touch had similar results to receiving the actual social touch [79, 80]. Huisman suggested that integrating visual and tactile feedback may be a promising approach for the mediated social touch experience; importantly, congruence between different modalities should be taken into account [41]. The result from the survey [67] stated two concerns for design mediated social touch devices, one aimed at perception, referring to the tactile sensations of the interface with the skin, construction of haptic primitives by the actuators, and the realism of the sensations, which is primarily attuned by physical composition.

5.2.4 Body location

Body location being touched for mediated social touch are usually fixed and need to be chosen; unlike the natural social touch setting, it could be coordinated. Hands are the most commonly stimulated body location, perhaps explained by the organ most often used for applying and perceiving the touch in the daily context, and embedded sensitive "touch sensor" intensively. It might be the most intuitive way to give or receive touch by using hands; therefore, choosing the hands for the mediated touch can lower intrusiveness and generate a greater perception of touch. While previous prototypes have explored larger areas of the body, for example, torse worn by the vests emulating the hugging sensation [70, 68], and chest [58] and lap [57, 63] are also stimulated by mediated touch. Besides, different body locations will involve different meanings and settings. For example, lips have been touched by a device in the kissing settings, cheek has been touched for developing the shared symbolism meaning. Most applied touches are static or near-static, applied to one body location without massive movement over the skin. More body location involved for mediated social touch may enhance the immersive experience but potentially result in greater feelings of intrusiveness.

5.3. For communication: what should be concerned?

Above discussion stands from a general scope for mediated social touch, more specifically, aiming at interpersonal communication, variables stated by the study [78] consists of data direction, data transfer, input/output mapping, and data content. Underlying these parameters, more consideration about mediated social touch for communication is disccsued in this section.

5.3.1 Intrusiveness from mediated

The level of intimacy and familiarity of sender and receiver impact the extent to which a specific body location and type of touch is acceptable to be touched in real social touch. Moreover, touch can arouse erogenous feelings, which is a private and sensitive experience. For huma social touch, intrusiveness and uncomfortableness may emerge when touch conduct in improper context, for example, the location being touched out of congruence with the relationship between interlocutors, or the unsuitable moment that is not congruent with social situatedness. Because the physical touch happens face to face, the intrusiveness could be solved by social coordination but mediated social touch could not. Therefore, mediated social touch

potentially causes significant intrusiveness.

Additionally, social touch with affection is mediated/conducted by the artefacts, non-living objects without emotion. It cannot simulate the real social touch ideally, and this discrepancy can not be eliminated due to the limitation of technologies and the mediated setting. Which increases the possibility to be intrusive. Therefore, designers should be careful about intrusiveness in mediated settings, not simply reproducing the real social touch, design choice should be built upon the competence of mediated social touch, considering the social situatedness and coupling the sensory perception to offer a smooth touch experience.

5.3.2 Active and passive touch

Gibson provided the concepts of active touch and passive touch [81]. Active touch refers to touching, which involves purposive and information-seeking sensory systems, whereas passive touch refers to being touched, externally generated sensory events. In the real social touch, recipients usually only involve the passive touch that the touch directly applies to the recipient's skin without the medium. However, under mediated settings, the social touch process is more complicated. On the sender's side, they initiate touching action on the artefacts to convey the touch, which is active touch with the sending purpose. Both active and positive touch enable receiving the mediated touch on the recipient's side.

Active touch path requires recipients to touch the artefacts spontaneously with the purpose of receiving the haptic message. Passive touch receiving path means that recipients would be touched/stimulated by artefacts, with or without awareness. For example, people may put their hands near the cat showing they want to be touched, it is a passive touch with awareness if the cat gives the touch as a response. But sometimes, the cat will touch people without a signal, which is passive touch without awareness. In the mediated social touch, the cat is replaced by the artefact. The former receiving way has a "ready" step before receiving the haptic messages, while the latter, without it, is potentially obtrusive. To initiate the interaction by touch being mediated, active touch for the sender is necessary. While most prototypes were designed with an active touch for the recipient to receive the touch, meaning they have to voluntarily touch the artefacts to receive the haptic messages, which potentially reduces the intrusiveness generated as recipients are aware of upcoming touch. However, the valid effect of active and passive touch for recipients, as a missing part for mediated social touch scholarship, could be explored further in future studies. The discussion of active and passive touch for the prototype in this project will be related to intrusiveness.

5.3.3 Giving and receiving touch

Actual social touch can be simplified by involving the active touch of senders(give) and a passive touch of recipients(receive). Due to the specialty of mediated settings, active touch is commonly involved for both senders and receivers as mentioned above, therefore "giving and receiving touch" stands at the scope of mediated setting, to discuss the perception of mediated social touch, as counterparts for active and passive touch in the actual social touch.

The effect of touch is primarily examined on the recipient's feeling rather than touch initiator in various aspects. The effect of receiving touch might be more significant than giving touch. However, the touch initiator is essential for interaction, without whom there would be no touch or no interaction. In addition, giving touch to the loved person makes the other person feel cared/loved, the giver also feels satisfied through giving touch. A study [82] showed that in actual social touch, being stroked between partners was perceived as more pleasant than stroking, but it also showed that both stroking and being stroking were perceived as pleasant. Additionally, giving touch action is the first step of the process for mediated social touch, which should not be overlooked.

Besides, an online survey[/refer] showed that participants showed their need to share negative feelings to use mediated social touch instead of only positive feelings, and the sharing experience highly depends on

giving actions. Therefore, based on the usage context and purpose of mediated social touch, giving and receiving touch should be valued equally, and ideally, be designed to enable mediated social touch carrying various personalised meanings.

5.3.4 Direction and I/O mappings

There are primarily two directions in a mediated social touch communication system: bidirectional and unidirectional. Bidirectional mode means each device can send and receive signals, whereas unidirectional mode means the device either sends or receives touch on one side. The bidirectional way is necessary for a complete communication system that can be used in real-life settings. The I/O mapping of interactive systems represents the overall pattern for the communication process showing the input and output on each side. Symmetric I/O mapping of a system means input and output are conducted in the same format, whereas asymmetric mappings offer different ways for input and output. Chang et al. [78] suggested applying asymmetric for each device to prevent interrupting an incoming transmission, meaning separate input and output channels for one device.

Additionally, the mediated setting impedes the immediate feedback(output) from social interaction, thus the output as interactive feedback should be concerned, it affects the interactive experience, which is emphasised in the frogger framework[83]. In the natural social touch setting, touch givers can receive immediate feedback in the social context from the recipient's verbal or nonverbal languages, while in the mediated setting, it is disabled. Unlike text-based mediated communication, the input, which is text, will remain visible on the screen, while mediated social touch could not make the communication trace visible without help from other modalities. Therefore, designers should carefully map the input and output in the interactive experience of mediated social touch, under the bidirectional channel to create a fluid mediated communication experience.

5.3.5 Asynchronous and synchronous

Most prototypes applied the synchronous mediated touch showed in the table A.1, which allows the dyad of communicators to interact through touch in real-time in a high level of immediacy. But it requires interlocutors to be present and available on the communication channel simultaneously, like voice- and video-call. In contrast, the asynchronous way allows interlocutors to be online at a different time with sufficient personal space for interpersonal communication. Touch has been stored and conveyed when the recipient is ready to receive in the prototype[63], but the asynchronous channel is insufficient in mediated social touch prototype. The possible reason may be the duration limitation in lab tests that makes asynchronous communication unnatural.

Additionally, the asynchronous channel is a promising solution for intrusiveness generated by mediated touch. It empowers users to receive the touching message in a comfortable timing, and the way could be both active touch or passive touch with awareness, underlying clear consent to be touched. Therefore, the investment of an asynchronous channel for mediated social touch is meaningful. Additionally, the potential positive effect of asynchronous communication for TMC has been discussed in the previous section 4.5. Although slow and less efficient, it may enrich the experience with affective value, integrating with mediated social touch, the effect of communication experience for distant relations is anticipated.

5.3.6 Content Of Mediated Social Touch

The content of mediated touch communication depends on the application's aim, related to the meaning and type of mediated touch, could be continuous or discrete. Designing continuous content is more challenging than discrete for mediated social touch because haptic communication is abstract without clear semantics unlike text-based communication. Continuous content may allow variety in the communication

with open-endedness, and may sustain the communication. However, discrete content also performs well for interpersonal communication particularly for close relationships,/refer, the possible reason is the equivocality of haptic communication.

Haptic communication has its own advantage for creating equivocality. It enables sharing symbolic meaning between interlocutors, through emulating the real social touch or through creating abstract form that does not exist in real social touch; both have been invested by previous studies, see table/refer. And the symbolic meaning could be predefined or developed by interlocutors with shared understanding, which is meaningful design space. Ambiguity of message seems promotes more behavioural coordination in the social interaction, motivating people to highly engage in understanding the social situatedness and co-creating the shared meaning during communication [33], similarly, the importance of equivocality in message convergence has been discussed by media richness theory and media synchronicity theory [32, 31]. However, equivocality and open-endedness might terminate communication due to a lack of sufficient coherence and legibility. Therefore, designing the mediated social touch should find the balance between equivocality and legibility of content to create sustainable communication.

5.3.7 Tactile experience matters

Mediated communication between two interacolutants begins with interaction between users and artefact. This direct tactile experience is essential for the whole interactive experience, because the tactile perception is activated at the first moment when touch on artefact. Shape and materials form the primary physical characteristic of the artefact and also afford the tactile experience. In terms of shape, many prototypes were designed as hand-like trying to afford touch communication in an intuitive way between hand and hand [66], some were animal-like [84] to emulate the mediated touch attributed to the creature. While some prototypes were designed to be wearable that can conduct touch when users wear them. Others were designed as the familiar object affording touch or being touched in our daily life, like pillow [58], and furry doll [70]. Notably, some prototypes designed abstract shapes affording touch in playfulness, like roller in [77], and squeezable balloon in [74].

Materials are essential to provide tactile affordance in touch-centred experience, and support other sensory affordance by the feature of vision, texture, humidity, which may influence the willingness of touch, consequently impact mediated touch communication experience. For example, the soft, smooth, furry, fine-hairy materials seem more inviting to touch, while rough, hard materials are not. A study [85] showed that the smoothness of materials evokes positive emotions with lively and comfortable feelings, whereas roughness evokes negative emotional responses with depressing and uncomfortable feelings. Besides, a study showed that the characteristics of frictional forces and average friction impact the sensation of pleasantness [86]. In the study of the object of affection, the softness is linked to attachment and is able to give comfort [87], shown by children's toys.

Common materials used in the previous prototype could be described as soft, smooth, squeezable, and furry. More specifically, choice of soft textile, rubber, silicone are commonly used in the prototypes. Similarly, they afford gentle force back. Moreover, some prototypes used inflatable materials [70, 88], sponge-like to provide moderate force back. The benefit of choosing the force-back feature is that it provides natural and immediate feedback for touch interaction, and it could afford playful, vivid and lively interaction. In a word, tactile experience provided by shape and materials is valued to be investigated when designing mediated social touch devices as it leaves the first perception in the communicative experience. Soft and force-back tactile perception is the main interest in the design phrase.

5.4. Summary

This chapter introduces the mediated social touch as the new articulate for TMC by description of its concept, relation with TMC and its effect. Afterwards, looking at previous prototypes refines the elements to design the mediated social touch system. Firstly, the general scope of mediated social touch prototype is

framed, subsequently aiming at mediated communication channels for remote close relationship, the design consideration in this project for mediated social touch has been discussed, forming an immature framework for design of mediated social touch system.

6

As an Observer: observe and understand asynchronous communication

We conducted the observation study before design practice, focusing on people in close relationships but distance-separated interact with each other in asynchronicity on instant-messaging tools. Observation on a small number of participants makes up for the lack of knowledge for asynchronous communication from desk research. Conducted before the design process, it aimed to collect qualitative results to help define the scenario and pain point of asynchronous communication, directing to the design direction for further project. The explanation of why focus on instant messaging tools and the executive of observation will be described. Interesting findings involve various reply styles between remote loved ones, subjective feelings about asynchronous communication, and effects of social connectedness.

6.1. Why observe the communication on instant messaging tools

Mediated social touch is a novel channel that is under development for everyday use in interpersonal communication, developing a usable mediated communication device in real life requires observing the situated communication, but daily usage for mediated social touch is unable to be observed. Observation of the instant message tool, as the prominent tool in TMC, could offer an insightful understanding from a bottom view. The knowledge from desk research has been discussed in the previous section4, but lack of view from real-life context, which the observation process could complement. The purpose of developing mediated social touch technology in this research is not to substitute text-based TMC instead fill the gap of text-based TMC that enhances the social connection, looking for the gap from instant messaging tools will be helpful to understand the pain point.

6.2. Observation executive

Observation process started from the researcher self-observation as one part of autobiographical study and followed by observation about others. Both observations were conducted by the diary studies asking the diary writer to write down their behaviours and feelings when TMC occurs. Self-observation was conducted before the observation on participants in order to reduce the researcher's bias that may influence her self-observation with understanding others. Information brochure and consent form are shown in the Appendix B.

6.2.1 Before diary study

For self-observation, a self diary study was conducted before the ethics check, after the ethical approval researcher invited her remote peer in a close relationship to conduct the diary study together as the communication dyad, which is expected to be self-observation plus second-person view. Participants in general observation include both individual and dyad participants, while dyad participants require to be in a close relationship, such as families, couples, close friends. And they should be able to and regularly use instant message applications for daily interpersonal communication and feel comfortable describing intimate details regarding their relation with the communicator and (possibly intimate) conversation they do online with the communicator.

6.2.2 During diary study

Diary asks participants to write down their behaviours and thoughts when the scenario appeared, which were given in the observation card, see in Appendix B, consisting of mainly three parts:

1. As the ***conversation initiator***, what response they receive and feeling about different responses;
2. As ***conversation responder***, how to respond and how do they feel about different responses;
3. Scenario about ***the feeling of connection/disconnection***.

The complete version of the observation card can be found in the Appendix. Not only self-perception but also perception about the other interactor has been asked to write about to look for the understanding/interpretation gap of TMC. Researchers sent the reminder at 9 pm each day during the study. Same way for self-observation.

6.2.3 After diary study

Complete logbooks were collected when the study was over. The researcher has interpreted diary studies, then participants were invited to interview to deepen the understanding of information collected from the diary study. Each interview started with questions to explicate the content of the diary study according to the logbook, and with a discussion about their general feeling of various TMC channels, the role of mobile phones for interpersonal conversation and feelings about social connection. Interviews ended with views about mediated social touch.

6.2.4 Participation

Three dyad participants (including researcher dyad) and three individual participants conducted the diary study lasting 3 5 days. Three dyad participants are romantic couples, all living apart distantly. During observation, couples fixated on their partner as a remote interactor and individual participants focused on communication with close relationships. Post-diary interviews have been conducted on two couples and three individual participants. The researcher had an interview with her partner as dyad participant. Couple participants proposed to attend the interview together and showed the willingness to discuss openly, thus the interview of them was organised together. The semi-structured interview questions could be seen in the Appendix B.

6.3. Data collection and analysis

Logbooks collected from diary studies provided specific cases in participants' daily life about remote communication through instant messaging tools, involving contextual and situated details with response and thoughts. Interpretation of the diary helped with forming the questions for the interview further. Posterior interviews is supposed to uncover the information collected from the logbook and look for general thoughts for the aspects related to the further design project. To analyse the qualitative data provided by diary studies and interviews, the researcher interpreted the raw data, afterwards summarised and analysed them together. As one of the participants, our self-observation has been discussed with other participants, marked by P1. According to the interpretation, data from diary study and interview have been summarised and discussed together.

6.4. Finding and discussion

6.4.1 Information matters for response of remote communication

Participants commonly express it: that as the responder, the obligation is felt to reply soon if the communication initiator sees the message has been read, and reading the message but not responding, is regarded as impolite behaviour. While as the initiator, expectation of immediate response commonly emerges, particularly if users know the peer is online or has read the messages. One participant [P3] keeps all her status visible because in this way, she could check how her own messages are processed by the tool or by the peer, except for the "last seen time" status, it makes the online trace overt that leaves her pressure to react to the social interaction in the instant message tool. One participant showed that he would feel obligated to wait for the reply if the peer is online[P4]. Similarly, the reason to keep these statuses visible is for self-check about message processing.

However, one mentioned that he dis-enabled the message's visibility to reduce the unnecessary information for instant messaging communication. Compared to the conversation with intimate peers who enable and disable read receipt, the read receipts seems causing higher expectation for real-time conversation and more pressure for immediate response according to the participants[P5][P6].

From the participants' feedback and the researcher's self-observation, it has been found that expectation for response and the feelings about different responses is related to the amount of information the initiator knows about their pair's current situation. The information could be summarised as **global information and local information.**

Global information is about the brief schedule of remote pairs or what the remote peer is busy on. Participants mentioned that knowing global information will help attune the expectation for a real-time conversation, and the negative feeling about the postponed response will lessen. Besides, knowing global information is likely to reduce the uncertainty about remote lovers in the sense of being together, as a means to create social connectedness.

Local information is about the message processing and digital status of remote peers provided by the instant message tool. Whatsapp and Wechat are the main tools used for the participants. Both tools enable users to know if the peer is typing, and for whatsapp, the message processing status (delivered, received and read) and peer's status (online, last seen) could be visible for users. Knowing local information is a way to update users about the stage of message processing, helping to check the effectiveness of communication tools, while more local information seems to increase workload to process the information about the mediated communication and causes more mental activities both for responder and initiator, which probably impact the mediated communication negatively.

As discussed above, the global information and local information have different roles for mediated communication, respectively affecting the workload of the information process. An effective communication tool

should be able to give provide global information and local information, but designers should consider how to balance the amount of information to reduce the processing workload but provide a sufficient knowledge of communication process.

6.4.2 Real-time and asynchronous communication

- ***Real-time communication***, or synchronous communication: both dyad communicators could respond immediately, which means they are both online and present in the communication
- ***Asynchronous communication***: one initiates the interaction, but the other could not respond in real-time, one is present and one is absent in the communication, or both dyad communicators are absent, but the previous interaction initiated by one is waiting to be progressed, communication in the time difference.

Response styles

From participants descriptions, several common response styles could be summarised: ***Immediate response*** is that the responders take action to respond to the message immediately once they have seen the notification or messages, while three phenomena have been found centred on immediate response: 1)***immediate response with presence***: responder responds to the message and could be present in the conversation for a period of time which means available into a real-time conversation; 2) ***responsible immediate response***: responder could not be present sustainably for a conversation, but respond to the message immediately by informing the peer in a busy situation that could not respond immediately or with an available time slot to give global information; 3)***immediate response with partial presence***: responder responds to the message itself immediately, but could not guarantee a sustainable response and distributes the attention on other stuff during remote communication. ***Postponed response*** is the case in which responders have seen the notification or message but ignore them to delay responding. **No response** is the case that responders do not know the notification or message, in busy situations or could not access the phone.

For the time-emergent and emotion-related conversation, participants primarily performed immediate response once knowing the messages, and immediate response with presence and responsible immediate response is more likely to be taken. And it showed that responsible immediate response effectively reduces the initiator's concern and anxiety from no-reply according to participants. While most participants described that responsible immediate responses are less often conducted in the daily conversation for close relationships as it has fewer manners based on mutual understanding. Immediate response with partial presence, postponed response and no response has been seen occuring often in mediated communication, particularly in casual chats, which results in asynchronous communication.

Immediate response with partial presence

In the immediate response with partial presence, the responder could be present for a moment but could not guarantee a sustained conversation, usually busy on something but not fully concentrating on it. This response shows the potential of a real-time conversation, therefore initiator and responder will distribute attention to the communication and the presence of conversation for both communicators in dynamic, as the person who is more present in the conversation is likely to wait for the response from who is less present and the one may attune his/her presence level to associate to the other, but it is not the real-time communication with slightly time difference during the interaction session, which is how the asynchronous communication is caused.

In terms of the intention of this reaction, one participant described that in the social activities with friends, he would like to chat with his girlfriend intermittently to reduce his guilt which comes from not

accompanying her in person, showing sufficient attentiveness and presence to remote lovers. However, meanwhile, his guilt for asynchronous communication has generated. Another participant described that the asynchronous communication involved immediate response with a partial presence felt as a toss-and-catch game, making communication less meaningful, even annoying, and dragging each other's attention. However, this toss and catch game brings the remote companion from her boyfriend, and she gets used to continuing this conversation although she realised the negative effects of communication quality.

Postponed response

A common reason for participants to postpone response is being unable for a sustainable conversation, and the postponed response is expected to signal their unavailable status. Participants who mentioned this reason also emphasised that they would like to a sustainable conversation when they respond, thus response synchronicity from their peer is expected.

Another reason is that the participants feel like postponing the interaction to keep boundaries between online and offline personal space. Interestingly, one described that keeping the messages unread without response leaves the conversation in a still condition, and the waiting message plays as the companion from the remote lovers. Moreover, similarly, one described that seeing a notification from his peer but not read yet makes him warm and feel he was thought of. However, the postponed duration will be concerned by these scenarios described by participants to avoid the partner's feeling ignored and worried.

