



Remote social touch framework: a way to communicate physical interactions across long distances

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Abstract

Nowadays, living away from loved ones is a common practice due to various reasons such as work, study, or certain health-related concerns (e.g., infection diseases). Such practice aggregates certain negative emotions such as depression due to the loss of physical, mental, and emotional awareness about loved ones. Because of the importance of social touch for one's wellbeing, this paper reports the research focusing on remote social touch (RST), as a way to stimulate the sense of touch remotely to regain some of the lost awareness. The research identified various dimensions of RST and the process of communicating social touch remotely through a product. This is done through an extensive literature survey, online diary keeping, and interviews. The paper also presents the early proposed RST framework that consists of three elements (actors, product, and communication) and their dimensions, that explain the process of how RST communications can be successfully achieved through a product.

Keywords Remote social touch · Remote interpersonal touch · Communication framework · Product design · Design prototyping

1 Introduction

Living away from loved ones can lead to an accumulation of negative moods due to the lack of connection. For example, touch deprivation may develop, which then may lead to depression [1]. To address this problem, a number of researchers have looked into communicating certain information to raise connectedness among individuals, who are apart. One of such information is stimulating the touch sense remotely, such as by 'sending' to a loved one a social touch, which is defined in this article as any physical exchange taking place in a shared space between people (such as a hug) for any reason, such as greeting. This communication can be achieved through computers or similar technologies that can (digitally) deliver the sense of touch through haptic technologies to stimulate touch sense over a distance. Haptics refers

to sensing and manipulating by touch [2], and haptic technologies are the technologies responsible to deliver or sense touch, an example of that is "Huggy Pajama" by Teh et al. [3]. Such communication is identified as "Remote Social Touch" (RST) by this article authors, "digital touch" as named by Jewitt et al. [4], or "mediated social touch" by Haans and IJsselsteijn [5].

1.1 Definition of remote social touch (RST)

Remote Social Touch as illustrated in Fig. 1, starts with person (A) interacting with a product interface either to initiate a haptic communication or show interest in receiving one. Product (A) communicates to another remote product (B) via communication technologies (i.e., the internet). Product (B) interface delivers the haptic communication by stimulating the haptic sense of person (B). Person (B) either or not acknowledge and continue the communication with person (A) so the cycle (loop) of communication continues or stops. The haptic communication can be in a live manner (real-time synchronous, like a phone call) or with a delay as a haptic message (asynchronous, like a SMS). The haptic communication or the message can be stimulating real touch (e.g., hug) or symbolic abstract haptic feedback, and it may include

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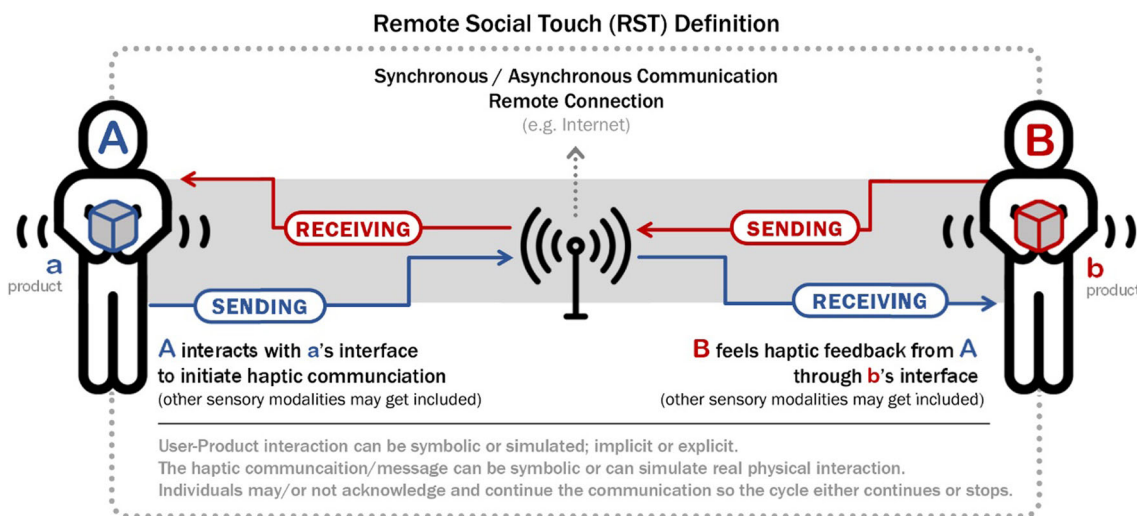


Fig. 1 Illustration of the basic principle of Remote Social Touch (RST) along with its definition

other sensory modalities. RST can carry certain functions and meanings, for example, to perceive a real touch (e.g., hug), to give emotional support, or to communicate nonverbally.

There are few reasons for RST to be explored by various researchers. First, social touch is a need [6], the absence of social touch among loved ones may contribute to the development of stress and impact health [7, 8], and it may jeopardize the development of social relationships [4]. Enabling touch (interaction) in remote communication can potentially help in reducing negative moods [9], it can encourage more interaction between people, and improve social connection [10, 11]. It has also the potential to increase social awareness and impact emotional wellbeing positively, for example communicating discrete emotions such as love, or valence emotions such as positively arouse emotions [12, 13].

Even though the importance of social touch and the establishment of research related to technologies for RST exist, as previous surveys discussed these technologies [5, 12–14], there are still some underdeveloped or missing areas in the related literature. Additionally, there is no well-defined layout of the process of transmitting a physical interaction (PI), then translating it from the human to the product and back to the human. These issues make the authors to focus on establishing a clear understanding of RST and the various considerations involved in it, and the proposition of the RST framework.

Therefore, this paper proposes the RST framework that aims to provide an easy path one can take to research or design for RST, and tackle some of the considerations that are missing in the existing frameworks. Accordingly, the driving question behind the research reported in this paper was “How can a product facilitate delivering a ‘social touch’ between people who are geographically apart?”.

2 Methodology

In the development of the proposed RST framework, the following steps were undertaken.

- i. Systematic review of literature on various dimensions of RST in the fields of haptics, interpersonal communication, product design, and human–computer interaction.
- ii. Literature review analysis to construct data gathering tools and materials (e.g., interview questions, exploration sage, low fidelity working prototype of haptic communicator, and RST elicitation cards for the fieldwork.
- iii. Analysis of the fieldwork findings led to extracting recurring themes and terms related to RST. The findings were then organized in a way to explain the elements and dimensions of RST which were then used to propose the final RST framework.

For the present research, the target user group (individuals who were living away from their loved ones) was an important source of information to enhance knowledge about RST. The feedback gathered from the target user can serve as a source of inspiration for future RST designers and researchers [15], as it provides new opportunities for technologies and products that may later impact individuals’ life. This can be achieved by exposing the target user group to technologies even through rough mock-ups [16]. For this reason, while carrying out interview sessions, the participants were not restricted in their comments, especially about future projections, and were told that “everything is possible”. This helped to explore a wider range of RST possibilities and considerations related to elements involved in the RST.

2.1 Literature review

A systematic literature review was carried out looking into existing RST research outputs, prototypes, themes, technical information, and frameworks. The criteria used for the review are presented in Fig. 2, resulting in forty articles that discuss prototypes for RST communication. The review differed from the previously completed ones [5, 12, 13] as it focused on and analyzed the research output (the prototypes); the prototypes were analyzed from a product design mindset to assess e.g., design characteristics, functionality, user experience, and interaction; it also updated the earlier reviews.

After analyzing these prototypes, some aspects frequently stood out across 40 prototypes (“Appendix 1”, for the full list of articles and prototypes). The following aspects were found to be useful to integrate at the later stages:

- ‘*User-count*’ refers to the total number of users interacting with each other, one interacts with many users at once [17], many users interact with one user [18], or one interacts with only one user [19].
- ‘*Direction of sending and receiving*’ here, ‘one direction’ refers to only one user sending and the other one is receiving [20], and ‘two directions’ refers to both users are able to receive and send RST communication at the same time or not [21].
- ‘*Touch representation*’ includes ‘simulated’, meaning that the user must simulate the real gesture to send the haptic message (e.g., kissing an object to send a kiss message [22]); or ‘symbolic’ meaning that the real gesture represented by a symbol or communicating the feeling through an abstract touch (e.g., thermal hug [23]).
- ‘*Message synchronization*’ involved two forms as ‘synchronous’, meaning that it is occurring at the same time of receiving [24], or ‘asynchronous’ occurring at a different time with the possibility of being recorded and then felt later [25].
- ‘*Interaction type*’ the way individuals interact with RST communication/ product which comprises of ‘implicit’ interaction, meaning the communication established and felt by the receiver immediately without the receiver needs to interact with the product [26], or ‘explicit’ interaction, which requires the user to intentionally interact with the product to receive (feeling) or send (establish) a RST (i.e., one needs to accept the feedback to be felt) [27].
- ‘*Haptic rendering type*’ refers to the technology intended to render the haptic feedback and its qualities (intensity, duration, and frequency), such as force [28, 29], vibration [30], or temperature [31, 32].
- ‘*Haptic detection type*’ refers to the technology intended to sense the touch utilized in the prototype, such as contact [33], force [34], squeeze [35], or movement [36].
- ‘*Gesture type*’ shows the type of a physical interaction the prototype intended to communicate, for example a hug [37], a handshake [38, 39], a stroke [25], a tickle [40], or an abstract touch [41].
- ‘*Body location*’ points out the location that the prototype targets, or placed on, for example, upper body [18], feet [30], or hands [42].
- ‘*Object characteristics*’ describes whether for example it is stand-alone [43], embedded in the object [44], portable [45, 46], or wearable [18].
- ‘*Other sensory modalities*’ inform whether there are additional modalities used with the haptic feedback, for example visuals [24] or sounds [38].

