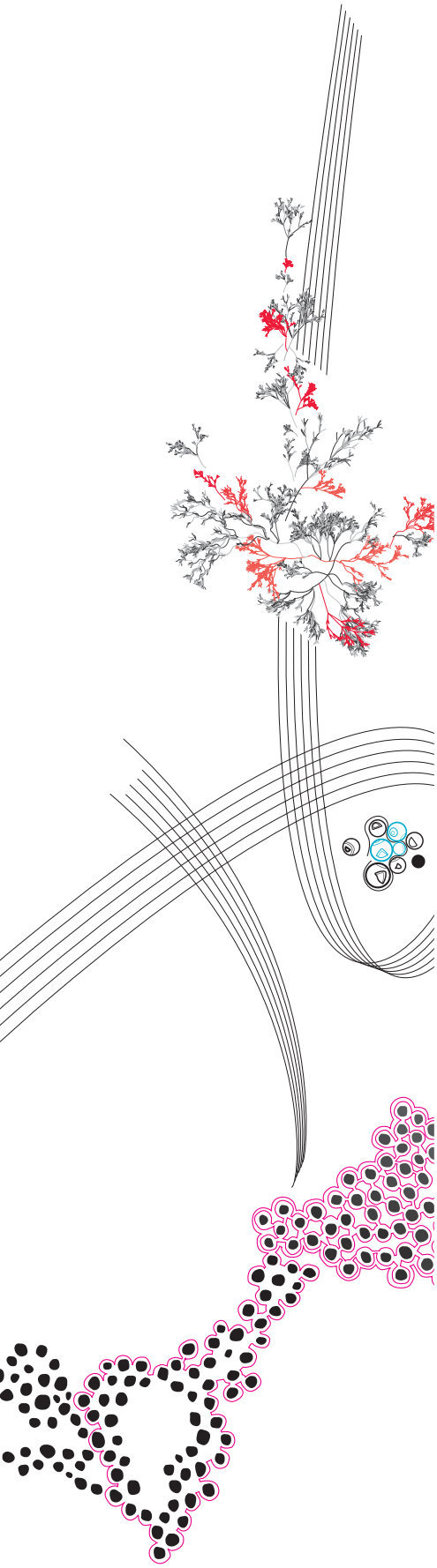

MSc Thesis Interaction Technology

"How can I touch you?": Reducing intrusiveness in mediated touch

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Summary

Mediated social touch can be used to bridge the gap of physical touch between two persons. By each touching a tactile device two persons are able to send touches to each other without being in the same room. However, receiving a mediated touch might not always be convenient for the recipient. If the recipient is occupied with another task, receiving a mediated touch could become intrusive. To understand the occurrence of these intrusive touches, the problem space surrounding mediated touch and intrusiveness was explored. This was done by setting up a self-test conducted by the author and a focus group to gain insight into the thoughts of potential users. Consequently, a design process was set up to create a wearable prototype that was used to investigate how to reduce the possibility of intrusiveness within mediated touch. Different solutions were generated and narrowed down by using divergent and convergent thinking. Three possible solutions were integrated in a wearable device; a status mode in which the user can choose whether he or she is available for receiving mediated touches, a snooze mode in which the user can delay the touch if it is not convenient and a voicemail mode (asynchronous communication) in which the touch is saved to a voicemail which can be played at a chosen moment. These three solutions were compared to a normal mode in which users can send touches without any additional settings. During the user test, five pairs of participants tested each mode and answered a series of questions regarding their perceived intrusiveness. It was found that there is no statistical difference for the perceived intrusiveness between the modes. It was proposed that the perceived intrusiveness of a mediated touch might not be only caused by receiving a mediated touch but it might also be a result of a need to react to the received touch. With this research, it is proposed that future research needs to consider that a mediated touch is not always welcome. Therefore, it is important to take into account alternative design considerations that tackle these moments.

Contents

Chapter 1
Introduction

In recent years, people are more easily able to connect to each other via the internet and making new friends in all places of the world has become relatively easy. Long distance relationships are not unthinkable and there are many ways to stay connected with a loved one who lives in another country. Calling and texting with that person can be a continuous day to day task. However, there is one aspect that cannot bridge this distance between two people and that is physical touching. Mediated social touch could overcome this distance by allowing people to touch each other over a distance via a physical device. Mediated social touch is defined in [16] as "the ability of one actor to touch another actor over a distance by means of tactile or kinesthetic feedback technology." Thus, one person can use the mediated touch device to send a touch to the other person. This touch can be diverse; from a squeeze around the wrist to the sensation of a hug.

Mediated touch is an alternative option for people that are not in proximity of one another to communicate. It gives them an extra dimension of connecting that is not only via an audio or video connection. However, mediated touch is not the same as a physical social touch. It can be more difficult to interpret the intention of the other person and it is more difficult to anticipate on what the other person wants and needs. Within social touch, there is a possibility for prior consensus on the touch, since there are procedures in place to achieve this consensus. For example, the recipient sees that the sender is initiating a touch and the recipient is able to reject this touch if it is unwanted. However, this is more difficult in mediated touch. It is possible that a mediated touch is not expected or wanted by the receiving side. This can be due to several reasons, for example, one's attention is elsewhere and receiving a touch can cause a distraction. In these situations the mediated touch can lead to a feeling of intrusiveness, because it can make a person feel uncomfortable when a mediated touch is not wanted and it is given without the consent of the recipient. In this report, the problem space surrounding intrusive touches will be explored and different solutions will be sought.

The contribution of this report lies into exploring the problem space of intrusive mediated touches, how these occur and how this could be solved. This could be valuable for future researchers, since it is important to consider how to handle mediated touches

that are not welcome. These options should go beyond simply telling the user to take off the device when they do not want to receive a mediated touch.

1.1 Research questions

By identifying the possibility of intrusive mediated touches, the following research question was constructed:

RQ: How can the possibility of an intrusive touch be reduced in mediated social touch technology?

To be able to answer this question, different steps were followed. Firstly, it is important to gain insight into the mind of users that would use a mediated touch device. With these perspectives in mind, a design process can be started to find suitable solutions that can be implemented into a wearable mediated touch device. This device is then be tested to get feedback from users and to what extent they believe these solutions could be useful. This results in the following sub questions:

sub-RQ 1: What kind of different forms of intrusive behaviour can occur when using a mediated touch device?

sub-RQ 2: How to design a mediated touch device that can reduce the possibility for intrusive mediated touches?

sub-RQ 3: How to evaluate a mediated touch device that incorporates different solutions to reduce the possibility for intrusive mediated touches?

1.2 Report outline

Firstly, some background information on mediated and human social touch will be provided. This background was gathered during a literature study in the Research Topics phase (chapter 2 to 4). Then, the occurrence and possibilities of intrusive mediated touch was investigated. This was done by letting the author run a test to see how a mediated touch device would be used in daily life. A focus group was also conducted to gain more insight into the views of the potential users of a mediated touch device (chapter 5). With their input in mind, a clear definition of intrusiveness could be put forward (chapter 6). Then, a design process of convergent and divergent thinking was started to generate solutions on how to solve the possibility of intrusiveness (chapter 7). By narrowing down these solutions, a first prototype was be presented (chapter 8). After some alterations to the first prototype, the final prototype was created (chapter

9) and this was used for the user tests (chapter 10). Lastly, the results of the user tests will be presented (chapter 11) and interpreted (chapter 12). In the end, a conclusion will be drawn.

Chapter 2
Human touch

Human touch is an important aspect in our daily lives and in our development. Research has shown that during the first months as an infant, touch can help to form secure attachment and family bonds [5]. The neurophysiology behind human touch is an important aspect to consider when designing a mediated touch device. Therefore, in this section human touch is explained and how this can have an effect on one's affective state.
There are two sub-systems within human touch; the cutaneous system, which refers to the the tactile information that is obtained by receptors in the skin and send to the brain, and the kinesthetic system, which refers to the position and movement awareness surrounding the body [16]. The cutaneous system can be divided further into different receptors that each focus on a different modality, such as pain and temperature.
A touch can be classified as either being a discriminative touch or social touch [28]. For example, the sensation that one feels when touching a hot plate can be very different than the sensation one feels when a loved touches their back. This is because discriminative touch is used to identify the object that is being touched by using for example texture [28]. The receptors from the cutaneous system that are divided in their respective modality, obtain information on for example the warmth and texture of an object. These receptors are myenalited fibers, also referred to as Aβ afferents [29]. More recently, it has been found that there is a separate pathway for affective social touch, which is used to convey emotions and transmit behavioural responses [27]. Since mediated touch is more involved in conveying emotions and in regulating one's affective state, social touch will be explained in more detail in the next section.

2.1 Social touch

If social touch is processed separately from discriminative touch, then there must be a subsystem of receptors in the skin that can process this information as well. In 1993, Vallbo observed the presence of mechanoreceptive afferents that have unmyelinated fibres in parts of the hairy skin [45]. These C tactile (CT) afferents respond to slow stroking, between 1-10 cm/s [33]. This suggests that they are not suited for discrimina-

tive touch, which relies on fast conducting receptors, but they more useful for affective touch. Furthermore, they only appear in the hairy skin, where they are most present in the face and the arms. It was found that subjects who lack myelinated tactile afferents (Aβ), which are used in discriminative touch, but do have CT afferents, can detect soft stroking on the forearm but cannot detect the same stroking on the palm of the hand (glabrous skin) [29].

The speed of the movement is found to be very important for the activation of CT

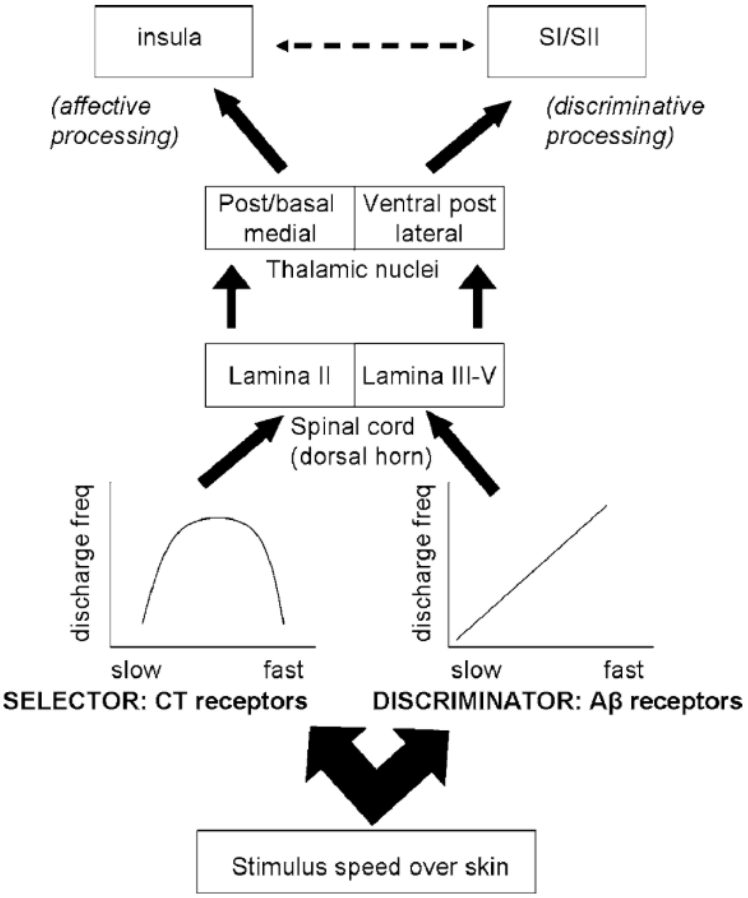


FIGURE 2.1: Summary of affective touch and discriminative touch pathways. Where the CT afferents in the end project to the insula and the Aβ afferents project to SI/SII (somatosensory cortex) [29]

afferents [29]. CT afferents were found to prefer a speed between 1-10 cm/s, where the discharge decreases if the speed it outside this boundary. Whereas in Aβ afferents, the firing of the neurons increase when the speed of the stimilus increases.

Furthermore, it is also suggested that there is a dedicated pathway to the brain for affective touch that differs from discriminitative touch [19]. The CT afferents that are involved in social touch project mainly to the insular cortex [28], which is primarily involved in affective processing. This is in contrast to Aβ afferents, which project mainly to the first and second somatosensory cortex (SI and SII). SI and SII are found to

be involved in respectively processing sensory information and sensory experiences by remembering tactile information.
However, Aβ afferents are much faster at decoding tactile information, then why would it be beneficial to use CT afferents to decode affective stimulation seperately as well? This question gave way for the social touch hypothesis, which suggests that social touch is a distinct domain of touch [29]. The CT afferents select the information that is needed for affective processing, in the proposed velocity range in parallel with the Aβ afferents that still process the discriminative properties. The CT afferents select a range of velocities that are used for affective communication and the rest is processed rapidly by the Aβ afferents. The pathway from an initial touch to the brain for both Aβ afferents and CT afferents are summarised in figure 2.1.

2.1.1 Versions of social touch

There are different forms in which a touch can occur. The following three different categories of social touch are defined in [29]; Simple, protracted and dynamic touches. Firstly, there are simple touches such as poking and padding. A simple touch encompasses a brief touch on a body part during a social interaction, such as a pat on the back by a friend. Secondly, protacted touches are longer skin-to-skin touches, such as holding hands or hugging. Protacted touches are usually more intimate and less restricted in contrast to simple touches. Thirdly, rubbing and stroking are seen as dynamic touches, where there is a continuous movement along the skin. It is important to distinguish these different forms of touch, since each of them will elicit a different emotion from the receiver. Where a simple touch is more accepted to be given to people that are not familiar with each other, a protacted or dynamic touch is more intimate and therefore more restricted to people that have a close relationship.

2.2 Context

Social touch is dependent on the context that surrounds the touch. How a touch is perceived by the recipient depends on who is giving the touch and where the touch is given. Research has shown that the areas that are accepted for touching directly relates to the strength of the emotional bond between the person receiving the touch and the person giving a touch [44]. According to the research done in [44], romantic partners find it acceptable to touch each other everywhere on the body. This is in contrast to strangers, where it is only acceptable to touch the hands of a person. An overview of the different areas that can and cannot be touched based on the relationship between the toucher and receiver can be found in figure 2.2. The authors also found that the sex of the person that is touching is important. Females are accepted to touch more body parts than males, and this difference is especially apparent when the person giving the touch is a stranger. This suggests that whether a touch is pleasant or not, is not only dependent on the touch itself but also on the relationship between the two persons

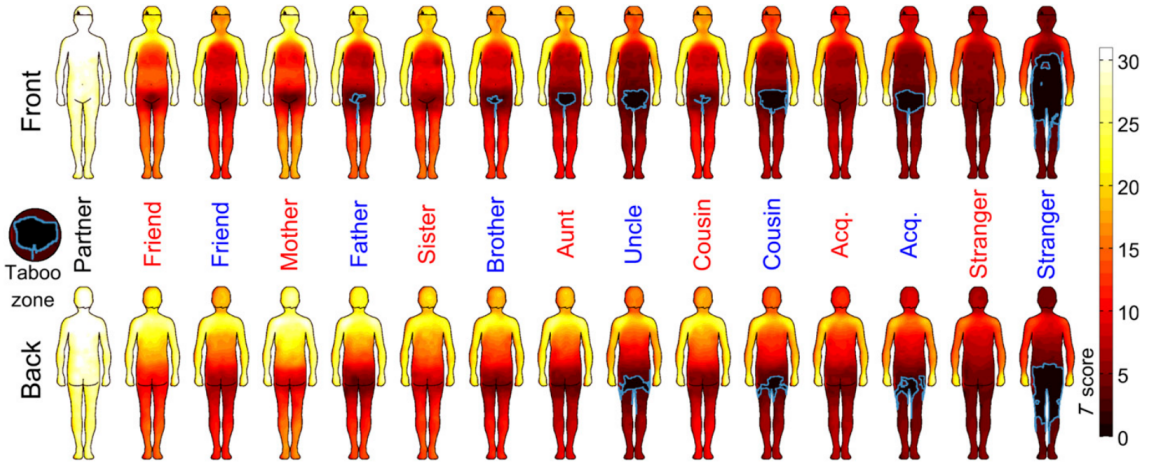


FIGURE 2.2: Topography of social touch, visualizes where a person with the indicated relationship is able to touch [44]

touching.