6.4.3 Feeling about asynchronous communication

Immediate response with partial presence, postponed response and no response forms the asynchronous communication. As real-time communication require strict presence for mediated communication under space difference, asynchronous communication happen more often occurs, and remote pairs seemed to get used to it, and various feelings of communication quality have been found.

For initiator: Duration impact on feelings

According to participants, no response is acceptable and understandable because no one could not be available for online communication at any time, but the duration of no response mattes for feelings. Common feeling about duration is: moderate duration of no response may slightly generate the feeling of being ignored, but the longer duration of no response, the more concern and worry about loved one may emerge.

One participant mentioned that with a period of no response, he would try to find an excuse of no response for the remote lover to comfort himself. Generally expressed that before the concerned and worried feelings emerge, as the initiator, they would not send more messages because the personal space could be interpreted.

The needy moment of communication commonly involves sharing the emotion or unusual experience. It showed participants have more expectations and need of real-time communication in those moments; it is the primary means to look for empathy and comfort in daily life. Participants showed significant needs for immediate response, particularly, expression of negative feelings, like feeling lonely or frustrated. And female participants seemed more likely to feel ignored and worried about peers; these negative thoughts may reduce the female initiator's willingness to share feelings and make them less active in the further mediated conversation.

All negative feelings resulting from asynchronous communication may generate feelings of disconnection, mentioned by participants. However, an interesting finding is that the responder could resolve the negative

by giving the response with a reasonable excuse of being absent and showing they care; subsequently, the strong connection would be generated for two peers after disconnection.

Besides, one participant mentioned she would eagerly look for the online connection when she feels exclusive or embarrassing in real-life social interaction and expects a quick response from close people through instant messaging. Similar to the description from one participant, "if the social connection in real-life could not satisfy me, I will look for it online...; online communication could make up the deficiency of social interaction in real life"[P5].

For responder: more than guilt

As for the responders in asynchronous communication, guilt is commonly felt among the participants for the case when the cared one needs support or companionship. To fix the guilt of being absent from the conversation, participants usually provide the reason for being absent.

While guilt seemed not to involve the casual chats too much, the social protocol between remote loved ones has an invisible agreement with asynchronicity due to respect of personal space. Besides, one participant pointed his has guilt from being absent in the partner's real life, and he makes it up through mediated communication, which results in an immediate response with particle presence frequently happened, and meanwhile another guilt from being unable to reply constantly has been generated.

One participant mentioned that after a long duration of no response, the response of previous interaction becomes weirder because messages lost the time-effectiveness; therefore, she might keep the non-responsive message until the peer starts a new topic or until she has to talk to her peer, in which she would find an excuse to explain why she did not respond to break the embarrassment.

Not only negative, maybe positive?

According to the above description, asynchronous communication may negatively impact communication quality, summarised by generating negative feelings: ignored, worried, disconnected, even annoyed. In addition, misunderstanding is likely to emerge because the unclear text or misreading the meaning could not be explained promptly under the temporal gap, commonly remarked by participants.

However, the participants seemed to accept and agree on the inevitability and importance of asynchronous communication. This intermittent communication could create a consistent mediated companion, whether in time or not, which is powerful means to make up for the absence of a remote partner in real life, as participants described. Besides, the notification and messages waiting to be replied represent the companion of the remote pair, which is an interesting finding of asynchronous communication.

Moreover, the finding of intentional no-response implies that asynchronous communication serves a buffer zone between personal and social space for mediated communication. The case that participants delay the response for a sustainable communication, points that asynchrocity is likely to give more time and space to process the message to establish a better quality communication. Additionally, participants described that sometimes they just want to express themselves, but without expecting an immediate response from loved ones, sending the message has satisfied their needs to be heard. In this case of expectation for asynchronicity, a spark may be generated by the coincidence of immediate response, which gave a remarkable feeling of connection described by participants.

6.4.4 Ending the conversation

It is shown that the ending moment for a close relationship is relatively vague during mediated communication. While some responsible participants may inform the peer about being absent as the ending signal. Generally, communication ends with night sleep. One participant described that after ending the "goodnight" video call with his partner, he needs to take some time to attune himself into a single mood in real-life settings from the affective mood. While participants who have similar "goodnight" sessions, warmth and companionship left from the affective conversation were commonly felt. Besides, conversation involving emotional topics with a cheerful ending is likely to generate a strong feeling of connection; however, affective conversation may evoke a strong feeling of missing each other, subsequently, feelings upset may occur.

6.4.5 Notification role

In terms of notification, most participants muted the notification for all messages, but some expressed that they set a special notification for the cared ones in case there is an emergence for the instant response. Notification is generally regarded as a distraction; interestingly, one pair described that notification is the means of visible care and affection from the remote lover. The connection could be generated once seeing the notification without knowing the message content as the notification has shown that remote lover is or was thinking of them. One mentioned that she regarded the unread message as one means of the presence of a remote partner; once she read or reply the message, the presence might be gone; therefore she might keep the message unread. Therefore, an interesting finding of notification is described that notification not only enables to convey the interaction signals but also represents the virtual presence of the sender in a visible mean. Moreover, these roles of notification works for providing both local and global information, as mentioned before.

6.4.6 Roles of Mediated communication tool for distant loved ones

Critical questions about the relation between real communicators and mediated communication tool have been asked, and some reflective reaction from participants were collected and shown below:

- "He seems like my digital pet...; sometimes the mobile phone seems like an external organ that helps me connect to the rest of world, also with him"[P4]
- "Phone might be the way or a channel of his presence"[P2]
- "I would feel disconnected if we could not access to mobile phone"[P5]
- "(if the phone is gone)I will feel anxious and try my best to find the other way to connect her, maybe borrow others' phone"[P6]
- "Several days will be fine (if the phone is gone), I would not feel anything change I suppose..., I know she is there, in my mind. But when we connect again, it might take a while to reduce the gap..." [P7]
- "The online her and real life her have quite a different personality; I do not like the online her,..., but it could make up for the fact of being apart. "[P8]

It is clear that mobile phones play an indispensable role for remote close relationships. Not only as a mediated communication tool, the phone may be a part of a long-distance relationship, or may be the means of presence of remote lovers, or even one part of remote lovers. These finding provides a critical views about mediated communication tool for remote relationship, which will be discussed in the end of report.

6.5. Wrap up and design implication

Above mentioned findings and discussions highlight that asynchronous communication is an inevitable channel of technology mediated communication. Instead of affecting communication quality negatively as generally assumed, it seems to provide a buffer zone to process and prepare the information and bridge personal and social space for mediated communication that supports mutual understanding. Instead of lowering the efficiency of communication, embracing the asynchronous channel may alleviate the misunderstanding results in the temporal gap, and decrease the expectation of immediate response that is likely to support forming a smooth communication experience. Moreover, it could even spark the moment of synchronous communication. Therefore, asynchronous communication is valued to get more attention in the application of technology mediated communication.

Additionally, scenarios about asynchronous communication primarily happen in two scenarios: 1) the communicator is busy in physical life or unable to access devices; 2) keep personal boundaries with social space that ignore or block social communication. Further design for asynchronous communication should establish these two contexts.

Based on the previous findings, establishing the broad temporal dimension, design asynchronous channel for mediated social touch should consider:

- Remain the effectiveness of message: because the long duration of no-response may negatively affect both the value of the message and the feelings of initiators, design should ensure the information carried by the message could be conveyed efficiently with delay;
- Sustainable in the temporal gap: the interaction with delay should be able to easily picked up and be proceed both for sender and recipient;
- Representing sufficient information of message processing but avoiding overload: in the case of reducing temporal information, sufficient information, including local and global information, should be provided to support generating shared understanding, but the amount of information should be balanced to avoid overload;
- Calm and functional notification: notification could correspond with the message delivered or with the recipient's reaction, when and how signal communications about interaction needs to be considered for further design, but it requires to be calm and functional;
- Reducing the immediate response with partial presence: this response may result in feelings of disconnection, design of asynchronous communication could consider alleviating the possibility of this response happening or transfer this response to responsible response or immediate response with presence.

7

Designer and Maker Cycle I: Ideation and specialisation

The outcome of this development cycle is the usable prototype for in-lab evaluation. This cycle is a process of divergence that involves discovering the inspiration, materials, actuators, electronic components. Several hands-on experiments were conducted with self-test. Test results help us to form a complete system concept.

7.1. Ideation

7.1.1 Design Directions

Concept development is divided into two direction: **Communication experience** focuses on how the device serves as the mediated communication tool. It stands at the global view to define the overall communication process, considering how to enable the mediated communication between remote loved ones and how to generate a pleasant mediated communication. We anchored our interest on ***affection communication*** in ***asynchronous communication channels***.

Touch experience stands on the local view concerning the touch sensation given by artefacts and how to realise "touch and being touched" remotely. We started hands-on experiments to discover tactile sensation given by physical materials, and integrate with electronics to provide haptic feedback. The integration offers the possible tactual stimulation given by technology. Completed by the input touch and corresponding the input to output, we could implement mediated social touch by a tangible artefact.

Based on these two directions, we will implement a mediated communication system for affective communication, with following goals:1) realise mediated social touch in asynchronous channels; 2) offer a pleasant mediated social touch experience; 3) enable users to convey affection; 4)eventually enhance social connectness.

7.1.2 Inspiration

Based on our personal tactile experiences, we present our intuitive ideas visually in the moodboard, showed in the collage 7.1. Inspirations will be introduced in the following paragraphs.

Figure 7.1: Moodboard for inspiration

For touch experience

Soft and smooth materials Materials like moss, velvet, and the bottom surface of mushroom plates provide soft, fine and smooth tactile sensation, related to the sensation when we touch fluffy and furry pets, giving a warm, pleasant and satisfied experience. Those soft and smooth materials could be derived from the bushy fur or textile, and their visual affordance could imply the tactile sensation. For example, pile fabric as velvet and corduroy. And the long pile could offer softer, and pleasant tactile sensation.

Soft forceback When we touch the foam or jelly, this squeezable feature offers a soft force back, connecting to human-skin-like or human-body-like tactile experience. The force back is related to the resilience and elasticity of physical property, and pleasant feelings of force back require the low-resilience and large contact areas. Otherwise, it will give tension or tightness, which is commonly connected to being cold and unpleasant.

For communication

Inflatable pleasantness and presence The inflatable is an object inflated with air or other gas, and the size and shape can be flexible depending on the presence of air. It could supply force/pressure slowly with low pressure, offering a pleasant "being touched" experience, which has been explored in many art project[89]. Especially, lying down in the inflatable, the body could be supported by inside air pressure with feelings of being wrapped, giving a floating fantasy with relaxation and peace. Additionally, the gas is invisible, but the formation of inflatables depends on the presence and amount of air, which ingeniously makes the presence of air visible and concrete. Link to the mediated communication, the presence of air can be applied to imply the presence of a remote lover, making the invisible presence visible and tangible. The unique affordance makes the inflatable an ideal application for mediated social touch technology.

Messagebox and mailbox for asynchronous communication For asynchronous communication, the inspiration is from voicemail on old phones. The caller leaves the message on the phone; when the recipient

Figure 7.2: Hands of love from Brazilian hospital[90]

is available or willing to reach the phone, they receive the voice message then reply to it. In this way, no intrusiveness for recipients and notification has been offloaded; the communication process is empowered for recipients more than callers. This old way seems inconvenient but gives the surprise in mediated communication because messages could be unexpected. Besides, the physical mailbox also offers a similar surprise, and the message in the mailbox is carried by physical form, which makes the mediated meaningful and tangible. We wonder maybe this old fashioned way of communication could generate new sparks for technology mediated communication, providing a pleasant communication experience.

7.1.3 Sparks from water gloves

We obtained the idea of the water gloves from a Brazil hospital, namely "hands of love"[90] that helped patients against isolation during pandemic without social touch with families and friends. Nurses have discovered to use latex gloves with filling warm water to mimic human touch7.2. This case enlightened us that water could be applied, similarly as air in the inflatable, for mediated social touch application affording a soft tactile sensation with force back. Thus, we formed the initial concept applying water-filled bag, as a soft interface with soft force back. And haptic feedback could be given by water movement.

Based on water gloves inspiration, we conducted the first hands-on experiment to experience the water-filled gloves by ourselves. The soft interface offered pleasantness, thus we centered on the water-filled materials for further development in the specialisation phase.

7.2. Specialisation

The specialisation in this iteration loop is a divergence process to discover possible actuators to generate haptic feedback integrating with the water. Several experiments have been conducted to look for the possible tactile sensation applied by different actuators. Our self-test helps with choosing actuators for haptic feedback.

The figure 7.3 below shows the discovery in the specialisation process primarily in two directions, one is discovery of the fluid as filling material, another one is the discovery of haptic sensation produced by possible actuators. We will share the experiments process with comments and thoughts, followed by the design decision of the specialisation process.

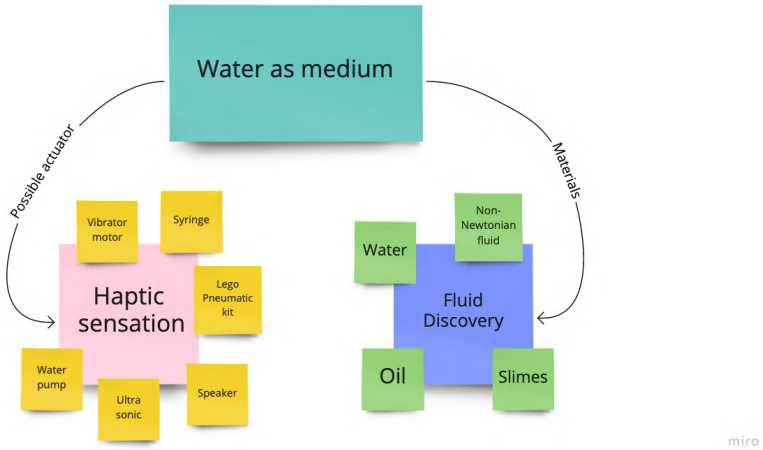

Figure 7.3: Specialisation Discovery

7.2.1 Fluid discovery

We found three types of fluid from daily life for experiments: water, oil, Slimes. To compare the tactile experience, we touched gloves filled with these materials by squeezing, poking, contacting and holding. Comments and thoughts of experience are shown in the table below.

Table 7.1: Fluid experiments

Water	Oil	Slimes
▪ More dense(heavier) than oil ▪ Feeling is common and familiar ▪ Natural, more acceptable ▪ Sensed the warmth after touching /holding for a while	▪ Lighter than water ▪ Forceback sensation similar to water ▪ Lubricant feelings leave unpleasantness ▪ Too smooth	▪ Thicker, heavier and more solid than the others ▪ Higher viscosity, forceback is slower which is more feelable ▪ Colder than the others in the same environment ▪ Playful

Overall, water offered a pleasant tactile sensation, which is familiar in daily life; oil generated similar force back as water but left an unpleasant sensation because of unnatural lubrication. Slime felt highly squeezable and playful, even helped to relieve the stress. As a Non-Newtonian fluid, it offered both fluid-like and solid-like sensation. But it was colder than the water and oil in the same environment. Based on these results, we used water and Slime for following experiments. Latex has been found as a suitable container in our experiments. The elasticity of latex make the shape changing is possible according to filled materials.

7.2.2 Haptic sensation discovery

With ideas of possible actuators inspired by experts, we conducted experiments with several actuators, including the syringe, the speaker, the air pump, the water pump, the vibrator, to look for suitable tactile stimulation. The table below briefly introduces the experiments and experience.

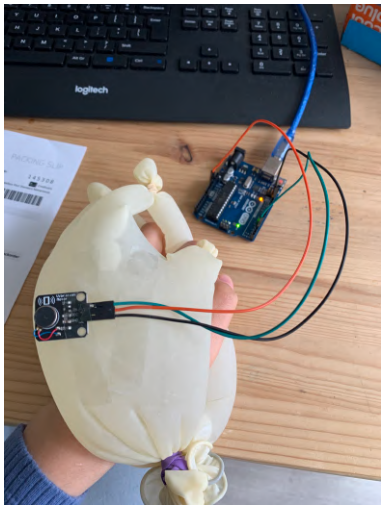

Figure 7.4: vibrator on the water gloves

Figure 7.5: Applying speaker for haptic feedback

Table 7.2: Overview of different actuators

Actuator	Experiment	Notes, Thoughts & Comments	Generated sensation
Syringe	Researcher held the glove, and water was introduced by the second person	▪ Feeling flow by injecting water ▪ Change water amount influencing the weight ▪ Feeling is relatively linear ▪ Need to work with motor	Flow, weight
Speaker (see figure 7.5)	▪ Speaker connected to power and controlled by Arduino board, giving commands for different sound frequency ▪ Put the gloves filled with fluid(water/Slime) on the speaker ▪ Researcher put hands on the gloves to sense the vibration	▪ Sonic frequency transfer to tactile vibration ▪ Vibration frequency varied by sound frequency (could be a communication channel for messages in rich variables) ▪ Low frequency provided more perceptible vibration, high frequency provided more intensive but more subtle vibration ▪ Difficulty to reduce the noise to unnoticeable level ▪ Slimes was nicely for reducing noise but heaviness impact the perception	Vibration in different frequency
Water pump	▪ Water pump connected to power and controlled by Arduino board ▪ Put pump in the gloves filled with water ▪ Researcher put hands on the gloves	▪ Water amount could be changed, offering tactile sensation and as the signal of communication ▪ Working engine generated perceptible but subtle vibration ▪ Less noise ▪ Affordable price ▪ Tactile sensation might be linear, could integrating with other modalities	Vibration, weight, flow
Vibrator (see figure 7.4)	▪ Connecting to power and controlled by Arduino board ▪ Putting vibrator on the surface of water gloves, directly contacting Slime ▪ Researcher held the gloves or Slimes to feel the sensation	▪ Flexibly located ▪ The most commonly used haptic actuator ▪ Applied with Slime feels like breathing heart ▪ Multiple motors could generate variable format of vibration ▪ Affordable price ▪ Noisier than the water pump	Vibration
Pneumatic actuator (air pump)	▪ Desk research	▪ Quickly control air flow ▪ Linear but fast-generated sensation ▪ Noisy	Size (inflate/deflate)

Eventually, the water pumps were applied for further development among all these actuators. Water pump could activate the fluidity of water, enabling water waving, flowing even jetting. Working with tubes, water can transfer water between containers that change the weight of water; when users could sense it by holding or lifting, serving for kinaesthetic sensation but requiring active movements. Water exchanging in the tube may explicitly display the communication process, making the abstract remote communication process tangible. Besides, a working water pump could generate the vibration similar to a vibration motor, and the water flow can be subtly sensed.

While it should be noted that the speaker and vibrators performed nicely to generate tactile stimulation as well, the speaker experiment showed variable vibration could be generated by the different sound frequencies, which may support various formats/meanings of touch messages for communication. However, the difficulty is to reduce the sound or attune the sound corresponding to touch sensation. Besides, as the most common tactile actuator, vibrators could be placed flexibly and stimulate the sensory receptor easily. Applying multiple vibrators could generates various distinct touch stimulation. The syringe and the air pump also could be an option to generate tactile stimulation for future study. Although these actuators were not applied further in this project, the experiments with notes are expected to give implications for researchers who implement similar application.

Integrating water-filled materials to water pumps, the sensation of being touched is available for mediated social touch. We will develop the systematical concept based on this combination in the next section.

7.3. Concept development

According to the previous exploration, the complete concept of the communication system for remote loved ones has been generated. The following description introduces how our system implements mediated social touch and enables asynchronous communication.

7.3.1 Two ports for communication

The communication system consists of two devices, which are assigned to each communicator respectively. Each device has two containers filled with water, called sending port and receiving port, see figure 7.6. Simply, touch the sending port to send the touch to the remote peer whereas touch the receiving port to receive the touch sent by the peer. Two ports serve for sending and receiving respectively, which enable input and output happening at the same time in real-time channels. It could be analogised to microphone for input and speaker for output on a phone, supporting fluid transmission between speaking and listening. This concept corresponds to the asymmetric input and output mapping as mentioned in the section 5.3.4.

Figure 7.6: System overview for first prototype

7.3.2 Interaction and Sensation

The action of sending and receiving applies the same interaction between users and devices, and both are active touch as discussed in section 5.3.2. Users could squeeze, hold or contact the port to input touch to send. When putting the hand on the sending port, the sender will feel vibration immediately to be informed that the touch is sending, whereas the vibration will stop when the hand leaves the port, indicating that sending touch is over.

Receiving the touch message requires users to touch the receiving port voluntarily. Same as sending, touch action could be squeezing, holding or contacting. Therefore, users need to input the receiving signal as consent to being "touched" by the device. If any touch message is sent and stored on the device, the user could feel vibration; otherwise, no actuation on the device will be triggered. Giving the receiving signal enables users to be aware that haptic feedback will be conducted by the artefact, which is expected to reduce intrusiveness from mediated social touch.