Fig. 2 List of criteria used for the systematic literature review

Database	Google Scholar, ACM Digital Library, IEEE Xplore Digital Library, and Springer.
Timeframe	Between January - December 2018, with final updates in January 2021.
Reasons for inclusion	1) the publication should be related to communication over a distance between humans, 2) haptic feedback on individuals should be one of the sensory modalities used in the communication.
Reasons for exclusion	1) sole engineering background of the haptic technology, 2) human to non-human communication, 3) communication without using haptic and/or the touch sense.
Keywords	remote social touch, mediated social touch, remote interpersonal touch, mediated interpersonal touch, remote touch, remote haptic interaction

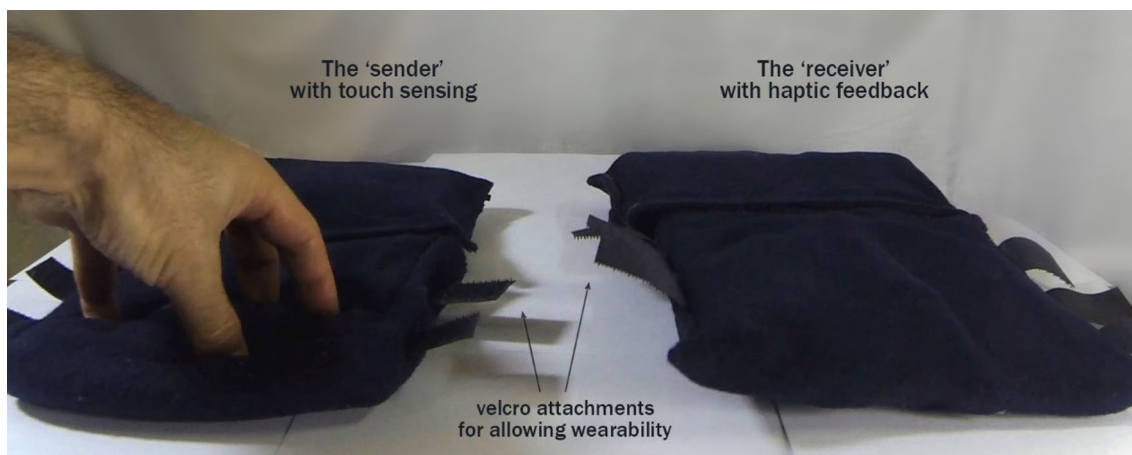


Fig. 3 A rough physical prototype achieved at the end of the exploration stage (full making instructions are available at <https://www.instructables.com/Remote-Social-Touch>)

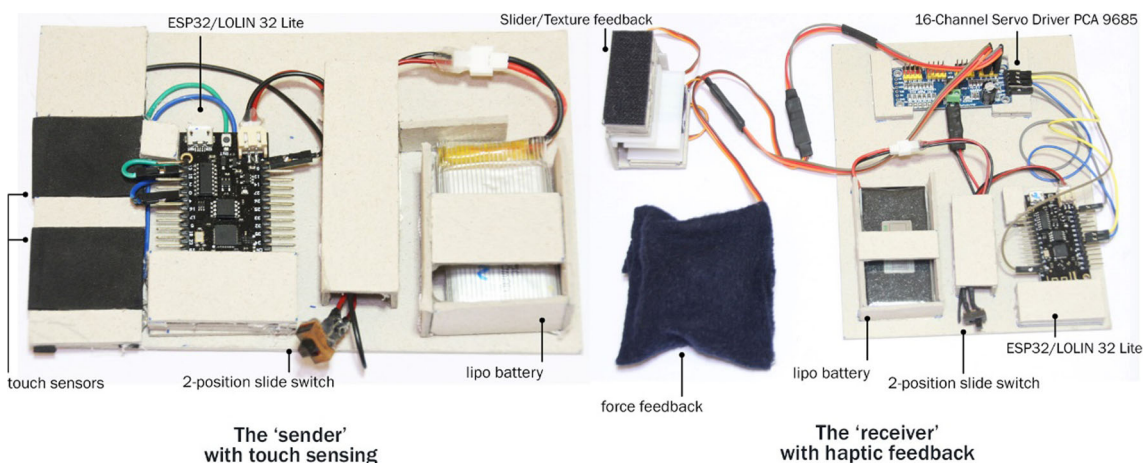


Fig. 4 Demonstrational prototype from simple off-the-shelf materials, a low fidelity prototype to be shown to participants as a tool to explain RST

2.2 Exploration stage through a working physical prototype

The literature review is followed by a prototyping activity undertaken by the first author in order to: explore the technical construction and characteristics of RST; experience RST in firsthand; and, to develop a tool for designers to test out the RST concept (Fig. 3). At the end of this stage, a rough prototype was achieved as a tool to demonstrate the principle of RST to the research participants (Fig. 4). It also helped the authors to gain knowledge on how RST can be implemented in an artifact and how RST can be achieved with the use of simple off-the-shelf materials.

2.3 The fieldwork

User research was carried out; an online diary keeping and one-to-one interviews were used to gather information from the target user group. Each method used certain research

materials (such as questionnaires, cards, etc.) to elicit information from the participants (Fig. 5). Before carrying out the fieldwork, necessary ethical approvals were also obtained from the Graduate School of Natural and Applied Sciences at Middle East Technical University that has the number: 28620816/438.

2.3.1 Participant selection

The main criterion for the participant selection was to be living away from loved ones. There was no specific relationship considered, rather, the invite was open to any individuals including, for example, the ones living away from their partners, family members, etc. This was to allow information to be gathered from various backgrounds. Opportunity sampling method [47] was used, asking members of the population of interest if they would take part in this research. It was decided that the university students would represent an obvious user group, as potentially there are a lot of students living

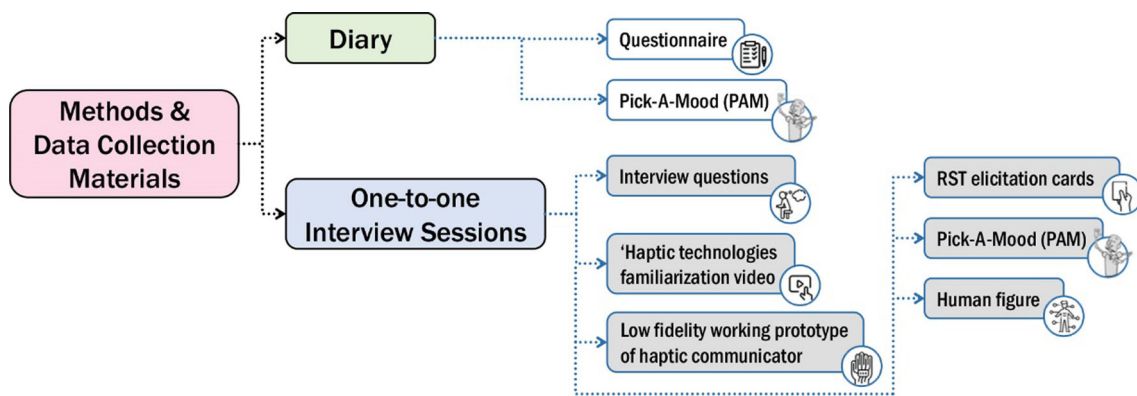


Fig. 5 Methods and data collection materials utilized in the fieldwork

away from their loved ones to study, including international and non-international students. The authors do acknowledge social touch experience vary among different cultural groups, however the cultural aspect of the participants was not considered to keep the proposed RST framework not based on a certain culture. All the participants who were interested in the research were invited to fill in an online Google form to leave their contact details. In total, 42 participants were secured to participate in the study (42 participated in the online diary, 36 continued to interview stage), and most of them were directed from Middle East Technical University’s international student group email list that the authors sent their invites to.

2.3.2 Online diary

It was believed that a diary can elicit structured personal information that documents individuals’ everyday routine of a certain issue [48]. It was also expected to serve as a tool for the participants to reflect on their own behavior towards the main topic of this research and to sensitize them before the interview session. The format of the diary was a brief online questionnaire that the participants were asked to fill in every night without specifying certain time (to have a higher chance that throughout the day they did contact their loved ones) for 7 days (see “Appendix 2”). The questions were directed to understand the participants’ daily communication behavior with their loved ones.

2.3.3 One-to-one interviews

Social touch can be a sensitive and personal subject to discuss when surrounded by other people. Therefore, each interview session with each participant was carried out separately on one-to-one basis. Due to COVID-19 pandemic constraints, 19 of the 36 participants were interviewed face-to-face, while the remaining 17 were interviewed online. The interviews for face-to-face sessions were carried out in a quiet environment

(e.g., a lab or a classroom located at the university campus), and the online sessions were managed through Zoom or Skype, video-conferencing platforms. The interview sessions were audio and video recorded, and each session took around an hour to one hour and a half. The main purpose of the video recording was to capture the participants while acting out a gesture to send a certain physical interaction and the way that they interact with an imaginary product.

The interview consisted of open-ended questions to allow the freedom for the participants to share their thoughts and experiences in an organized manner (“Appendix 3”). Within the interview, the questioning methods used had certain criteria—everything is possible, keep the imagination wild and open, and there is no wrong answer. This is because RST is a new technology that (most of) the participants had no prior experience with it. The questions incorporated in a single scenario: sending or receiving touch without technology limitation.

2.3.4 Data collection materials

In the interview sessions, specially designed data collection tools and materials were used to elicit information. These were the set of RST cards, a video clip exemplifying haptic technologies, and an early-stage physical prototype of haptic communicator.

The set of “RST cards” (Fig. 6) (see also “Appendix 4” for full explanation) was used to initiate discussion and elicit information from the participants about RST communication characteristics. The cards encompass the necessary terms and elements synthesized from the literature. It was believed that utilizing visual cards about the terms used in RST can trigger the intended discussion much easier than verbal explanations by focusing on one thing at a time. The set included the following card categories: (a) Pick-A-Mood (PAM) cards to elicit feelings; (b) frequency card to check the frequency of communicating with loved ones; (c) communication characteristic cards; (d) haptic feedback characteristic cards; (e)

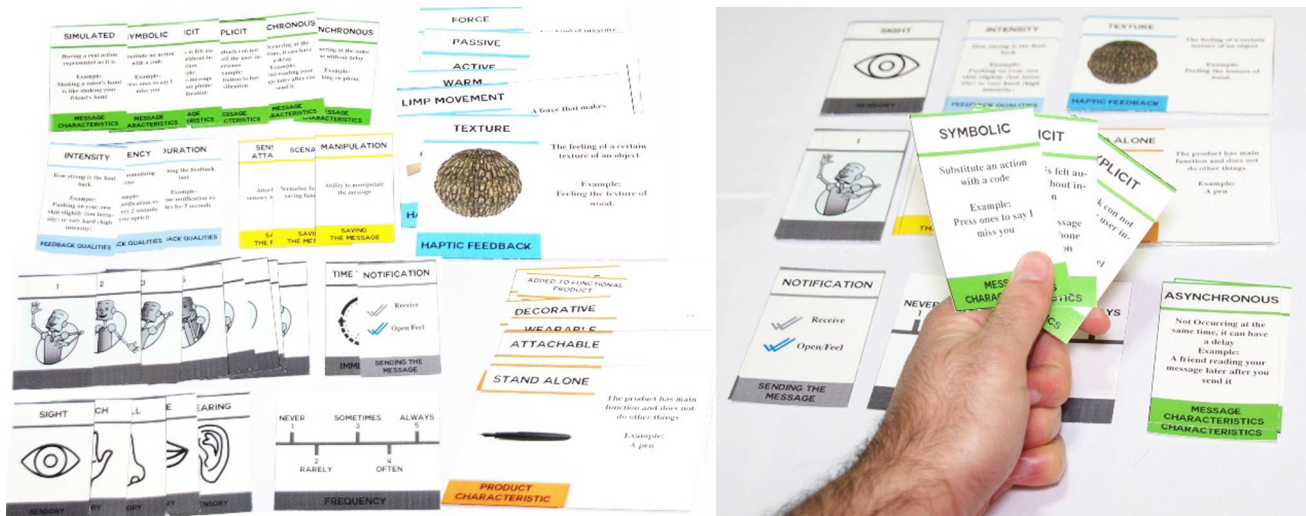


Fig. 6 RST card set to help in RST field research with prospective users

haptic feedback qualities cards; (f) product characteristics cards; and (g) human figure card to locate a wearable product and haptic feedback on the body.