Furthermore, the facial expression of the person giving a touch also affects the pleasantness of the perceived touch [9]. When a person is smiling, their touch is received as more pleasant than when that same person is frowning. This suggests that the way a touch is perceived does not only depend on how the touch is given, but also what happens surrounding the touch. Moreover, a touch is not only interpreted based on the touch itself, but also by other factors, such as the relationship with the other person and their facial expression. A touch can be ambiguous and therefore other nonverbal signals are also used to interpret the intention of a touch. Not only facial expressions influence the way a touch is perceived, but the smell can also affect the touch [9]. A touch together with a unpleasant smell, results in the touch also being more unpleasant. Even when the participant was aware of the fact that both cues originated from different sources. This suggests that subconsciously, the sensation of the touch and the sensation of the smell are linked together, even though this is not the case. As a result, there is a cross-sensory affect, where one sense influences another even if they are not related.

Chapter 3
Mediated touch

Physical social touch is not always possible, for example in the case when two people are distant from each other and cannot physically see or touch one another. Nowadays, it is common to maintain a relationship by using an audio or video connection with someone who is not in your proximity. However, it is much more difficult for people to touch one another over a distance. Mediated social touch aims at mediating touch over a distance via a tactile device [16]. In this section, different examples of state of the art devices are discussed as well as the characteristics of mediated touch devices and how this can be compared to human social touch.

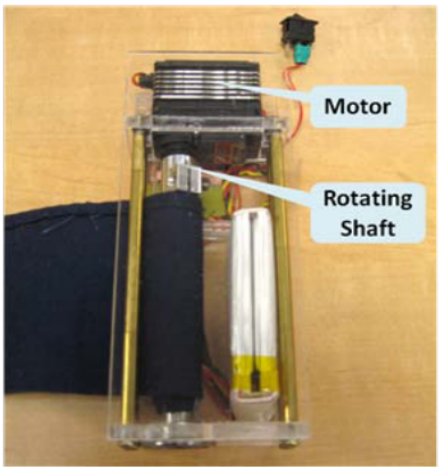
3.1 State of the art devices

There is a great variety of devices that have incorporated mediated social touch in order to sent a specific form of touching over a distance. These devices each aim at communicating different forms of touch via different types of actuators. They could for example communicate the feeling of a hug, a squeeze or a stroke. These different sensations are evoked using different types of actuators, such as inflatables or vibration motors. In this section, some examples of these devices will discussed.

3.1.1 Squeezing

One form of touch is squeezing, in which pressure is exerted by touching another person. The authors in [49] tried to replicate the feeling of a squeeze on the upper arm with a mediated touch device. The squeeze is generated by squeezing a connected mobile phone. The pressure resulting from this squeeze is sent to the device (see figure 3.1b) that is worn around the upper arm of receiver (see figure 3.1a). This device is attached around the upper arm as a bracelet, upon receiving a touch it will contract slightly simulating the feeling of a squeeze. It was found that the touch is similar to human touch, but there are still some notable differences. For example, human touch and its pressure is not evenly distributed, whilst this is the case for the prototype. Furthermore, the authors indicate that heat is also an important indicator for human touch, but

(A) Prototype squeezing upper arm [49]



(B) Motor input device [49]

FIGURE 3.1: Prototype proposed in [49]; the total prototype and the input component with the motor used to contract the band around the upper arm.

this is missing as well in the prototype. These differences make that the prototype is distinguishable from human touch. However, the participants do find it pleasant to receive such a mediated touch.

3.1.2 Stroking

There are also different prototypes that try to mimic the feeling of stroking. One of these prototypes is proposed in [20] where the authors created a 'tactile sleeve for social touch' (TaSSt). With the TaSSt, people can send touches by touching the device that is wrapped around their own forearm, see figure 3.2a. By stroking the sleeve a touch with a specific intensity can be send to the other person. The TaSSt was used to determine to what extent different sorts of touches could be communicated, from simple touches (poking and hitting) up to protracted touches (pressing and squeezing) and dynamic touches (rubbing and stroking). The authors found that their prototype was most useful in communicating simple and protracted touches, especially pressing and squeezing movements were identified accurately. Dynamic touches such as stroking were difficult to identify by the participant, this suggests that these specific movements are more difficult to generate in mediated touch. This research implicates that mediated touch is more suited to convey touches such as poking and squeezing than it is at stroking. This could be because it is more difficult to interpret dynamic touches and what the sender is trying to communicate with these touches.
In [8] two prototypes that could send and receive strokes over a distance were compared. One was designed to be able to fit in the hands organically and the other was designed to be placed on other body parts as well. In figure 3.2b the final prototype that can

(A) Prototype TassT [20]

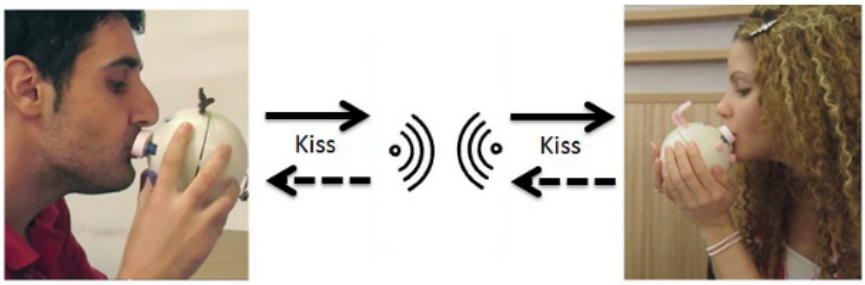
(B) Stroking device presented in [8]

FIGURE 3.2: Prototypes used to send stroking touches

fit in one's hand can be seen. They focused on the shape and feeling of the device, where they aimed at creating an organic prototype that feels natural to the user. This was also underlined by the participants, who preferred the presented prototype since it fitted well into their hand. They also reported that the output was more gentle and therefore also resembled a stroke more.

3.1.3 Kissing

There are also other forms of touching and intimacy that can be replicated over a distance, such as kissing. One such device is the Kissenger, which can be used to transmit a kiss between two people over a distance [40]. For this device, the shape and look of the prototype was especially important, since users would have to interact with the device in an intimate manner (kissing). Therefore, the material and the feeling of



(A) Overview of the Kissenger device [40]

(B) Overview of the updated Kissenger device [6]

FIGURE 3.3: Prototypes of two Kissenger devices

the lips also had to resemble human lips. This was done by using silicone rubber at room temperature, see figure 3.3a. For the Kissenger device to be used most effectively, the two people have to kiss at the same time, therefore an additional channel such as an audio or video connection is needed to communicate to each other about the right moment. Another version of the Kissenger is proposed in [6], which uses a more simple version that could be used together with an iPhone (see figure 3.3b). In this version, there are force sensors underneath the silicon rubber which can communicate the force of the lips to the other user. There was a positive effect found of this Kissenger device in couples in long distance relationships. The couples that used the Kissenger device where found to have an increase in relationship satisfaction and a decrease in stress levels [6]. However, this could be a result of the novelty effect as well. Something new is introduced in the relationship, and because of this novelty it is used more often and seen as something positive. The Kissenger was only used for a week, but it could be that if it was used for a longer period of time, this increase in relationship satisfaction will disappear.

3.1.4 Hugging

In [30] the authors aimed at creating a vest with inflatable compartments that could resemble the feeling of receiving a hug. This mediated touch should be unobtrusive, and to this extend they created a wearable vest that is not visible from the outside. The vest has small air compartments that can inflate when a touch is send, which gives a pressure sensation that resembles the feeling of receiving a hug. However, it was observed that participants would not use the prototype on a daily basis, they questioned the added value of such a device. The participants also highlighted the importance of interaction, where it would be possible to send touches back and forth instead of only one way, as in this case it was only possible to send or receive a touch.

3.1.5 Touch combined with video/audio

Research has also been done in combining remote touch with either audio or video aids. For example, in [31] an experiment was done to research whether a touch channel could enrich video conferences. The participants were placed in a video conference with a robotic hand under the screen (see figure 3.4a), they could shake the hand of this robot and their movement was then mirrored to the robotic hand of the person on the other side. They showed that mutually shared haptic feedback enhances the feeling of telepresence in video conferences. However, they also found that the visual way on how the handshake is presented also plays an important role. Interestingly, showing the hand of the presenter together with the robotic hand seemed to give rise to a duplication feeling which canceled out the effects previously mentioned.
In [41] the authors created a pair of gloves that could be used to feel the flexing of the fingers of the other person (see figure 3.4b). This means that if one person flexes their index finger, this can be felt on the index finger of the glove of the other person. The authors compared the use of their gloves in a video connection compared to an audio only connection. The video connection was preferred to the audio only connection, because the participants also wanted to see the facial expressions of their partner. Because the gloves are big and very present, the participants would not use it throughout the day, they preferred to use it at particular times, such as during a video call. Furthermore, it is a one-way prototype, meaning that it is only possible to receive or send touches, not both. As a result, there is less interaction possible between the sender and receiver.

3.2 Charateristics of mediated touch devices

A mediated social touch device has different characteristics and different aspects that need to be considered when designing a mediated touch device. As previously mentioned, there are different forms of touch, such as squeezing and hugging. Depending on the form of touch that is conveyed, there are also different possibilities for actuators, where one is more suitable than another. In this section, the different characteristics

(A) Prototype remote handshaking [31]

(B) Prototype Flex-n-Feel, left is the glove administrating a touch and on the right is the glove receiving the touch. [41]

FIGURE 3.4: Prototypes of devices used in combination with an audio or video connection

and aspects that need to be considered when designing a mediated touch device will be discussed.

3.2.1 Forms of touch

Prototypes that convey different sorts of touch have been discussed in section 3.1, such as squeezing, stroking and hugging. When designing a mediated touch device, it is important to consider what should be conveyed with the device; is it a more intimate way of touching such as kissing, or is it more general such as squeezing? Moreover, some forms of touch are more preferred by users than others. In a survey users were asked what kind of social touch interactions they were missing [38]. It was observed that between friends, respondents missed hugging as a social interaction or a form of greeting one another. When it comes to romantic partners, respondents missed more intimate touches such as cuddling. Dependent on the intention of the device, there are

different forms of touch that can be used to communicate emotions and this should be considered throughout the design process.

3.2.2 Sensors and actuators

Depending on the form of touch that is used, different mechanical components that can sense and translate the touch are used. On one side, sensors are used to sense the touch that is given and on the other side actuators are used to generate the output based on the input of the sensor. Which sensor and actuator are being used influences in which manner the touch is felt and how it is interpreted.

In the research done in [51] the authors used shape memory alloy (SMA) actuation to send and receive touches. SMA is a metal for which the shape changes when it is heated. As a result, it is possible to create very specific touches that can be send to the other person.
Force sensors are often used to sense whether pressure is being exerted onto the device. In [36] force sensors are used to sense whether a user is squeezing the device. At the receiving end, vibration motors were used to communicate this squeeze to the other person. In [41] flex sensors are used to measure the amount of bending that is happening in the fingers of the sender. The more a finger is bent, the higher the value of the flex sensor. For the receiving end, vibration motors are used as well to communicate the movement. Meaning that if a finger is bent on the sender side, the receiver will feel a vibration on that same finger. It is also possible to mimic the sensation of a squeeze, by using an actuator that can rotate and contract the mediated touch device, such as proposed in [49]. In the TaSST, Lycra pads filled with conductive wool are used to sense the force exerted when stroking [20]. This was done because they can detect change in forces easily and can be used as a wearable device. Furthermore, vibration motors are used as actuators well. The force of the vibration motors is also dependent on the amount of pressure that is exerted on the wool.

It is observed that within mediated touch, there is a great variety of sensors that are used to sense the specific touch that is given. However, when it comes to actuators that generate the touch, there is less variety. A vibration motor is most often used as the actuator that generates the touch on the receiving side. This is perhaps because vibrations generate a distinct reaction on the skin that is easily recognized by the receiver.

3.2.3 Body placement

Where a mediated touch device is placed is also important to consider during the design process. In [52] a design guideline for wearable technology is proposed and different factors that should be considered are put forward. This includes proxemics, weight distribution, body mechanics, movement and social acceptability. For a mediated touch

device, it is important to consider that both active and passive touch needs to be possible with the device. The vibration motors that are often used upon receiving a mediated touch, can be felt better on certain body locations. The glabrous skin of the hand and the forehead were found to be most susceptible to pain and touch [25]. Furthermore, to be able to send a mediated touch, there needs to be a form of active touch. For active touch, it is important that the device needs to be reachable and easy to find [52]. Because touching usually happens using a hand, it is important that the device can be reached through one's hand.

Furthermore, the social acceptability of the active and passive touch also needs to be considered. Giving and receiving a mediated touch might happen in a public area, where a third party might also witness the touch. If the mediated touch device is placed at areas that are less socially acceptable to be touched in public, uncomfortable social situations may arise. Therefore, it is important to consider the perceptions of the user and the third party observers when interacting with wearable technology [34]. In [34] six different locations were considered; wrist, forearm, collarbone, torso, waist and front pant pocket as placement for the wearable technology. The authors found that there appears to be a gender difference, where the use of the device was more accepted on and by males. Furthermore, they found that the wrist and the forearm were consistently rated positively. Meaning these areas were found the most neutral for these interactions.

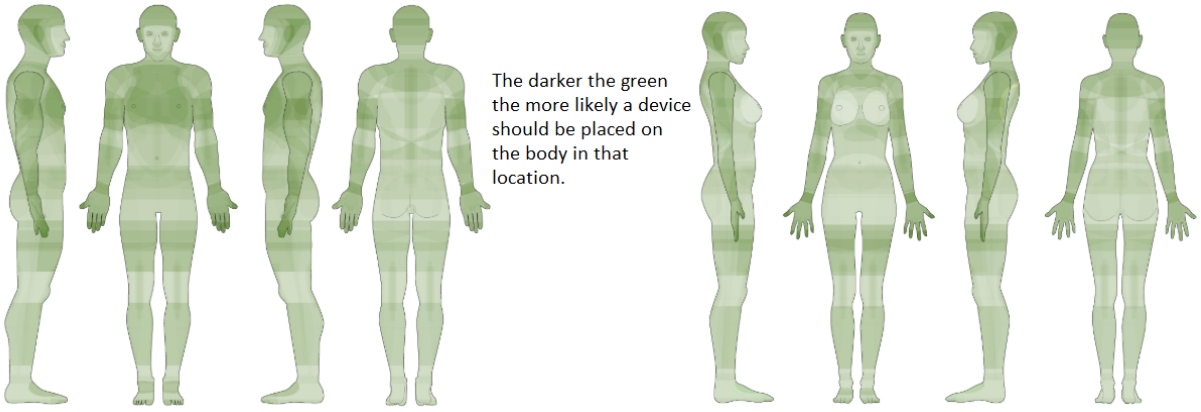


FIGURE 3.5: Most likely on-body locations for wearable technology if all considerations are weighted equally [52]

In figure 6, the most likely location for a wearable technology can be found. This includes, among others; the hand, wrist, forearm, upper arm, upper chest above the breast [52]. This is in line with the findings of [34], where the wrist and forearm were also rated the most positively.
It is also possible to not limit the touch to a certain body part. This was proposed in [8], where the authors created a device that could be held in the hand and used to send stroking sensation to the receiver. This design was not only limited to the hand,

but the device could be placed anywhere on the body to feel the receiving touch. As a result, the device can be used in a wide range of touches. However, participants also reported that as a result they viewed the mediated touch device as more private and were less likely to use it in public. Nonetheless, when designing for a mediated touch device, it is important to consider what the intentions are of the mediated touch device and how this can be translated to a suitable body placement.