In addition to vibration, because the water pump flows the water resulting in the change of water amount. The changing weight is expected to be perceived by users, perhaps with the subtle fluid flow.

7.3.3 Communication format

In the communicative system, the pair of devices' performance is synchronised according to the user's input, meaning what happens on one device will happen on the remote device, and we illustrate asynchronous synchronous communication in figures 7.7 and 7.8 below.

The water pump in the sending port will be triggered on the sender's (user A) device when sending the touch. Water flows from the sending port to the receiving port, the amount decreases in the sending port but increases in the receiving port. At the same time, the remote device will produce the same actuation.

If the recipient (user B) is not online, asynchronous communication happens and messages will be delivered and stored in the recipient device. Later, the recipient touches the receiving port to receive the touching message that activates the water pump in the receiving port. Then the water flows to the sending port, the amount of water is decreased in the receiving port but increased in the sending port. The same performance will be conducted in the sender's device. If user B wants to send instead of receiving, s/he could input on the sending port, and performance will be the same as when user A sends. Moreover, more water will be flown from the sending port to the receiving port. See illustration for asynchronous communication in figure 7.7. For real-time channels, users could send and receive simultaneously, or send and receive respectively, and the system performs the same pattern as the asynchronous channel according to users' input, seeing figure 7.8.

7.3.4 Messages format

Touch duration forms touch message content. Multiple touch messages could be sent and added up by the duration. The recipient receives the touch message by decreasing the stored duration until it is eliminated. For example, if the sender touches the sending port for 10 seconds, the touch message containing 10 seconds vibration will be sent to the recipient. Before the recipient receives the message, the sender may send a touch message within 5 seconds, which will be added up to the previous 10 seconds. Thus, the recipient could receive 15 seconds of touch in total. However, the recipient could partly receive or receive all the touch messages. If touching the receiving port for 7 seconds, the recipient still has a touch message within 8 seconds for later. If the recipient touches the receiving port for 15 seconds, the vibration will stop after 15 seconds, which means the message is received completely. Employing touch duration as the content is supposed to create variables for touch messages, allowing users to play with flowing the water by touching duration.

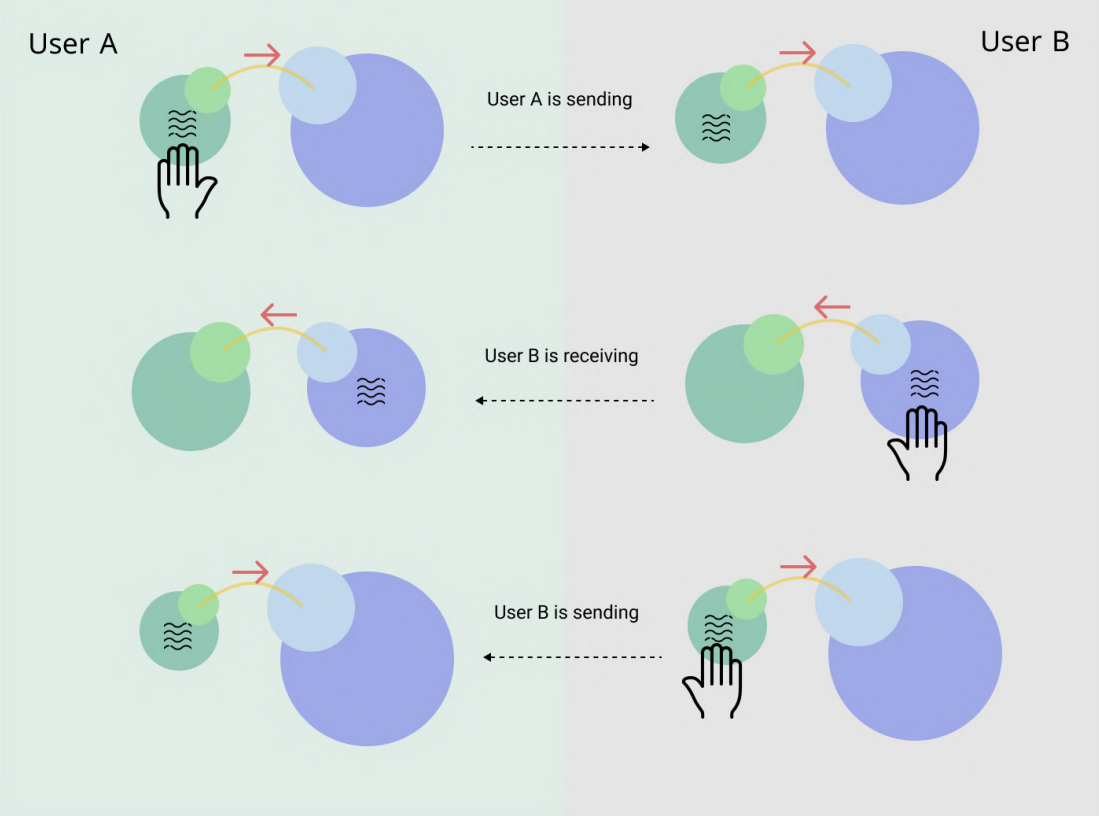

Figure 7.7: Illustration: asynchronous communication; the waving lines represent vibration, red arrows represent the water flowing direction

7.3.5 Calm communication

Notification is designed to be calm and less obtrusive on the communicative system. Size changing port and slight sound from the working pump is regarded as the calm notification of a message. If online, the user could "pick up" the device to receive a message for real-time communication. If offline, the changed size of the port could tell the recipient there is a touch message. For the sender, if the recipient received the touch, the port size will change to the state of before sending, seen as the notification of that message being replied. Unlike the notification on smartphones, functionality is not the main purpose of these notifications. However, in case users need information about the communication states, these subtle and calm signals could fit this need and also support being as a calm communication channel.

Based on the above concept development, realisation of usable prototype will be described in the next chapter.

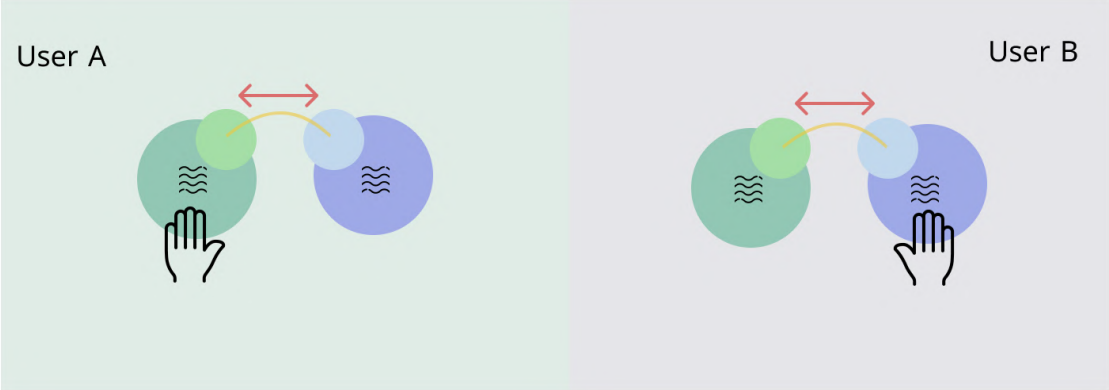

Figure 7.8: Illustration: synchronous communication

8

Designer and Maker Cycle I: Realisation and evaluation

Based on the design choice from the specialisation phase, this chapter we will share how did we form a usable communication system. And we conducted the lab evaluation to find out usability problems, which led us to produce redesign in the next iteration.

8.1. Realisation

We will introduce realisation process including hardware setup, software setup, realising remote communication and complete physical form.

8.1.1 Setup Hardware

Components

Microcontroller: Esp32 The microcontroller is the core of the prototype, required to detect the touch input, process the input data, control the actuators, send and receive messages for remote communication. Equipping a WI-FI chip and touch sensor, the prototype applied ESP32 development board (Wemos D1 R32 UNO pinout), having enough input/output pins for the sensors and actuators and supplying enough power for all components.

Capacitive sensing The capacitive sensor is prevalent to detect a touch in haptics applications due to its simplicity and accessibility. As the capacitor in an electrical circuit, it can measure the changes in the electric field made by touch, pressure, humidity etc. Besides, capacitive sensors are accessible in daily life and cost-effective, such as aluminium foil, which could be placed flexibly even on the curved and soft surfaces.

Prototype applied aluminium foil as the capacitive touch sensor, which has been attached on the surface of containers, connected to the microcontroller through the wire to detect the touch input. In order to avoid users contacting the electrical components, aluminium foil is covered by transparent tape as protection.

Actuators Mini submersible DC water pumps requiring DC 3-5V power supply are implemented into the prototype as haptics actuators. This pump is small, low-noise and has low power consumption, which is suitable for the device. The ESP32 board could supply the power without an external power supply.

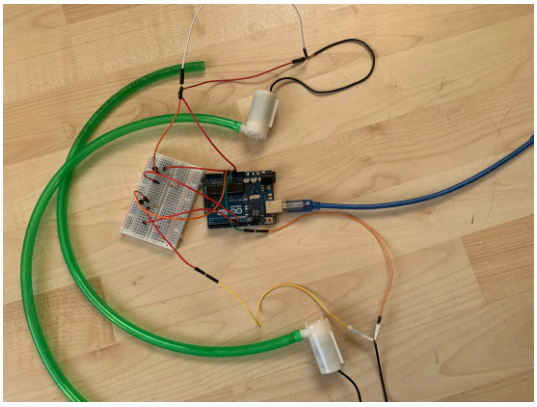

Figure 8.1: Setup water pump

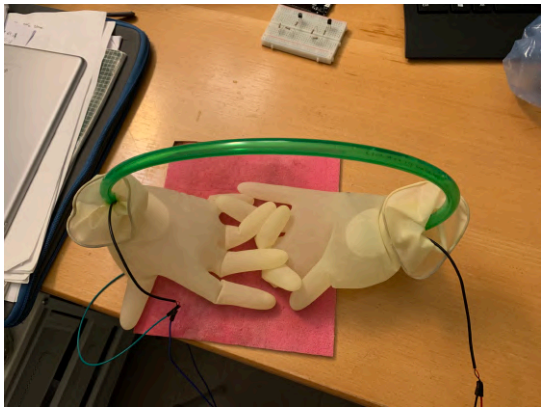

Figure 8.2: Unfinished prototype

Electronics setup One device integrated sending and receiving messages, equipped with two touch sensors and two water pumps, respectively for sending and receiving ports. Because the touch sensor is embedded in ESP32, aluminium foil is directly connected to the board to detect the touch. Turning on the pump requires a 100-200mA current, but the maximum output current of the microcontroller is 45 mA, therefore the NPN transistor is applied as the amplifier. To get the suitable range of base current for the transistor, a 3K ohm resistor is connected between the microcontroller and base pin of the transistor. Avoiding the current backflow from the pump's motor, the diode conducting current primarily in one direction is applied as protection.

8.1.2 Setup software

The software implements the concept of the prototype functionally. The complete processing map of software is: 1)Detect the sending touch input;2) Process the input data to control the actuators and send the message to the remote peer; 3)Store the messages from the remote peer until the receiving touch sensor detects the touch input, once previous message is received, receiving feedback will be sent to the remote peer. Touch sensor thresholds have been determined based on the difference between touching and without touching. In order to avoid accidental touching, the bounce time for detecting touch is added to make detection reliable. Not only one bit of communication, but the content of touch messages is also varied by the duration, and the duration of the new messages adds stored messages.

8.1.3 Remote communication

The HTTP protocol serves remote communication that exchanges data between client and server through a sequence of request-response messages. Firstly, the server is set up to be accessed through the internet for clients. Secondly, the board connects to the WIFI to access the internet then, as the client, connects to the server. Once client and server are connected, data could be exchanged through request-response messages.

Two clients connect to the server in this communication network, indicating the desired action by GET and PUT as request methods. The messages are formed by touch detection of starting and ending, sent to the server, and then transferred to the peer through the server. The GET method requests the server to transfer the messages from the peer, and the PUT method requires the server to create a new message from this client. When the peer sends a GET request, this message will be sent. If the clients are offline, the

messages will be stored in the server and sent when the clients are online. Request-response actions between client and server happen each 250 milliseconds based on the setting.

8.1.4 Complete form

Prototype forms require being able to hang up one pair of water containers and store the electronics in a safe place to protect them from accidental contact. Concerning the function and stability of the prototype, the size could not be portable or small. Considering as an ambient device we designed a form integrating the functionality and aesthetics as an interactive installation. A curving "X" frame has been designed, as am symmetric shape, see figure 8.3. Two containers will be hung up in the side tips of the frame, as shown in the figure 8.4. The curving feature is corresponding to soft and fluid feelings of the tactile experience. The board and wire have been hidden in a box made by laser cutting.

Figure 8.3: "X" shape frame

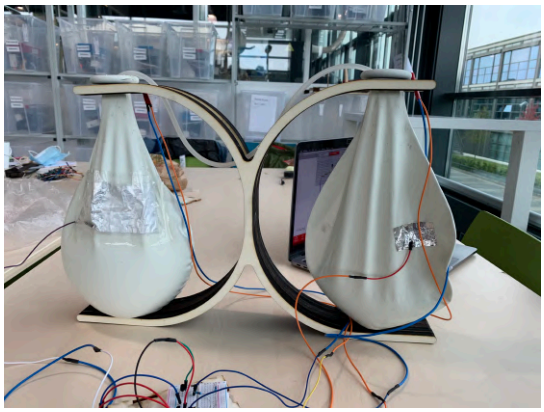

Figure 8.4: Organising sensors and balloons

8.2. Evaluation

8.2.1 Executive

The lab-session test aims to evaluate the usability and availability of the device. Collecting the feedback from users, it is expected to find out potential usable issues that we may have overlooked from the self-test. Therefore a lab-session evaluation was conducted in DesignLab, see figures 8.5. The evaluation was open both for one pair of participants and individual participants. For a pair of participants, each one was assigned one device to try out, individual participants tried out the device with the researcher as the partner. Each pair of communicators sat together side by side to test.

Firstly, participants read the information brochure and signed the consent, see Appendix D, then we introduced how to use the device for remote communication. Secondly, participants were asked to freely interact with the device to get familiar and discover the tactical sensation given by the prototype. Subsequently, participants tried out the device to communicate with their partners primarily for real-time communication. The tryout session took about 15-20 mins. Afterwards, they were asked to fill in a questionnaire(see Appendix C) and have a short interview based on questionnaire.

The questionnaire is divided into feelings about interaction experience and communication experience, all the scale questions applied to a 7 points linear scale. The following interview was based on the questionnaire but looking for explanations and open opinions for further development. A complete session took about 45 mins. In total, 10 participants, including one pair of romantic partners, three pairs of close friends, and two individual participants, participated in the lab-session evaluation. The result will be discussed in the next session.


Figure 8.5: inLab evaluation

8.2.2 Results

The discussion below combines the results from the questionnaire and interviews.

Most participants liked the soft and squeezable tactile sensation that **pleasantness** given by the device performed positive, adding the playfulness for remote communication. Compared to **balloons and gloves**, five participants preferred gloves, four participants preferred balloons, and one had no preference. The common comment about the glove are that it would be intuitively played with, with human-like features, like putting fingers between fingers of the glove and holding it as hand in hand. But comments about the balloon referred to "abstract shape without human features seem to be more comfortable", and "seeing balloons has no expectation about tactile sensation, but gloves look like hands, I linked it to hand-related sensation, while it felt highly soft, out of my expectation".

About ease of usage, participants showed confusion for the usage of communication. Three participants expressed it was not easy to use, and three participants had neutral about easiness to use, which showed that the prototype had space to improve the ease of use. Specifically, the mentioned confusion comes from the notification of real-time communication. When the remote peer is sending a message, one water pump will turn on the same as the sender sending a message, which causes confusion about if the remote peer is sending or "I" am sending. Sending and receiving actions and containers are the same, sometimes it is unknown which one is to send and to receive.

For the question of whom to use the device with, romantic partners have been selected the most, followed by close friends and families. Interestingly, two participants mentioned that they would like to use it with a person they just met but would like to know more about each other, regarding the device as the tool to deepen the closeness. And one participant would like to use the device with everyone as it does not involve intimacy. By asking how likely they would be to use the relationship they selected, most participants showed interest in further usage in daily life setting, while one participant did not like it as the need for connection with a remote partner could be satisfied through instant tool messaging by text, audio or video.

From interviews, several open opinions have been collected, listing below:

- expectation for warmth in the water.
- touch message could be various instead of 1-bit messages
- vibration is subtle and requires to pay more attention on the device during interaction
- two water containers seems to invite two hands to hold them simultaneously to fill symmetric feelings

Last but not least, during the lab-test, water may flow out and the frame performed unstable for usage.

The weight of water and the feature of hanging increase the fragility of the prototype, and water dynamics plays as the advantage for tactile sensation and also as the threat for electronics. Therefore the stability and safety issue should be considered for further development, and final evaluation is expected to put the prototype in the user's place without researcher's charge, the physical components should be more sturdy.

8.3. Intermediate discussion

In this section, the discussion about the arrangement and confusion from the lab-session test will be described. Secondly, discussion related to the visual information about messaging processing will be described.

In the lab test, the pair of participants could see each other and when the peer touched the device, as they sat together side by side to try out the device, missing the property of mediated communication. And due to the limited duration of the lab-test, mediated touch in real-time communication may be more intriguing than that of asynchronous communication. Therefore, the feeling of desiring and waiting for a message may be significantly generated. This impacted the prototype's efficiency as a remote communication tool and weakened the advantage of asynchronicity of prototype meanwhile confused usage. The more suitable setting should be arranging participants into two individual spaces or applying the plate to make them invisible for each other, simulating the remoteness of mediated communication. Specifically, these effects showed the value of evaluation in a daily life setting, as it could realise real remote communication and enable the time-space for asynchronous communication.

The visual information given by communication tool should be reconsidered. This implementation updated several states of message processing including messages are sending, sent, received, read and replied, which is similar to Whatsapp and seems to lock the users attention on visual information. These information were shown by changing ports size or through vibration sounds, which is subtle and vague without legible information, increasing the complexity of reading the information given by the device. Besides, asynchronous communication is supposed to leave more personal space for communicators to respond to messages. However, this implementation served as a "screen" to display the message states, asking people to watch the responding states instead of offering a peaceful and relaxing communication channels.

Therefore, as a result, the redesign space will be posited at minimising unclear information to offer a relaxing asynchronous communication space and improve the robustness and pleasantness.

8.4. Conclusion

This chapter introduced the first iteration process from forming the initial concept to realising the prototype, including divergence and convergence process. Subsequently, evaluation in the lab was conducted to define the improvement for the next iteration. As a conclusion of this chapter, the next iteration will focus on the following design direction:

- Re-design the mediated communication process to refine the information given by the communication tool and reduce the confusion of usage
- Improve the tactile sensation with the warmth of the water
- Making a robust prototype for reliable usage at home

9

Designer and Maker Cycle II

Starting from the pre-inLife evaluation was conducted to look for potential unreliability of the prototype. The outcome of cycle II is a robust prototype that can be placed in the participants' homes for final evaluation. The heating element has been integrated into the prototype to provide warmth as a tactile sensation, and the form of devices with safety measurements has been improved. Eventually, inLife evaluations were conducted, applied diary study after usage and questionnaire with the interview.

9.1. Pre-study in real-life

9.1.1 Aim and executive

During the specialisation in the second iteration, prototypes had been tried out by ourselves with friends to test the stability of the connection and physical form in the real-life setting. It is expected to find out possible issues for real-life use and be fixed in the second iteration as the pre-study for final evaluation.

We improved the tactile affordance by wrapping the balloons with soft textile, offering a warm sensation, see the figure 9.1. Because the subtle vibration given by the pump may be weakened by the textile, vibrator motors were attached under the textile to intensify the haptic feedback. These vibrators work at the same time with water pumps. Communication format is the same as the previous prototype. Two devices were placed individually to participant's and our place for four days. The participant was asked to use the device at least once a day. During the test, we observed the odd actions made by the device. After this test, the participant was interview about experience and functionality.

9.1.2 Results

The result of the pre-study showed that communication through server and electrical components is stable for in-life usage, while touch sensors performed unstably that triggered the water pump randomly on. Besides, the vibration applied with fluid properties provided pleasantness, but the water weight could not be significantly sensed during the communication. And the physical frame should be improved to be sturdy.

Subjective feedback from the participant described that balloons wrapped by the fabric provide a warm and comfortable tactile sensation, which was preferred compared to that without wrapping. The participant described that as real-time communication is available, he would expect to experience real-time communication more than asynchronous communication. However, underlying the current communication mechanism,

he could not distinguish between real-time touch or stored touch; he noticed the notification for real-time communication sometimes, but when he touched the device, it seemed the peer was offline, which generated frustration.

The result of pre-study in real life pointed to the improvement for a sturdy prototype. Touch sensors need to be ensured to work reliably, and physical frames should be more robust. Notifying the real-time communication seems to weaken the effectiveness of asynchronous communication, therefore we redesign the communication format in the following development.