Apart from “Pick-A-Mood (PAM)” tool by Desmet et al. [49] all other card sets were prepared by the authors. PAM expresses eight different moods states divided into four main categories: energized-pleasant (excited and cheerful), energized-unpleasant (irritated and tense), calm-pleasant (relaxed and calm), and calm-unpleasant (bored and sad). The moods are represented through three potential characters (i.e., female, male, and robot). Any of these characters can be used in research based on their suitability. In the present research the robot version representing a genderless character was used for probing the participants about the following question: “How do you feel about doing/missing the physical interaction?”. It was also used to generate insights about the participants’ feelings, and to motivate a discussion about their interests in physical contact and the importance of social touch.

The “Haptic Technologies Familiarization” video was used to introduce the concept and principles of RST to the participants (“Appendix 5”). A one-minute video consisted of multiple clips representing specific haptic feedback technologies. The video was meant to catalyze the participants’ imagination while discussing RST, and to make them aware of various possibilities of haptic technologies. The video clarified the following terms: tactical feedback, low- and high-resolution tactile feedback grids, texture feedback, force feedback, contactless haptic feedback using ultrasound, joint manipulation feedback, temperature feedback, simulated feedback, and symbolic feedback.

An early-stage “Working-Prototype of Haptic Communicator”, developed by the authors, was used to show the

principles of RST. In addition to the video clip, a physical prototype was developed to facilitate communicating the ideas to the participants and to help them experiencing the concept (of haptic feedback) directly, rather than witnessing someone else experiencing it [50]. The prototype was considered as a technical illustrative tool, but not meant to present a complete design to allow the participants freedom for imagination. Utilizing a low-fidelity prototype is a common approach in RST research [51–53]. The authors were aware of a potential bias it could have risen, therefore the prototype was kept minimal to demonstrate the working principle.

2.4 Results

As mentioned before, 42 people participated in the online diary and 36 in the interview sessions. The online diary results revealed four types of reasons for one’s communication with loved ones: “simple communication” (e.g., greeting saying hello only), “complex communication” (i.e., to learn more about one another, both parties must engage in comprehensive communication, such as discussing a topic.), “sharing communication” (i.e., share something with other e.g., sharing self-picture), and “one be among others” (i.e., one be included in group communication such as family gathering).

When necessary to communicate, current communication media has certain constraints, such as when technology fails or when it is not possible to know whether the other side is available to establish communication or not. There are many physical interactions individuals may miss whilst interacting with their loved ones. Among the participants of this research “Mother” relationship was the most frequently discussed one, and “Hug” was the most missed physical interaction.

The participants stated some perceived benefits of RST related to emotional wellbeing, connectedness, and enhancement of current communication media. The participants also raised some perceived concerns of RST related to negatively impacting emotional wellbeing, the impact on real-life physical interaction, and concerns about the communication or the product that would be used for communication. The most common keywords mentioned were privacy, safety, devaluing the real physical interaction, not being able to move on, not tending to the real person, not being authentic, and emotional concerns.

Concerning the cycle of RST, the participants discussed how they would be sending, receiving, and replying a touch message. Some physical interactions (PI)s were only for receiving, and some for only sending. Also, the reply would depend on the direction (from which relationship to another) and/or the kind of PI. The meaning of the same PI could be different between the relationship depending on who would send it and who would receive it. Additionally, one would reply to a PI with the same PI received or would reply with a different PI from the PI received or even with a different sensor modality. Remote social touch (RST) characteristics are driven based on context, mood, and usual physical touch behavior among individuals. Also, a participant could pick feedback close to how the real PI usually feels. Accordingly, individuals may incline to choosing something more toward realistic manner to social touch to communicate the physical touch within the cycle of communication.

In this research, ‘saving the touch (message)’ is considered as a frequency of an emotional event that can impact feelings. Most of the participants wanted to save the physical interaction message, in contrast only a few did not. However, the participants had some concerns with saving the message such as devaluing the physical interaction, impact on the other person, emotional concerns, and concerns related to ethics and privacy. Again, most of the participants did not want to manipulate the saved message because the meaning and value of the message could be lost and the altered message could feel unnatural. Attaching other sensory modalities to the saved touch message was also a discussion point.

RST products can present various characteristics such as being a one-part product, wearable, attachable, and decorative. Some desired characteristics commonly discussed by the participants were: wearable, attachable, portable, and accessory-like. To interact with such a product one can either mimic a simulated way of interaction, using the essence of physical interaction, or try a familiar way of interacting using existing electronic gadgets, e.g., swapping on a smartwatch. Similarly, the placement of a product on the body can be similar to where an actual physical interaction is felt on the body, e.g., a hug felt on the upper body. However, if a symbolic

way was intended for the use of RST product, a more familiar location on the body with the current electronic gadget can be chosen such as a wrist.

3 The RST framework

Carrying out researching in and designing for Remote Social Touch (RST) is a complex task due to the many elements involved in the RST experience. For this reason, the framework proposed in this paper highlights several important considerations that should be taken into account. It also provides a formalized and comprehensive background including the process and the principles of the RST.

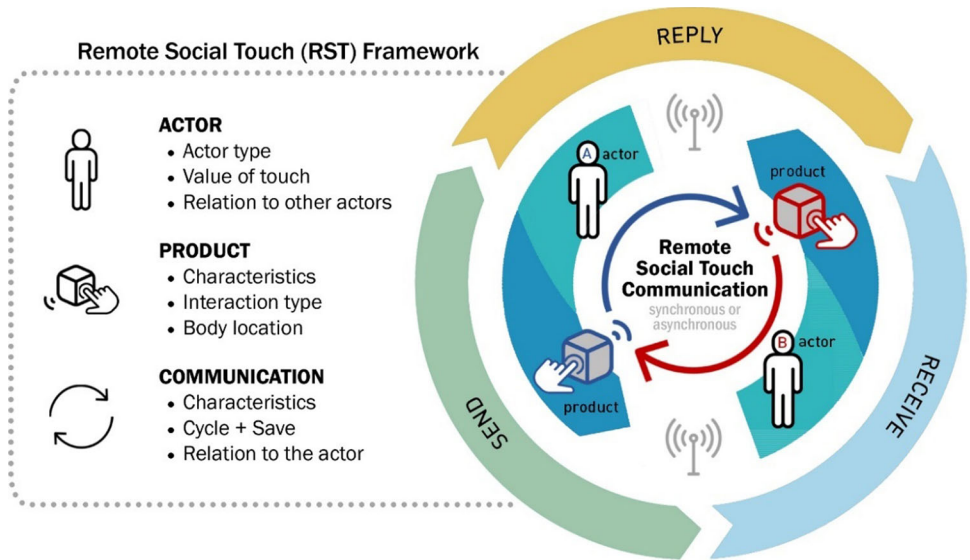
The proposed RST framework is divided into three main elements: ‘Actor’, ‘Product’, and ‘Communication’, each element has its own sub-dimensions involved in the framework. The framework has gone through various iterations after conducting a systematic literature review, online diary analysis, and participant interviews. Considerations related to each dimension were reflected upon in each of the iterations.

Remote social touch (RST) in this framework is realized through a cycle of communication (synchronous or/and asynchronous) back and forth between the actors (Fig. 7). Such a cycle would continue unless one of the actors decides to stop. The cycle can be described as follows.

- First, a simultaneous exchange of touch messages among actors,
- Second, actors receive a touch message from other actors synchronously or asynchronously.

Figure 8 further illustrates the RST process, actor (A) initiates an interaction with the RST object/product’s interface to establish a communication or to record and send a haptic message. This communication and the message content are subjected to certain dimensions e.g., the context surrounding both actors, and their relationship with each other. Throughout the interaction, there could be an emotional impact (positive/negative). Additionally, the interaction could carry certain qualities (e.g., intensity and duration of the message). The object then interacts with the object on the other side to deliver the message through connection technologies such as the internet. When the object on the other side (B) receives the communication or the message, it needs to initiate an interaction with the actor (B). Such interaction could carry certain qualities (e.g., implicit or explicit). Moreover, the interaction of the object with the actor may produce an emotional change due to, for example, the content of the message received. The process of RST communication can continue from (B) side to (A) side in a similar way when actor (B) acknowledges the message and replies to actor (A) for example.

Fig. 7 The proposed “Remote Social Touch” framework



Remote Social Touch Communication Process

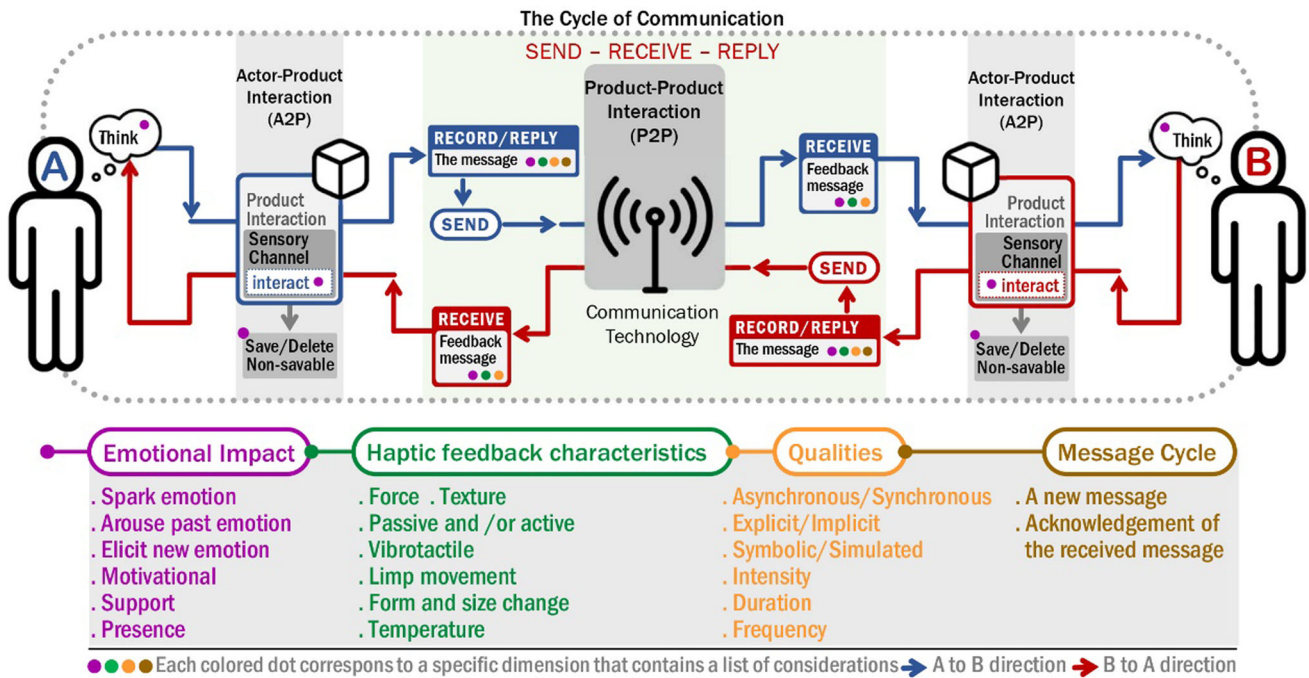


Fig. 8 The proposed “Remote Social Touch” process

In addition to haptic interaction, communication can be established through non-haptic manner for the other person to receive it through a haptic manner, e.g., one side sends a text message for the other side to receive it as haptic feedback. Moreover, the meaning of the communication (or the messages) among the actors involved can be constructed as a vocabulary understood by the actors themselves. This process shows the main elements and dimensions combined to produce RST communication.