3.2.4 Symmetry and synchronicity

In human social touch, two people are able to both give and receive touches, meaning that the touch is symmetrical. However, mediated touch does not have to be symmetrical. It is possible for one person to give a touch, without being able to receive a touch. One such example is the research done in [41], where the authors created a mediated touch glove. In this study, one person has a glove that is able to give touches, whilst the other has a glove that is only able to receive touches. However, this can be less desirable in a mediated touch device, because there is no interaction possible between the two parties.
Furthermore, a social touch is received at the same moment in time when it is given. Meaning that at the moment that someone is giving a touch, this is instantly felt by the receiver, therefore social touch is always synchronous. In mediated social touch however it is also possible for a touch to occur asynchronously. Then the touch is send at a certain point, but is felt by the receiver at a later point in time [19]. This means that it could be possible to store a touch and only give it to the receiver at a later point in time, for example when it is more welcome.

Chapter 4

Comparing mediated touch to social touch

Social touch has many characteristics and benefits that goes beyond the simplicity of a touch. It can be used to convey emotions and to enhance one's physiological well-being. But to what extent can mediated touch be used to achieve these same aspects? Is it possible that mediated touch elicits the same behaviour as social touch? Different studies aimed at comparing mediated touch to real social touch and have found mixed results. Some studies found that mediated touch has a similar effect as real touch, for example in the midas touch effect [15]. When it comes to affecting the emotional state of a person, a mediated touch seem to be different than a real social touch [10]. In this section, the similarities and differences between mediated and social touch are discussed and to what extent the properties of social touch can also be attributed to mediated touch.

4.1 Midas touch effect

The Midas touch effect is a phenomenon in social touch, where people are more inclined to help the other person after receiving a touch. It was found that a brief touch on the shoulder can help people with requests, such as getting a free bus ride [14]. This effect seems to exist for physical social touch, but studies have also been conducted to see to what extent this exists in mediated touch as well. A virtual Midas touch effect seems to exist, since in [15] the authors found similar behaviour with mediated touch compared to real touch. By using a tactile device, similar helping behaviour occurs when a mediated touch is given as when a real touch is given. This suggests that mediated touch has some similarity with social touch when it comes to the Midas touch effect. However, not all studies have found this same effect, when it comes to virtual agents the midas touch effect does not seem to work [21]. The authors studied the effect of a social touch by a virtual agent on the compliance during a negotiation. They found no evidence of a virtual midas touch effect, since the compliance did not increase. Moreover, if the virtual agent was perceived as untrustworthy, they were even

less compliant. This suggests that, at least for virtual touch, touch has no beneficial effect on compliance. There is however a difference between receiving a mediated touch and receiving a virtual touch from an avatar. Therefore, it remains difficult to compare these studies and their conclusions.

4.2 Convey emotions

Research has shown that social touch can be used to convey different types of emotions [18]. It was found that people were able to identify emotions such as anger, fear, disgust, love, gratitude and sympathy based on a touch on the shoulder. This is possible since these different emotions are associated with different types of touch. For example, sympathy is related to stroking and patting, whereas anger is associated with hitting and squeezing [18]. In a later study it was also found that happiness and sadness can also be identified based on one touch [17].
Different studies looked into mediated touch and whether this can be used to identify and convey emotions as well. For example in [3] the authors studied to what extent people were able to recognize emotions that were communicated via a force feedback joystick. The same types of touch that are used to identify social touch, were also present in mediated touch. In mediated touch, anger was seen as fast movement with a higher acceleration, whereas sadness was a slow and short movement. The valence and arousal of an emotion can also be communication via mediated touch [37]. The valence of an emotion is related to the level of pleasantness that is associated with that emotion. Whereas the arousal refers to the level of intensity, ranging from a calm or exciting emotion. A squeeze is a more direct way of touching and therefore better at communicating unpleasant and aroused intentions. This is in contrast to a stroke, which is more soft and better at communicating relaxed and pleasant intentions.
These studies suggests that when it comes to conveying emotions, mediated touch does share some of the characteristics as social touch. Since both can be used to correctly identify emotions. However, in [3] the comparison between a mediated touch handshake and a social touch handshake was also made, and it was found that the accuracy for a human handshake was higher than that of a mediated handshake. This suggests that although mediated touch can be used to accurately convey emotions, it is not as good as human touch.

4.3 Psychological well-being

Social touch can also be used to affect one's emotions [46] and to enhance our psychological well-being [7]. In [47] the authors studied the effect of remote touch on the emotional state of the participants when listening to a story. In one group, participants would listen to an emotional story while receiving a touch at certain points in time. This touch was administrated to their upper arm at points in the story that were

identified as highly emotional. In the second group, no touch was administrated. The authors found that mediated touch can reduce the sadness of a person significantly [47]. The mediated touch at these sad points in the story resulted that the effect of the story was amplified and therefore the touch had a soothing affect. However, the joviality of the participants did not increase, suggesting that increasing happiness does not work the same for mediated touch as reducing sadness. The same authors did a follow up study in [48], where they compared the occurrence of a mediated touch to that of a flash of light. They also studied whether knowing that the touch is actually given by a person instead of a machine also influences the connectedness towards the speaker. It was found that the group who was given a touch and were told that this touch was a result of the storyteller administrating the touch, was more emotionally involved and felt a higher sense of connectedness towards the speaker [48]. Both groups that knew the touch was given by a person showed a increase in joviality and a decrease in negative emotions. This suggests that knowing that a touch is given by a person has an influence on how the touch is received and can help influence the emotions of the receiver.
However, the study done in [10] did not find these positive effects on one's emotional state. In this study, people were asked to watch a sad clip to induce sadness, followed by a funny clip to evoke a recovery from sadness. They could signal another participant every time they felt the need to communicate something. In one group, participants were given a hand held mediated touch device and in the other group participants could press a button to communicate. They found that the recovery from sadness, the affective experience and the trust towards their partner did not differ between the two groups. Suggesting that in this case mediated touch had no effect on the emotional state of the users. These mixed results could be because of the different mediated touch devices that were used in [48] and [10], but it could also be that the stimuli presented evoked a different response. Furthermore, in [10] the participants were the one's administrating the mediated touch, whereas in [48] the participants received a mediated touch. This could also result in different findings, since giving a touch will evoke a different response than receiving a touch.

4.4 Temperature of the device

Different mediated touch prototypes also aimed at implementing a warmth component in their device, suggesting that this resembles social touch more closely than a cold device. In [31] a warmth component was implemented in a robotic hand used for handshaking to enhance the social presence. The participants responded positively to the warmth component and noted that this improved the feeling of being close. However, there are not many studies that have looked into this effect more closely. In [50], the authors aimed at verifying the positive effect warmth should have on the pleasantness of a mediated touch. They found no evidence that warmth has any effect on social cognition or their emotional state. This suggests that adding a warmth component to a mediated touch device can be useful, but it is probably not the same as social touch.

Chapter 5
Understanding the problem space

In this chapter the problem space surrounding intrusiveness in mediated touch was explored. First, a hands-on experience is necessary to gain insight into the workings of a mediated touch device. To this end, a test conducted by the author was done to explore the problems that can be encountered whilst wearing a mediated touch device. Consequently, an exploration with users was done in the form of a focus group. During this focus group, potential users explored the use of a mediated touch device and expressed their ideas for potential problems when using such a device.

5.1 Using the Hey Bracelet for an author self-test

To be able to gain first hand knowledge on how a mediated touch device is used in a daily life setting, a test day was conducted with the Hey bracelet (figure 5.1). The Hey bracelet is a mediated social touch device that can send touches over a distance. It is worn around the wrist and whenever one wants to send a touch to the person wearing the other bracelet, they can place their hand on the face of the bracelet. This will then send a touch to the other person. As a result, on the side of the receiver the Hey bracelet will contract slightly, giving the feeling of a squeeze around the wrist of the receiver. The Hey bracelet was chosen as a test device, because it is a ready to use mediated touch device and therefore no adjustments had to be made to be able to use it.

For this initial test, the author conducted a self-test together with her partner. During the day the two are separated, and could communicate via the Hey Bracelet and text messages. A detailed report on their thoughts during this day can be found in Appendix A. In the following sections, the observations that were made during this first test are discussed and the conclusions that can be drawn from these observations.

5.1.1 Observations

It was observed that in general the touch of the Hey bracelet feels pleasant. This is partly because the user is aware that the touch is given by the other person and not by

FIGURE 5.1: Pair of Hey bracelets

a stranger. It is a gentle reminder that the sender is thinking of the recipient and this gives a pleasant feeling. During the starting phase, it is interesting to test the limits of the device. For example, to see how many touches can be given at once. The touch can also be a wake-up call when the recipient is drifting away, to let them know that the other person is still out there. There are a few other positive things that were observed:

- It feels good: the touch is a reminder of the other person.
- If a touch is given, the recipient feels an urge to give a touch back.
- It can be a nice interruption from a daily task.

During the test it was observed that the touch given by the Hey bracelet is very present, it is hard to ignore the touch. This means that whenever a mediated touch occurs, the attention is immediately shifted towards the Hey bracelet. This is also because the motor inside the Hey bracelet is very loud. Other people that are in the vicinity of the recipient will also hear the Hey bracelet. Whenever a mediated touch occurs, the Hey bracelet is immediately present in the center of attention of the receiver. However this is not a choice of the person being touched, instead the person who is sending a touch is making this decision. This means that the person receiving a touch is not in control on whether or not they are touched.
There seems to be a lack of feedback on whether the touch was received or not. In the app that is connected to the Hey bracelet, a notification is given when the touch is sent to the other device. However, sometimes the touch was not received, but a notification was given that it was sent. This could be for example due to a communication error or because the other bracelet is not connected, but this is not communicated at all. This makes it difficult to determine whether the touch was indeed received by the other person. Some other problems that were observed are:

- Lack of feedback: It is not known how the other person reacted to the touch and whether or not the recipient liked the touch.
- No diversity in touch: There is only one touch possible, the squeezing of the bracelet. This makes it harder to convey emotions and to interpret the meaning of the touch.

- No diversity in placement: The Hey bracelet is worn around the wrist, which limits the use of touch.
- Technical issues: The battery life of the Hey bracelet is not optimal and different technical issues occurred during the test, such as not receiving a touch although it was correctly sent.

5.1.2 Conclusion self test

From these observations, it is possible to draw some conclusions on what the potential problems are in a mediated touch device.
Because the Hey bracelet uses a squeeze as a form a touch, there is no diversity possible in the touches that are given. As mentioned in section 2.1.1, there are different forms of touch. Currently, only simple touches are considered by the Hey bracelet. However, protacted touches or dynamic touches can communicate a more diverse range of emotions and might therefore be more suitable in a mediated touch device. Furthermore, an expectation patterns occurs when using the Hey bracelet. When a touch is sent, it is expected that a touch is sent back in return. However, the context of the other person upon receiving a touch is unknown. For example, what they were doing and with whom when the touch was received could make it more difficult to sent a touch back, but it is not possible to communicate this back to the sender. The sender can also not know whether the touch was actually received, since there is no notification that the touch was successfully received by the other person. This could lead to a miscommunication between sender and receiver.

As previously mentioned, it was observed that the person who is receiving a touch cannot decline this touch. This lack of mutual consent could lead to a form of intrusiveness from the mediated touch device. Because there is no way of communicating the context a user is currently in, the touch could lead to a disruption or interruption and can even be unwanted. The only way to avoid a mediated touch would be to physically take off the Hey bracelet. Even in that case, there is still no way to communicate this to the person on the other side. This was such a notable problem within mediated touch devices, that it was decided to explore this further by conducting a focus group to gain more knowledge from other users.

5.2 Focus group

During the design process, the thoughts and views of the potential users should be considered. To gain more insights into the experiences of the user of a mediated touch device, a focus group was set up. The method of focus groups was selected to gain a broad insight into the thoughts of potential users. During this focus group, it was important to investigate which problems these users could identify when using a mediated touch device.

5.2.1 Methodology

The topic of the focus group was centered around the following question:

How do users experience the possibility of intrusiveness in the use of the Hey bracelet?

Since many users had never encountered a mediated touch device before, it was important for them to gain hands-on experience with such a device. To this end, the Hey bracelet (figure 5.1) was used during the focus group. The participants were paired up with someone they were already familiar with and each participant received a Hey bracelet for the duration of the session. They could give one another mediated touches throughout the duration of the focus group.

Two focus groups were held in total. However, due to COVID-19 restrictions one focus group was held online via Microsoft Teams. This resulted in a incomplete focus group, since a lot of technical difficulties made it difficult to complete the focus group. Participants were recruited via the social network of the researcher. Prior to conducting the focus group, ethical approval was obtained via the ethical committee of the University of Twente. Participants had to sign a consent form prior to participating in the focus group. The questions of the focus group can be found in appendix X.
None of the participants had any prior experience with using a mediated touch device. Therefore, they were given some time at the beginning of the focus group to use the device with their partner to see how they would react to it. First, some questions were asked about their general feeling and opinion of the mediated touch device. Secondly, the potential problems were explored, especially related to intrusiveness. The researcher acted as moderator during the sessions. The duration of the focus group was approximately 45 minutes.

5.2.2 Results

In this section, a summary of the points made during the focus group will be provided. A complete walk-through of the focus group can be found in appendix B. During the focus group, participants were asked on how they perceived the Hey bracelet and how they experienced giving and the receiving of touches. It was noted that this was an exciting way of communicating with one another but it lacks the variety of the types of touch that human touch provides. For the Hey bracelet there is only one sort of touch that can be given and it was noted that this is not enough to fully communicate emotions and intentions through the Hey bracelet. Furthermore, participants also noted that it could be exhaustive since there is an expectation pattern that occurs whilst wearing such a device:

If I send one touch and get nothing back then it is okay, but then I would touch again and if I get nothing back again then I would wonder if there is something up"

There were also different situations explored in which a touch could be inconvenient. For example, when the recipient is in an important meeting. Participants noted that they would be distracted if they would receive a touch at a moment that is not convenient. When participants were asked how they would tackle these situations, different solutions were proposed. One solution put forward was to warn the recipient with a voice originating from the device. However, this idea was not received well by other participants. Another participant suggested the following idea:

"If you would send the other a touch, but the other is busy, you get a light or message back saying that it is not possible"

Furthermore, it was noted that at the moment of sending a touch, participants would not consider the situation of the receiver.

5.2.3 Conclusion focus group

From this focus group, it became clear that a number of issues could be improved in the Hey bracelet. This relates not only to the technical problems but also to the sorts of touches that are given. The issues that were raised by the focus group can be categorized as follow:
- Lack of variety of types of touch.
- Unease when no touch is given in return.
- Intrusiveness in situations when you are busy.
- Intrusiveness in situations where you are in your private space.
- Sender does not want to consider the context of the receiver.

As to how to solve this intrusiveness problem, the opinions differ. Most participants agree that it should be a minimalist approach, with for example lights. Warning someone with a voice was also suggested, but other note this is too loud and it would startle someone. Then, the warning would become intrusive instead of the touch itself. There should be some sort of warning or indication but it should not be louder than the touch itself. These design aspects should be taken into account during the design process.

In conclusion, the focus group supports the hypothesis that using a mediated touch device could lead to a feeling of intrusiveness. They have put forward some possible solutions, such as using lights or signs to indicate whether someone is available or not. As a result, the recipient of the mediated touch can choose whether or not to receive the mediated touch at that point in time.