Figure 9.1: Prototype for pre-inLife evaluation

9.2. Specialisation

9.2.1 Sensor

To improve the touch sensors, we did experiments with two types sensors, one is force sensors, which could convert pressure, weight, tension and other input mechanical load into an electrical output signal, another is copper tape. The results turned out that copper tape is highly sensitive to touch, the output value related to capacitivity changed significantly by touching. The force sensor is reliable to detect the touch as it requires the user to apply force to the sensor instead of just contacting. Considering copper tape has more flexibility that could stick on the water containers, we chose it to alternate the aluminium foil for realisation phase.

9.2.2 Actuator

In order to add the feature of generating warmth, heaters had been discovered with the consideration of the size, power supply, working power and safety. Specifically, size should be suitable for the prototype; the power supply should be consumption affordable; working power should be sufficient to generate warmth in the acceptable duration; heater should be protective for safety usage; integrating with other components is feasible. The table below 9.1 showed the possible heater element, and they were scored by each requirement.

Based on the overall score results, a camping water heater is applied to generate the warmth, although the size is not ideal as the cartridge heater or DIY heater that could be flexibly placed into the container, but it could quickly warm up the water to a perceptible temperature. The heating mat could be the suitable heater element for the prototype. It requires less power supply but sufficient working power to warm up the mat in a safe way. But the main concern about the integration. It should be attached on the flat surface, which generates the difficulty of putting on water containers. Cartridge heater and DIY heater have size advantages that could be flexibly placed and integrated with other components. However, the working

Table 9.1: Heating elements comparison

Heater element	Size	Power supply	Working power	Safety	Integration	Total
Heating mat	3	4	5	4	2	18
Camping water heater	3	3	5	4	4	19
Cartridge heater	4	3	2	4	4	17
DIY heater	5	3	3	1	4	16

Figure 9.2: heating mat & water heater

power of the cartridge heater is insufficient to generate the warmth quickly, and DIY heater element might be unsafe. Therefore the camping water heater was applied to the prototype to generate warm sensation. We set temperature threshold as 35 Celsius, closing to average human body temperature. When the water temperature reaches the threshold, the relay will turn off the heater.

Underlying previous discoveries and dynamics and fluidity of water, we discovered various sensations, for example, waves made by fans or plastic plate movement; spraying fountain to feel the water bumping made by the pump, could be the notification as well; feeling movement of Slime made by servos. Eventually, considering the previous prototype's integration, these actuators were not applied to the prototype but could be options to generate liquid-related tactile stimulation for future study.

9.3. Concept development

Concept development is centred on the redesign direction given from inLab and pre-inLife evaluation. To generate the warm sensation, we integrated the heater with two ports. A third container, namely the heating port, to place the heater is needed.

9.3.1 Practical limitation nudge to change

The initial ideas were that the heating port could be the station to store the message and warm up the water. Water in heating ports comes from the sending port and goes to the receiving port. Water flows to sending ports from receiving ports as a circulatory system. However, the heater element requires the specific water level with minimum and maximum, so we simplified the circulatory system so that water only flows between the heating port and the receiving port, see the figure 9.3. Still, active touch is needed to receive the haptic feedback.

Figure 9.3: System overview for second prototype

9.3.2 Conveying warmth

Warm sensation is generated by warm water flow from the heating port. Once messages from the sender are delivered to the recipient's device, the heater will turn on to warm up the water. When the recipient gives the input to receive the messages, the water pump in the heating port will flow the warm water to the receiving port, generating a warm sensation. At the same time, the receiving port also pumps the water back to the heating port. Heater will completely turn off until the recipient receives all the messages. Otherwise, the heater will continue to work keeping the water warm. See illustration of this communication in figures 9.4 and 9.5

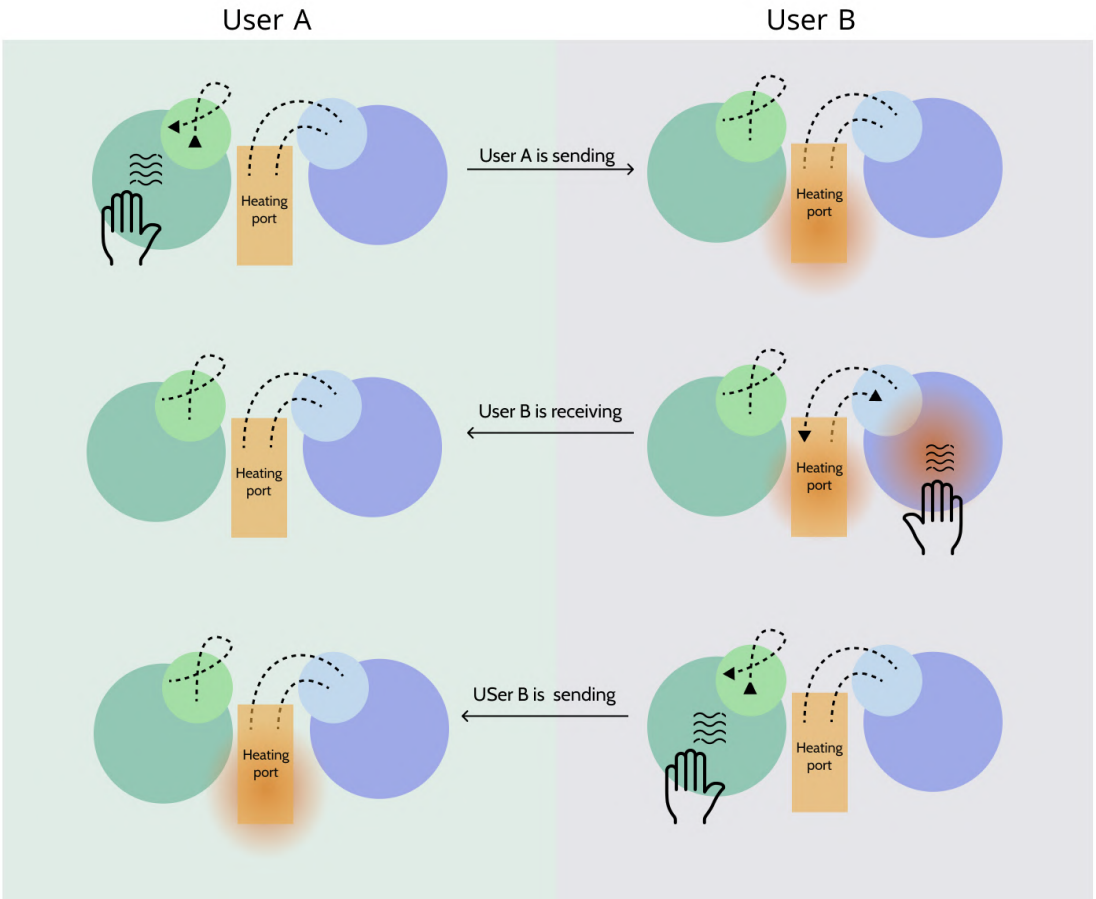

Figure 9.4: Illustration for asynchronous communication in the second prototype

9.3.3 Minimised information given by the device

Information is minimised in this implementation. Notification is removed and users only know whether there is a message by touching the device. Users could not know if the message had been received or when the peer sent the message. Only the action of sending a message will turn on the remote peer's heater, which is supposed to be quiet. Other actions will not influence the state of the partner's device. We keep real-time communication but without notification, and users could send and receive at same time9.5.

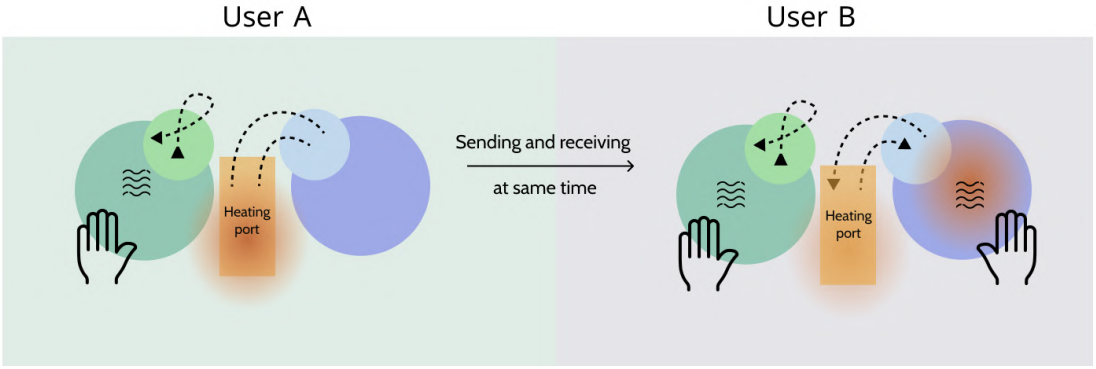

Figure 9.5: Illustration for real-time communication in the second prototype

9.4. Realisation

Realisation in this loop focuses on updating the electronic part integrated with the heating element and generating robust prototype frames, described in the following paragraphs as electronic update and re-design robust frame.

9.4.1 Electronic and software update

The update of electrical components is primarily for the heating system, which consists of a heater, relay, temperature sensor, and resistor. Powering the water heater requires the 220V AC, and a relay has been applied in the circuit to connect the microcontroller and heater as a switch. The microcontroller inputs are current to the switch-on relay, making a closed circuit for the heater. Temperature sensor DS18B20 was applied to prevent the water from overheating. When the temperature in the heating container reaches a threshold, the relay will switch off the heater. The complete circuit has been shown in the appendix C.1.

The software was synchronised with applying heating elements, we shared the implementation on Github[1]. Sending a request to the server checks the message from the peer and updates the inbox touch message. Stored messages in the box and temperature below the threshold both control the heater states to be on, but it will be off once the temperature is higher than the threshold. The heater will be on again when the temperature is below the threshold, and the inbox message is not empty.

Besides, compared to the previous prototype, the water pump could not be controlled by the action from remote peers but only triggered by who is using the device. When the sensor detects the touch input from the sending port, the water pump in that port will be activated. When the sensor detects the touch from the receiving port, the water pump in the heating container and receiving port will be activated, exchanging water in between. Warm water comes from the heating container, and the receiving port sends back the water to ensure the water level meets the restriction of the water heater. Communication setup is the same as the previous prototype.

[1] https://github.com/iranwei/thesis

9.4.2 Form a robust frame

We focus on building a robust frame in this process, concerning the safety and stability to use. The final design of prototype frames is shown below 9.6 with a portrait 9.7. Glass bottle is fixed in the middle of the prototype to place the heater, temperature sensor, and water pump. In order to protect the water pump from the hot heater element, it has been glued in the corner of the glass bottle. The other two pumps were placed in the sending and receiving port, respectively. Each pump is connected to one side of the tube, and the other side of the tube is open to flow the water into the terminal port.

We applied tubes with different colours to make sending and receiving ports distinguishable. The receiving system used grey tubes, exchanging water between the heating port and the receiving port. Sending system applied the green tube, flowing the water from the sending port to itself. It looks unfunctional, but serves as an real-time feedback to visualise that messaging is sending, replacing the weight lost in the previous prototype. Besides, we added bouncing balls to the sending port and flour-filled balloons to the receiving port, enriching the tactile sensations.

Besides, other electrical components have been hidden behind the standing wall, preventing users from contacting electronics. And all these electrical components were soldered to prevent the unexpected disconnection from transportation. Copper tape as the touch sensor was attached on insulated tape and stuck to the surface of balloons. The insulated tape prevents the touch sensor from being influenced by the water, which is a conductive material. A power strip was fixed behind the wall, supplying the power to the development board and the heater.

The frame was formed from acrylic plates through laser cutting. A basin with a 2cm depth made of the same materials was put on the bottom to prevent the water from flowing out. Two sponges wrapped by soft fabric were placed under the balloons. It serves as the soft cushion when holding the balloons and absorbs the flowing water in case. We did a self-test about usability, and finally the communication system including two devices were ready for real-life evaluation, see figure.

Figure 9.6: Final prototypes

Figure 9.7: Portrait of prototype

Figure 9.8: Pair of prototypes

10

Evaluation: inLife study

As a communication tool, it should be applied in daily communication context, so we conducted the final evaluation in the real-life setting, aiming to evaluate the communication experience and effect of social connectedness between remote loved ones.

10.1. Executive

10.1.1 Recruitment and setup

We recruited participants in pairs with the requirement that they have a close relationship but live apart and accept the physical touch from each other in real life. And they were asked not to meet each other during the study because physical interaction may impact mediated communication. Ideally, participants should live a long distance apart, but we could not implement it due to the physical setup; thus, we narrowed down the regions of remote pairs in the Netherlands. Eventually, five pairs of participants were recruited, including three pairs of close friends and two romantic couples. Two couples and one pair of friends live in different cities in the Netherlands, and the other two pairs live in the same city. Participants gave their consent to set up the device at home. Before the study, participants read the information brochure and declared their consent, see templates in Appendix B.2 and D.4. Besides, as a new device at home, we provided a user brochure to explain the usage, mechanism and potential practical issues of the system D.1.

10.1.2 Data collection

InLife study lasted for 3-4 days, considering the acceptance of novel devices and leaving sufficient duration for asynchronous communication channels. Participants were asked to use the device whenever they wanted but at least once a day. User experiences were collected in the context by a diary study, see Appendix D.2. After inLife usage, we collected the general feedback from a questionnaire with an interview.

Our questionnaire D.5 focuses on the effect for communication quality and social connection, divided into three sections: effect of touch communication, asynchronous communication, and the overall experience of the device. Based on the dimensions of the measurement of social connectedness presented on the study [91], “we are together” and ”we are closer” in the questionnaire refers to the dimension of relationship salience and feelings of closeness; “we are connected” is expected to link the feeling of connection. As an exploratory study, posterior interviews were expected to collect explicit information towards experience.

Figure 10.1: inLife evaluation

10.2. General feedback

We will share the qualitative results from the questionnaire and quantitative results from diary study and interview. Results will cover the touch experience and communication experience, with the impact of social connectedness. Raw data of individual logbook and interview summary could be given with request.

10.2.1 Results from questionnaire

Questionnaire results provided an overview of general user experience on pleasantness, communication quality and social connection, see results in AppendixD.6.

The result illustrates that mediated touch communication in our implementation provides pleasant feelings. While receiving touch felt more pleasant than sending touch. And receiving touch seems to impact the feelings related to social connectedness, more significantly than sending touch, particularly for the feeling of "being together". The feelings of "being connected" and "being closer" are greater than "being together", given by touch communication. Results showed our implementation of asynchronous communication offered pleasantness. Most participants agreed it improved remote communication quality, but it is not similarly enjoyable for everyone.

Compared to the effect between touch experience and asynchronous communication experience, they both affect the feeling of "being connected". However, touch communication has a greater impact on "feeling closer" and "feeling together", which is less affected by asynchronous communication. Results of overall experience presents our implementation could improve the communication quality. The impact given by mediated social touch is greater than asynchronous communication. The impact on feeling "being connected" is greater than "being closer" and "being together" given by overall experience.

However, the feeling of social connectedness is abstract and subjective, where understanding and perception may be strongly personalised. Results from questionnaires only offer a brief overview of evaluation for experience. Due to a small number of participants our results are limited, lacking generalisability. The feedback from the quantitative study could be more implicative as an exploratory study, which will be described in the next sections.

The result shows asynchronous communication on the prototype provided pleasantness and also contributed to the feeling of "being connected", but less effect on "being closer" and "being together". Most participants agreed it would improve remote communication quality, but it is not enjoyable for everyone. Overall experience given by the prototype presents that it would improve the communication quality and enhance social connectedness. While among the indexes of social connectedness, feeling "being connected" is more favoured than "being closer" and "being together".

The abovementioned result gives an overview of user experience evaluation. The feeling of social connectedness is subjective, that understanding and perception may be strongly personalized. Thus the feedback from the quantitative study may be more implicative for further design, which will be described in the next sections.

The result is separated into two directions: touch communication and asynchronous communication, corresponding to the design direction as mentioned in the section/refer. Touch communication concerns the action of sending and receiving and the tactile experience provided by physical affordance. The description below includes the questionnaire results and the subjective feedback from the diary and interview.

10.2.2 General feedback from touch communication

The feeling of sending and receiving collected from the dairy study is shown below, overall feedback of touch communication is easy to use and pleasant.

Sending

In terms of sending feelings, many participants mentioned that they anticipate the peer to receive their touch and are curious about their reaction[/refer], even likely to imagine the peer's facial expression, description as "... I'm sending 'I miss her' in a concrete way..." [P3],"...sending my care to him..." [P5] and "prepare something special for her..." [P1] has shown in the diary study. While compared to receiving, sending only provides the vibration, which was felt less encouraging, and even making users impatient and slightly bored, and more interactive experience is expected.

Receiving

Warmth significantly enriches the receiving sensation that is mostly preferred compared to sending by participants, particularly when receiving touch messages with long duration and when their hands are cold. Receiving experience was favoured and described as, "got something tangible from a remote peer being satisfied" [P7], "... she did think of me[P2]", "feeling like he is on my side" [P4], "unlike cold text, I receive warmth from him" [P1]. Happily surprising has been commonly experienced, as mentioned," feel like opening a magic box, but it is the affection from my partner".

Sending and receiving

The result shows generally checking the message before sending the message. It seems like a pleasant receiving experience is encouraging to sustain the interaction, as described by participants" I could not wait to send touch back" [P2] and "would like to send immediately" [P7]. And if there is no message in the box, although some participants experienced disappointment, sending a touch would be conducted voluntarily for all participants, and one participant mentioned that "this disappointment seemed to be resolved by sending touch[P2]". Two participants mentioned that they might hold the sending and receiving port at the same time[P2,P6], "quite fun" [6] and "I feel we are literally hand in hand" [P2]. Interestingly, one participant closed his eyes to hold two ports, "...feel quite immersive but need some imagination" [P5].

The tactile sensation afforded by materials has been favoured describing as skin-like, squeezable, playful, and pleasant. It is not shown a significant difference for the preference between bounce balls(hard) and small balloons filled with flour in water balloons, but the common description for bounce balls is that hardness combined with softness gives the distinguishable tactile sensation, for Non-Newton fluid balls is that more squeezable and pleasant to squeeze. Vibration given by the water pump is described as “comfortable and not

intrusive"[P3], and the sound made by the pump feels "calming and relaxing"[P5]. However, one participant expressed that transparent plastic water bags with colourful components inside left the impression about hospital or food, the information afforded by visualisation did not correctly match the tactile experience; bags hanging is intuitive to use, but slightly weird and [P5].

10.2.3 Feeling Special for Touch communication

Touch communication is described as a unique channel making the communication more meaningful[P1][P2][P4][P6]. Exchange touch is a tangible way which is an unusual mediated communication channel, the feelings were described "I literally do some movement to show my affection, it amplifies the action of sending instead of simply typing on the screen[P10]", "it makes my affective message touchable and concrete[P1][P2]", "you can not lie to the touch, it is not happening in a virtual movement, so real..."[P6]. While touch message itself is abstract, carrying the affection but without semantic meaning, favoured by participants and described as "abstract features create more mystery and surprise[P2]", "no need to find the words/topic to start the conversation"[P5], "...more willing to send or initiate because it is abstract"[P7]. This special way could be summarised by "it is a tangible experience to express something abstract; in-between the tangible and abstract makes communication more intriguing, and great affection is generated."[P2]

10.2.4 Asynchronous communication

It is shown that participants enjoyed the asynchronous communication in the prototype, and described it as providing a calm and pleasant communication experience, leaving sufficient empowerment to check and send the message for both interactants, relieving the social pressure that no need to reply in a certain way, described for instance "have the freedom to use it at any time"[P6], " I am more willing to initiate interaction in this non-disturb channel, and sending feels more like share my life moment[P7]", "receiving touch is like the echo for what I sent, the larger temporal gap makes it more special[P10]".

Asynchronous communication has been put on a par with old-fashioned communication methods, like answering machines[P2], writing a letter[P1], and writing a postcard[P5], performed improving the communication quality "...leaves more temporal space, I would like to be more concentrated on the communication although there may be no immediate response"[P3]. "No need to distribute my attention when being busy; when I feel like I want to communicate, I give more sincerity to our communication, filtering the distracting thoughts[P4]"," not looking for the attention for sending, I am more immersed into the communication"[P2]. Interestingly, compared to old-fashioned mediated communication, "the response performed especially tangible and easy to fulfil,... made me more willing to sustain the interaction"(sending immediately after I receive)[P6].

10.2.5 Real-time channel

Not all the participants experienced real-time communication. One pair tried real-time communication happened during the video call, and it is described as"As an extra channel, it augments our video-calling experience"[P2], "...fun to feel each other in this way, but I prefer it would happen without informing each other, more special... "[P4]. One participant experienced it without prior-knowing, "...surprisingly connected! The feeling is quite strong..."[P1]. Those who did not experience the real-time showed their expectation, "... assume it will be more fun"[P5] and "it would be more special because it is rare, maybe sensed as the real-time companion, no need to convey something legible but show she is there"[P6]. However, the lack of real-time communication did not influence the communication experience expressed by participants.