3.1 The ‘actor’ element in RST

‘Actor’ in this proposed RST framework is the initiator(s) and the receiver(s) of the RST communication. This element consists of four dimensions: actor type, value of touch, relation to other actors, and personal features. Each of these dimensions can be further detailed into specific considerations as presented in Fig. 9.

Actor type	Human
	Robot
	Pet
	Digital virtual avatar
Value of touch	Emotional reaction to touch
	Frequency engaging social touch
	Type of touch-persona [Touch-avoider / Touch-deprived / Touch-neutral]
Relation to other Actors	Relationship [Kind / Imposing Power]
	Type of social touch exchanged
Personal features	Gender of each Actor
	Age of each Actor
	Cultural background of each Actor

Fig. 9 ‘Actor’ element of RST framework and its dimensions

3.1.1 Actor type

The main actor type that this research focuses on is human-to-human, however, facilitating RST can be made not only between humans but also other parties such as a robot, a digital virtual avatar [54], or even a pet can be integrated. The proposed framework opens a potential route for further research through which other actors can engage with humans. For example, human–robot interaction research focuses on eliciting affective responses in humans and encouraging affective communication with humans such as robot caring for humans [55] or for emotional regulation [56]. It is also possible to interact with digital agents through touch which can add an extra layer of human-likeness [57]. Additionally, some people may be interested in having a pet on the other side of the RST communication.

3.1.2 Value of touch

Value of touch may vary among individuals living away from their loved ones. Results of the online diary show that: a) more than half of the entries indicated missing touch ones a week to every day in the week, b) only 5 out of 42 participants mentioned that they did not miss touch at all, and c) some indicated that they feel sad, frustrated, or try to “hide the emotions” when not engaged in social touch. For example, “...when missing a hug you feel like you want to you need it but you need to hide your emotion that’s why you are straight you don’t want to show you need hug.” [P06].

People using an RST product may represent different personas based on their relation with “touch”. Accordingly, they could be: (i) *touch avoiders*—individuals who rather stay away from engaging in a social touch [58]; (ii) *touch-deprivers*—individuals who need, want, or interested in a social touch but they lack physical contact for some reason

[6]; or (iii) *touch-neutral* (proposed by the authors)—an individual who does not restrain from social touch and receives enough physical contact.

The online diary and the interview results show that individuals may describe certain needs within RST based on the way they feel about physical interaction. For example, Participant 3 (touch-avoider) stated a lack of care about the haptic feedback of the message: “I just say send a hug (the message code is already recorded then just sweep to send it again) sending it as simple as possible maybe just a press a button swipes up swipe away automatically will send a hug or something...”. On the other hand, Participant 14 (touch-deprived) while talking about the mother’s hug, stated that: “Intensity is more important than duration and frequency. For intensity and duration, I would like to be able to manipulate it depending on the situation I am in. For example, if she sends me a light hug then after that I want to replay it and I change the intensity to be more because I wish she was here. So, still I want to feel it as the sender but still have the ability to change its intensity and duration, but the frequency is not that much important”.

3.1.3 Relation to other actors

There are certain dimensions concerning the actors involved in RST: type of relationship, and the type of social touch exchanged. The research shows certain considerations can change the meaning or the content of a RST message, these are relationship levels either similar or different levels, e.g., mother–child not the same level, friend–friend same level. Also to this point, the sending direction (from what relationship to what relationship) may change the meaning. For example, a patting on the shoulder message from a parent to a child could mean “well done”, but, a similar message sent from a child to a parent could mean “don’t be sad”, as exemplified by a participant: “I don’t think I will pat my mother’s shoulder. But sometimes, it is not for well-done maybe for calm down, everything ‘s going to be okay ... If my mother is doing it to me, it is usually for well done, not for calm down ... When I do it, it means calm down to my mother, because I don’t usually say ‘well done’ to my mother”. [P16].

Also, depending on the relationship, missed physical interaction can be a usual kind of social touch (e.g., a hug) or more specific to a relationship (e.g., sleeping on a mother’s lap). Some relationships can be accompanied by diverse and sometimes unusual missed physical interactions. Figure 10 illustrates the distribution of missed physical interactions in relation to gender and ten relationship categories (e.g., mother, little sister, boyfriend) as identified by the research results.

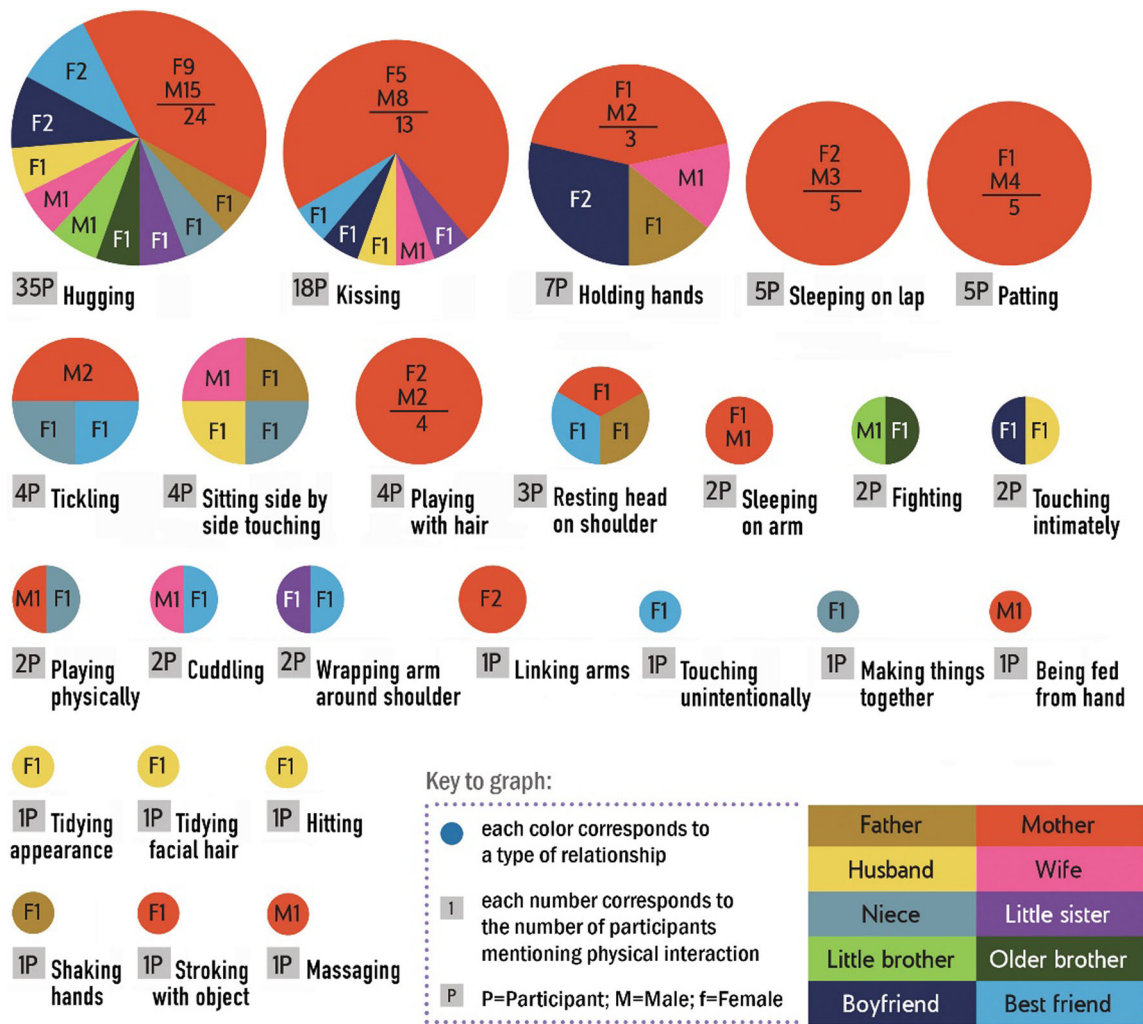


Fig. 10 Distribution of missed physical interactions in relation to relation types and gender

3.1.4 Personal features

There are certain dimensions that are considered personal feature related to the actors: gender, age, and cultural background. Gender and age among the touching individuals may have an impact on the social touch such as frequency, initiation of touch, and type of touch [59, 60]. Also, cultural background plays a role in social touch for example certain cultures could contribute to avoiding touch [61]. These dimensions contribute also to non-vulnerable body parts (NVBP) and vulnerable body parts (VBP), where is one allowed to touch and where is prohibited to touch [62].

3.2 The ‘Product’ element in RST

In the proposed RST framework, ‘Product’ is the object that the Actors interact with to establish or to receive the communication. This element consists of certain dimensions as presented in Fig. 11.

Characteristics	Single-piece / Multiple parts Product attributes Actor’s ownership [Customization / Creativity / Personality] Visible / Hidden Materials Symbolic meaning to actor
Interaction type	Simulated Symbolic Other means Gesture style Familiarity
Location on the body	Product location Haptic feedback location Physical interaction location

Fig. 11 ‘Product’ element of the RST framework and its dimensions

3.2.1 Characteristics

The research findings exposed some of the characteristics that impact RST concerning the products individuals want to interact with. These are the parts that constitute the product (single-piece or multiple parts) and a set of attributes linked to the product: such as wearable, portable, attachable, decorative, fashionable, familiar, entertaining, and transformable. Moreover, the private and intimate nature of the social touch can be translated into RST product characteristics preferred among some RST users such as being unnoticeable, hidden, and not attention-seeking. For example, a participant expressed that it is not always desirable to have the RST artifact noticeable by other people, it may rather look like an accessory the RST function embedded in it, “They [other people around] will talk to you while you are using it [the product] and ask who am I communicating with and such, I wouldn’t want to answer such a question.” [P01].

Additionally, material selection for the product can contribute to the interest individual may have in having the RST product. Touching a product can arise certain affect, the material selection can impact product evaluation and may/may not provide a positive experience [63, 64]. For example, in relation to receiving a pat on a shoulder message, a participant wanted to feel a soft texture like animal fur to represent a “patting” (physical interaction): “...something smooth like an animal fur.” [P11].

Another consideration could be the symbolic value of the artifact that develops over time or RST is attached into (e.g., a ring gifted from the loved one). For example, while the participant was talking about where RST can be embedded, he mentioned “...I’m wearing a ring from my father I really like it so if it has a button to contact my father it will be nice more special.” [P05].

3.2.2 Interaction type

Actor-to-product interaction refers to the way an actor interacts with a RST product which can be through a simulated or symbolic way (Fig. 12). When the participants were asked “how would you like to send a physical interaction message to your loved one?” most participants performed very similar physical interaction to communicate or to send a message, as if they were hugging the air or an object to communicate a hug (Fig. 12a). On the other hand, the participants who chose to communicate symbolically wanted to interact through: (i) a familiar gesture to a current electronic gadget, such as a swipe (Fig. 12b1); (ii) a close proximate to the essence of the physical interaction intended to be sent, such as ‘squeezing’ for sending a hug (Fig. 12b2); and (iii) through other means, such as texting (e.g., sending the text: “hug”), which is similar to working principle of iFeel_IM! [41]. One participant suggested that the product could understand the user’s

thoughts which is similar to brain-computer interface technologies [65] (Fig. 12b3).