Chapter 6
Intrusiveness

Based on the exploration of the problem space, the notion of an intrusive touch is put forward. Within mediated touch there is a possibility for intrusiveness, this is because a touch is not always expected by the recipient. It could be that the recipient is occupied with another task and therefore the touch can be disruptive. It is also possible that the recipient is surprised by a touch since that person was not expecting to receive a touch at that point in time. Within human social touch there is also a possibility for intrusiveness. For example, when a touch was not expected by the recipient. However, in social touch there is also a possibility to reject the touch when it is not wanted, this is more difficult in mediated touch. Within human social touch the recipient sees that the sender is initializing a touch and he or she could deny this touch either verbally or non verbally. This initialisation phase is not that apparent in mediated touch, since the recipient and sender are not physically together.
In this chapter, an understanding of intrusiveness in mediated touch will be formed. Within mediated social touch, there is no literature on intrusiveness and therefore it is difficult to provide a clear definition. To this end, other fields were explored to see how they define intrusiveness. Based on this understanding, a clear definition for intrusiveness within the context of mediated touch can be formed.

6.1 Defining intrusiveness

Intrusiveness generally refers to a behaviour or state that is undesired by the recipient and causes disruption or annoyance [11]. Intrusive behaviour is typically unwelcome or uninvited and the recipient may feel that the intruder is invading their personal space. To gain a clear understanding of what intrusive behaviour entails, different fields have been examined and different definitions have been explored. These definitions can then be used to gain a clear understanding of intrusiveness within the context of mediated touch.

6.1.1 Intrusiveness in psychology

One definition of intrusiveness is provided in psychological literature, in interactions between mothers with depression and their infants [11]. In this situation, intrusive behaviour is defined as nonverbal actions executed regardless of the behaviour of the infant and as a result violating the autonomy of the infant [11]. Interrupting a self-initiated action by the infant to force another action upon this infant can be viewed as intrusive behaviour from the mother. This definition suggests that intrusive behaviour comprises of forcing one action on the recipient above their own chosen action. Thus, the independence of the recipient is removed.
Another definition can be found within the relational framework between families and their adolescents [4]. For this proposed Family Intrusiveness Scale, the amount of intrusiveness is defined as "the adolescents perception of the legitimacy of family members' involvement in their lives" [4]. If an action from a family member is seen as legitimate by the adolescent (the recipient), then it is not intrusive. However, if the adolescent beliefs that the action is not legitimate, then the behaviour becomes intrusive. This definition suggests that how intrusive a behaviour is, depends on how the recipient perceives the action. Furthermore, it is also possible for an action to be viewed at one point in time as intrusive, but at another point it may be not as intrusive, because the recipient beliefs that it is now justified.

6.1.2 Intrusiveness in applications

An application or advertisement can also become intrusive. In [42] the perceived intrusiveness of users when using an AR app was measured and the effect this has on the persuasiveness of the app. In this research, the perceived intrusiveness is defined as a feeling of annoyance or irritation towards a certain media or advertisement. When the user is interrupted by a commercial break, this commercial can cause annoyance and therefore the perceived intrusiveness of the advertisement is enhanced [22]. Whenever advertising becomes too personal, this can also evoke feelings of intrusiveness. This could also happen in the case of augmented reality, where users provide camera access and expose a lot of personal information.
This feeling of intrusiveness can cause annoyance or disturbance and results in an unpleasant feeling when using the application. This can in turn negatively effect consumer reactions towards the application.

This definition suggests that the intrusiveness is caused by the intruder, who enforces their content on to the recipient. The feeling of intrusiveness evoked in the recipient becomes apparent since they are forced to undergo the action that is inserted by the sender.

6.2 Intrusiveness in mediated touch

These different definitions suggest that whether a behaviour is perceived as intrusive, depends on how the receiver views the action and whether they believe this action is legitimate. The receiver's perspective is leading on whether the behaviour is intrusive or not. Thus, when defining intrusive behaviour in mediated touch, the perception of the receiver should be the main focal point. If the receiver beliefs that the sender is violating their personal space, this should be enough to view a touch as intrusive. The context in which a mediated touch is given also plays a role in determining whether or not a touch is viewed as intrusive. It is important to consider what the recipient is doing whilst they receive a mediated touch. If that is an inconvenient moment, the touch will be also inconvenient. Furthermore, the same touch could be intrusive in one moment, but in the next moment it might not be intrusive anymore.
In conclusion an intrusive touch can be defined as a touch that, in a given context, is perceived by the receiver as inconvenient. The given touch violates what the receiver beliefs should be the action of the sender, since the receiver does not want to receive a touch at that point in time.

6.2.1 When does an intrusive mediated touch occur?

Whether a mediated touch is viewed as intrusive depends on the context surrounding the touch. To be able to see when exactly an intrusive touch occurs, a set of user scenarios were created. A user scenario is a story to understand how a user interacts with a system or product [32]. This was done to understand the actions and needs of the user. In this case, these user scenarios were used to see in which cases a mediated touch could be intrusive and what could be the consequence of an intrusive touch. The scenarios were also used to gain insight into the context of the recipient surrounding a touch. At the end of the design process, the prototype could be employed on these user scenarios to see if it would indeed solve the problem proposed in that scenario. A total of 15 scenarios were described that highlight different situations in which a mediated touch was received but it was not convenient for the user. Two examples will be highlighted in this section, the other scenarios can be found in appendix C. During one scenario, the recipient is in a meeting:

Scenario 5; Office - in a meeting
David is working at the office and has a meeting with the whole team. During the meeting, David has to give a pitch regarding his topic. While he is giving the presentation, he receives a touch from the bracelet. The noise is quite loud and distracting. As a result, not only David is distracted and does not know what to say next, but everyone is able to hear the bracelet. David feels embarrassed and distracted, because now everyone has heard the bracelet.

Another example is where the recipient is working on a task that requires precision and concentration. The mediated touch could surprise the recipient, which could have consequences for the task he or she is carrying out:

Scenario 9 - Home - focus task
David is at home working with great concentration on repairing his game console. He is soldering two parts together, which requires a lot of focus and precision. Right at that moment he receives a mediated touch from Anna. As a result, his hand is out of balance.

6.2.2 Conclusions of user scenario

All these scenarios are examples of a situation where a mediated touch occurs, but it is perceived as inconvenient by the receiver. If it was up to the receiver, then that touch would not have been given at that point in time. There are different reasons for why this mediated touch is perceived as intrusive, some reasons were identified by using the user scenarios. These include the following: the recipient is occupied with another task; the moment for mediated touch is inconvenient; receiving a mediated touch can be embarrassing; focus is needed thus a distraction is dangerous; the recipient is emotionally unavailable and the use of the mediated touch device is not suited for public.
This suggests that there are multiple reasons for why a mediated touch can be intrusive. For example, whenever the recipient is occupied in a task that demands concentration and precision, such as soldering, the touch be distracting. This could lead to frustration, wish could in turn be projected onto the sender, but they were not aware of the context of the recipient and could not know that a touch was inconvenient. It could also be the case that the recipient is enjoying themselves and does not want to be disturbed, for example whenever they are reading a book or watching a movie. However, in these situations the need of the recipient could also be the opposite; where a touch is wanted for emotional support.
This means that there are multiple reasons why a mediated touch can be intrusive and it is not likely that there is one universal solution for these situations. Therefore, it is important to keep the context of users in mind when designing for intrusiveness in mediated touch. In the next sections, this definition of intrusiveness will be used to design a wearable prototype that implements different possible solutions to reduce the possibility of an intrusive touch.

Chapter 7
Methodology

In this chapter the design process that was undertaken to create a prototype will be discussed. In this chapter the following sub question will be answered:

sub-RQ 2: How to design a mediated touch device that can reduce the possibility for intrusive mediated touches?

7.1 Solution generation

To be able to generate a number of solutions, a process of creative design thinking is followed. To guide this process, the design process for creative technology as proposed in [24] was used. During the design process, a combination of divergent-convergent thinking and spiral models was used. Divergent thinking is the concept of intuitive, associative and creative thinking, whereas convergent thinking is a reflective process in which ideas are narrowed down [13]. By first applying divergent thinking, it is important to think wide and creatively, spitting out many solutions without thinking about their implementation. Only after this process, the ideas are evaluated on their usability and possible implementation.
When using divergent thinking, it is proposed to focus on analog methods over digital methods, since digital methods could lead to more convergent thinking [12].

For the purpose of generating solutions, different strategies were employed to stimulate creative thinking. For example, it was proposed to think about the use of the five senses in a prototype (touch, sight, hearing, smell and taste). Furthermore, to stimulate the creative process it was also considered to think about how a design could be the most intrusive to a user and use this to generate a possible solution. Even solutions that do not seem realistic in the first place can potentially lead to new ideas in a later phase. A number of solutions were generated by the researcher, all these ideas can be found in the mind map in appendix D and the table in appendix E.

7.1.1 Categorizing solutions

The next step was to categorize these ideas to see which of these solutions can be grouped together. To create an overview of all the solutions, a mind map was created, see appendix D. In this mind map, a bracelet is depicted where each part of the bracelet symbolizes a category. The solutions start from the center and fade to the rest of the mind map. With all solutions clearly written down and categorized, they were narrowed down. First, the ideas that were not realistic and were not believed to be a feasible idea where removed. This was done by making an overview of all solutions in a table and write down to what extent this solution was seen as a good idea and whether or not it was realistic. In appendix E an overview of all the solutions can be found.
All the solutions were color coded using red, green and yellow. If a solution was either not realistic or not a good idea, the row was marked red. This meant that it was not a feasible idea and it would not be explored further. If a solution was both a good idea and realistic then the row is marked green. Suggesting that these ideas have the most potential for further development. If the columns were a combination of maybe and yes then that row was marked yellow. These yellow rows could have potential, but there could be some future problems. For the next phase both the yellow and green ideas were extracted and the red solutions were removed. The ideas that will be explored further can be found in appendix F.

7.2 Convergence in solutions

With a number of possible solutions presented, each solution was carefully considered to what extent it would be a possible implementation. During this convergence phase, solutions were eliminated if they failed to meet the design requirements [23]. It was decided that the mediated touch device that would be created, would take the shape of a wearable device. This also meant that the solutions suggested needs to fit into a wearable. Furthermore, the prototype should be usable in a real life setting. Meaning that a user can wear the device whilst doing other activities at home. This is an important aspect since the user test centers around the possibility of intrusive touches. If a user is actively engaged with the prototype throughout the duration of the experiment, the receiving of a touch will be experienced differently than if the user is also engaged with other tasks. Based on these design considerations, different criteria were drawn up to which a solution needs to adhere to. In this section, the criteria will be discussed and the solutions that were eliminated as a result of these criteria.

Solution needs to directly tackle the problem of intrusiveness
Some solutions that were proposed do not directly tackle the possibility of an intrusive touch. For example, it would be interesting to use biosensors to gain more information on the recipient. However, these indications alone are not enough to determine whether or not a touch should be given. If the heart rate of the recipient is high, would this

mean that the touch should be given or not? Other indication factors will be necessary to make an informed decision. As a result, the following ideas were removed:
- Biosensors that can measure heart rate and stress level to decide whether or not a touch can be given.
- checking the intensity of a touch prior to sending it
- Using a silent mode of touch; in silent mode the touch is softer and less present
- Covering of the display of the device to reduce distraction.
- Remove the mediated touch device from your body.
- Save different sorts of touch in a library to signal intention or meaning; a long touch means 'I am busy'
- Use voice control in the device that listens for a code word to switch your status

Prototype needs to be a wearable device that can be comfortable worn whilst doing other activities
If the device would solely be used to give touches actively, then there is probably no intrusiveness since users are constantly actively giving touches whilst wearing the device. It is desirable that a user can also do other activities whilst wearing the device. The following solutions were dropped:
- Warning in which the device inflates itself prior to an incoming touch.

Quick interaction is wanted; it should be easy to give a touch
The user should be able to quickly send a touch whenever they want without having to go to a large procedure beforehand. It is difficult to determine how quickly this should be, but giving a touch should not be more than one or two seconds. Therefore, the following ideas were removed:
- Mutual acceptance is needed prior to giving a touch
- 'password' that both users need to enter correctly to give and receive a touch.
-Warning before a touch, in which a voice asks if you want to accept or decline the touch.

Touch experience should be dynamic; several moments that can be used to give a touch
The device is used whilst also doing other activities. Therefore, the touch can be given at small breaks between tasks for example. If long time intervals are blocked without a possibility to lift this block temporarily then these small moments cannot be used to give a touch. The following solutions were removed:
- Set preferences at the beginning of a day for which time frame a touch is allowed

Solution resembles other (better) solution
Some solutions resemble each other. In those caes, the solutions were compared and considered which of these solutions would make a better fit. This applies to the following solutions, thus they were removed:
- 'not present' button that can be pressed when the recipient does not want to receive

a touch.
- Multiple options for the intensity of a touch.
- Voice that warns the recipient prior to an incoming touch.

All the solutions from appendix F that were seen as potential solutions were considered to what extent they met the above mentioned criteria. The solutions that were removed based on a specific criteria were mentioned above. As a result, the remaining solution do adhere to all the design criteria and could therefore be used as potential solutions. When removing the prior mentioned solutions based on the criteria, a set of six possible solutions remained. The following six solutions will be considered further:

1. Touch is send to a voicemail, which can be played by the recipient whenever they choose (asynchronous communication)
2. Prior to a touch a small vibration will warn the user of the incoming touch
3. Prior to a touch, the warmth of the device will increase, to warn the user of the incoming touch
4. Device connects to the online calendar of the user and blocks touches whenever something is planned in the calendar
5. User is able to set their corresponding status on either available or unavailable.
6. User is able to snooze an incoming touch. Meaning that if they press a button, the touch is not played but instead snoozed and repeated after an x amount of time.

7.3 From informal solution towards a formalisation

To be able to visualize how these solutions would fare in a system, a set of protocols were created. A protocol is a set of rules that determines how a program should behave. By generating a protocol for each solution, it is possible to create an overview of how this solution works in practice and whether there would be any problems with implementing this solution. With these protocols, the solution is formalized such that it can be implemented in a later stage. Two protocols are described below using the examples of Alice and Bob, the other four can be found in appendix G.

C5: Colour coding status on screen *1. Setting the status:*

1. If Bob is available for touching; he sets his status to available by pressing a button on the device.
   (a) Alice will see the status of Bob on a LED display, it shows that his status is green. This means that Bob is available and Alice can send him a touch.

2. If Bob is not available for touching; he sets his status to unavailable by pressing a button on the device.

   (a) Alice will see the status of Bob on a LED display, it shows that his status is red. This means that Bob is not available and Alice cannot send a touch to Bob.

2. Sending a touch:

1. Alice wants to send a touch to Bob
2. Alice checks her display screen to see the status of Bob
3. If the status screen is green, Alice can send a touch to Bob
4. If the status screen is red, Alice is not able to send a touch to B.

C6: Snooze button for incoming touch

1. Alice wants to send a touch to Bob
2. Alice touches her device such that a touch is send
3. The device of Bob receives the signal that a touch is received
4. The device will do one of the defined warning functions (warmth/pre-vibration/LED button)
5. Bob will feel the warning function and can decide whether or not to accept the touch
   (a) If Bob does not want to feel the touch, he can press a snooze button
   (b) If Bob wants to feel the touch, he does nothing
6. If the touch is snoozed, it will be repeated in an x amount of time

With these protocols a clear description of each solution is formed. In the next section it is possible to implement these functions immediately based on their corresponding protocols.

Chapter 8
Creation of first prototype

The concept of each solution has been formalised to such a degree that the design and production of the prototype can be implemented. First, a set of requirements and design considerations will be put forward. With these requirements in mind, an initial design was set up and the solutions were implemented using Arduino. In this section, the process from initial requirements to the production of the first prototype will be described.