10.2.6 Notification

In terms of notification for communication, most participants preferred zero-notification as what it is given by current prototype, described as: "I like it is being quite in this way, when I feel like to connect to my partner, I will able to aware of the message"[P7]; "I will not like it with notification; the notification may make me feel like the device is saying 'touch me, touch me' inviting me to use it, the affection in the message will be deteriorated"[P2]; "...enabling notification like you buy a gift to your loved but telling that you bought a gift...surprise is gone..."[P4]; "notification is not important for me in this communication method; ... empowered to check message with anticipation makes me like this a lot!... Like opening a gift box when I use it"[P3].

However, two participants mentioned that notification of unread messages could be added, reducing the disappointment from no messages to receive, and it remains non-intrusive if the notification is on the same device[P2][P5]. And one participant showed that she would like to know the message amount in an abstract mean[P1].

10.2.7 Independence of other communication tools

Participants showed that this communication channel has the independence to other communication tools, not influencing the usage of other tools but as a favourable complementary. It is shown that participants utilised the instant messaging tools as usual, and this channel supports tangible communication by exchanging affection. "feels like the fourth sensation of the 4D movie, it augmented the overall experience"[P4], "what we experienced is a dis-replaceable channel for me and my partner"[P2], "not to convey explicit information in time, rather I want to share that 'I am thinking of you at any time, it differs to that text or saying"[P1]," not for communication, but for connection"[P7][P3]. In addition to sensation, this channel serves as a topic for text-based communication, and participants may talk about it during the conversation.

10.2.8 Effect on social connectedness

Although described separately above, mediated social touch and asynchronous communication work in conjunction, affecting feelings of social connectedness. According to participants, how the usage of device effect on the feeling of social connectedness could be summarised by enhancing the closeness, by enhancing awareness and presence, by sharing experience and improving the communication quality, we present some interpretation in the table below 10.1:

Table 10.1: Participants feedback and interpretation

Feedback from participants	Interpretation
"I feel strongly connected, when I receive the warmth, I feel he is being my side[P3]",	Enhance closeness, presence
"I can literally feel we are hands in hands, feel we are closer, both mentally and physically, I can 'touch' her affection"[P2];	Enhance closeness, presence
"not physical, but mentally closer, somehow this nonverbal(communication) decreases the burden of distance;"[P5]	Enhance closeness
"it is honest interaction, can not lie to the touch action, the message seemed precious"[P6]	Improve communication quality
"...connected because it seems like our affection is amplified ..."[P10].	Improve communication quality, enhance affection
"More concentration on communication... and it makes me immerved as well..."[P2]	Improve communication quality
"when I arrived home seeing the device, I am aware she were there, maybe sended me some messages[P7]",	Enhance awareness, presence
"seeing the device make me think of him, I know he is there"; "...feel like we can do little thing together by using this device" [P4]	Enhance awareness, presence, shared understanding
"...strongly connected, particularly when I receive the long message, I guess he miss me a lot"[P1]	Enhance awareness
"...helps with remembering friends, particularly for those I do not contact that often but we have strong connection" [P6]	Enhance awareness
"...I share my moment to her when I feel like touch; "[P7]	Shared experience

10.2.9 Practical usage

Considering our communication system for practical usage, not a one-time experience, we investigated feedback about practical usage in the long-term. The usage time does not show a significant difference reported by participants in the logbook. By asking willingness about practical usage, participants showed the expectation of a final product, which developed by our implementation and could be practically used in daily life. And expectation is varied by the relationship of participants. Romantic couples showed more interest in practical usage in daily life, and one-to-one usage has been emphasised. Although they could accept usage with families and close friends, they would feel more comfortable to utilise it only with a romantic partner. And one participant mentioned that "...using it with families and friends depends on how much physical contact we have in recent life"[P4].

The feedback from participants in friendship showed the avoidability for frequent usage, but practical usage is expected. As described "I would like to use it sustainably but may not often"[P5]. One participant expressed that she could use it with more friends or families who frequently contact her on the instant messaging tool[P7]. While two participants thought it would be an interesting tool to use with friends who live apart but are not often in contact. It helps with remembering each other and reconnecting after a long time of disconnection, and the abstract message seems ideal to open the conversation in a cool way, instead of "how are you? ". And one-to-multiple usage is acceptable from these participants, as it said our implementation offered an affective communication, it is playful but not intimate[P5].

10.2.10 Favorite and expectation

In terms of favourite experience, receiving a warm message is most mentioned, working with vibration performed well to activate the tactile pleasantness. As mentioned by participants, water-filled materials affording soft sensation and force-back and non-intrusive communication mode are also favoured.

The expectation for further development is primarily mentioned by the information viables, confirmation feedback, modalities integration and practicality improvement. As for information viables, participants expected to receive the single messages. It is supposed to be an interval between each message, knowing how many single messages are sent by the remote partner. And emotional expression and personal information, for example personal temperature, has been expected for information variables as well.

Additionally, according to participants, confirmation of sending was successfully given by visualising water flow in the tube, but the interactive experience for sending could be richer. One participant specifically mentioned that he would like to feel his personal warmth on the sending port [P5], and the temperature derived from him could be sent to the remote partner. So his partner would receive the same temperature as he feels in the sending port. Besides, they enjoyed the mediated communication with minimised information given by tools. But some expectation for information about the communication process had been mentioned, including giving confirmation of sending success, and providing notification of unread messages. And they would like to keep all notifications muted, thus visualising information could be given by visual modality.

Practical improvement from participants expects that, firstly, devices could be safer and more robust. They had worries about water flowing out by a hard squeeze. Secondly, the size of the device could be smaller and portable, romantic participants expressed that they would like to carry the device in daily usage. But one participant presented the wearable as not preferred because touch is applied by the device, she feels uncomfortable to wear the technology to sense affection.

10.3. Summary: conclusion from inLife evaluation

From the result described above, this mediated social touch device applied warmth and vibration seems to have succeeded at enriching the sensation and building up the affection in mediated communication. A flexible

synchronicity channel is likely to alleviate the issues caused by temporal gaps and improve the communication quality. Minimised information on tools seems to support a non-intrusive mediated communication and generate surprise when checking messages. Overall, this "body-honest" mediated communication seems could imply the closeness for people who live apart in a close relationship, raises the social presence and awareness and supports shared understanding under time differences. By any of these ways or jointly, it succeeded in enhancing social connectedness, described as "a tool for exchange of affection, not for sending information"[P1]. Furthermore, the novel and pleasant communication experience given by our implementation raised the interest for practical usage in daily life, particularly for romantic partners.

While participants have expectations for practical usage like portable size, refined form and durability for long-term usage. Exchanging abstract messages with affection seemed to make communication meaningful, but the desire for more variables in touch messages has been expressed. We will give more insightful discussion in the next chapter.

11

Discussion

In this chapter, we will respond to the first research question discussing the effect of our implementation on social connectedness, describing the impact of mediated social touch and asynchronous communication. Following a review of the design process, we will present our design considerations and insights towards touch experience and communication experience. Compared with traditional mediated communication tools, reflection on technology mediated communication tools will be discussed in the "screen is gone" section. We will share thoughts about our methodology in creative technology design practice answering second research questions. In the end, this chapter will end with limitations and future work.

11.1. Discussion: enhance social connectedness

This part will answer the first main research question, "How can a mediated social touch artefact with the asynchronous channel enhance social connectedness for remote loved ones?". Response for sub-question 1 about effect of asynchronous communication will be described in section 11.1.2. And section 11.1.3 will respond sub question 3 about evaluation of social connectedness.

Our study created a pair of communication tools applying mediated social touch on asynchronous communication for loved ones who live apart. The results from inLife study showed our devices provide a pleasant experience for affective communication for remote loved ones and successfully enhance social connectedness. We will discuss social connectedness in two aspects: mediated social touch and asynchronous communication.

11.1.1 Effect of mediated social touch

The feedback from participants illustrated that mediated social touch succeeds at allowing the exchange of affection in mediated communication for remote loved ones. It could be attributed to two features of mediated social touch: it affords tangible interaction and conveys the ambiguous message with affection.

Tangible interaction shorten the distance in mind

Building upon touch as the intuitive way to interact with the world, our implementation makes affective communication tangible for remote loved ones, beyond traditional mediated communication based on the screen. To fulfil the mediated touch communication, firstly, communicators have to conduct the body movement moving in a physical space to send the message. This spatial interaction amplified the mediated

communication action, rather than simply typing on the screen. Additionally, according to participants, this "amplification" established on touch, as an affective action, makes mediated communication more meaningful. Secondly, the body can perceive the message by haptic feedback. The message from the remote one is perceptible and concrete. As participants mentioned that "You can not see the message, but you can feel it; and the body perception does not lie". Moererve, building upon mediated social touch given tangible interaction, the communication initiated by body movement seems easier to fulfil than verbal communication through text or audio. Thus participants expressed they were willing to initiate or respond to the interaction in our communication tool.

Besides, this tangible artefact facilitates the embodiment of remote loved ones, describing as "I can feel (that) he was there when I see the device", which may raise the awareness and presence of remote loved ones.

Additionally, social touch is a physical action that is only possible with the two communicators being at the same physical location. Although nothing has changed about spatial distance, tangible interaction given by our prototype makes the physical distance vague, creating the fantasy of physical proximity. Participants' described their feelings by referring to "feel closer"," close by", "together", implying that distance shortened psychologically. This impact may turn into improving the feelings of social connectedness by increasing social presence.

Affection in Touch with ambiguous information

Our implementation provided channels to exchange touch messages, conveying affective meaning for remote loved ones. Unlike text messages with certain legibility, touch messages have ambiguous information that brings openness to interpretation in mediated communication space. This open-ended interpretation increased affective feelings given by touch messages. As we showed in the results, participants perceived much stronger affective feelings in mediated social touch than that conveyed by other modalities. And due to abstract information, the affection could be interpreted by the personal context. The affective feelings obtained from touch messages may vary by their moods but always felt pleasant and affected, according to participants. Additionally, the results showed that abstract information from touch massage promotes more behavioural coordination in the mediated interaction, motivating participants to more engage in mediated communication and co-creating the shared meaning, corresponding to theory from [15], which impactfully enhance the social connectedness between remote loved ones.

11.1.2 Effect of asynchronous communication

This section will answer the question of "How does **asynchronous communication** impact the experience of technology mediated communication for loved ones?" Our research found that asynchronous communication could generate sparks of connection for remote loved ones. From the observation results, we found that asynchronous communication is normal and inevitable for remote loved ones, and temporal gaps in text-based communication may generate conflicts for remote loved ones. More importantly, the impact of asynchronous communication is not simply negative. Rather, it opens the space for remote loved ones to understand each other under time differences in mediated communication. Besides, message notifications in asynchronous channels have the opportunity to create an unexpected affection for the recipient.

Following these findings, our design implementation embraced asynchronous communication. It alleviated the deterioration of affective communication made by the postponed response. Furthermore, we found that asynchronous communication generates flexible temporal space that improves communication quality. And by giving limited temporal clues, asynchronous channels create an ambiguous context that improves affective experience.

Flexible timing for communication quality

Asynchronous communication provides a flexible timing to respond to the messages, it provides a pleasant and calm mediated communication to our participants. This channel relieved pressure for recipients from social norms where they are expected to respond to messages immediately. Moreover, senders were less affected by a postponed response, because they did not expect an immediate response in this channel. Thus, participants felt more empowered during communication with freedom and relaxation. Additionally, without time pressure to respond, participants would filter the distraction to concentrate on the mediated affective communication, which improves the communication quality.

Besides, flexible timing alleviates the negative effects of postponed response rather enriches the affective experience. When receiving the touch sent a while ago, the recipient may imagine the context of the peer sending the message. Meanwhile, s/he may anticipate the future moment when the peer receives her/his touch. This process associates the past, present and future. Although the response may not be real-time, the effect of communication could involve a broad temporal dimension, enriching the affective communication experience.

Ambiguous context for shared understanding

We minimised information on asynchronous channels, and participants did not know when the messages had been sent or what the content of the messages were. Asynchronous channels with minimised information creates an ambiguous context, allowing participants to openly interpret the affective meaning. Moreover, interpreting the messages in ambiguous contexts relies on mutual understanding; this interpretation encourages them to co-create shared meanings, which improves mutual understanding.

As participants described, according to mutual understanding, they may assume when their partners send the message or when their partner will check the messages. Later, conversations on messaging tools may cover the ambiguous context from our prototype. This process helps participants learn more about each other and develop shared meanings in mediated communication. It is likely to raise social presence and strengthen social connectedness.

Additionally, our implementation keeps the opportunity for real-time communication. Real-time communication may unexpectedly happen in this ambiguous context, and it showed that participants might feel connected remarkably by this coincidence. The ambiguous context seems to make real-time communication more special in asynchronous channels, therefore we recommend the future study to still keep the space for synchronous communication in asynchronous channels, which could enrich the communication experience in ambiguous contexts.

11.1.3 Evaluation for social connectedness

This section will answer the research question: "How to evaluate the effect of mediated communication tools on social connectedness?", and provides the implications for future studies.

InLife study was conducted to evaluate our design for social connectedness. We set up the communication tools in the participant's home for several days. We conducted a diary study during home usage, and applied a survey with posterior-interview to collect general feedback. This combination provides quantitative and qualitative data and gives contextual information and general information, helping us form a comprehensive view to evaluate the social connectedness; thus, it is recommended for future study. Limitations of our evaluation will be discussed in the later sections **??**.

The results showed that ongoing usage in actual life settings is necessary to evaluate the social connectedness, particularly mediated social touch application is novel for users. From the diary information, we

found that a single interaction with momentary affective experience could generate social connectedness. According to the survey and interview, these momentary experiences influence the general feelings of social connectedness. Therefore affective communication seems to be promising to enhance the social connectedness, and the design for social connectedness could build upon the momentary affective experience, but ongoing experiences need to be evaluated.

To analyse the quantitative information, we referred to the interaction between social presences, awareness and social connectedness 3.3, and five directions of social connectedness, which were introduced in section 3.1. We interpreted this quantitative information as enhancing closeness; enhancing affection; enhancing social presence; enhancing awareness; supporting sharing experience, and improving communication quality. This could be the design directions for future research, but its validity needs further exploration.

Additionally, the results showed that our implementation raised the awareness of remote peers, indicating the importance of relationships. Besides, tangible interaction given by our physical artefact is likely to enhance the social presence of loved ones. These results give two design directions for future study. Firstly, the existence of a physical artefact in the daily environment could increase the awareness of another person, which may or may not improve the social presence of another person, but consequently enhance feelings of connectedness. Secondly, tangible interaction creates the fantasy of physical proximity, implying the social presence of another person that results in a feeling of social connectedness. Therefore, raising the awareness and enhancing social presence of another person could be the design resource of connectedness, and they could, individually or jointly, impact the social connectedness, as we discussed in the section3.3, which could be the design direction for future study.

11.1.4 Articulate the new and embrace the old

Our practice showed an example to articulate the new and embrace the old. Although mediated social touch is not a new topic for technology mediated communication, it is novel for massive users in daily life. Temporal asynchronicity is regarded as an unavoidable gap for mediated communication, instead of applying advanced technology to resolve this gap, we look for the opportunity from the old fashioned communication style, which is slow and less efficient, and apply it into a novel channel. The results turn out this combination creates the sparks for technology mediated communication, affording users a calm and pleasant communication experience. Therefore, we ask HCI researchers and designers to look for opportunities from old-fashioned communication to articulate the novel communication. The old and slow communication style is not outdated, rather, it makes the communication experience less obtrusive but more meaningful. Through articulating the novelty by embracing the old-fashioned, more calm and pleasant communication experiences are expected in the future study. Additionally, to develop new mediated communication channels, we invite future study to be more concerned about affective effectiveness, transferring the focus from efficiency to affection. In this way, design for social connection should be driven by affective experience instead of advanced technology.

11.2. Review of implementation

This part we will answer "How to design a mediated social touch tool with an asynchronous channel for remote loved ones?" by summarising our implementation flow. Subsequently, explicit design considerations will be entailed in the following sections.

11.2.1 Define the relationship for mediated social touch

We aimed at opening a channel to convey affection for close relationships who live apart, including families, close friends and romantic relationships. Specifying the user's relationship defines the intimacy level involved by social touch. It helped us set the design boundary to avoid inappropriate body location and physical actuation. Therefore, we suggest future studies, before producing design practice, to define the level of

intimacy based on the relationship of the target user, ensuring mediated social touch experience is unintrusive. A more insightful discussion about relationships will be described in the next section.

11.2.2 Dividing communication system

In terms of implementation, we divided the communication system into two aspects: touch experience concerns the tactile sensation and haptic feedback given by our prototype; communication experience concerns the effectiveness of the communication system. The overall implementation is summarised in the following paragraph.

Based on observation on remote communication for loved ones on messaging tools, we developed the concept for asynchronous channels inspired by inbox messages. Meanwhile, we explored the physical composition of the touch experience, including the tactile sensation offered by materials and haptics feedback given by actuators. Integration of the chosen materials and actuators makes the artefact able to trigger the touch sensation, which is the output in the communication system. Subsequently, we defined the message variables as touching duration and allowed the messages to be stored in the device for asynchronous communication. Besides, we implemented touch detection as the input, mapping them to the output, which realises the sending and receiving in asynchronous channels. Finally, we connected two devices remotely, achieving the bi-directional mediated social touch communication.

Our implementation flow could be an example for future design practice. Based on this flow, we will discuss meaningful findings and give the implications of future study in the following sections from two aspects: touch experience and communication experience.

11.3. Discussion for touch experience

11.3.1 Tangible affordance of mediated social touch

Soft and warmth are compelling for mediated social touch device

Water-filled materials with warmth remarkably impact, creating a pleasant and affective touch experience. Compared to the normal materials of digital artefacts as cold, hard and solid, this soft tactile sensation with warmth offers a squeezable, playful tactile sensation with humanity. Particularly compared to the results from the first and second prototypes, warm water significantly contributes to increasing affective feelings. This warmth is attributed to the feature of the actual human touch. However, it should be noted that applying warmth on solid materials may not have this significant effect. A study that applied warmth on a teddy bear for haptic interfaces did not increase social warmth/refer. Our findings showed that the warmth applied with fluid materials is compelling for affective mediated communication.

However, applying the water increases safety risks, as fluid is flexible to flow, damaging the electronics. We recommend the less flexible materials for future study. For example, Non-Newton fluid, as Slimes we tried in the specification, could afford a similar tactile sensation but more solid with fewer safety issues when integrated with electronics. Moreover, a combination of hard and soft sensations could be explored by further exploration, as we showed hard bouncing balls putting in the water balloons, which participants have preferred. In terms of the container for fluid, it should be stretchable soft with a smooth surface. In addition to latex, textile could be an opportunity for future studies, which could afford soft and smooth sensation and retain warmth. However, applying furry textiles for artefacts should be cautious because it might connect to unnatural creatures.

Haptic feedback

Besides, we applied water pumps to offer vibration feedback and change the weight. We expected water weight changes by flow could represent the input/output process. However, the tactual perception given by weight change is too subtle to feel. Although our practice did not implement it successfully in the communication process, it might be worth exploring in future mediated communication studies.

The vibration given by the water pump performed calmer and quieter than the vibration motor. Beyond the vibration, more possibilities of haptic feedback could be explored under the dynamic of fluid, for example, waves and water flow generated by motors or fans. Look back to chapter9 to get inspiration for actuators.

Importance of tangible affordance

Last but not least, we ask for more attention on tangible affordance in mediated social touch. We are touched when touching in actual human touch. In the mediated settings, this simultaneous reaction for action is offered by the artefact, instead of remote communicators. As the first trigger of tactile perception, immediate reaction could impact the overall experience remarkably, therefore tangible affordance is worth attention for future study. More importantly, looking for opportunities from tangible affordance help us to generate embodied interaction. We expect the interactive artefact could offer a pleasant and calm tactual perception, creating the aesthetics of interaction design, instead of simply imitating real human touch.

11.3.2 Relationship-specificity but open for relationships

Our final evaluation opened for all kinds of close relationships, as long as they accept to touch each other in actual life. Eventually, our participants involved close friends and romantic couples. Commonly, all the participants experienced affective feelings through the artefact, and social connectedness was enhanced. While we also found a significant difference in experience between them.

Participants in a romantic relationship showed stronger needs to utilise mediated social touch to convey the affection. Moreover, they expressed expectations to share more private information, e.g., personal temperature and emotions, and they prefer to use this device only with their romantic partner. However, we found that participants in friendships showed an interest in one-to-multiple communication mode, probably due to a low level of intimacy. Not just with one friend, the remote friend could be multiple. In addition, participants showed the willingness to apply the device with the person they just know and willing to learn more from each other, which is not a close relationship but potential to be closer.

Above mentioned differences between romantic relationship and friendship present the relationship-specificity of mediated social touch, which shows the importance of pre-define the relationship of users for design practice. More importantly, it points out the opportunity for our implementation that could be massive and diverse usage as a communication tool. One-to-multiple communication is possible for future development, and the target group could be broader to involve the people who are not in close relationships. Furthermore, this finding also implies that mediated communication through mediated social touch is possible to be built without actual social touch, which means mediated social touch communication could be pleasant even if the toucher and touchee do not have an actual social touch.