3.2.3 Location on the body

RST products may or may not be located on the user’s body, depending on whether the haptic feedback and/or the physical interaction sensing technology are contact-haptics or contactless-haptics type, such as air jet tactile simulation [66]. However, if the product is going to be located on the user’s body, three main considerations are relevant to RST: (i) location on the body (whether it is wearable or attachable), such as a product worn on the wrist (e.g., Feelhey, feelhey.com); (ii) the haptic feedback location and the location where the user will feel the touch message, such as feeling a hug on the upper body (e.g., [3]); and (iii) the physical interaction body location such as shaking hands includes the hands (e.g., [38]) or the kiss include the lips (e.g., [22]).

One of the findings of the research is that the body location, where a product can be located, is almost identical to the locations where the participants wanted to feel the haptic feedback, especially in the case of a simulated messaging, “...the back, the front and the side of the face because when you hug you can feel that...” [P21]. However, for symbolic messaging, a more familiar body location utilized by current technology (e.g., smartwatch) could be preferred, such as on the wrist: “...maybe something not too intrusive, something familiar, if it is an asynchronous communication like smartwatch. If it is clothing, then the top part”. [P03] For example, while investigating the mother’s hug within RST scenario, individuals may choose the “upper body area” to receive the haptic feedback and to wear the product? “...maybe the hands, because when you’re hugging someone usually you use your hands... shoulder for receiving, lower back remind me of a real hug”. [P33]. Figures 13 and 14 show maps of all the areas mentioned by the participants for receiving the mother hug as well as the desirable locations of the product.

3.3 The ‘communication’ element in RST

‘Communication’ in this proposed remote social touch framework highlights certain dimensions related to live (real time) communication and to sending or receiving touch messages among the actors. Figure 15 presents these dimensions.

3.3.1 Characteristics

Communicating social touch remotely has certain characteristics and qualities that may have an impact on the usage scenario, including the meaning intended in the message, and user behavior. Understanding the following characteristics will help in setting up the RST communication that best suits the target user group.

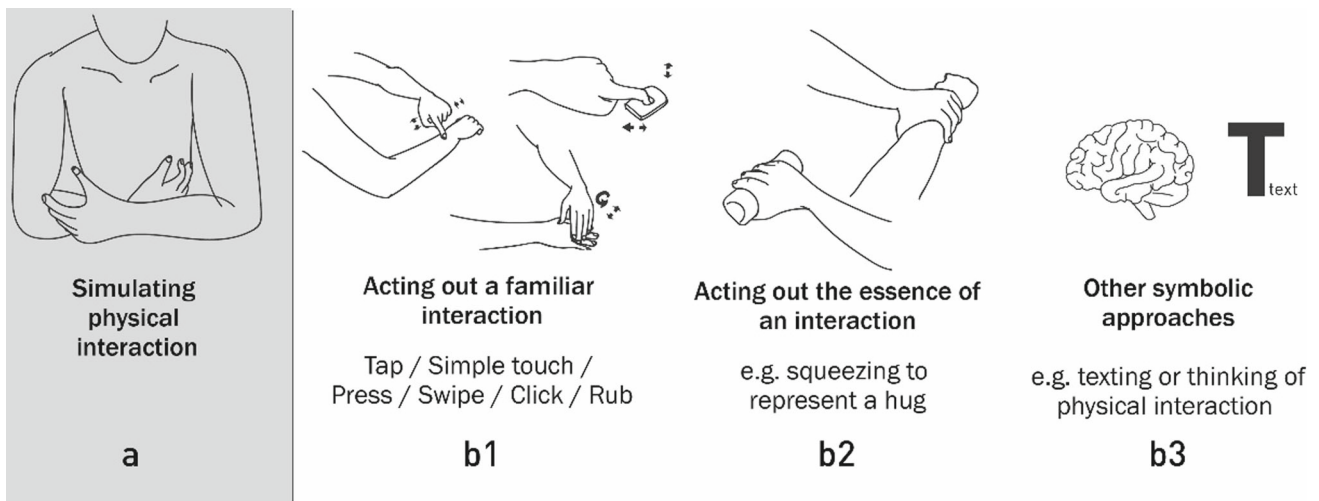
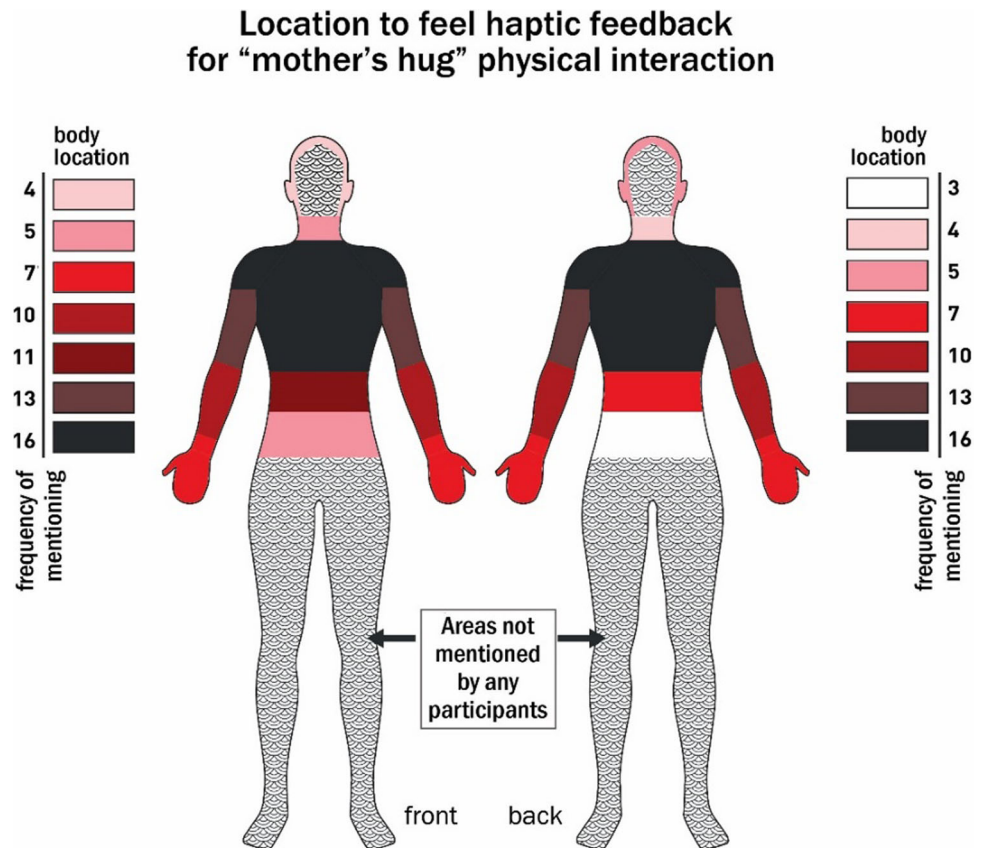


Fig. 12 Four different interaction styles resulted from the interview sessions

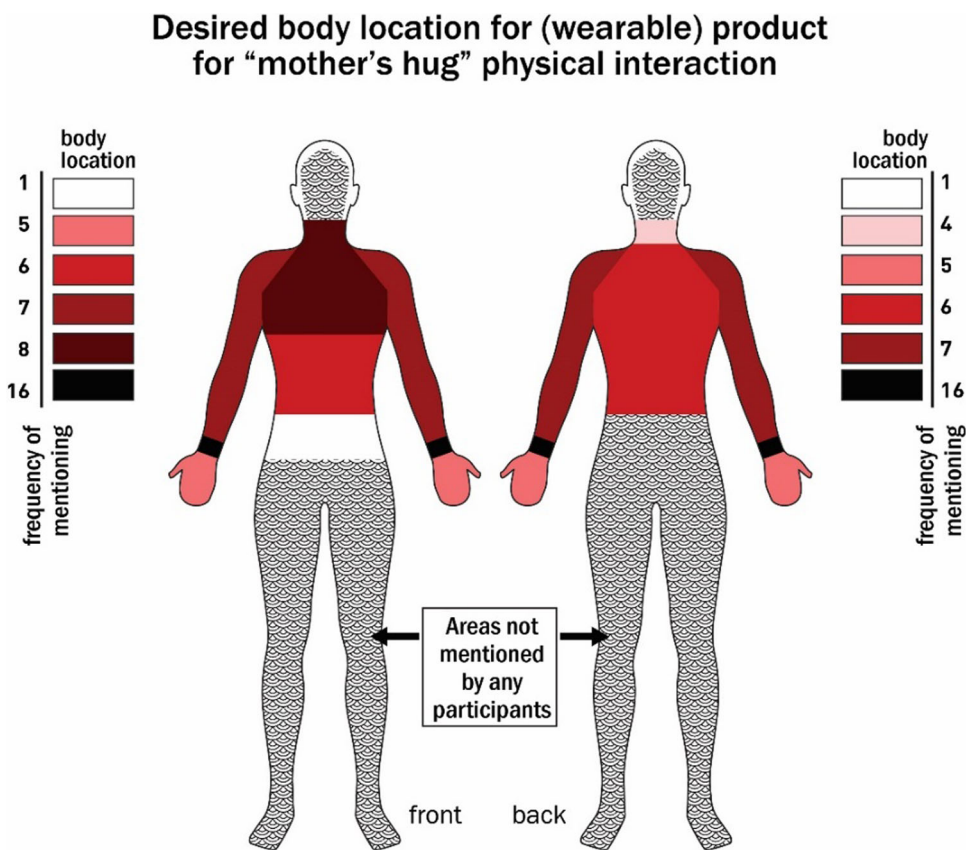
Fig. 13 Desired locations to feel haptic feedback for “mother’s hug”



- **Haptic feedback characteristics** Force, vibrotactile, texture, limp movement, form and size change, passive and active, temperature change, etc.
- **Haptic feedback qualities** Intensity of the feedback (e.g., how strong the hug feels), duration (how long the hug lasts), and frequency (how many hugs does the message contains). A participant stated: “Intensity duration frequency I would like to leave it to the person sending the

- message not in my control, giving the power of changing these to the person sending it make the message unique and valuable to me.” [P21]
- **Communication qualities** Simulated and/or symbolic (acting out the exact physical interactions ‘PI’ and/or substitute the PI with code); synchronous and/or asynchronous (live link, when one press something the other side feels it immediately and/or record the message then send it, can

Fig. 14 Desired body locations for (wearable) product for “mother’s hug”



Characteristics	Haptic feedback characteristics
	Haptic feedback qualities
	Communication qualities
	Direction of the message
	Sensory Channel (Multisensorial)
Cycle	Relation to current media
	Acknowledgement / Frequency
	Send / Receive / Reply
	Message
Relation to 'Actor'	Save
	Emotional impact
	Ethics
	Private / Public

Fig. 15 ‘Communication’ element of RST framework and its dimensions

be saved and reply any time); implicit and/or explicit (one will feel the message without the need to interact with the product and/or one need to interact with the product to start feeling the message). For example, BioSync [67] is an example of simulated, synchronous, and implicit RST that allows kinesthetic experiences for two people.