8.1 Design requirements

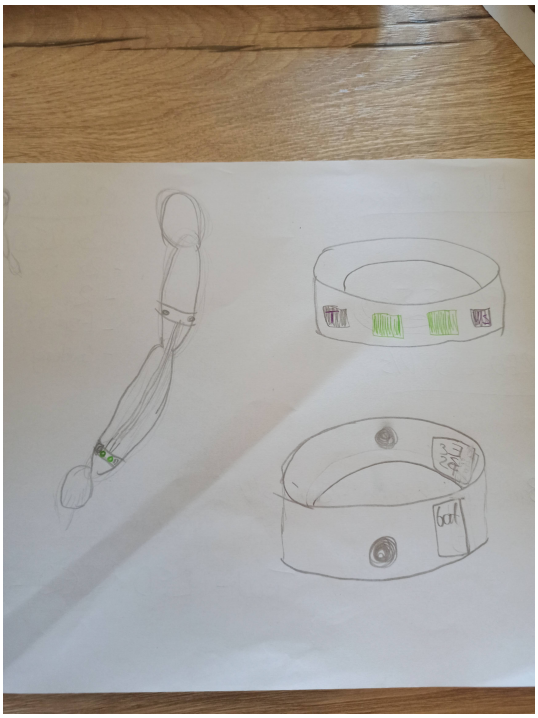
One of the criteria that was put forward during an earlier stage was that the wearable device should allow users to partake in other activities as well. This requirement needs to be taken into account for the design of the prototype as well. Meaning that the device should be robust. Some other requirements that will be necessary to guarantee the workings of the solutions are the following:

1. The wearable should contain lights to be able to display the status
2. These lights should be easily visible by the user
3. A touch sensation needs to occur when receiving a touch
4. Touch sensors need to be easily reachable
5. Wearable should be robust
6. Wearable should be easily removable without additional help

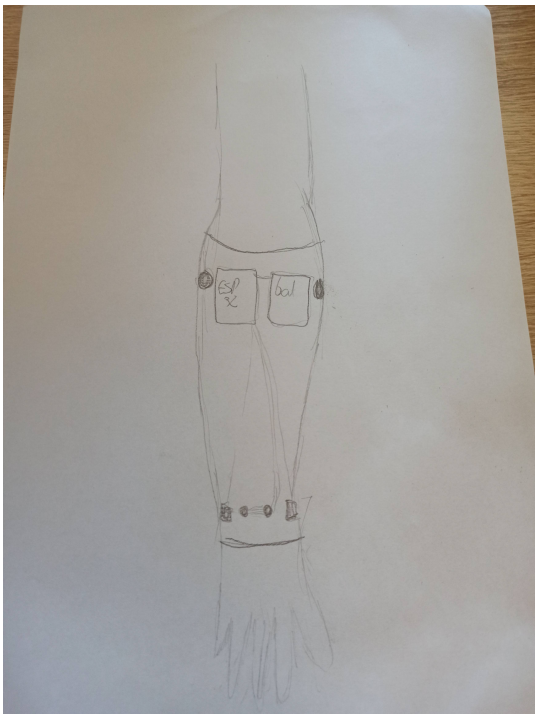
8.1.1 Body location

A mediated touch device can be worn on all different sorts of body locations. In section 3.2.3, the most likely body location of a wearable was discussed and the body locations that were found are: the hand, wrist, forearm, upper arm and upper chest above the breast. Therefore, the body location of the prototype was chosen between these options. Based on the requirement that the LED lights should be easily visible and the touch sensors need to be easily reached, it was decided to use the wrist to display the LED

lights and the touch sensors. However, the location of the vibration motors could be



(A) First sketch for using upperarm



(B) First sketch using sleeve

FIGURE 8.1: Initial sketches for prototype design

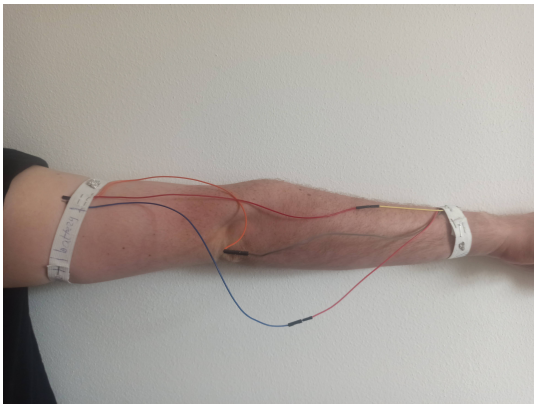
different, for example the upper arm. To display the different options for the placing of the prototype, several drawings of a potential prototype were made, see figure 8.1a and figure 8.1b. As a result, there were to two options for a prototype:

1. Use both the upper arm and the wrist. In this case, the upper arm contains the vibration motors, the EPS32 and the battery. Whereas the wrist is used for the LED lights and the touch sensors

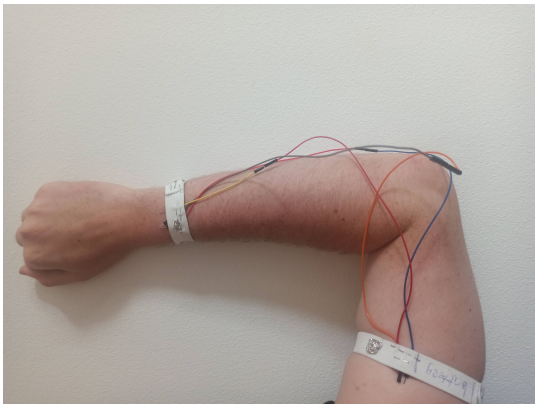
2. Use the wrist and forearm to create a sleeve. In this case, the wrist is used to display the LED lights and the touch sensors. The upper part of the forearm is used for the vibration motors, the ESP32 and the battery

A potential challenge for option one is that the wires between the upper arm and the wrist run across the entire arm. This could lead to a reduction in wearability, since the movements of the user are restricted. To figure out to what extent this design would be problematic, a series of self tests was run with a mock up design. This mock up design was made with two elastic bands around the wrist and the upper arm and connecting them with wires, see figure 8.2
It was observed that the movements of the users could lead to damage of the wires and thus the prototype. By using different wires with a variety in lengths, it was observed

that the length of the wire should not be too long when the arm is stretched. But on the other hand, when the arm is bent all the wires will curl. It would be very easy for the wires to get hooked by an object, since there will be always some space between the wire and the arm. Therefore, this design was not practical for this prototype and it was chosen to use option 2. In this option a sleeve will be created such that all the components are on one part of the body.



(A) Arm is stretched



(B) Arm is bent

FIGURE 8.2: Design option with band around the upper arm. Different length of wires were used to see how this would effect wearability

8.2 Hardware components

To create a wearable device, different hardware components had to be integrated into one device. To generate a touch sensation, it was decided to use coin vibration motors since these are light-weighted and easily integrated into a wearable. Furthermore, Adafruit Neonpixels were used as LED lights, since these are light-weight LED lights that are easily controlled. The other hardware components that were used are the following:

Microcontroller; Huzzah feather ESP32 with Wifi connection - The microcontroller is used to govern the process between the input and output. It consists of a processor, a memory and different in- and output nodes to which other components can be connected to.

LiPo Battery - The microcontroller needs to have sufficient power to work for multiple hours a day. A LiPo battery of 2500 mAh was used for this purpose.

Capacitive touch sensor - Two capacitive touch sensors are connected to the ESP32. These touch sensors can sense variations in anything that holds electrical charge. For

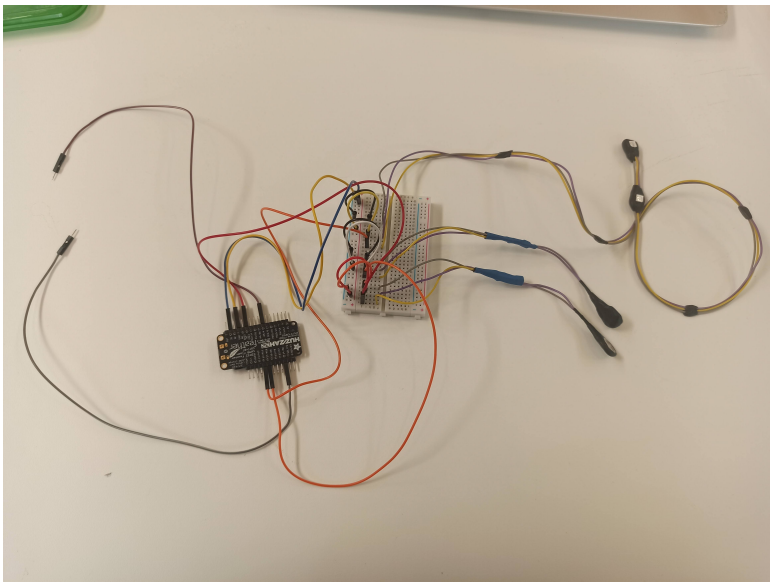
this prototype, they will be used to sense whether or not they are touched by the finger of the user.

Neopixel RGB LED lights - Two single LED lights are used. They can be used to show any predefined RGB color.

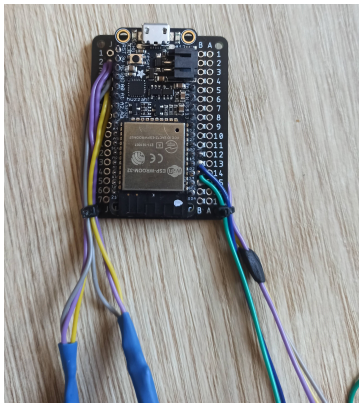
Vibration motors - Two vibration motor coins were used to generate a touch sensation.

8.2.1 Hardware integration

To get a clear idea of the circuit of the hardware, a breadboard was used to test different connections, see figure 8.3a. The pin out reference of the ESP32 was consulted to make sure that all the components were attached to a correct pin [2]. Once the program worked on the breadboard, it was possible to solder the ESP32 on a soldable breadboard such that the wires could be soldered to this breadboard, see figure 8.3b.



(A) Breadboard setup



(B) ESP32 attached to soldable breadboard

FIGURE 8.3: Set up of hardware components

8.3 Realisation of the first prototype

With the hardware integrated, the software and the physical appearance of the sleeve had to be designed as well. In this section the first the software implementation will be discussed. Then, the initial design and creation of the first prototype will be presented.

Based on section 7.2 there were six possible solutions. However, during the integration of the software it was found that not all six solutions were feasible. Integrating warmth into the device was perceived as difficult in a wearable, since it brings more risks associated with overheating and it is difficult to remove the heat afterwards. Furthermore, a small vibration prior to the touch was tested and found to be the same as experiencing the touch itself. Lastly, connecting the device to the online calendar of the user was proposed as infeasible for this user test. Since it required participants to use an online calendar and give access to this as well. Therefore, the following three solutions were implemented into the device and will be discussed in the following section:

1. Touch is send to a voicemail, which can be played by the recipient whenever they choose (asynchronous communication)
2. User is able to set their corresponding status on either available or unavailable.
3. User is able to snooze an incoming touch. Meaning that if they press a button, the touch is not played but instead snoozed and repeated after an x amount of time.

8.3.1 MQTT protocol

In order to send information between two sleeves, a protocol needs to be set up. The Message Queuing Telemetry Transport (MQTT) protocol was chosen since this is a lightweight protocol that is prominently used on different IOT devices [43]. The concept of a MQTT protocol is that a device does not have to check all the incoming information, but instead it uses a broker and specified topics to filter out important information. All the information is published to a specific topic located on a broker. The broker keeps a list of devices that are subscribed to this topic. If there is any new information published to the topic, the broker will send this information to all the devices that are subscribed.

For the purpose of this research, the MQTT protocol is used to send the touch value obtained via the touch sensor to the other device. For example, in device A the touch sensor is pressed and therefore this touch value changes from high to low. The touch value will be published to the broker on the selected topic. If a value is published on this topic, the device that is subscribed to this topic will be notified. In this example, device B will be notified of the touch value of A such that he can act accordingly. An overview of this interaction can be found in figure 8.4. The MQTT broker provided by the university of Twente was used throughout this research.

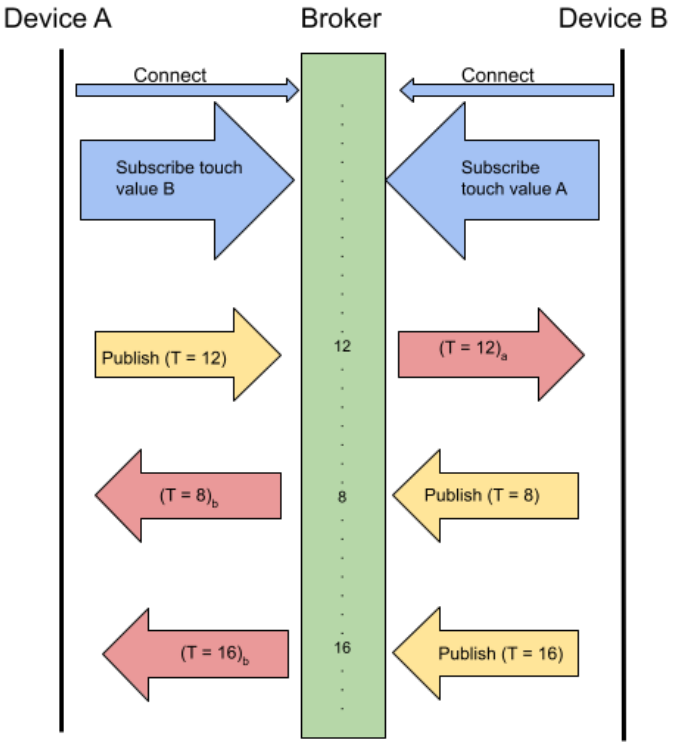


FIGURE 8.4: Overview of MQTT protocol interaction

8.3.2 Implementation of each solution

For each solution, a different code was set up. In a later stage, these codes will be combined such that they can work in one program. There are four possible modes, three solutions and one base line. The three proposed solutions are; status solution, snooze solution and voicemail solution.

Normal solution

This is the base case, a scenario where the users can give touches back and forth, once a touch is sent it will also be experienced by the receiver.
The program will listen for incoming touches on the touch sensor. If the touch value of the touch sensor is below the threshold previously specified, this means that a touch is given on the touch sensor. This value is consequently published through the MQTT protocol to the broker. The program will listen for incoming information on the subscribed topic. If a value is published to the subscribed topic, the other device has registered a touch on the touch sensor and thus a touch has to be given. This is done by vibrating the vibration motors for some seconds.

Status solution

In this solution, the device has to publish the touch value to the MQTT and listen for incoming touches, as previously explained. Besides the basic format, there is also a possibility to set your status to unavailable, in that case a touch cannot be given. Before the touch is published to the MQTT, the status of the other person is checked. If the other person is not available, the touch is not published to the MQTT.
This means that the device has to listen to the touch sensor of the status switch as well. If the status switch is pressed, the status has to be switched. Meaning that if the status is available it needs to become unavailable and vice versa. Consequently, the updated status is published to the MQTT to inform the second device.
Furthermore, the device is also subscribed to the status of the other person. If a touch has come in through the status topic, the status of the other person has to be switched.

Snooze solution

For this solution, the timing of several aspects is of great importance. Once the touch sensor of one device is pressed, this value has to be published to the broker. If the touch signal is obtained by the receiver, a warning loop starts to warn the receiver that a touch is incoming. If the snooze touch sensor is pressed within this warning time, then the touch is not given and it is snoozed for some minutes. However, if nothing happens on the touch sensor then the touch should be given.

Initially, the solution was to use either a pre vibration warning or an increase in warmth for the device as warning. However, both solutions were not suitable. The increase in vibration would lead to a disruptive feeling as well and is therefore viewed the same as a touch. There would be no use in snoozing the touch, since the receiver is already experiencing a similar touch. Using warmth would be an interesting alternative, but it seemed not feasible in this project. This is partly because reducing heat afterwards is a difficult issue. Especially in a closed wearable this could lead to problems. Therefore, it was decided to use the LED light to signal the warning sign. The LED light blinks for 5 seconds to warn the user before a touch is given.