Massive and diverse usage of mediated social touch could be the opportunity for future study. However, we suggest that the level of intimacy given by mediated touch could be adjustable in massive usage. The way to give mediated touch and receive mediated touch could be changed to fit the relationship boundary, which will be a challenge for future research.

11.3.3 Relevance to human social touch

We found that users intuitively linked what they felt in the mediated social touch to the actual social touch, which impacts the acceptance of mediated social touch and affects the affective experience. Therefore we will discuss the relevance of human social touch and direct two important aspects of mediated social touch. One is the linkability of mediated social touch to actual social touch, covering the acceptance and ethics concern of mediated social touch. Another is the two layers of association between touch and being touched, which is the key for embodied interaction.

Linkability of mediated and actual social touch

Linkability of mediated social touch refers to the touch experience, given by mediated social touch, is able to link to the touch that exists in actual human interaction. Holding of the ports is expected to hold the hands in our implementation, and warmth given by the receiving port is expected to link to peer's warmth. Participants said the experience makes them feel like holding a remote peer's hands, but also very different; it still had mechanical features but felt pleasant to hold.

Instead of imitating the actual human touch, linkability emphasised that mediated touch should be distinguished from real human touch, but could invoke the memory of actual human touch offering embodiment interaction. In this way, the mediated experience is not completely strange, which increases the acceptance of novel mediated channels. More importantly, the distinguishability keeps the boundary between mediated and actual human touch. Because social touch could involve high intimacy in real life, keeping this boundary avoids affective feeling generating between artefact and users, reducing the ethical issues.

Two layer of association between touch and being touched

In actual life, we are touched when we touch. This action and reaction happen simultaneously, an essential feature of actual touch. To generate the embodied interaction, we emphasised the association of touch and being touched in mediated social touch communication, in which "touch" corresponds to "sending", and "being touched" to "receiving". We will point out two layers of this implication in the following paragraphs.

The first layer of touching and being touched is situated between two communicators. It entailed that reaction, offering tactual perception for the recipient, could be associated with the action being taken by the sender, which emphasises the authenticity of social touch. Although it is conducted by the artefacts, it is derived from a remote partner. Designers should make communicators believe the mediated touch are actually made and sent from the remote partner. The second layer of touching and being touched is placed between users and artefact. As an agent to mediate the social touch, we emphasise that artefacts should immediately react based on the user's action to imitate the "touch and being touched" process in the actual human touch. Therefore, the fluid-filled materials are ideal for mediated social touch because they give the force back simultaneously when users touch it. Its tangible affordance naturally implies the "touch and being touched". Besides, it is vital to offer immediate feedback in the interactive loop, which forwards the interaction process, emphasised in the study/ref.

In our implementation, we applied the water flows to support this association. In the first implementation, when users touch the ports, water will flow to another port and weight will reduce. This process imitated the playing of the seesaw. Each action from users could influence the states of weight. Moreover, it nicely fits sending scenarios because something is lost when sending. However, it was unnatural to represent the receiving scenarios because the water flowing away is not matched to the reaction of receiving. In the second implementation, we kept the water flow and made sending as losing water and receiving as gaining water. Besides, we added warmth for receiving ration, impacting the affective experience positively.

However, our solutions may not ideally fulfil the two layers of association between touch and being

touched, but provide a practical example for future study. We believe these two layers of "touch and being touched" will be key for embodied interaction, as the challenge for mediated social touch study, which deserve more exploration for future studies.

Last but not least, upon these two layers, sending experience is equally important as receiving experience, which gained less investigation from previous practises. Besides, our results also showed that sending impacted the pleasantness for users, and they expected richer interaction in the sending inaction. Therefore we ask for more attention on interaction for sending in the future practice.

Active touch for calm experience

Our implementation requires users to apply active touch both for sending and receiving. Users have to touch the ports before receiving, and the artefact produces tactual stimulation when detecting the input. This process makes the artefact ask the consent of users to touch them, and it alleviates the intrusiveness made by mediated social touch. Joint with asynchronous communication, it offered a calm communication experience. Therefore, we suggest applying active touch in the future implementation of mediated social touch research to provide a non-intrusive experience. However, we analysed this impact based on the conversation with users and did not conduct evaluation systematically; thus, we would like to see more explicit investigation for intrusiveness, passive and active touch.

11.4. Discussion for communication experience

11.4.1 Content Variables in touch message

Information in our communication system has affective but abstract meaning and is formed by touching duration. Beyond 1-bit information more than Yes/No, senders could send multiple messages even though the recipient does not receive them. Stored messages were added up by new messages from the sender or subtracted by the recipient checking out. Sending and receiving channels are independent and could happen simultaneously, as the speaker and microphone on the phone. The results showed that the touching duration made the meaning of touch messages more variable. Moreover, the touch messages with long duration could provide more pleasantness and enhance affective feelings. We found that abstract messages with limited variables could achieve the goal of conveying affection and impact affective feelings. However, in the conversation with users, they expressed that there is an expectation for richer variables in touch messages for long-term usage. For example, expressing personal emotions and sending personal temperature has been mentioned. Therefore, more variables in mediated touch messages could be developed for future study. However, it should be noticed that variables should be balanced with ambiguity. Rich variables in touch messages, which is ambiguous information, may cause a heavy workload for message processing, deteriorating the communication quality.

11.4.2 Ask for attention on asynchronous channel

We have discussed the effect of asynchronous communication in the previous section 11.1.2. The performance of asynchronous communication is worth gaining more attention from technology mediated communication academia. Reflecting on our implementation, we will introduce our discussion for asynchronous communication in the following parts, offering design considerations for future study.

Concern for continuous communication Asynchronous communication offers a calm communication experience. However, the calmness may make it an ambient device, impacting continuous communication. For example, one user keeps using the device, and another forgets to check the message for a while. This

case deteriorates the user experience and communication quality. We had this concern before the evaluation. Probably because of the device's novelty and the short experiment period, asynchronous channels did not cause a negative impact on continuous communication. Users could communicate smoothly under temporal gaps, over hours or the night. However, future studies could produce long-term tests to investigate this concern. To resolve this concern, we suggest the design could make the mediated touch interaction easy to pick up, so that users do not make an effort to recall the previous interaction. Moreover, add playfulness for an interactive experience to leave an enjoyable memory to users. Besides, richer variables in the message that opens the space for co-creation could also help produce continuous communication. However, it should remain as a calm and non-intrusive communication tool.

Keep real-time channels for coincidence We ask to focus on asynchronous communication, but it does not mean blocking real-time communication. Real-time channels play an indispensable role in mediated communication. From the observation and final evaluation results, we found that receiving the immediate response from the remote partner in an unexpected context could boost the social connection. Therefore we recommend keeping synchronous channels in asynchronous communication to leave an opportunity for coincidental real-time communication, generating the sparks of connectedness.

11.5. Screen is gone

11.5.1 Comparing to messaging tools

Compared to messaging tools, the most significant difference is that the "screen" is gone in our implementation. Firstly, touch messages do not contain any text information, which is not visible or readable but perceptible. Users could send or receive touch messages while closing their eyes. Secondly, the second implementation minimised the information about the communication process. There is no visual clue to notify the incoming messages or illustrate message processing states. Moreover, the history of previous communication is not given. To obtain the information, users need to input the signals to request information. Thirdly, sending touch or receiving touch requires users to be present in the communication settings, both mentally or physically. Unlike messages on the screen, users may conduct something else in physical settings during mediated communication. In the communication setting given by our communication system, tangible interaction filters out other physical distractions. One user described it as immersive mediated communication in his mind.

This no-screen communication experience creates ambiguities for mediated affective communication, bringing a novel and embodied mediated communication experience for remote loved ones. Therefore, we present the creating ambiguities for affective communication as design implications. Based on the study "ambiguity as a resource for design"[92], we implemented ambiguity in two aspects: ambiguous information and ambiguous context. Joint of these two succeeded in creating the space for open-ended interpretation, making mediated communication more intriguing and enriching the affective experience for remote loved ones. Thus, by giving two bright directions: ambiguous information and ambiguous context, we look forward to more exploration on creating ambiguities from the future study.

However, in the context of the no-screen, how to supply the information to process continuous communication for communicators is an interesting challenge, which will be a design space for future practice. We will discuss our implementation centred on the notification to offer design considerations in the next section. It should be noted that the notification we discuss here, does not only mean the information that notify the incoming messages, but also the information that notify the message processing states.

11.5.2 Thoughts about notification: what information should be given?

We found that notification is an influential element in mediated communication, particularly under the time differences in asynchronous channels.

From observation on messaging tools, as for the notification of incoming messages, participants are likely to enable or set special notifications for messages from remote loved ones on instant messaging tools, as a reminder to check the messages. Moreover, it showed that notifications could deliver affection without the message content. Seeing the notification may make recipients feel they were thought of. Interestingly, some participants may intentionally keep the messages unread, in order to maintain the affective feelings given by the notification. As for notification of communication process, one participant pointed out that blocking all the communication process notifications could avoid unnecessary information that reduces the workload to process information during mediated communication.

In design practice, our prototype implemented two different patterns of notifications.

We notified all the states of communication processing on the first prototype. The device will notify the incoming messages, receiving moments, and receiving messages finished. All the states will be synchronised for both sides of communicators. However, the results showed that notifying all states increased the complexity of asynchronous communication, confusing users, which was unnecessary in our channel. On the second implementation, we minimised the given information to look for valuable notification for mediated affective communication. The device did not provide any notifications unless users input the request. When users input the sending and sending over signals, the device will notify them that they are sending or stopping. When users input receiving signals, the device will present touch messages stored in the device. The results showed that participants enjoyed this zero-notification communication style. Moreover, this experience could surprise them when they found there were touch messages stored, similar to opening the mailbox to get a postcard.

Additionally, under these minimised information channels, there are two types of information that participants have mentioned: 1)whether there are messages; 2) how many messages are left when being touched. Information of whether there are messages is similar to notification for incoming messages on the messaging tools. Participants mentioned this because they experienced disappointment from no messages stored in the device. However, some participants expressed that it may ask for more attention that deteriorates the calm and surprising feeling given by our implementation. Information of how many messages are left is for the context when users are receiving. We assume the need for this information comes from feeling in control of artefact. Offering this information enables users to know when the artefact will stop producing the touch stimulation. Besides, visualising the number of stored messages seems to present the amount of affection the remote partner gives.

However, rather than giving the recommendation, we hope the above discussion could stimulate researchers' thinking about the information given in mediated communication systems. On top of this, we want to emphasise that "less is more" is practical for affective mediated communication. As a bridge to connect loved ones who are apart, The communication tool should focus on the effectiveness of "sharing myself" and "knowing another", eventually achieving the goal of enhancing social connectedness. Therefore, instead of concluding what information should be given, we reframe the question to "what is meaning information for affective communication given by a mediated communication tool?", and look forward to more design practice to respond to this open question.

11.6. Discussion: multiple perspective in research journey

In this section we will answer the second research question: How can switching between multiple perspectives for one researcher be used to enlighten the research through design practice?

We were assigned different roles in each stage by applying the auto-ethnographical design method and

the creative technology design process. It offered multiple perspectives and enlightened our research-through-design journey.

The auto-ethnographic design method asked us to be the users, giving the first-person perspective to complement third-person perspective as the researcher, offering meaningful information in research-through-design. In the creative technology design process, we were both designer and tinker, integrating ideation and realisation to implement our design practice. As a tinker, the making process helps us think from practical aspects, which is inspirational for creative technology design. Besides, the limitations occurring in tinkering experiments could be helpful for concept development. We will describe explicit discussion in the following parts.

11.6.1 First-person perspective in the research

The auto-ethnographical design method asked the researcher to be one of the participants in the research, which provides meaningful information from a first-person perspective. In particular, we studied interpersonal communication for remote loved ones, which involved private experience. The first-person perspective in the observation offered information that is hard to uncover from a third-person perspective; meanwhile, it reduced the privacy concern from third-person perspectives.

Besides, understanding and reflecting on ourselves seems to resolve the difficulties from emphasising with others. Putting ourselves in actual context as users allows us to notice the subtleties in experience design. Moreover, the information collected from the researchers' self-study is likely to be anchored on research questions, generating insights focused on the researcher goal. Additionally, this design method asks researchers to be flexible between first-person and third-person perspectives, which helps train critical thinking. Therefore we recommend the auto-ethnographical design method for the design practice, which involves private information, and the researchers themself are the target users.

However, studying ourselves has limitations. Because of the focus on research questions, we may ignore general information from a third-person perspective. Lack of user's feedback may affect the practicality of design implementation. In the early development stage, self-test feedback could make the design process quick, but to resolve this potential practical issue may require more workload in the re-design phase, slowing down the following design phase. To avoid this potential issue, we conducted user research combined with self-observation in the observation phase, helping to form a comprehensive understanding of asynchronous communication. Besides, we conducted the intermediated user test in the design implementation phase, which pointed to the design directions for the second iteration.

Therefore, the user's perspective is indispensable, although the first-person perspective is beneficial for creative technology design practice. Moreover, we suggest researchers invite users to be involved in the evaluation timely, as our intermediated evaluation, to avoid potential self-bias from the auto-ethnographic design method.

Additionally, the documents about self-study for this method are vital, which presents a valid design story. Our practice missed a systematic document to tell the story of the design process, which should be improved in the future work. Moreover, future studies could explore the practical framework, offering working files to document the design process as scaffolds to support researchers to produce an auto-ethnographic design.

11.6.2 Design with tinkering

Tinkering is embedded in the divergence design process, specialising at practicality and helping us to converge the design implementation. We conducted many tinkering experiments to explore suitable tactual stimulation, and these tinkering makes the implementation possible. In addition to offering practical solutions, more importantly, the tinkering process is inspirational and helps to open our minds from practical

aspects. Thinking is interwoven with tinkering, and tinkering serves as scaffolds for thinking in technology design process. The ideas developed from tinkering makes the concepts more feasible from technical aspects.

Besides, tinkering experiments bring us to think with technology, making us quickly aware of limitations of technology. These limitations might cause barriers for design implementation, but it also helps for concept development in creative technology design. In our implementation, the redesign has been nudged by limitations of practicality. Due to practical limitations, the first prototype failed to provide clear and calm visual clues for notification. This limitation led us to reflect on the boundary between technology and humans; thus we decided to minimise the information given by the communication system, which successfully improved the communication experience. Instead of compromising, a decision made upon the limitation helps to define a sustainable relation between technology and humans. The challenge for creative technology designers is not to resolve the technology limitation but rather find an ingenious way to make limitations the resource of design, which could help design a calm technology.

Therefore, we suggested that creative technology designers should develop and strengthen tinkering skills, think with tinkering, embracing tinkering to open the inspiring space from practical aspects.

11.7. Limitations

11.7.1 Limitation for generalisation

We ran inLife evaluation with five pairs of participants. Although we obtained rich qualitative results, there is a limitation to apply our insight to the general population.The diary study and interview are both user-centric methods, and the usage is at home with a close person. The given information is limited in individual context in a small group of users. Besides, our participants are limited to technology university students or graduated students, in the age range of 23-30, who have the research background and intermediated technology knowledge. And more female than male participants joined the study. Therefore we cannot generalise our findings to younger or older groups, and also to people who have less knowledge about technology. A larger group of participants with diversity needs to be involved to support the generalisability.

11.7.2 Self-reported data

We applied the diary study during observation and final evaluation, asking participants to record their experience of using communication tools. Diary study across several days demands a large amount of engagement. Likely, participants may not document the experience in time but finish the logbook before researchers collect the logbook. They have to recall the memory in previous days, and the description of experiences may be influenced by the events happening afterwards. The same issue may involve the posterior interviews that participants have to recall past experiences. Besides, our diary study and interview are expected to reveal personal feelings, which researchers will view and analyse, generating social pressure from the review of a third person. Thus it is possible there is fabrication in the self-reported description. Moreover, as they were informed of the research purpose before the study, participants might report the experience and answer the questions with bias influenced by prior knowledge. It is worth mentioning these biases as our research depends on self-reported data, although we cannot completely remove them in self-report.

11.7.3 Missing common understanding about notions

We introduced it in desk research, related to belongingness and loneliness, understanding it related to awareness and presence. Still, it is missing a unified definition of social connectedness. In the survey, we evaluated the experience by “feeling togetherness”, “feeling closed”, and “feeling connected”, which are

refined from study[15]. However, participants may have a different understanding of these notions, which influence the validity of survey results. Besides, social connectedness is an abstract experience that causes difficulty to describe the experience. We found that participants applied analogy examples to describe feelings about social connectedness, and some participants used similar terms but represented different meanings. This makes our data analysis complex and probably causes misinterpretation of self-reported data. Therefore steps to unite a shared understanding about notions should be considered, and specific indexes with higher validity to measure social connectedness are needed for future work.

11.7.4 Mixing groups, not a controlled study

As an exploratory study, we did not control variables in inLife evaluation. We mixed friendship and romantic relationships in the final evaluation. The closeness in friendship and the stage of romantic relationships is not well defined; these variables may influence how and how often participants produce affective communication. Besides, the physical distance between participants is varied. Distance between participants may be across the Netherlands, but some live in the same city. This might be a variable for mediated communication because the people who live apart but close may have fewer needs for mediated communication as physical meetings are accessible. Moreover, the duration of the inLife study is varied in the range of 3-5 days. As a novel technology, usage period might impact the experience because it involves acceptance and familiarity. Our results only offer initial insights for mediated social touch technology in asynchronous communication.

11.7.5 Limited research ground in HCI

Our design implementation aiming at affective communication in mediated social touch with asynchronous channels is grounded in the HCI field. However, this is an interdisciplinary topic, and an abundance of work has investigated each aspect. Technology mediated communication has a home in the communication science field; social touch and social connectedness is embedded in sociology but interwoven with multiple subjects. Although we introduced the basic knowledge about computer mediated communication and social connectedness, our perspective is built upon HCI researchers, and experts in other fields are absent. Therefore we acknowledge that this work lacks expertise from these two fields, which may have different interpretations of our results; still, we hope our findings could support research in other domains.

11.8. Future work

Based upon current implementation, we will discuss some potential directions for future work focusing on device improvement.

11.8.1 Present original information

It is expected to add the interval between individual messages, which means recipients would know how long for each single message, presenting original information given by the sender. Moreover, this could enrich the information variables. Users could co-create shared meaning from various duration like Morse code. And they could even send a rhythm. Moreover, different variables for touch messages could be explored instead of sticking on duration.

Additionally, the warmth that the recipient gets could be built upon the sender's hand's temperature. It enables users to send exact body temperature to remote loved ones. In this way, temperature becomes another variable. However, it should be noted that richer variables still should remain the ambiguities in this mediated communication.

11.8.2 Richer sensory experience

The richer sensory experience could be established from two directions. One is to augment touch experience, and another stimulates more senses by applying different modalities.

As for augmenting touch experience, future work could continuously explore the physical composition to generate tactual stimulation. As we showed, fluid dynamics have the potential to generate various tactual experiences. For example, fluid could drip, wave, and be sprayed. All these could be resources of tactual perception, meanwhile offering the visual affordance of a communication system. Additionally, perhaps exploration on touch gestures could be applied for more prosperous input action, e.g., squeeze, tickle, scratch, and so on, but it may require more complicated work on realisation.

However, for touch sensation we only focus on the hands as the sensation receptor organ. Skin as the largest sensation organ, different body locations with more regions could be explored to provide a more immersive experience by giving the same tactual sensation. For example, making a device in a chair or couch size where users could lay down or lean on, with water-filled materials, subtle vibration and warmth, but pretests for acceptance and pleasantness are needed.

Richer visual modality could be applied as many prototypes did in terms of applying other modalities. As participants mentioned that sending experience could be more interactive with sending confirmation, applying light could be a peaceful and practical solution. For example, light with the gradient colour represents the message being sent, and solid colour represents the message being delivered. However, visual modality should aim at enriching the sensory experience instead of offering more unnecessary visual clues.

Interestingly, participants mentioned the expectation of exchange smell modality in the observation. Smells could carry personal features/preferences and convey private information, and it is similar to touch offering ambiguous information. Combining touch and smell modality may generate more affection between distant loved ones, giving a unique and novel experience, which will be a challenge for future work.

11.8.3 Practical improvement

Due to exploratory study, our implementation is still a fragile artefact in the early stages and should be more robust. Instead of integrating the parts given by laser cutting, 3D printing could form a device at one time, offering a more robust structure. In addition, we did not completely solve the potential safety issues about water-filled materials. Besides, although a basin was added to contain the flowing water, the electronics contact to water may cause serious problems. Waterproof protection for electronics may need to be considered. Further development could either make the fluid container closed or replace the water with Non-Newton fluid to avoid safety issues made by flowing water.

However, we applied the camping heater in our implementation. It warms up the water quickly but may warm it continuously and remain the heat without a power supply, which leaves safety issues. Future work should look for an efficient heating element in a smaller size, and with a temperature controller embedded in the element will be safer. Additionally, we found some practical issues about electronic components, describing with solutions in the Appendix E.