- *Direction of the message* One-to-one, many-to-one, or one-to-many. RST can be established in which one actor communicates to another actor (e.g., [68]), one actor communicates (send RST) to many actors at once (e.g., [17]), or Many actors (send RST) to one actor (e.g., [18]).
- *Sensory channel (multisensorial)* The feedback of various senses (e.g., auditory, visual) at the same time with the haptic feedback that the individual feel. For example, The Hug’ [27] uses audio to represent incoming hugs with customizable melody notifications to emphasize the personal nature of such a message. Another example is [69] which uses light with the haptic feedback. Some participants talked about this point, for example, Participant 13 said: “...probably if I attach sound or sight to it, it will strengthen the message she recorded with it, it will bring back more memory ... at this point I would like to attach smell too as it is a strong reminder ...”. It is important to consider the effect of multimodal experience as it may have an impact on emotions [70].
- *Relation to current media* RST may have certain features related to existing media such as notifications, warning messages, ease of use, the cost of the medium, the commonality of the medium among peers and loved ones, familiarity with the medium, or ease of access. Additionally, RST can be used to replace or be combined

with current media, or in case individuals are not satisfied with certain media, such as “texting”, RST can be used to enhance it. For example, individuals who are more familiar with features associated with current communication mediums such as WhatsApp’s notifications, incoming calls, or asynchronous communication (messaging) may like RST also to adopt such options, as Participant 21 expressed: “Yes, I’d like to be notified both receiving and (they) felt a message it will bring more human interaction ...even with WhatsApp If the other person have the gray tick (setting) that is will be boring to have communication with but if the Blue Tick (setting) it will be more interesting to communicate with...”.

3.3.2 Cycle

RST communication can be simultaneity real-time like a real social touch, which is direct interaction among the actors in a synchronous way of communication, and/or consists of a cycle send–receive–reply (asynchronous manner). Understanding that social touch is simultaneous using the word cycle (send–receive–reply) could sound misplaced however the term cycle will be used for both synchronous and asynchronous RST. In a synchronous way of interaction, the cycle is considered as follows: the actor initiating the touch is the sender, the actor receiving the touch is the receiver, and if the receiver is applying touch back at the initiator becomes the reply. In asynchronous RST, the cycle is considered to have message-like features that could happen in a separate time frame.

In the proposed RST framework, communication is advised to have acknowledgment and frequency of events. *Acknowledgment* gives some reassurance to actors in the communication, as in real communication where acknowledgment is seen as part of the evidence in grounding i.e., understanding the conversation [71].

Another point is *frequency*, the frequency of encountering an event by an individual has a higher chance to impact emotional wellbeing [72]. The frequency achieved in this framework by: (i) allowing the communication to continue back and forth either in a live manner or recorded; and (ii) allowing to save the physical interaction message to be accessed at any time as one desires.

There are certain considerations related to sending, receiving or replying to RST communication. For sending and receiving communication characteristics (simulated/symbolic, synchronous/asynchronous, implicit/explicit) discussed by the participants while talking about RST. For example, while sending a hug to a mother, Participant 31 is interested in utilizing the hug gesture to send RST to his mother “...I guess simulated because I want to actually perform the action so that I feel like I actually

did it. rather than sending some messages...”. Similarly for receiving mother’s hug participant 32 expressed that “...I would like to feel the hug real more satisfactory than substituted with the code...”.

On the other hand, another chooses to send a kiss to her mother symbolically to hide her feeling and use such a message to withdraw a kiss from her mother “... symbolically because I don’t want her to know my feeling, I don’t want her to know the intensity my feeling if I have to ask for it ...” the same participant choose to send (establish) RST synchronously “...because I immediately need attention...”. Moreover participant 7 stand against simulated RST rather interested in having a symbolic message from his mother “...I don’t want to receive it I don’t want to feel it I don’t want to feel a robotic or device doing this to me unless it is just a symbolic message from my mother she’s saying that I am thinking of you ...”.

Similarly, implicit RST communication is discussed as a way for a natural way of interaction and feels immediate “...because when I wanted to happen immediately...” [P29], “...directly without interruption...” [P32]. Also, if one is receiving RST, participant 35 chooses implicitly when RST is happening with a trusted relationship such as mother “...so I do trust her with whatever she would do. and I think if it all if it asked me whether I want it or not, and for me in my mind, it will lose its purpose. I wanted to be like, you know, when just out of the blue, she hugs me or something like that. it should be natural...”. However the explicit way of communication may allow recovering from miss communication “...because if I cannot delete is problem maybe I will send the wrong message...” [P14]. Or if one wants to have control over the communication such as in the case with participant 29 “...you don’t really need it to happen at a specific time having both of us living in different places different timing we don’t have the knowledge what the other person is doing ...”.

Additionally, participants discussed haptic feedback quality (intensity, duration, and frequency) of RST, for instance, these qualities can be used depending on one’s mood “...it depending on how my day is going if it was not that bad maybe it will be fast or no message sending but my day is very very very bad the duration will be longer the frequency always one but the important is duration depending on the day how’s it going...” [P29]. Similarity for participant 8 “...it depends on how I’m feeling ... generally for the hug I want it to be medium intensity but if I am sad I want the duration of the intensity to be more but if I am feeling okay duration can be less also intensity less for frequency only one...”.

A reply to a message in RST has a similar aspect to sending, however it has an extra aspect defined by this diminution. Also, a reply is different from receiving as it is an action taking (i.e., taking the effort to reply to a message or a communication) not an action being applied to the actor (i.e., feeling the message or the communication). A reply to a

message in the RST cycle can be: (i) a similar physical interaction (PI) message as the one sent; (ii) a different PI; (iii) in addition to the PI can contain other sensor modalities; or (iv) no PI but only other sensory modalities. For example, if one sends a hug message, the receiver either sends a hug back, a kiss, or just a video message, for example, Participant 24 said while talking about replying to a mother hug “...my mother generally like to see my reaction to understand my expression and how I am feeling it would be useful for her to see that...” however, Participant 25 said “...touch will give her the real feeling that I really miss her and I want to touch her.”

Additionally, the urgency in replaying can be in the form of an immediate reply, or replying when one is available. While talking about replying to mother’s hug, Participant 25 mentioned “...it depends on the method if I’m outside and she send me a message and I have the ability to reply back I will reply immediately but if the method (the device) is not with me as soon as I go home I’ll reply.”

Replying to the RST message can be either by the receiver taking control over the reply and sending something back or the product takes control over the reply such as sending an automatic reply based on a pre-recorded message. Participant 6 while talking about mother’s hug mentioned “I think it should be an automatic response, for example if I am in my class and she sends me a hug, she may also want to receive a hug back. So maybe a customizable message can be sent as an automatic response.”

A ‘Message’ in RST, whether it is in synchronous or asynchronous communication, has also some dimensions. Four kinds of possible usage of messages were identified in this research, (a) ‘simple’ e.g., “...going to be impulse thing you can initiate the physical touch at any moment you are thinking of that person, I just like texting hey I’m thinking of you...” [P02]; (b) ‘complex’ e.g., “I would use it to supplement Facetime. I would use it to improve the experience of other communications, like I’m chatting with someone on Skype and they can touch me ... maybe I’m texting with someone instead of sending a hug emoji I could actually hug them...” [P12]; (c) ‘sharing’ e.g., “...when I’m very happy that I’ve achieved something, let’s say I got an award and my mom is not around and I would want to hug or kiss her for all the hard work that she has put in.” [P35] Another example, “...besides that I can record myself experiencing it... my mother cooking I can feel and smell and taste and everything if I want to pass on something to a later generation.” [P21], and (d) ‘be among other’ e.g., “...I think this RST can be used with a patient isolated in ICU. The family cannot be there, no one can be there, and this moment they will feel really isolated so they can have that to feel their family still with them.” [P23].

Additionally, the message in RST is also affected by some dimensions, such as the relationship i.e., the type of RST

communicating among friends (e.g., squabble [73]) may differ from long-distance relationships (e.g., kissing [22]). The direction of communication between the actors can affect which sensory modality is used. For example, a participant, did not like the idea of receiving a haptic message, but wanted to send a haptic message to his mother “I will just send a symbolic message just sent something that presents me saying there I would expect that my mother would like something sophisticated more simulated and related to a hug so she will receive it as she wants.” [P03] In contrast, a participant highlighted “My mother generally likes to see my reaction to understand my expression and how I am feeling. It would be useful for her to see that [sight] and touch. [P24].

However, the ambiguity of the meaning of the tactile feeling that comes from RST, can be translated to a certain meaning understood only by the actors involved in the communication. For example, actors can construct their own vocabulary (e.g., with POKE scenario [11]). RST could resemble a real physical touch (simulated touch, e.g., the feeling of someone’s hug [20]), or a very basic tactile message (symbolic touch, e.g., vibration [17]).

The message in RST can be saved to be felt (replayed) later, this can be considered as a frequency of feeling certain emotions. Participants discuss various settings where they will use such feature, keywords used by the participants such as using it while missing a loved one, for emotional support, motivation, keeping it for future generations. For instance, participant 25 thinks to use saved RST as emotional support “...I will use it when I am extremely happy when something good happened or when I achieve goals in my life when I’m feeling down or miserable or something terrible happened so either extremely happy or depressed then I would play the message again and again...”. Or it can be used as a way to save cherished memories of passed away loved one, “...I think it would be interested when the person died after preserve precious memories...” [P8].

However, there are certain concerns participants mentioned about saving RST, main keywords discussed are devaluating the other person’s touch, ethics and privacy, and unpleasant experiences. For example, participant 1 worries of the loss of intimacy over time “...if you can do it any moment you want it, it will stop being intimate...”. Another participant worries that will negatively impact an individual with deceased loved one “...it would make something harder someone died you need to be able to move on if you have these messages you can play it again and again it will make it more harder for you to move on with your life...” [P13]. Also, he expressed concerns related to the ethics of saving RST as he was concerned with the privacy of such messages “...first my thoughts go to a privacy because if someone sends you a voicemail someone else can hear it so if someone sends you a hug or something else it is more private because it is physical I don’t want someone else to feel it...”, participant

28 worried of exploitation of RST saved messages “...it’s going to take something that is humanistic individual, and it’s going to turn into a commodity that you can exploited anytime for your own”.

3.3.3 Relation to actor

RST has certain considerations concerning the actor, they may have certain reasons to use RST depending on the situation and context. First, the emotional state of the actors in RST could be impacted positively or negatively based on the context and perceived meaning from the communication, the objects/products used, and the interaction among the actors, and among the actors and the product. Generally, the participants thought RST would impact their lives positively.

“If it becomes a reality, it will solve a lot problem not just for me but for all the other students. Even though no one chooses to talk much about loneliness and homesickness, everyone experiences it. I think if it does that, it will cure a lot of problems.” [P23] “I came from a country where they are having war right now and I cannot go back and see my family so remote social touch can give the people a chance to feel something from their parents even if they are worried about them also is going to give the feeling that they are still with you.” [P25].

Some participants expressed their reservations as well. “Maybe in the beginning it’d provide interesting affectations but overtime I think it will become depressing having a robot to substitute physical contact.” [P07], and “Maybe it will turn into something like Instagram: everybody’s sending a hug to each other or touching each other, but no one is really touching anymore—digital closeness brings about physical distance.” [P12].