Using millis instead of delay()

Since several functions require a delay, it is important to time these correctly. Arduino has a function called delay(), which could be used to let the program wait for a reaction in the snooze scenario. However, delay() stops your program for the specified amount of seconds. Meaning that nothing can be run simultaneously, if a touch would come in during this delay then it would not be registered. Therefore, the alternative millis() function was used. This millis() function returns the amount of seconds since the program has been booted up. It uses the integrated timer module that is used in the ESP32. This can in turn be used to make a timer.
In the snooze solution, the millis() function is for example used whenever a touch is

snoozed. If a touch is snoozed, a timer starts to determine when 3 minutes have elapsed. Once the 3 minutes are over, the touch is given.

Voicemail solution

In the scenario of a voicemail, a touch is not given immediately but instead sent to a voicemail. The principle of giving and receiving touches is the same as previous solutions. However, if a touch is received on the corresponding subscription, a voicemail value will be increased and the LED light will turn green, informing the user that a voicemail is waiting. If the users touches the voicemail sensor, all the touches that were waiting are played.

Combining solutions using web server

The user experiences all the different solutions one by one and they need to be able to initialize these different modes. In order to let a user independently use the prototype, an online solution was sought. Such that a user could go to a web browser and enter the specified mode. Consequently, the program can act on this change by switching between modes.

To achieve this, the web server of the ESP32 was used. This web server can be accessed from any device that is on the same local network by typing in the IP address of the ESP32 in a browser. It uses HTTP to send information between the user and the server. An example of using the webserver for receiving inputs was obtained from [1]. When a user types the IP address of the ESP32, the ESP32 receives an HTTP request and it responds with the predefined website. On this website, the user is able to type in a word (the mode that is desired) and press submit. Once the word is submitted a HTTP get request is initiated, and the word will be saved in a variable. This variable is then stored on the SPIFFS (SPI Flash File Storage) system of the ESP32. This system acts as a memory card for the ESP32. Thus, when the system reboots the input on the SPIFFS remains. This can be very useful since a user does not have to initiate a mode repeatedly if the system fails.

8.3.3 Making of wearable sleeve

In this section, the production of the first prototype is discussed. Since the prototype contains a battery, it is important to choose a fabric that is not flammable. Furthermore, the sleeve needs to be worn for multiple hours a day, thus it should be comfortable as well. A soft cotton fabric was chosen since this meets both requirements.

To be able to meet the requirements set in the beginning of the chapter, it was important to put the LED lights and the touch sensors near the wrist and the vibration motors at the opposite side of the forearm. Since the microcontroller and the battery should be in a practical place, they were also placed at the end of the forearm, near the

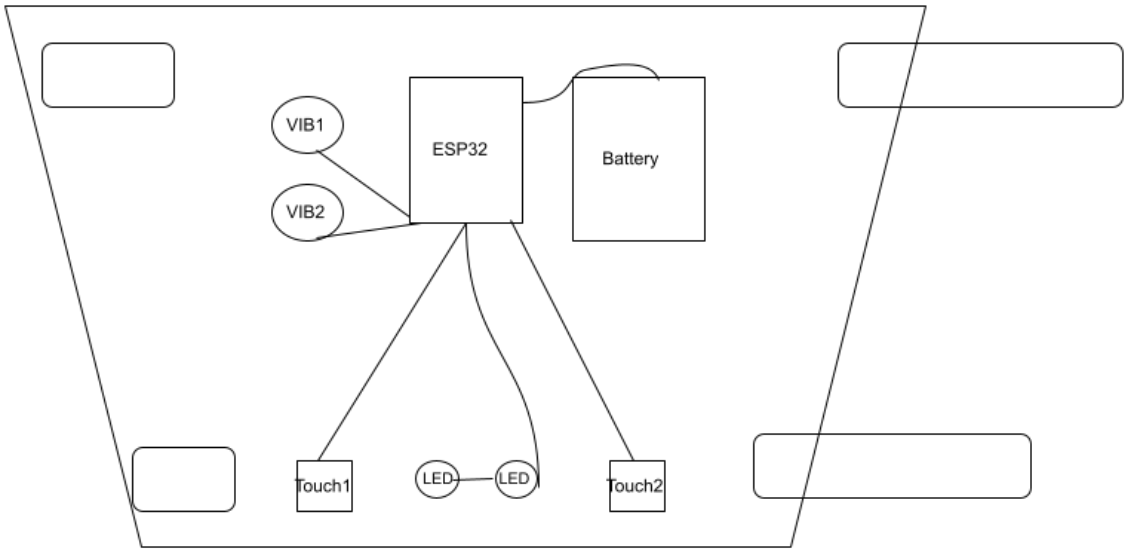
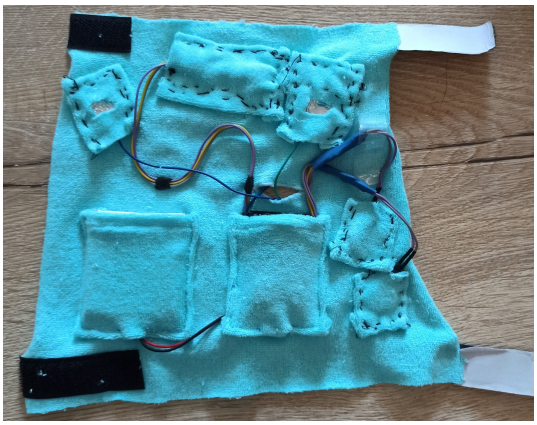
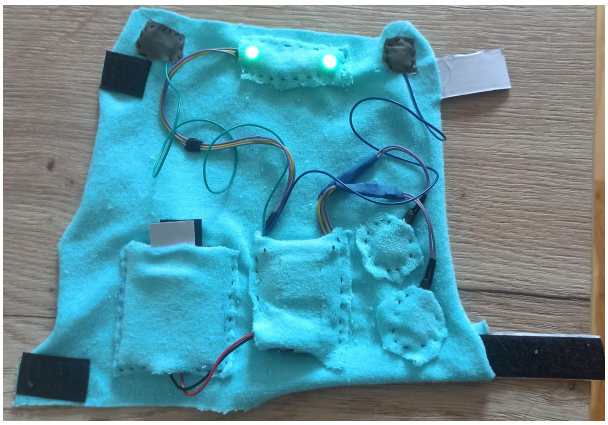


FIGURE 8.5: Sketch of prototype sleeve

elbow. A drawing of the placement of all the components can be found in 8.5. In final iteration a second layer of fabric is placed over all the components, such that none of the electrical components are exposed to the users. However, for the first test and for the purpose of debugging the sleeve was left open.
The first set of sleeves can be found in image 8.6a and 8.6b.



(A) prototype 1



(B) Prototype 2

FIGURE 8.6: Pair of two sleeves as first prototype

8.4 Evaluation of prototype

By using this first set of sleeves an initial test and evaluation was done. The sleeves were tested on different places and via different wifi networks, to see if it was able to

connect to all the networks and whether there were any issues. It was tested by the researcher, where it was most important to see if the software worked satisfactorily and whether there were any bugs or problems that should be fixed in the software.

8.4.1 Working of the modes

Each mode seems to work correctly. It is possible to give touches simultaneously. Even in the status mode, it is possible to switch status whilst the other person is giving a series of touches. Approximately two touches will still come through, after that the device is notified of the switched status and the other touches do not come through anymore.

8.4.2 Web server

It was found that accessing the web server is not always possible and this leads to difficulties connecting. On some networks, the web server would not load and therefore the user is not able to specify any mode. This is not a stable way of initializing the modes and a different solution needs to be found before the user tests. For example, it would be possible to try to access the web server from another network or it is possible to initialize the modes via the MQTT protocol. The latter solution means that users cannot initialize the modes themselves, but it has to be done by the researcher.

8.4.3 Placement of touch sensors

The touch sensors were placed alongside the LED lights, one touch sensor on each side of the lights. However, it was noted that this is not a comfortable way of applying touches. The touch sensors are too far off to the side. This also resulted in some accidental touches if the wrist was tilled and pressed down on a table. Therefore, it might be necessary to place the touch sensors above the LED lights, such that they are more easily reachable.

8.4.4 Wearability

The fabric that was chosen is soft and stretches. This resulted in the sleeve being comfortable to wear. However, multiple users will have to wear the sleeves and they all have different arm sizes, the fabric can stretch out to such a length that the sleeve does not fit tightly around one's arm. Another fabric with less stretch should be chosen. This will also make the sleeve more robust since it will fit more tightly around the forearm.

Chapter 9
Second iteration of prototype

Based on the evaluation of the first prototype, multiple alterations were made to the design and the software. In this section, the changes that were made and the creation of the second prototype are discussed.

9.1 Code alterations

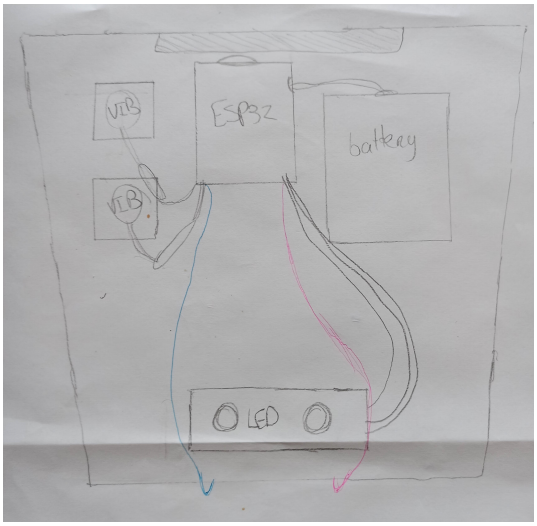
As mentioned in the previous chapter, the use of the web server was not a robust solution. An alternative solution is to initialize the modes via the MQTT server. This could be done by publishing the desired mode to the MQTT and let the devices subscribe to this topic. If a certain mode is published, the device will then react to this by going into the specified mode.

To communicate problems and the current state of the program to the user, the LED lights were used. If no mode is chosen, the LED lights will turn pink, suggesting that the program is currently not in a mode. Once a number on the mode topic is published to the MQTT, the program will write the corresponding mode to the SPIFFS system. In the loop, the content of the SPIFFS file is read to check the mode. If a new number is published to the mode subscription, the current mode will be removed from the SPIFFS system. As a result, the system will go back to the starting state and the pink lights will turn on again.
This makes it easy for the user to spot errors, if the lights are pink they know that something went wrong in the system and they are not in a mode currently.

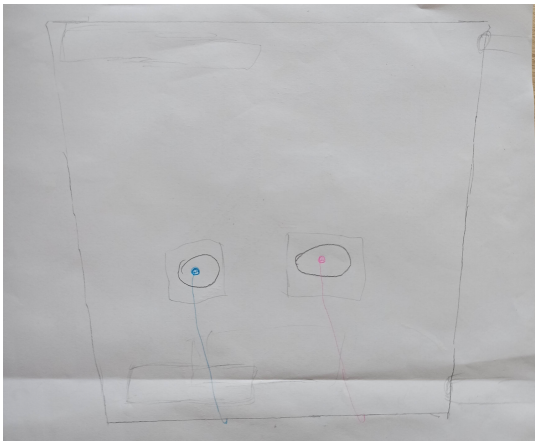
9.2 Creation of sleeve

For the final prototype, a more robust and strong material had to be used, with less stretch in the fabric. A soft jeans fabric was chosen, since this still is cotton and therefore less flammable but there is also less stretch present. It is also a comfortable fabric to be worn for several hours a day.

Some adjustments had to be made to the placement of the components. To make sure that there was not too much pressure on the wire connected to the battery, the battery had to be placed a slightly lower than the ESP32. Furthermore, conductive fabric is used for the touch sensors. These touch sensors would have to be placed through the second layer such that they are directly in contact with the conductive fabric. Furthermore, an opening has to be made between the two layers such that the micro controller can be charged. With this opening, it would also be possible to reach the hardware if any problems occur. A drawing of the updated sketch of both layers can be found in figure 9.1.



(A) Sketch of inner layer with components



(B) Sketch of inside outer layer, for touch sensors

FIGURE 9.1: Final drawings prototype

9.2.1 The final sleeve

In order to create the second prototype different steps were undertaken. First, all the pouches of the components were sewed on the lower layer (figure D.1). Consequently, the second layer had to be added on top of the first layer. To achieve this, the placement of the touch sensors had to be marked on the second layer. A small opening was made in the fabric and the conductive fabric was sewed to cover this small opening. In a later stage, the wires of the touch sensor were sewed to the conductive fabric. Then, an opening with velcro was made on the upper side of the sleeve. The last step was to sew the lower and upper layer together.

Once the hardware components were inside, they still had to be sewed by hand to stay in one place. It was decided to do this by hand in the last stage, such that the hardware and the sleeve could be separated without damaging one or the other. This way, the threads made by hand can be cut loose and the hardware can be taken out. This could be also convenient when replacing hardware or checking for errors without

FIGURE 9.2: Overview of lower layer with components pouches

damaging the remainder of the wearable.
In the end, the inside of the sleeve can be seen in figure 9.3a and the bottom of the outer layer, where the touch sensors are attached can be seen in figure 9.3b. The final version of both sleeves can be seen in figure 9.4.

(A) under layer with components

(B) bottom side of outer layer with touch sensors attached

FIGURE 9.3: Inside of sleeve

FIGURE 9.4: Final version of the sleeve

Chapter 10
User tests

With this final prototype, a series of user tests were carried out to gain insight into the experience of the user. For this user test, the differences between the four modes were the most important. In this section, the experimental set up and the procedure that was followed are discussed.

10.1 Experimental set up

The goal of the user tests was to investigate the effectiveness of the different solutions on receiving intrusive touches and the feeling of intrusiveness. Furthermore, it was also important to gain insight into the experience of users that are using these additional modes. Since this user tests revolved around intrusive touches, it was important that users are also occupied with other tasks whilst sending and receiving touches. If they are actively engaged with the prototype for the whole duration of the experiment, they will probably not experience any intrusive touches since their focus is shifted to the prototype. Thus, the users were given the prototype home and were asked to perform a session of each mode. At the end of each session, they were asked to fill in an online questionnaire.

Each pair of participants experienced all four modes; normal, voicemail, snooze and status. All the modes were randomized across the pairs, such that each pair would have a different order. This was done to ensure that there would be no bias in the order of the modes.

10.2 Participants

Participants were recruited through the personal network of the researcher. A requirement for participation was that the participants had a close relationship with one another such that they would also touch each other in real life. Participants were asked to not be together during the sessions. Ideally, they would be apart throughout the duration of the experiment. However, this was not possible for all pairs.

5 pairs of participants were recruited with different relationships. One romantic couple in a long distance relationship and one couple that live together were recruited. One pair consists of a sister and brother who lived apart. And another pair consists of two friends who live in different cities. The last pair was supposed to consist of another romantic couple. However, due to scheduling issues one of the participants had to drop out. As a result, another person stepped in. This meant that the last pair consisted of a son and father who live in different cities. The age of all participants was between 24 and 68 years old and they all live in the Netherlands.

10.3 Procedure

Before the start of the user test, participants were given a brochure and an instruction guide with information and a troubleshooting guide (appendix H). Before the start of the experiment they were asked to sign the consent form (appendix I). At the start of the user tests, the pair of sleeves was handed to the participants. To make sure that everything works, all the modes were be tested together before the start of the user test. Participants were asked to coordinate the start and end time of each session. Since the researcher needed to initialize the sessions, it was important to agree on starting times beforehand. Each session had a duration of 3 to 5 hours.

Initializing the sessions
15 minutes before the start of each session, participants received a reminder text message stating that their session was about to start. They were also asked to give a thumbs up if they had woken up the device and the pink lights were displayed (meaning they were connected to the WiFi). Once both participants gave the thumbs up, the researcher initialized the mode of this session via a publish message on the MQTT server. The participants were told that if the lights went off or turned green, the mode would be initialized correctly. If their lights were still pink, they could send the researcher a message. Usually this meant that the device had to be rebooted.