Realising the design concept of shape and size was limited by the available materials. If possible, the colour of the device should be muted. If customised materials are possible, building upon current features with soft and warm affordance, an organic shape in portable size having ergonomics considerations will be expected.

11.8.4 Future evaluation

All further developments require evaluation. For future evaluation, long-term studies should be conducted, considering the period for technology acceptance. A larger number of participants should be invited to join the study, with the diversity of age, gender, and technology knowledge. Besides, the variables should be controlled for participants, which could be implemented in the recruitment process or data analysis. In addition, inviting experts in communication science might broaden perspectives to analyse the results.

12

Conclusion

Our research question has two-fold: 1)how can mediated social touch technology with the asynchronous channel enhance social connectedness for remote loved ones, and 2)how can switching between multiple perspectives for one researcher be used to enlighten the research through design practice.

To investigate the study, we firstly conducted a user research on the daily usage of messaging tools, and ourselves being participants. We found that asynchronous communication could make affective communication cross over a broad temporal dimension and create unexpected moments for social connectedness. Thus, we articulate mediated social touch into asynchronous channels. Our implementation enables users to communicate by touch sensation remotely, in a flexible temporal space. To contextualise this artefact, we deployed user evaluation in daily life settings over a few days. In total, ten pairs of participants used it and wrote a logbook for user experience in the context. Questionnaire and interview were conducted after inLife usage.

Results showed that mediated social touch in our implementation enriched the sensory experience for technology mediated communication, whose tangible affordance made remote loved ones feel closer in their minds. It performed as a promising way for mediated affective communication. Embracing asynchronous channels resolved the time gap embedded in technology mediated communication, offering a time-flexible and relaxed communication experience. Jointly, it offered a pleasant and calm affective communication experience, improving the mediated communication quality that enhanced the social connectedness.

We used a combination of diary study, questionnaire and posterior-interview to evaluate our prototype and obtained rich qualitative information. However, quantitative data obtained in questionnaires seem to lack sufficient validity because a mutual understanding of social connectedness terms is missing for participants. A systematic measurement for social connectedness in technology mediated communication is needed for future study.

Our design practice explored physical composition for tactual sensation. Materials like water-filled balloons, affording the softness with force back, offered a pleasant tactile experience. Warmth added enriched the affective feelings in the given experience. Thus, we recommend the fluid-filled materials as the tactile affordance for mediated social touch application, and Non-Newton fluid is a safe and effective option. We suggested integrating warmth with materials that offer a soft and smooth sensation, like water-filled materials.

Reflection on the design process offered insights for embodied interaction in mediated social touch. Designing mediated social touch should consider the relevance of actual social touch. Firstly it should be linkable to actual social touch offering familiarity, but distinguishable to actual social touch avoiding ethical issues. Secondly, we propose that the association between touch and being touched is the key to create

the embodied interaction by presenting two-layer aspects. The first layer is between users and the artefact, emphasising the importance of immediate feedback and corresponding between input from users and output from the artefact. The second layer is between two remote communicators. The sensation to send should be associated with sensation to receive, matching touch and being touched remotely. It ensures the mediated social touch is authentic because touch is made and given by remote partners. Besides, we used active touch for input as consent for haptic stimulation, alleviating the intrusiveness of mediated social touch experience, which is suggested for future application.

As for message information in communication, we employed the touching duration as the message variable. Feedback presented that it is sufficient to convey affection, but expectation for richer information in touch messages has been expressed. More variables in touch messages could be developed for future study. Additionally, feedback from a limited number of participants showed the experience of mediated social touch depends on the user's relationship. But the application of mediated social touch for communication seems not limited in that close relationships. Future study could explore the relationship in different degrees of closeness in mediated social touch application.

Our results hope to ask attention from designers and HCI researchers on asynchronous communication, transferring focus on efficiency to effectiveness and meaningfulness in technology mediated communication. Meanwhile, we suggest keeping the real-time communication in asynchronous channels, leaving the opportunity for coincidental immediate response. Compared to the common mediated communication tools, our implementation removed the screen and minimised the visual information, making the mediated communication perceptible but not readable. This experience is filled with ambiguity, and could be a design resource for affective communication. Importantly, as a scaffold to convey affection, we opened a question for future study, namely what could be meaningful information given by communication systems for affective communication.

Standing at a third-person perspective, we accomplished this exploratory work, hoping to offer insights for future study. These insights were contributed by multiple roles we played in this work: the participant, offered first-person perspective; the designer, produced inspirational ideation; the tinker, made ideas happen. These multiple perspectives enlightened each other and formed a comprehensive perspective to reflect on the research. As a meaningful design method, the auto-ethnographic design method is welcomed to more design practice and we look forward to future study to develop a practical framework to support researchers to produce this design method. And we invite attention to value the tinkering, which could inspire our practical design thinking. In sum, we suggest, HCI researchers apply multiple perspectives by playing different roles and consulting different fields, to better serve the HCI community.

12.1. Closing thoughts

This work is inspired by touch deviation in the social distancing context. We studied human social touch and tried to imitate it by mediated social touch. However, we could not fill the physical gap between remote loved ones, and could not imitate an actual human touch by technology. Our implementation is meant to offer a possibility of tangible sensation. It could convey affection that bonds people in the distance.

Creating the message perceptible and making the affection tangible, we insist that experience in the physical world is indispensable. Although our work is devoted to in the mediated space, we believe "technology is best when it brings people together", hoping our implementation could bring people together, in and to, the physical world, where the sensation is authentic.

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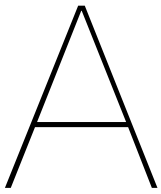


Table of prototypes

Table A.1: Table of mediated social touch prototypes

Prototype	Meaning	Type of touch	Body location	Actuation	Modalities	Materials and shape	Synchronicity
VibroBod [57]	Affection	Abstract, contact	Hand, abdomen, upper leg	Vib	T,A	Rubber; abstract shape	Syn
The bed [58]	Affection	Contact	hand, arm chest, abdomen	Temp,vib	T,A,V	Pillow,bed and fans	Syn
The hug [63]	Affection	Hug	hand, arm chest, abdomen, upper leg	Temp,vib	T,A,V	Robotic product with hug gesture; Soft textiles	Asyn/ Syn
Hug over a distance [70]	Affection	Hug	Torse	Force	T	Air-inflatable vest; furry koala	Sync
Huggy pajama [68]	Affection	Hug	Chest, abdomen, back	Force	T	Wearable jacket	Syn
HaptiHug [61] - 137	Affection	Hug	Torse	Force	T,A,V	Soft belt;hand shape; sponge-like rubber material	Syn
Thermal Hug [64]	Affection	Hug	Lower back , side	Temp	T	Padded harness; textile	Syn
Squeeze device [56]	Affection	Squeeze	Upper arm	Force	T,A	Armband, rubber	Syn
Stroking device [65]	Affection	Stroke	Hand	Force	T	Organic and abstract shape; soft textile	Syn
Kissenger [71]	Affection	Kiss	Lips	Force	T,A,V	Human/Animal-like;silicon rubber and plastic	Syn
YourGloves [66]	Inclusion	Holding hands	Hand	Force	T	Robotic hand, human-like forearm	Syn
HotHands, Hotmits [66]- 145	Inclusion	Holding hands	Hand	Temp	T	Hand shape device	Syn
Shaker [69]	Playful Affection	Abstract	Hand	Force	T	Metal rod surrounded by a wire coil	Syn
inTouch [77]	Playful Affection	Abstract	Hand	Force	T	Roller	Syn
HandJive [74]	Playful Affection	Abstract	Hand	Force	T	Ballon(liquid inside back and forth)	Syn
Tug of War [60]	Playful Affection	Abstract	Hand	Force	T,A,V	Rope, plastic wrap	Syn
KUSUGURI [75]	Playful Affection	Tickle	Hand	Vib	T.V	-	Syn
The Tickler [76]	Playful Affection	Tickle	Forearm	Force	T.V	-	Syn
HaptiTickler [62]	Playful Affection	Tickle	Side	VIb	T.V.A	Controller	Syn
ComTouch [78]	Symbolic	Abstract	Hand	Vib	T,A	Pads	Syn
CheekTouch [59]	Symbolic	Abstract	Hand, cheek	Vib	T.A	Acrylic panel, sponge; tissue	Syn
POKE [88]	Symbolic	Poke	Hand, cheek	Force, vib	T,A	Inflatable surface	Syn
Gestural haptic interface [49]	Symbolic	Abstract	Hand	Vib.	T	-	Syn

Vib. = Vibrotactile, Temp. = Temperature
T = Touch, V = Vision, A = Audition
Syn = Synchronous, Asyn = Asynchronous

B

Observation

B.1. Interview

Interview for observation

Asynchronous communication:

- How will you respond to your remote partner?
- How do you expect your partner will respond to your messages?
- What is the experience about immediate response and response with daly?
- If your partner gets used to reply with delay, does it have any effect on your communication?

Opening and ending the conversation:

- How will you open a conversation?
- How will you end a conversation?
- How do you feel after the conversation is over?
- What moments do you have a strong desire to talk to your partner online?

Thoughts & feelings about other channels and tools:

- In what case, you will choose audio, video-based chat?
- How do you feel between these different channels?
- How do you feel about mobile phones, as a communication tool?
- What will you do if the phone is unavailable?
- How do you feel about the relation between the phone, you and your partner?

Connection and disconnection:

- In mediated communication, in what case or what moments do you have a strong connection with your remote panter? Why?
- In mediated communication, In what case or moment do you feel a strong disconnection with your remote partner? Why?
- How do you maintain the connection remotely in daily life?

Mediated Social touch:

- Have you heard of or experienced mediated social touch?
- How do you feel about it?
- Will you try it with your remote partner?
    - If yes, which location? And what do you expect?
    - If not, why?

B.2. Information brochure with consent form

Enschede, date…..

Information brochure for Observation of Technology Mediated Communication

Dear reader,
In this letter, I would like to inform you about the research you have applied to participate in. In the proposed research, entitled “Design mediated social touch for social connectedness in remote communication with asynchronous channel.” This project will design an embodied interactive artefacts allowing mediated social touch with asynchronous communication channels.
Mediated social touch allows the people to exchange touch messages through a device, meaning the sender can send touch to the receiver by touching the device, and receiver can receive the touch from the sender but applied by the device. So the social touch is mediated by the device in this process and it can happen in distance. ***Asynchronous communication*** allows people to receive mediated social touch with delay so that people can receive the touch when they are ready to be touched.

Purpose
The aim of this diary study is to understand how people who are in close relationship but distance-separated interact with each other via instant messaging tool. This includes understanding when and how people will postpone reply to others, and their subjective feeling of no-reply or late reply. Which helps the concept development of designing interactive artefacts allowing mediated social touch for remote communication.

Participant Recruitment and Selection:
Both individual and dyad participants are welcomed for observation study. Dyad participants should be in a close relationship (families, couples, close friends). To be recruited for this study, all participants are required to be able to and get used to using instant message applications. You should be comfortable describing intimate details regarding your relation with your communicator and the (possibly intimate) activities you do online with your communicator. But you are free to choose to not answer certain questions, or not mention certain details.

What Will I Be Asked To Do?
During the study, you will be asked to write a diary to make a logbook, where you will record and summarize your use, activities and thoughts you may have about yourself and about the other communicator during the interactive process by using an instant message tool or video-calling.

Some detailed content about the diary is listed below:

- How does it feel when you wait for the contact?
- How does it feel like having been in contact at an earlier moment?
- How does it feel like to interact with the product even when the other person is not responding?

- How does it feel if you are the person who doesn't respond?
- How does it feel when you end the interaction?
- How does it feel and when you are connected/disconnected?
- About the above questions, what do you sense for the other interactor in the interaction process?

It does not necessarily include each question but you are welcomed to add your own self-perception and perception for the other during the online contact. For the diary, you can briefly introduce the context when your perception occurs, but it does not necessarily mention the content of your text message. And try to not disclose the sensitive/personal information of your communicator.
The total duration of this diary study is approximately 2-4 days. You don't need to write the diary for each interaction, but write it when you have perception, feelings and thoughts related to the detailed content as mentioned before. When the diary study finishes, the logbook will be collected. After diary study, I will invite you for an interview. For the dyad participants, you will be interviewed individually.

Your Participation
Participation is voluntary. If you agree to participate, you will be free to withdraw at any time for any reason. All data (even if it has already been collected) will be removed if you withdraw your consent.

What Type of Personal Information Will Be Collected?
Your anonymity will be strictly maintained. Any logbook will be labeled with an anonymous participant ID. Your diary will also be kept confidential; I will also ask you to use pseudonyms rather than real names of you and your communicator. For the interview, I will record it by audio to create a text transcript that will be used for further analysis, and then the original audio file will be deleted.

Are There Risks or Benefits if I Participate?
The risks of participation are intended to be none or minimal. However, because you are asking to share the personal feeling and perception, there is a risk of feelings of emotional discomfort such as embarrassment, and/or concerns about privacy. To mitigate this, you can choose what information you are comfortable revealing during the diary. As mentioned, I will scrupulously anonymise all data to mask your identity.
Besides, as you write the diary about interpersonal remote communication, you may potentially disclose information about each other. To address this issue, I will be vigilant of sensitive data points and proactively remove them from the logbook, and I will offer you the opportunity to censor details in the logbook. For the dyad participant, the logbooks will not be exchanged to each other.

What Happens to the Information I Provide?
No one except me will be allowed to view the diary. No names are recorded in the logbook. Information in the logbook will be summarized for presentation or publication of results. And your diary entries and exemplar interview comments may be used in the report via quotes, but I will ensure that the selected data does not suggest participant identities.

The logbook will be kept on my computer disk only accessible by myself and my supervisor. The diaries will be stored until I finish her project, at which time, it will be permanently erased. The logbooks as part of the study will be kept on a secure server computer in the Netherlands. Final report will be published in the library of master student thesis at the University of Twente.

If you have any questions not addressed by this information and consent brochure, please do not hesitate to ask. If you want to talk about this study with an independent person, contact the Ethics Committee of EWI at ethicscommittee-cis@utwente.nl.

Yours sincerely,
Yiran Wei

Researcher: Yiran Wei
Faculty of EEMCS University of Twente
Tel: +31 (0)638785922
Email: y.wei-5@student.utwente.nl

Supervisor: Dr. A.H. Mader (Angelika)
Department HMI, Zilverling building
Faculty of EEMCS
University of Twente
Email: a.h.mader@utwente.nl

Declaration of consent

(please tick each checkbox if you consent)

◯ **1.** I agree to participate in this study
◯ **2.** I have read and understood the information brochure and all my questions have been answered
◯ **3.** I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason.
◯ **4.** I understand that my identifiable data is recorded for research purposes as described above.
◯ **5.** I agree for my non-identifiable data to be stored until the researcher finishes her project.
◯ **6.** I agree for my project to be used as research data. This includes the logbook I handed in and an interview I had.

[Optional consent]

7. For audio recording during the interview:
◯ Yes, I consent to it
◯ No, I do not consent to it

8. For quoting diary entries and exemplar interview comments in the publishment under non-identifiable condition:
◯ Yes, I consent to it
◯ No, I do not consent to it

9. Would be contact for further final evaluation:
◯ Yes, I would like to be contacted
◯ No, I would not like to be contacted

If you have any questions not addressed by this information and consent brochure, please do not hesitate to ask. If you want to talk about this study with an independent person, contact the Ethics Committee of EWI at ethicscommittee-cis@utwente.nl.

.....	.....	.....
Name participant	Signature	Date

.....	.....	.....
Name researcher	Signature	Date

B.3. Observation card

Observing Card

Some content you can observe both for yourself and others:

- How does it feel when you wait for the contact?
- How does it feel like having been in contact at an earlier moment, both when you are the initiator or you are the responder?
- How does it feel like to interact with the product(device) even when the other person is not responding?
- How does it feel when you see the text left by others?
- How does it feel if you are the person who doesn't respond or respond lately?
- How does it feel if you respond to messages from others immediately?
- How does it feel when you end the interaction? And how do you end the conversation?
- When do you feel you are connected/disconnected? How does it feel?
- About the above questions, what do you sense for the other interactor in the interaction process?

*No need to cover or stick to all these questions during the interaction, feel free to find more interesting results about your synchronicity of communication and social connectedness through this observation study :)
*And remember to try to not disclose the other communicator's privacy
*Please send me all the log when the study is over
*There is nothing wrong or right and nothing will be judged, I would like you to be yourself freely when you write the logbook.
*Feel free to ask me if you have any questions and have fun during the observation!

Date/Time		
Brief scenario description	Self-perception	Perception for others

Date/Time		
Brief scenario description	Self-perception	Perception for others

C

Realisation and inLab evaluation

C.1. Survey for lab evaluation

"Touch in Flow" Experience

Please fill this form about your experience 😎
It will take about 2 mins

1. How name/nickname

_____

Interaction Experience with Device

Only think about the interaction with device

2. Which shape you prefer?

Mark only one oval.

- ◯ Gloves
- ◯ Balloons
- ◯ No preference

3. Pleasantness when you interact with device:

Mark only one oval.

	1	2	3	4	5	6	7	
Very unpleasant	◯	◯	◯	◯	◯	◯	◯	Very pleasant

4. Easiness of using this device for your interaction

Mark only one oval.

	1	2	3	4	5	6	7	
Very hard to use	◯	◯	◯	◯	◯	◯	◯	Very easy to use

5. Please use 1-3 words to describe your feeling about interaction experience with device✨

_____

Feeling about Communication Experience

About communication experience with your touch mate

6. How comfortable you are about communication experience

Mark only one oval.

	1	2	3	4	5	6	7	
Very uncomfortable	◯	◯	◯	◯	◯	◯	◯	Very comfortable

7. How playfulness you have about communication experience

Mark only one oval.

	1	2	3	4	5	6	7	
Not playful at all	◯	◯	◯	◯	◯	◯	◯	Very playful

8. Overall: How do you feel about communication experience?

Mark only one oval.