Secondly, ethics in RST should also be considered as discussed by Jewitt et al. [4]. Similarly, the participants highlighted consent, privacy, ownership, and safety in their feedback as exemplified by: “Privacy invasion... what if someone gets hold of it?” [P15], and “First, my thoughts go to privacy, because if someone sends you a voicemail someone else can hear it but if someone sends you a hug it is more private because it is physical, and I wouldn’t want someone else to feel it.” [P13].

Finally, engaging in communication can be either in a private or a public place, depending on the product’s appearance (i.e., the visual look and form of the product such as being visible or not), a simulated or symbolic communication, the commonality of the RST among the surrounding people, physical interaction, and the context. “Private or public, it depends on how the device looks. If something that I can feel it without people knowing that it shouldn’t be a problem. Also depends on how practical the device is, it doesn’t make sense if you are walking with a big thing. If nobody is looking or aware about the device that will be no problem to

do the action in public.” [P19], “... for the public [use] it can be an accessory like a wristband or a watch. It’d look good and do the function, you can always keep it on you.” [P13] Another participant while talking about using RST with his wife said “If it is a stand-alone product, it will draw attention and people will recognize it as a haptic communicator. They may interrupt you and ask who you are communicating with. That’s why, I wouldn’t like it to be attachable or stand-alone however, some accessories may look like an accessory but may have other functionalities.” [P01].

4 Conclusions

The paper proposed the Remote Social Touch (RST) framework as a means for transmitting a physical touch from an individual(s) to a remote individual(s). It is a way that the sense of touch is stimulated without individuals physically touching each other in the same place and time. The paper illustrated the RST process and what considerations are involved in such a communication with a specific focus on translating physical interactions among separately living individuals to enhance their sense of connectedness. The RST framework is suggested to have three elements: ‘Actor’, ‘Product’, and ‘Communication’ each with certain dimensions. The authors suggest that this framework can provide a useful direction to researchers and designers at the early stages of RST to guide them about for example, how the communication takes place, elements and their dimensions as well as becoming familiar with potential in what situations and contexts RST can be desirable, what concerns may present challenges as presented by the participants, what type of product characteristics should be considered, and so on.

One limitation of the research can be reported as the source of information used to generate the proposed framework, which was based on self-reporting (of the participants) during the interviews and online diaries. As the nature of such a research, which is investigating people’s perceived thoughts and impressions about future scenarios. However, exposing the participants to the world of haptic communication and haptic technologies through video demonstration and working prototype were useful to show the essence of the communication, and hence the resulting directions were valuable to gain the relevant information.

The present research gathered data from a certain group of people, university students living away from their loved ones. Thus, the resulted information especially in relation to ‘product’ element may differ if the research is carried out with a different user group. For example, if the research is carried out with children, desirable product characteristics and location on the body may change. However, the main considerations related to RST gained from this user group would be

still valid, different user groups may propose new considerations for RST or dominant characteristics may shift. As the next obvious phase and potential area for future studies, the proposed framework can be tested with more advanced stage working prototypes and in various scenarios. Additionally, the proposed RST framework can be enhanced and checked against Poggi et al. [74]’s description of the touch system and its various dimensions, such as the alphabet of touch, the lexicon of touch and the norms of touch usage.

4.1 Utilization of the remote social touch framework

4.1.1 Helping with the process of researching in RST

The proposed framework can be used while researching remote social touch, especially in the early stages of a design process. In relation to RST, the framework highlights several important considerations which can be used to guide a novice RST researcher. Additionally, the researcher can use the proposed RST framework as a reference to generate research materials to use while engaging with the research participants. For example, a researcher interested in exploring the impact of RST ‘Asynchronous’ way of communication on the individual way of interacting remotely with each other, can see all the elements and dimensions to keep consistent, while keeping the way of communication as a variable in the research.

4.1.2 Guiding in the process of designing for RST

Designers can also refer to the proposed RST framework while developing products or applications for RST. The proposed RST framework can guide designers to see the various considerations (elements and dimensions) together to allow them to focus on certain considerations that suit their design case. The framework can be used at the initial stage while designing for RST to allow various stakeholders to understand the RST process. Designers can also refer to this framework to explain the RST product concept to other stakeholders by pointing out how the product will tackle each of the elements and their dimensions. For example, if a design brief is focusing on a certain user group (the ‘Actor’ in the proposed framework), the designer can manipulate other elements and dimensions to find what best fits to a user group. Another example, if the user group focuses on children, then the designer can investigate various outcomes related to dimensions such as physical characteristics of a product or location on a body. On the other hand, if the focus is on individuals at work, the designer can look into dimensions such as the relation among the actors, the value of touch, and communication characteristics.

4.1.3 Evaluating an existing RST prototype or a product

Another way to utilize the proposed RST framework can be as an evaluation tool. Individuals could use the framework to check for example, if the existing RST products and prototypes are tackling the necessary RST considerations related to their user groups; or to check if they missed certain dimensions while developing RST that could impact their output product. Another example, researchers or designers could use the RST framework to evaluate an existing product for the addition of new features and to check how the new features could fit with the rest of the product functions.

4.1.4 Integrating the RST framework in various contexts

Although the present research focuses on human-to-human RST, other fields that utilize remote haptic or haptic feedback may benefit from the proposed RST framework. For example, it can be used in conjunction with task-specific communication in addition to other modalities such as for remote family gatherings, remote education, or remote collaboration. In this case, the actors in the proposed RST framework can be coworkers and instead of emotional reasons for communication, it will be for functional reasons.

Another field that the proposed RST framework can be utilized in is Artificial Intelligent (AI) based systems intended to understand social touch and how it can be replicated in digital format. For example, creating a social touch library for AI systems using the suggested RST process, this will help the AI to learn how to use touch in a manner that is akin to how humans behave. Then, the AI can learn how each element and dimension (within the framework) may affect the actors involved in the communication. The framework can also be integrated in virtual reality (VR) systems for gaming and social VR, e.g., while stimulating the touch sense interacting with other players/users over VR. Virtual agents may use this framework to establish ways to help with emotional regulation through remote haptic communication.

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Declarations

Conflict of interest The authors have no conflict of interest to declare that are relevant to the content of this article.

Ethics approval This research approved by the authors’ institute ethical committee with number 28620816/438.

Appendix 1: Remote social touch (RST) aspects from the literature

User count		
One to one	One to many	Many to one
[3, 10, 11, 19–46, 51–53, 67–69, 73]	[17]	[18]

Direction of sending	
1-direction (1D)	2-directional (2D)
[3, 18, 20, 23, 25, 29, 32–34, 37, 41, 53]	[10, 11, 17, 19, 21, 22, 24, 26–28, 30, 31, 35, 36, 38–40, 42–46, 51, 52, 67–69, 73]

Touch representation		
Symbolic	Simulated	Both
<i>Send</i>		
[10, 17, 18, 20, 23, 30, 31, 33, 37, 41, 42]	[3, 11, 19, 21, 22, 25, 26, 28, 29, 32, 34, 35, 38, 39, 43, 44, 46, 51, 52, 67–69, 73]	[24, 27, 36, 40, 45, 53]
<i>Receive</i>		
[10, 17, 18, 23, 25–28, 30–33, 35, 41–46, 53, 69]	[3, 11, 19–22, 29, 34, 37–39, 51, 52, 67, 68, 73]	[24, 36, 40]

Message synchronization

Synchronous	Asynchronous	Both
[3, 10, 11, 17–19, 21–24, 26, 28–46, 51–53, 67–69, 73]	[20, 25]	[27]

Interaction type

Implicit	Explicit
[3, 10, 11, 18, 19, 21–24, 26, 28–45, 51, 52, 67–69, 73]	[17, 20, 25, 27, 46, 53]

Haptic rendering methods

Force*	Vibration	Temperature	Electrical muscle stimulation (EMS)	Movement	shaking
[3, 11, 19, 20, 22, 28, 29, 34, 37–39, 52, 68, 73]	[10, 17, 18, 24–27, 30–33, 35, 40–43, 45, 46, 53, 69]	[3, 23, 24, 26, 27, 30–32, 38, 41, 44, 52]	[31, 67]	[36, 51]	[21]

*Force can include squeezing, air pocket inflation, and other force actuation

Haptic sensing methods

Force/pressure	Contact/touch/press	Movement/motion	Buttons	Flex
[3, 10, 11, 19, 21, 22, 26, 29, 32, 34, 35, 38, 39, 43, 44, 46, 68, 69, 73]	[18, 24, 25, 30, 31, 33, 37, 40, 42, 45, 46, 52]	[27, 28, 36, 46, 51]	[17, 23]	[32, 53]
Electromyogram (EMG)	Visual gesture tracking	Temperature	Text-based	
[67]	[28]	[32]	[20, 41]	

Gesture type

Arm wrestling	Shake	Handshake	Hand rolling	Contact/touch/abstract touch	Grip/grasp	Pressing/tap
[19]	[21]	[28, 38, 39]	[36]	[24, 25, 30, 33, 41, 43, 44, 53]	[26, 32]	[10, 17, 25, 45]
Squeeze	Stroke	Hug	Squabble	Massage	Movement	Hand holding
[27, 29, 34, 35, 46]	[25, 27, 45, 46, 51]	[3, 20, 23, 27, 28, 37, 41, 69]	[73]	[18]	[42, 46, 67]	[28, 52]
Poke	Pulling	Kiss	High five	Shoulder pat	Sexual stimuli	Tickling
[11, 45]	[68]	[22]	[28]	[28]	[31]	[40]

Location on the body

Upper-arm	Hand	Whole-body	Upper body	Feet
[29, 34, 67]	[10, 17, 19, 21, 26, 33, 35, 36, 38–40, 42, 43, 46, 51–53, 68]	[24, 25, 31, 44, 73]	[3, 18, 20, 25, 27, 28, 37, 41, 69]	[30]
Lower back	Cheek	Forearm	Lips	
[23]	[11, 42]	[32, 45]	[22, 43]	

Object characteristics

Stand-alone	Embedded in an object	Portable	Decorative*	Wearable
[3, 17–23, 26–29, 31–34, 36–39, 41, 43, 45, 46, 51–53, 67–69, 73]	[10, 11, 24, 30, 31, 34, 35, 40, 42, 44]	[17, 21, 22, 26, 28–31, 34, 37, 43, 45, 46, 51, 53, 67, 69, 73]	[22, 68]	[3, 18, 20, 23, 25, 28–32, 34, 37, 41, 45, 53, 67]

*Include entertainment

Other modalities besides haptic

Visual	Audio
[3, 24, 27, 30, 38, 43]	[27, 38]

Appendix 2: Online diary keeping questions

Think about the loved ones you are currently living away from:

Have you contacted your loved ones today? (Yes/No)

If YES: What medium(s) did you use to communicate?

If YES: How many hours/minutes did you spend communicating?

If YES: Can you briefly explain the reason for why you did contact them?

e.g., Just to ask how they are doing today; I had a problem and I needed their help

If NO: still did you want to contact them but you couldn't? if yes why you couldn't?