During the sessions participants were free to send touches whenever they wanted. They were given no specific instructions on how to use the device. At the end time of each session, they received a text message stating that the session has come to an end. Consequently, they were asked to fill in the questionnaire and charge the device.

10.4 Data collection and analysis

After each session, participants were asked to fill in an online questionnaire via Qualtrics [35], see appendix J. They were asked which mode they experienced that day and based on their chosen mode they were asked some questions specifically for this mode. Fur-

thermore, they were asked open ended questions on how they perceived each mode. The statements that were the same for each mode, were used to compare the perceived intrusiveness of each mode. The open ended questions were used to gain a general understanding of the view of the users on that specific mode.
Furthermore, the following data were collected from the MQTT server; the amount of touches that each participant gives in each mode and for the status mode the amount of time the status was switched, was also recorded. These figures could be used to gain insight into the touch behaviour of the participants.

After user testing, the data of the questionnaire and the data collected from the MQTT server was processed. The statements from the questionnaires were analyzed statistically for any relevant difference between the modes. Since each participants experienced each mode, this is a within-subject design. The independent variable is the mode and the dependent variable are the scores of the participants to the statements in the questionnaire. Since these questions are ranked on a Likert scale, the dependent variable has an ordinal level. To this end, the Friedman test will be used [26]. This is a test that can be used to test for a difference between groups, in which there is one group that is measured on three or more occasions. Since all the pairs can be grouped together and their opinion is measured four times, the Friedman test is an appropriate test.

Chapter 11
Results

Five pairs of participants performed the user tests and completed four sessions; one session for each mode. In this section, the results will be presented. First, the outcome of the statements for each mode and the statistical analysis are discussed. Then the responses of the participants on each mode are presented as well as other results from the questionnaire.

11.1 Statistical analysis

After each mode, participants were asked to rank several statements on a 5 point Likert scale ranging from totally agree to totally disagree. These statements were centered around the occurrence of intrusive touches and to what extent a mediated touch disrupted the user. For each statement a statistical analysis war run in R studio [39]. As previously explained, the Friedman test was run to compare any statistical differences for the statements between the four modes.
In table 11.1, an overview of each statistical analysis can be found. The statements that were answered on a 5-point Likert scale and will be analysed are the following:

1. Sometimes I received a touch, but I would not have wanted to
2. I experienced one or more incoming touches as unwanted
3. I wanted to give my partner a touch, but I did not because I was afraid they would not like it
4. I got disrupted during an important task because I received a touch from my partner

From this table it can be concluded that none of the four statements prompted a statistical significant difference. Meaning that the answers to the statements did not differ between the four modes. In the box plot in figure 11.1 the scores for statement 4 across the modes can be seen. Although there is no significant difference, it can be seen that the scores for the status mode and the voicemail mode are generally lower than the scores for the normal and snooze mode.

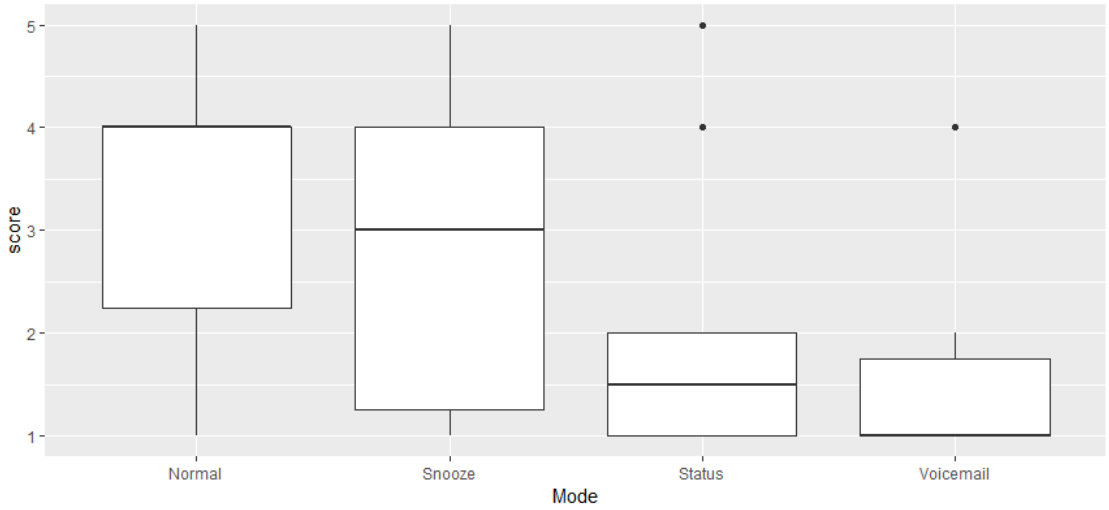


FIGURE 11.1: Scores on statement "I got disrupted during an important task because I received a touch from my partner", in which 5 is 'totally agree' and 1 is 'totally disagree'

statement	N	Chi-sqaure	df	P-value
1	10	3.3	3	0.3476
2	10	2.0625	3	0.5595
3	10	1.3256	3	0.7231
4	10	5.3289	3	0.1492

TABLE 11.1: Friedman test results for each statement

11.2 Open ended questions

Participants were also asked in open questions to describe what they liked and disliked about each mode. These answers were analyzed and categorized, to get a clear overview of the up- and downsides of each mode.

11.2.1 Normal mode

For the normal mode, where there was no additional method for rejecting touches, the up- and downsides were straightforward. In figure 11.2a and 11.2b the number of times certain comments were mentioned can be found. On one hand, participants liked the ease of use and the simplicity of just giving touches without any additional thoughts. On the other hand, receiving touches when it was not convenient was seen as a down side. This simplicity is rewarded in the sending of touches, but when it comes to receiving it is also seen as something negative. A participant mentioned the following: *"I feel like normal is the most straightforward function. You don't have to think about whether you're "available" or not, because there's no option for it."*. Furthermore, participants expressed that in this mode they felt like the touches were more 'live' than in some

other modes.
Lastly, the following was also mentioned by a participant: *"The touches aren't disruptive enough for me personally to distract me from studying or doing chores. I felt like giving touches is more disruptive, actually, because I had to look at the device to ensure that the touch was sent correctly (done by checking the blinking light)"*. She expressed that sending a touch takes more effort than receiving a touch, thus she experienced the receiving of touches not as intrusive.

11.2.2 Snooze mode

For the snooze mode, it became clear that many participants did not use the snooze function at all. In figure 11.3a and 11.3b the number of times certain comments were mentioned can be found. When asking what they liked about the snooze function, participants responded with: *"Not really used it."* and *"This mode didn't add any positive benefits compared to the regular use of the sleeve without any mode enables."*. Furthermore, there were not a lot of positive comments on the snooze mode. Instead, there were more remarks mentioned on why they disliked the function. Many participants mentioned that the light was not visible enough and they would notice too late that there was a touch incoming. At that point they had already received the touch and they missed the opportunity to snooze completely. Furthermore, there was a 3 minute window on the snooze. One participant also mentioned that he would have liked to see that he could set his own snooze time; *"I can imagine it being very convenient if you could set your own snooze-times"*.

11.2.3 Status mode

When it comes to the status mode, participants seem divided on the downsides. In figure 11.4a and 11.4b the number of times certain comments were mentioned can be found. Many participants appreciate the ability to turn touches off and that they have a guarantee that they are not disrupted by a touch when they do not want to. A participant made the following comment: *"It kind of felt like a "hi im driving right now so i cant text you back now but im not ignoring you on purpose!" message but for the sleeve."*. Furthermore, the availability status was also seen a a sort of acceptance on touching the other person; *"Also that I had the feeling that if my partner had the available status, my touches would be fine and not distracting them or making them uncomfortable because they had the option to become unavailable to touches."*. Thus, knowing that the other person chooses to be available can be reassuring as well.
When it comes to the downsides of the status button, different aspects are mentioned. One practical aspect that is mentioned, is the sensitivity of the button; *"Sometimes it happened that I bumped into something with the sleeve and it would change my status without my knowledge"*. Furthermore, it seems that the status of the other person also raises different feelings. One participant mentioned that she felt unwelcome if the status

of the other person was unavailable, another participant mentioned that he was often checking the status of the other to see if he could send a touch.

11.2.4 Voicemail mode

During the voicemail mode, participants appreciated that they were not disturbed by a touch when they would not want to. On the other hand, this had the disadvantage that touching felt less exciting since it is not a 'live' touch anymore. They missed the feeling of spontaneous touches, since the touches do not arrive at seemingly random intervals. In figure 11.5a and 11.5b the number of times certain comments were mentioned can be found. Furthermore, participants mentioned that they would not know how long a touch was waiting on the voicemail and how long their partner might have waited for a touch back; *"I feel like in the voicemail mode it is possible to forget you're wearing the sleeve and miss a lot of touches. This might be positive for some people but I experience this as a negative, as I would prefer to feel the touch whenever it is sent and be able to send one back whenever I want to (not only when I remember to check the light on my sleeve)."*. Participants also had to actively choose when to receive a touch, some participants mentioned that this took away from the experience.
It was also mentioned that there is a pleasant to receive many touches in one go. Some participants gave a lot of touches, such that their partner would receive an abundance of touches when listening to the voicemail. For most participants this was seen as something enjoyable. Although one participant also mentioned that this could be annoying since there is no way to pause the incoming touches on the voicemail; *"The downside is that you have to listen to the voicemail at once, so if the other send a lot of touches then it keep on going"*.

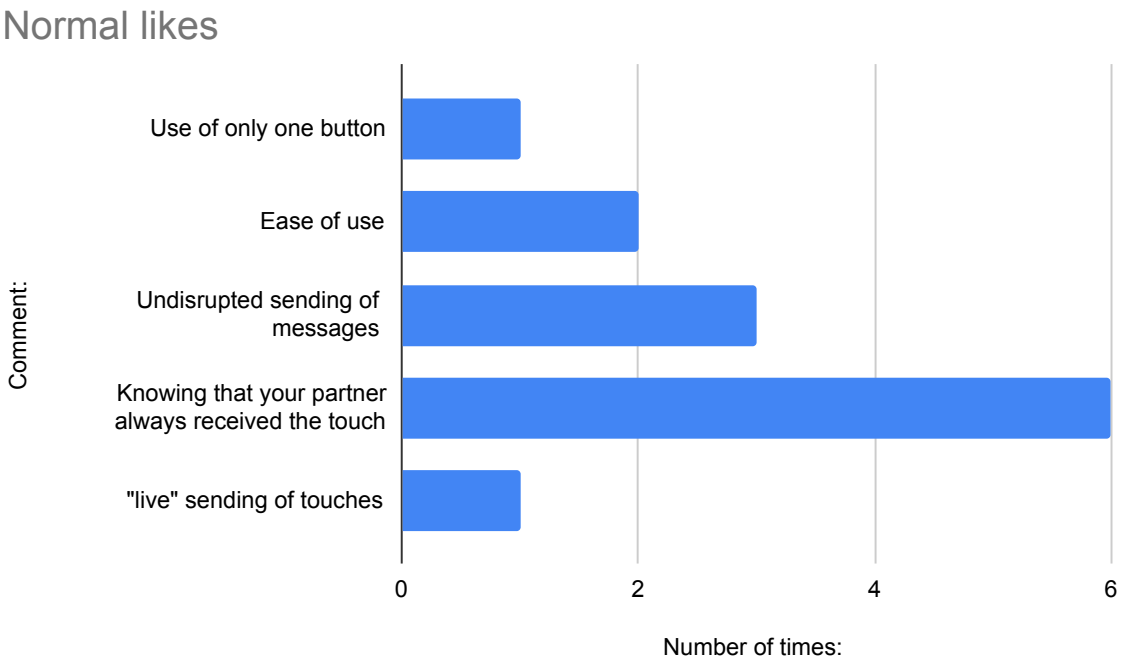
11.3 Other comments

The last question participants were asked during each questionnaire was whether they had any other remarks or suggestions. This revealed some interesting points that are put forward in this section.

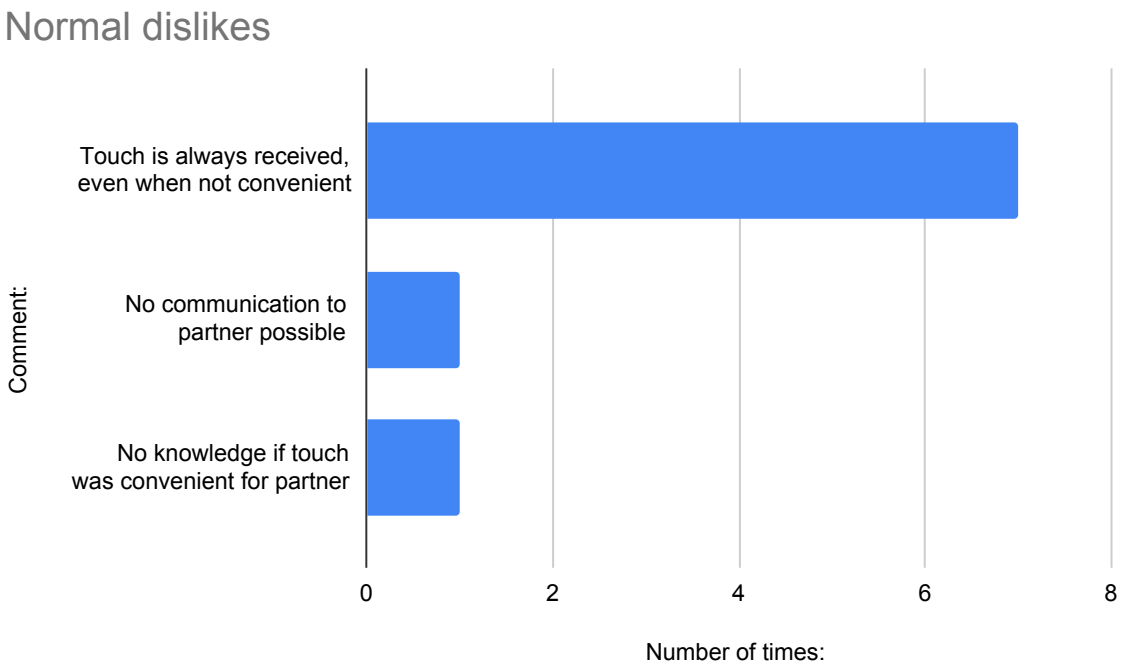
Likability of mediated touch
Different participants emphasized that they liked sending mediated touches to their partner: *"I thought sending touches to your partner was a fun way of communicating with to each other. I am going to miss it!"*; *"Touch is a nice way to keep in contact without having to talk"*.

Combination of solutions
A few participants mentioned that they liked most modes, but ideally they would like to see a combination of solutions: *A perfect solution with the current technology in the sleeve would be a combination of all these modes.*; *A hybrid between the voicemail and*

the snooze could be interesting. Where you have the option to snooze it again (maybe for 10 minutes instead of 3), or send it to your voicemail so you can experience the touches once your in a situation you'd like to receive it. . This possibility of combining solutions will be further explored in the following section.