	1	2	3	4	5	6	7	
Very dislike it	◯	◯	◯	◯	◯	◯	◯	Very like it

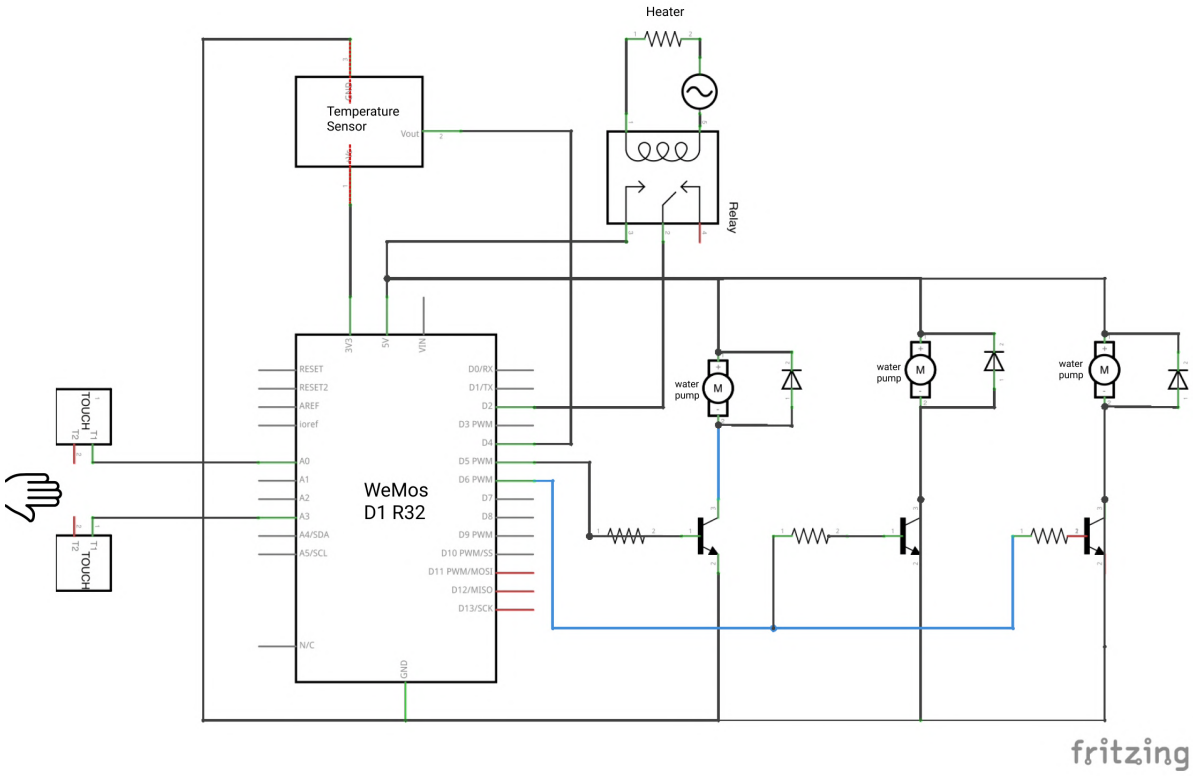


Figure C.1: Circuit of prototype

C.2. Circuit of prototype

D

inLife evaluation

D.1. User brochure

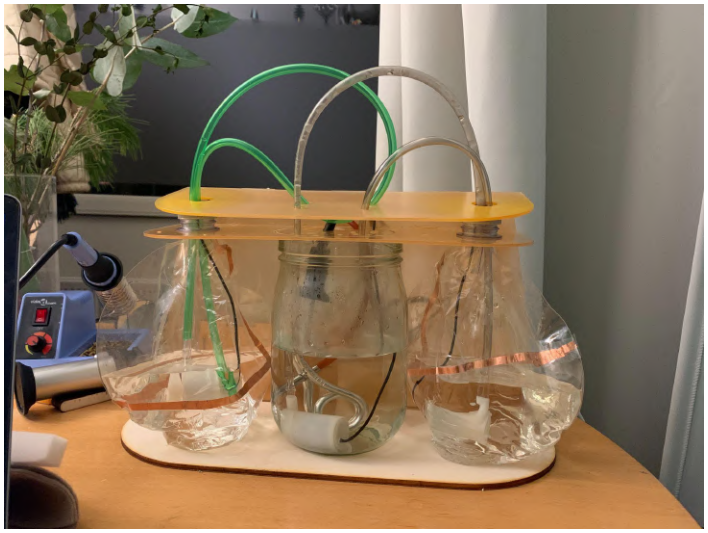
How to use:

Sending by touching left balloons (green tube)

- When you feel the flow with vibration → you are sendinging
- as long as you touch it, you will always get the feedback from device

Receiving by touching right balloons (grey tube)

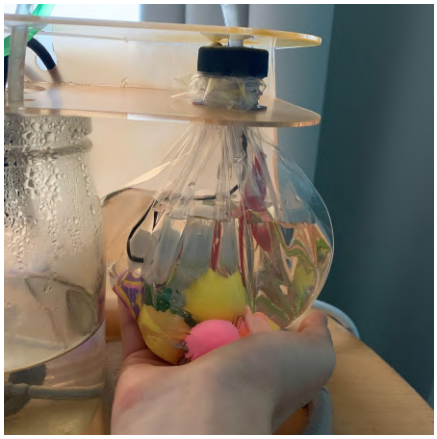
- When you feel the flow with vibration or with warmth → you are receiving
- if you don't feel anything by touching in many ways, perhaps no messages sent



The way to touch the device:

- You can hold it horizontally or on the bottom, play with it (squeeze/pinch)
- Due to sensitivity of sensor, real-time feedback from device may delay (2~3s)
- If still no feedback, try to change your touch way to invoke the device

- Hold horizontally



- Hold on the bottom

Understanding how device works:

Warm your partner:

- Once your partner send “touch” to you, your heater will be turned on to warm your device

Duration is the content:

- The longer duration s/he send to you, the longer you can receive the warm touch

No notification:

- No matter how much touch s/he sends to you, touch messages will be stored in the device until you touch to receive. NO notification, unless you touch to feel

Inform or not inform:

- You can inform each other on other communication tools, but also try not to inform each other to have different experiences. Unknown may generate more pleasant surprises.

Little playfulness:

- You can partly receive it, for example, if s/he sends to you 10s, you only want to receive 5s, the rest 5s will be stored in the device, while new messages will be stored as well.

Watch out:

- When you squeeze or pinch, attention for water flow out
- Water in the middle bottle between two lines

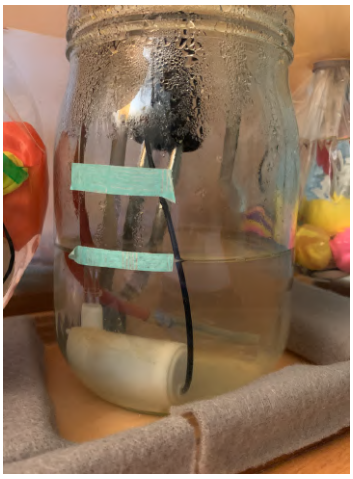


Figure: Middle bottle lines

Something wrong you can take following actions:

2 ways to plug out the power:

1. Plug out power strip ***(Figure.1)***
2. Open the back cover ***(Figure.2)***→ plug out the charger ***(Figure.3)***

If water flows out

→ plug out the power ***(see up)***

→ check if the tube in the right location and plug in the balloons nicely ***(Figure.4)***

→ plug in the power ***(see up)***

→ press the button ***(Figure. 5)***

If device works in a weird way, or out of your control

→ open the back cover ***(Figure.2)***

→ press the button ***(Figure. 5)***

→ still doesn't work, plug out the power strip ***(Figure.1)***

In any case you feel scared/annoying/uncomfortable

→ please feel free to plug out the power strip ***(Figure.1)***

→ and contact me

Figure 1: Plug out Power (power strip)

Figure 2. Open the back cover

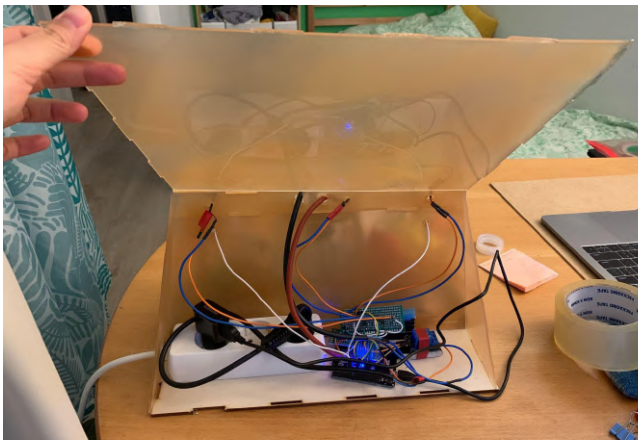


Figure 3: Plug out the charger

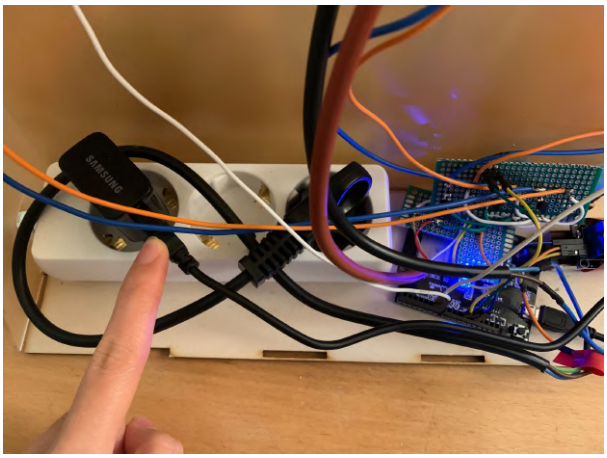


Figure 4 : tube direction

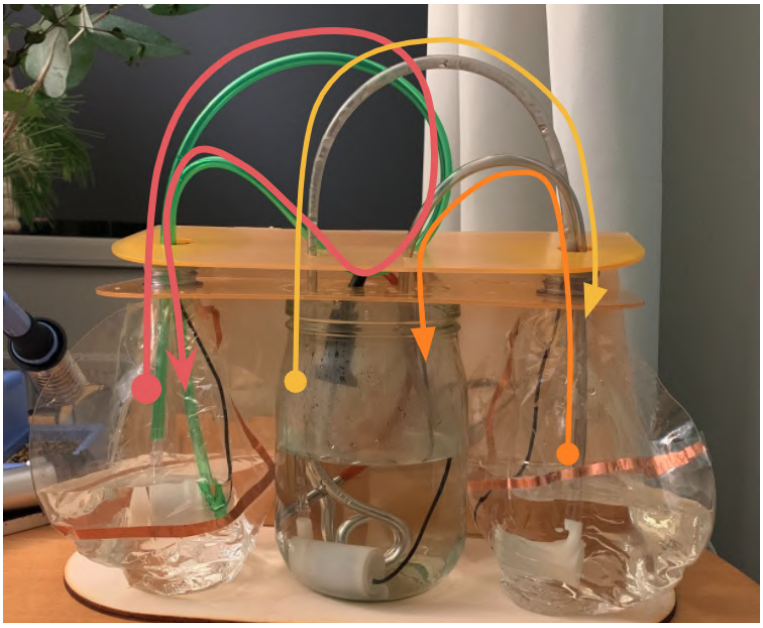
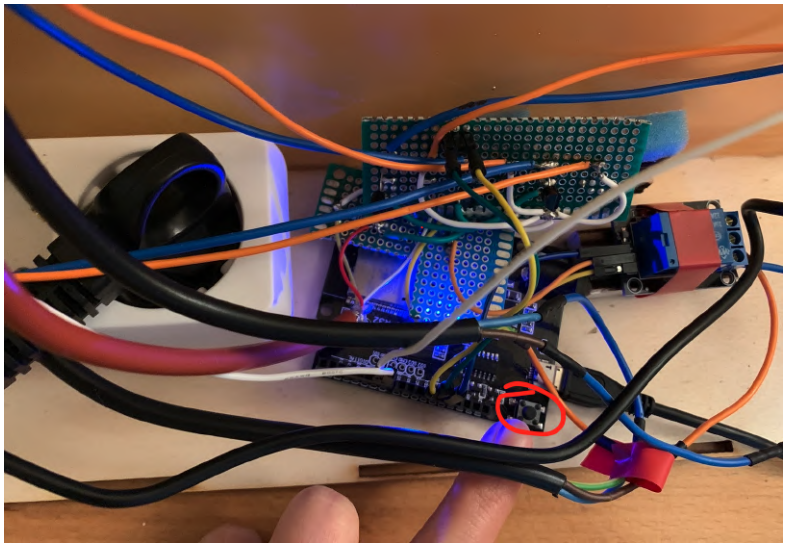


Figure 5. Press the button (red circle):



D.2. Logbook

Logbook for Final Evaluation

Hi there, thanks for your participation!
Please write down your feelings about experience of using "TOUCH_in_FLOW" device;
In order to catch your sparks of feelings,
hope you could write this logbook each day during experiments.

Anything you write down here will be precious for my research :-]
nothing could be right or wrong,
So feel free to share your feelings and thoughts!
Have fun with your partner!

Date	
How many times do you use the device? [Approximately]	
How do you feel when you send the touch?	
How do you feel when you receive the touch?	
How do you feel about real-time communication (if it happens)?	
How do you feel about asynchronous communication (if it happens)?	
By using the device, how do you feel about the connectedness with your partner?	
Any comments, thoughts and feelings?	

-----continuing by repeated tables

D.3. Interview

Interview for final evaluation

Touch communication, sending and receiving:

- Anything you like or feel uncomfortable?
- How do you feel about sending touch？
- How do you feel about receiving touch？
- Do you have a preference? Why?

Asynchronous communication:

- How do you feel about asynchronous communication?
- Have you ever experienced real-time communication?
    - If yes, how do you feel about it?
    - If not, do you expect it to happen between you and your partner?
- What is its effect on your communication experience?

Notification:

- How do you feel about this device without any notification?
- Is anything missing as a communication tool?

Connection:

- How does using this device affect the feeling of connectedness during the study?

Long-term usage:

- Will you like to use it in the future?
    - With who?
    - Do you mind using it with different relationships?
- Do you think this channel needs to be used with other communication tools?

General:

- What is your favorite part of the device?
- What is your dislike of the device?
- What do you expect for further development? About touch or asynchronous communication?

D.4. Information Brochure

Information Brochure of Evaluation for Embodied Artefacts with Mediated Social Touch

Dear reader,
In this letter, I would like to inform you about the research you have applied to participate in. In the proposed research, entitled "Design mediated social touch for remote communication with asynchronous channels." This project will design an embodied interactive artefacts allowing mediated social touch with asynchronous communication channels. ***Mediated social touch*** allows the people to exchange touch messages through a device, meaning the sender can send touch to the receiver by touching the device, and receiver can receive the touch from the sender but applied by the device. ***Asynchronous communication*** allows people to receive mediated social touch with delay so that people can receive the touch when they are ready to be touched.

Purpose
The aim of this experiment is to evaluate whether and how mediated social touch with asynchronous communication affect the remote communication for loved ones who live apart, but also evaluate the availability and usability of the device.

What Will I Be Asked To Do?

1. During the study, you and your partner will be asked to use a device to communicate with each other for several days at your own places, you can use this device whenever you want but at least once a day;
2. Each day you will write a short diary about your user experience, with specific questions (provided by researcher);
3. During the usage, you can communicate on the other communication tool, but also suggest you to not communicate on other platforms to try different experiences;
4. After this TakeHome study, you will be invited for an interview with your partner and fill a survey about general experience.

Your Participation
Participation is voluntary. If you agree to participate, you will be free to withdraw at any time for any reason. All data (even if it has already been collected) will be removed if you withdraw your consent.

What Type of Personal Information Will Be Collected?
Your anonymity will be strictly maintained. Any logbook will be labeled with an anonymous participant ID. Your diary will also be kept confidential; I will also ask you to use pseudonyms rather than real names of you and your communicator. For the interview, I will record it by audio to create a text transcript that will be used for further analysis, and then the original audio file will be deleted.

Are There Risks or Benefits if I Participate?
The risks of participation are intended to be none or minimal. However, because touch could arouse uncomfortable feelings for sensitive people, if you feel unwell about using the device, you can stop the study at any time. And because you are asking to share the personal feeling and perception, there is a risk of

feelings of emotional discomfort such as embarrassment, and/or concerns about privacy. To mitigate this, you can choose what information you are comfortable revealing during the interview. As mentioned, I will scrupulously anonymize all data to mask your identity.
Besides, as you write the diary about interpersonal remote communication, you may potentially disclose information about each other. To address this issue, I will offer you and your partner to censor details in the logbook individually, then the logbook will be exchanged to each other to censor the sensitive/personal information. And it does mean that you and your partner will read each other's logbook to censor your personal information that you do not want to be disclosed.

What Happens to the Information I Provide?
No one except me will be allowed to view the diary. No names are recorded in the logbook. Information in the logbook will be summarized for presentation or publication of results. And your diary entries and exemplar interview comments may be used in the report via quotes, but I will ensure that the selected data does not suggest participant identities.
The logbook will be kept on my computer disk only accessible by myself and my supervisor. The diaries will be stored until I finish her project, at which time, it will be permanently erased. The logbooks as part of the study will be kept on a secure server computer in the Netherlands. Final report will be published in the library of master student thesis at the University of Twente.

If you have any questions not addressed by this information and consent brochure, please do not hesitate to ask. If you want to talk about this study with an independent person, contact the Ethics Committee of EWI at ethicscommittee-cis@utwente.nl.

Yours sincerely,
Yiran Wei

Researcher: Yiran Wei
Faculty of EEMCS University of Twente
Tel: +31 (0)638785922
Email: y.wei-5@student.utwente.nl

Supervisor: Dr. A.H. Mader (Angelika)
Department HMI, Zilverling building
Faculty of EEMCS
University of Twente
Email: a.h.mader@utwente.nl

Declaration of consent

(please tick checkbox if you consent)

◯ **1.** I agree to participate in this study, from _____ (date) to _____(date)
◯ **2.** I have read and understood the information brochure and all my questions have been answered
◯ **3.** I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason.
◯ **4.** I understand that my identifiable data is recorded for research purposes as described above.
◯ **5.** I agree for my non-identifiable data to be stored until the researcher finishes her project.

[Optional consent]

8. For audio recording during the interview:
◯ Yes, I consent to it
◯ No, I do not consent to it

9. For quoting entries and exemplar interview comments in the publishment under non-identifiable condition:
◯ Yes, I consent to it
◯ No, I do not consent to it

.....	.....	.....
Name participant	Signature	Date
.....	.....	.....
Name researcher	Signature	Date

D.5. Survey

"Touch in Flow" Experience

This questionnaire includes three parts related to the user experience of "inFluid": touch communication, asynchronous communication, and overall experience. It will take about 3 minutes to finish it.

1. Your name:

_____

About Touch Communication

User experience about device that supports remote communication through touch between you and your partner

2. Sending touch to my partner makes me feel:

Mark only one oval per row.

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Pleasant	◯	◯	◯	◯	◯
We are connected	◯	◯	◯	◯	◯
We are closer	◯	◯	◯	◯	◯
We are together	◯	◯	◯	◯	◯

3. Receiving touch from my partner makes me feel:

Mark only one oval per row.

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Pleasant	◯	◯	◯	◯	◯
We are connected	◯	◯	◯	◯	◯
We are closer	◯	◯	◯	◯	◯
We are together	◯	◯	◯	◯	◯

4. Exchange touch with my partner makes me feel:

Mark only one oval per row.

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
We are connected	◯	◯	◯	◯	◯
We are closer	◯	◯	◯	◯	◯
We are together	◯	◯	◯	◯	◯

5. Exchange touch with my partner improve our remote communication quality

Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Strongly agree

About asynchronous communication

User experience about the device provides remote communication with time differences

6. Asynchronous touch communication makes me feel:

Mark only one oval per row.

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Pleasant	◯	◯	◯	◯	◯
We are connected	◯	◯	◯	◯	◯
We are closer	◯	◯	◯	◯	◯
We are together	◯	◯	◯	◯	◯

7. Asynchronous touch communication improves our remote communication quality

Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Strongly agree

Overall device

Your overall experience about this interactive device

8. By using this device, it improves our communication quality

Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Strong agree

9. By using this device, I feel “we are connected”

Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Strong agree

10. By using this device, I feel “we are close”

Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Strong agree

11. By using this device, I feel “we are together”

Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Strong agree

12. Welcome to add any comment or idea below :]

Thanks for your participation

Let’s keep in touch!

D.6. Results of survey

Sending touch to my partner makes me feel:

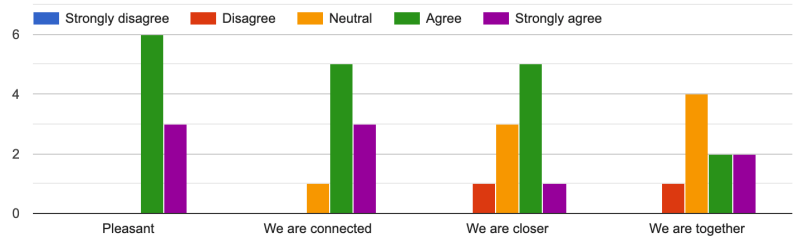


Figure D.1: results for sending

Receiving touch from my partner makes me feel:

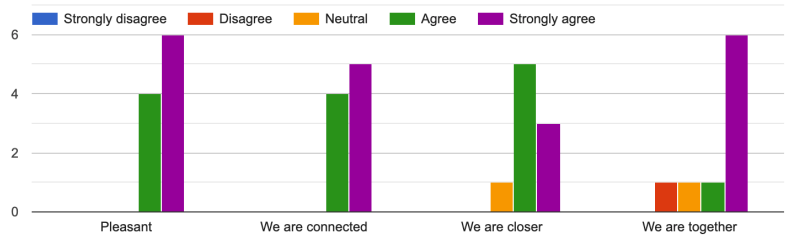


Figure D.2: results for receiving

Exchange touch with my partner makes me feel:

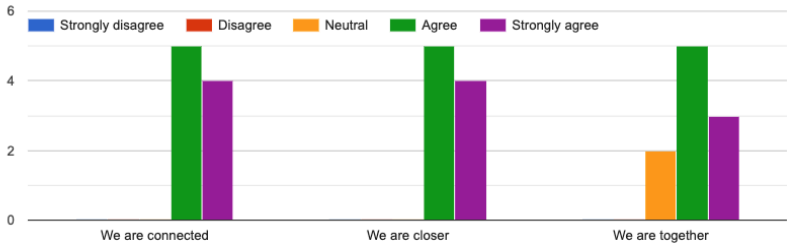


Figure D.3: results for touch communication

Asynchronous touch communication makes me feel:

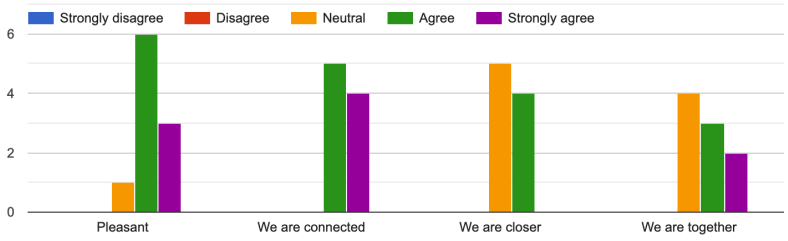


Figure D.4: results for asynchronous communication

E

Practical issues

We described several practical issues we found with possible solutions:

Unable to detect Wifi : the chip failed detecting WI-FI at participants' houses, probably because of insufficient power supply or embedded system issues. Updating the more reliable development board may help. Besides, using specific pins may cause this issue, the researcher could test output by applying different pins.

Remote disconnection: caused by an unstable server, could apply to a more reliable server or try other protocols, for example MQTT.

Sensitivity of sensors: instead of sensor problems, we found that unstable internet connection may have caused this problem. A reliable server could be used.

Unexpected noise relay generated noticeable sounds, which could be replaced by MOSFET