Did you feel you wanted to have some kind of physical contact with your loved ones today? (e.g., a hug or shaking hands) (Yes/No)

If YES: How did you feel by the absence of the physical contact? [Using the 'Pick-A-Mood' wheel to pick one image]

Appendix 3: Interview questions

1. Introduction and consent

2. Questions—part 1

Reminding about daily assignment, then:

2.1 [in relation to diary assignment]. Can you please elaborate on your answer related to missing physical interactions?

For the next group of questions, please think about a loved one you lived away from for a certain amount of time (loved ones can include any kind of relationship that you define them in the circle of loved ones such as parents, friends, spouse, etc.)

2.2 What is the relationship with the loved one you are thinking of?

2.3 The maximum years/months lived away from loved ones?

2.4 During the time away from the loved ones, which medium did you generally use to stay in contact? [why]

2.5 What kind of physical interactions do you miss while being away from the loved one?

2.6 How do these physical interactions make you feel? [explain through PAM cards]

2.7 How did you feel missing these physical interactions? [Pick-A-Mood]

2.8 How often do you initiate or receive these PI: 1–5[never/rarely/sometimes/often/always]

3. Questions—part 2

Video clips [example technologies] and the prototype explaining RST

Knowing that everything is possible in this scenario:

3.1 [think about the physical interactions you provided before] How would you want technology to represent these physical interactions? If you: Receive it / Reply it/Send it/Save it

3.2 Do you want a single product to do all the functionalities (i.e., receive/reply/send/save) or one for each? What are the product characteristics? How would you want to interact with the product?

3.3 What kind of scenario would you use RST?

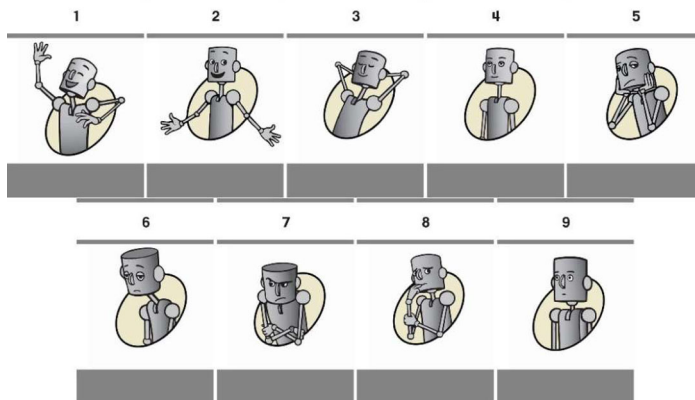
3.4 In your point of view, what advantages and disadvantages do you think RST may have?

The end

Appendix 4: Remote social touch (RST) card set

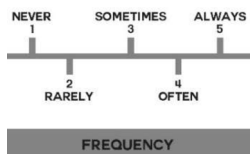
Card set

a Pick-A-Mood (PAM) cards [52]



Nine cards representing various emotions/feelings (i.e., excited, cheerful, relaxed, calm, bored, sad, irritated, tense, neutral) through a robot-looking character.

b Frequency card



This card is intended to accompany the question ‘How often...? It is believed to make it easier for the participants to have a reference scale of frequency in front of them. The scale included the following evaluation: Never (1) - Rarely (2) - Sometimes (3) - Often (4) - Always (5)

c Message characteristics cards

SIMULATED	SYMBOLIC	ASYNCHRONOUS	SYNCHRONOUS	EXPLICIT	IMPLICIT
Having a real action represented as it is Example: Shaking a robot's hand is like shaking your friend's hand	Substitute an action with a code Example: Press ones to say I miss you	Not Occurring at the same time, it can have a delay Example: A friend reading your message later after you send it	Occurring at the same time without delay Example: Talking on phone	The feedback can not be felt until the user intervenes Example: Press a button to feel the vibration	The feedback is felt automatically without intervention Example: As soon as a message comes to your phone you feel vibration
MESSAGE CHARACTERISTICS	MESSAGE CHARACTERISTICS	MESSAGE CHARACTERISTICS	MESSAGE CHARACTERISTICS	MESSAGE CHARACTERISTICS	MESSAGE CHARACTERISTICS

This category of cards consisted of explanations of *simulated* (performing the PI to send it) vs *symbolic* (substitute the PI with a code), *synchronous* (feeling the PI at the same time) vs *asynchronous* (the PI message can be recorded and felt later anytime), *implicit* (feeling the PI message without the user intervention) vs *explicit* (the user intervenes to feel the PI message).

d Haptic feedback characteristics cards

<p>ACTIVE</p>  <p>Feeling the haptic feedback because of your own movement</p> <p>Example: Moving your hand over wooden surface</p> <p>HAPTIC FEEDBACK</p>	<p>COLD</p>  <p>The feeling of the temperature getting cold</p> <p>HAPTIC FEEDBACK</p>	<p>FORCE</p>  <p>Any kind of pressure on your body part or skin, small or big, on small area or large area</p> <p>Example: An object pushes against your skin</p> <p>HAPTIC FEEDBACK</p>
<p>FORM</p>  <p>The feeling of the object changes its general shape</p> <p>Example: Object shape changes from sphere to cube</p> <p>HAPTIC FEEDBACK</p>	<p>LIMP MOVEMENT</p>  <p>A force that makes your limp move</p> <p>Example: Arm move</p> <p>HAPTIC FEEDBACK</p>	<p>PASSIVE</p>  <p>Feeling the haptic feedback because an object is moving while your body part is static</p> <p>Example: A piece of cloth brushed against your skin</p> <p>HAPTIC FEEDBACK</p>
<p>SIZE</p>  <p>The feeling of the object changes its size</p> <p>Example: The object size becomes small</p> <p>HAPTIC FEEDBACK</p>	<p>TEXTURE</p>  <p>The feeling of a certain texture of an object</p> <p>Example: Feeling the texture of wood.</p> <p>HAPTIC FEEDBACK</p>	<p>WARM</p>  <p>The feeling of the temperature getting warm</p> <p>HAPTIC FEEDBACK</p>










This category of cards included representations of various haptic feedback. Vibrotactile feedback is excluded from the set to study how other kinds of haptic feedback can be utilized as the vibration was widely used in RST literature.

e Haptic feedback qualities cards

INTENSITY	DURATION	FREQUENCY
<p>How strong is the feedback</p> <p>Example: Pushing on your own skin slightly (low intensity) or very hard (high intensity)</p> <p>FEEDBACK QUALITIES</p>	<p>How long the feedback last</p> <p>Example: A phone notification vibrates for 5 seconds</p> <p>FEEDBACK QUALITIES</p>	<p>How often something Occur</p> <p>Example: A phone notification vibrates every 2 seconds until you open it</p> <p>FEEDBACK QUALITIES</p>

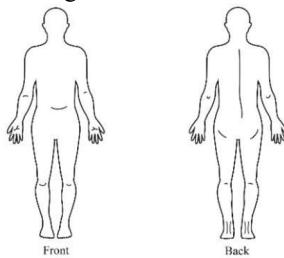
This category of cards help to initiate discussion about certain haptic feedback qualities while discussing receiving and sending haptic feedback in RST.

f Product characteristics cards

<p>ACCESSORY</p>  <p>An accessory product</p> <p>Example: A necklace</p> <p>PRODUCT CHARACTERISTIC</p>	<p>WEARABLE</p>  <p>Any product one can wear it</p> <p>Example: Wrist watch</p> <p>PRODUCT CHARACTERISTIC</p>	<p>STAND-ALONE</p>  <p>The product has main function and does not do other things</p> <p>Example: A pen</p> <p>PRODUCT CHARACTERISTIC</p>
<p>NON-WEARABLE</p>  <p>Any product one cannot wear</p> <p>Example: Wall clock</p> <p>PRODUCT CHARACTERISTIC</p>	<p>DECORATIVE</p>  <p>The object is used because of its decorative value</p> <p>Example: An artistic statue</p> <p>PRODUCT CHARACTERISTIC</p>	<p>CLOTH</p>  <p>Any clothing item</p> <p>Example: T-shirt</p> <p>PRODUCT CHARACTERISTIC</p>
<p>PORTABLE</p>  <p>A product that provide a mean to be carried</p> <p>Example: Shoulder bag</p> <p>PRODUCT CHARACTERISTIC</p>	<p>ATTACHABLE</p>  <p>A product that can be attached to another product</p> <p>Example: Smartphone cover</p> <p>PRODUCT CHARACTERISTIC</p>	<p>ADDED TO FUNCTIONAL PRODUCT</p>  <p>Adding another function to already existing functional product</p> <p>Example: A pen with LED light</p> <p>PRODUCT CHARACTERISTIC</p>









This category of cards aimed at facilitating the discussion on certain product features that would be desirable to the participants.

g Human figure card



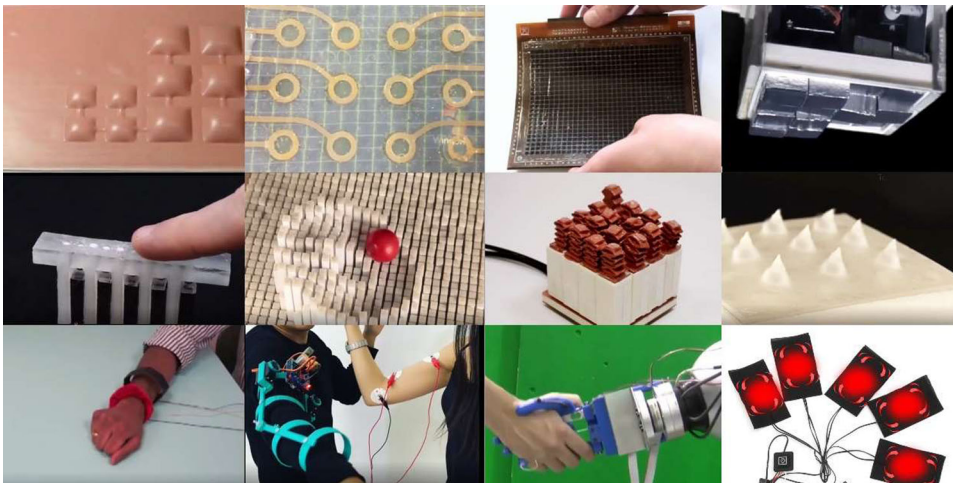
The participants were asked to indicate “where on their body they would like to feel the PI”, and “if a wearable product was available where it should have been located on the body”. The human figure is adopted from Jones and Yarbrough [53].

h Miscellaneous cards

HEARING	SIGHT	SMELL	TASTE	TOUCH
				
SENSORY	SENSORY	SENSORY	SENSORY	SENSORY
MANIPULATION	SENSORIAL ATTACHMENT	SCENARIOS	NOTIFICATION	TIME TO REPLY
Ability to manipulate the message	Attaching other sensory to the message	Scenarios for using the saving functionality	 Receive  Open/Feel	
SAVING THE MESSAGE	SAVING THE MESSAGE	SAVING THE MESSAGE	SENDING THE MESSAGE	IMMEDIACY

Various cards that meant to be used with few questions to act as a focal point for the participants while answering the questions.

Appendix 5: Video clips



A screenshot from the introductory video clip prepared for the participants, it shows these terminologies: tactical feedback, low- and high-resolution tactile feedback grids, texture feedback, force feedback, contactless haptic feedback, joint manipulation feedback, temperature feedback, simulated feedback, symbolic feedback.

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