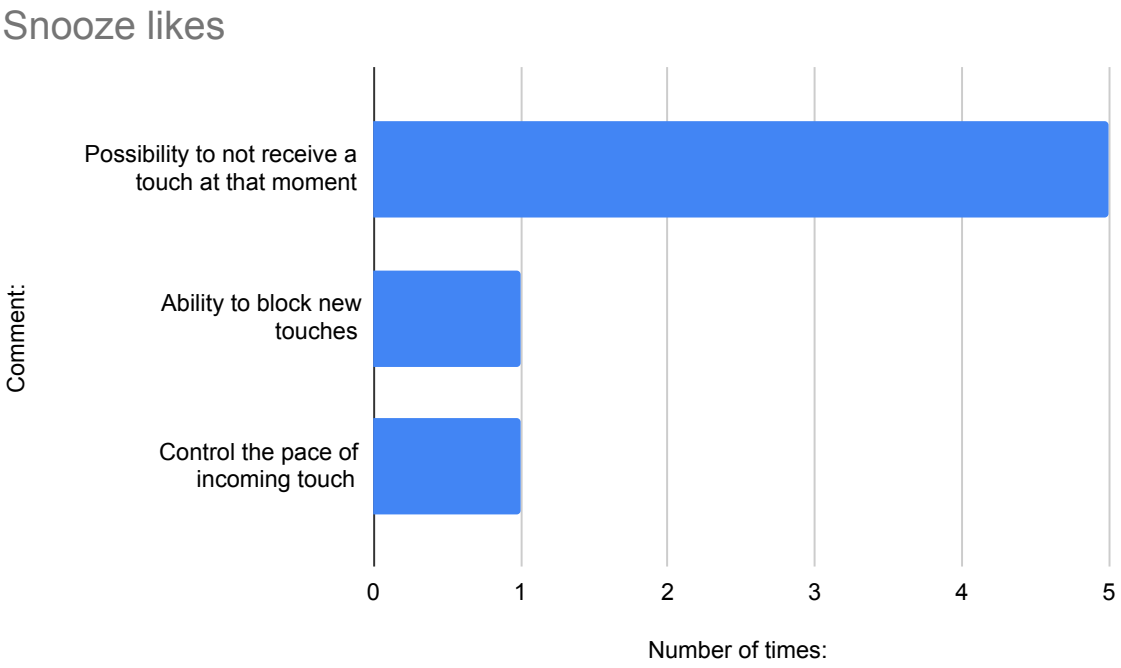


(A) Comments participants made on why they liked the normal mode

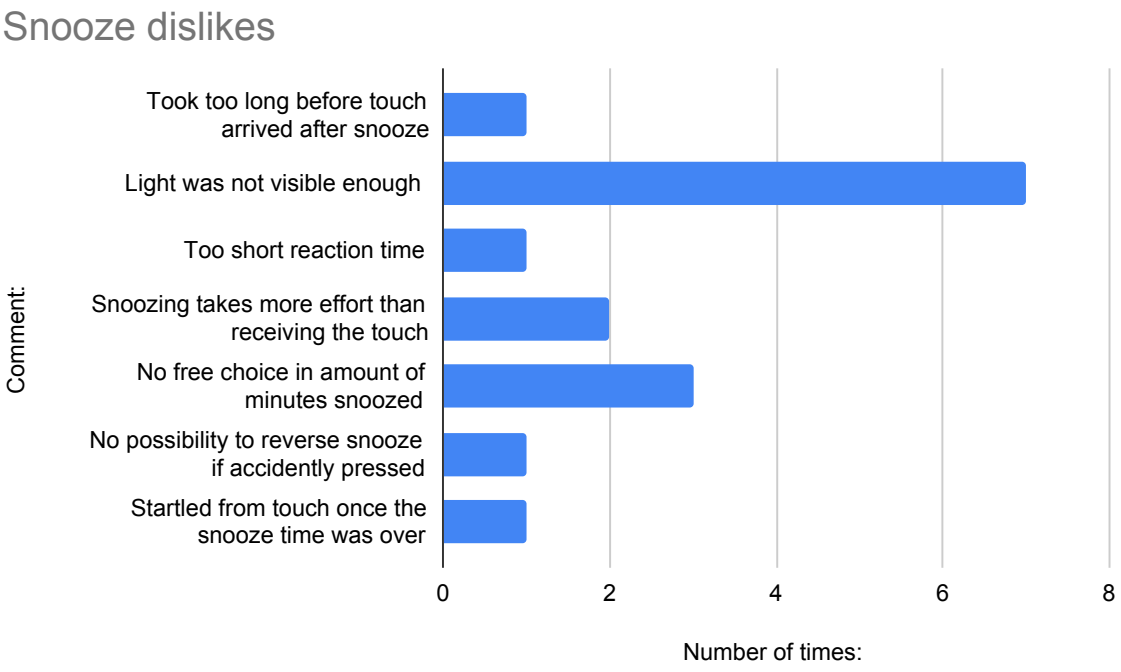


(B) Comments participants made on why they disliked the normal mode

FIGURE 11.2: Comments made by participants on the normal mode

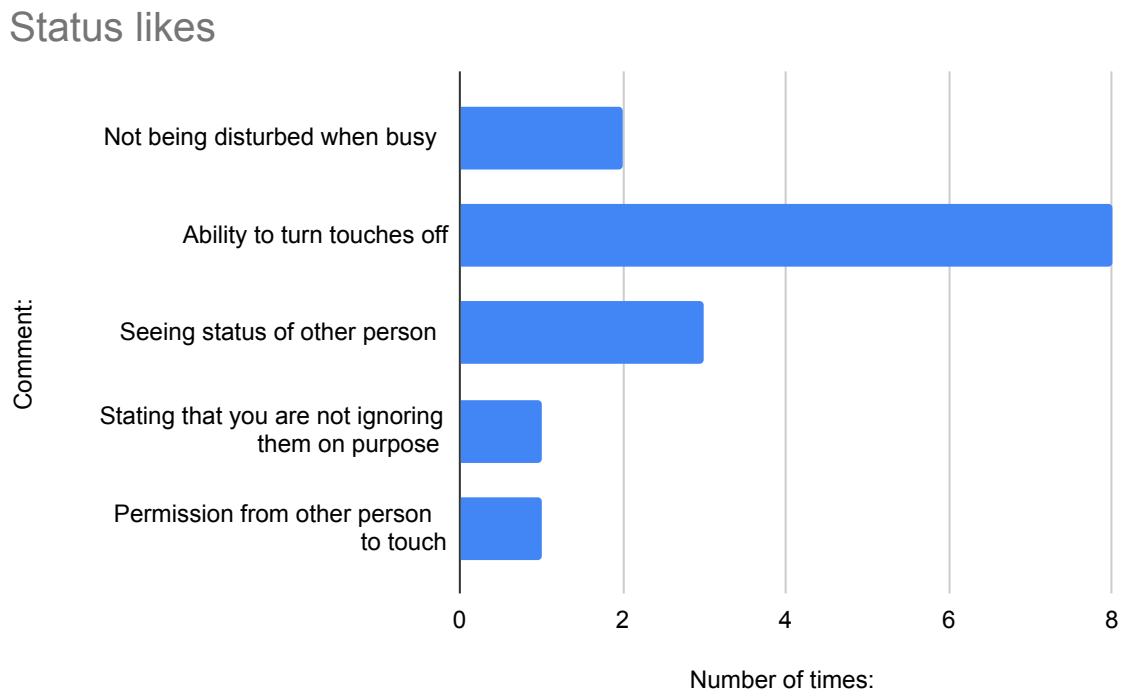


(A) Comments participants made on why they liked the snooze mode

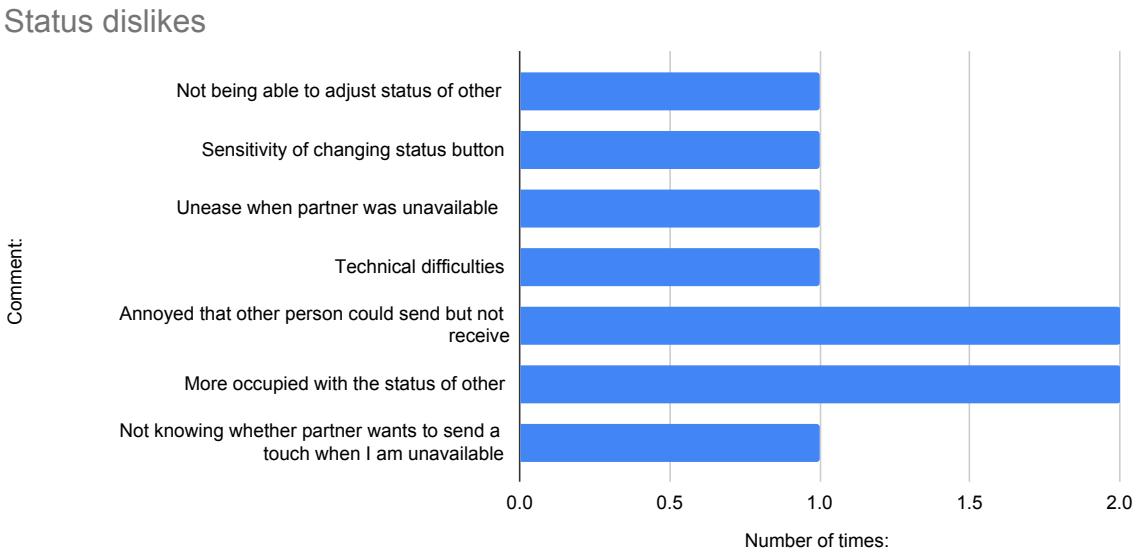


(B) Comments participants made on why they disliked the snooze mode

FIGURE 11.3: Comments made by participants on the snooze mode

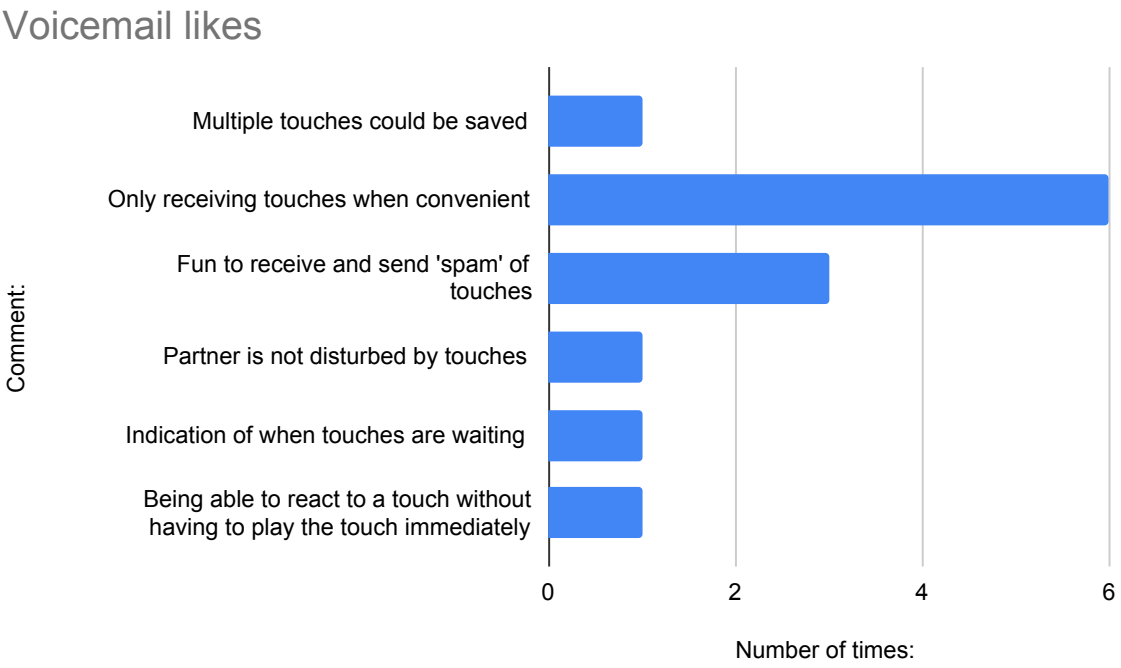


(A) Comments participants made on why they liked the status mode

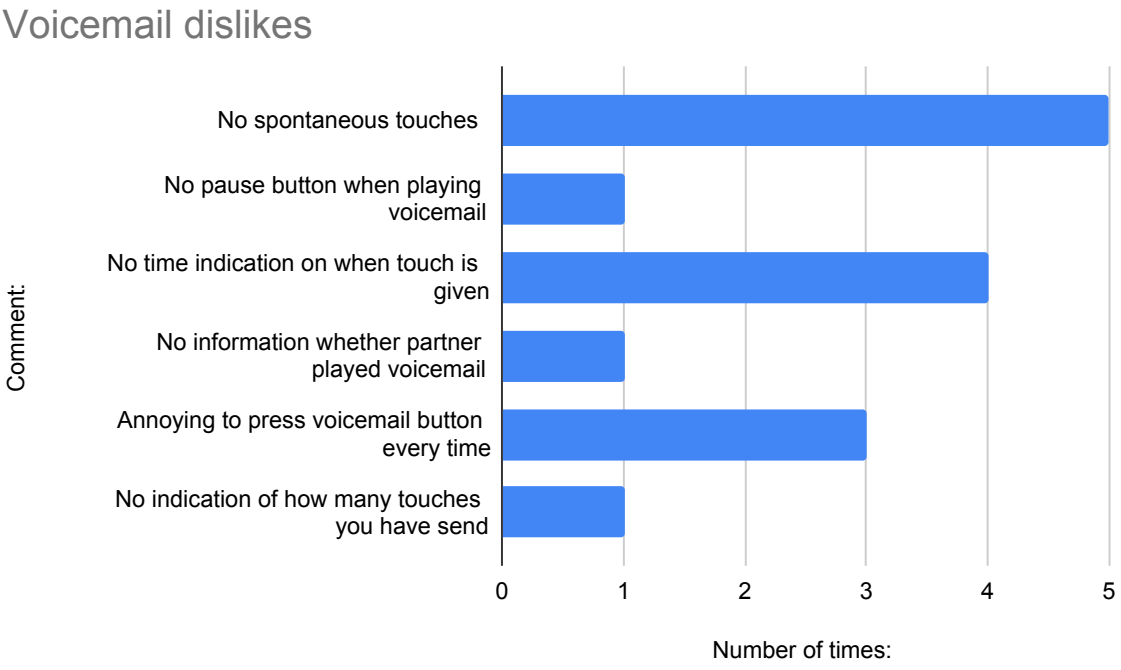


(B) Comments participants made on why they disliked the status mode

FIGURE 11.4: Comments made by participants on the status mode



(A) Comments participants made on why they liked the voicemail mode



(B) Comments participants made on why they disliked the voicemail mode

FIGURE 11.5: Comments made by participants on the voicemail mode

Chapter 12
Discussion

In this chapter, the results that were found will be interpreted and their implications will be discussed. Furthermore, the modes will be discussed and the differences that were encountered. Each mode could undergo different improvements, which will be put forward here. In the end, the implications of this research will be discussed and possible future research directions that can be derived from this research.

12.1 Differences between the modes

In this section the main research question: "How can the possibility of an intrusive touch be reduced in mediated social touch technology?" will be answered. During the user test, each participant experienced four modes; a status mode, snooze mode, voicemail mode and the normal mode. The purpose of the user test was to investigate whether users perceive any differences related to intrusiveness between these modes. The expectations were that in the normal mode users would experience the most intrusive touches, since there is no choice in whether or not the recipient wants to receive a touch. Between the other three modes, it was expected that the status mode would be appreciated the most, since this would give the user the most freedom in choosing whether or not they would like to receive a touch.

12.1.1 Interpretation of the results

The results showed that there is no statistical difference on the perceived intrusiveness between the different modes. This means that participants did not experience any significant difference between the modes regarding perceived intrusiveness. This could be because of several reasons. One aspect that was difficult to control is the tasks that users were doing whilst wearing the device. Since they were aware of the research that was taking place, they might have planned less important tasks during the sessions and therefore experienced less intrusiveness from the mediated touch. Since the device was new to all the users, it could be that receiving a touch was seen as more positive simply because it was new and users were intrigued by the touch. Moreover, it was

mentioned that receiving a touch was not always seen as disruptive. Instead, sending a touch was more disruptive. The questions focused on the receiving of a mediated touch and to what extent this would disrupt the recipient. Perhaps this means that receiving a mediated touch is not what causes the intrusiveness, but instead the need to reply to this touch. This theory will be explored further in section 12.2.

12.1.2 Analysis of each mode

Each mode had positive and negative effects. The normal mode seems to be the easiest in use, but the aspect that is seen as positive for a sender, is also a negative aspect for the receiver. The sender can send touches at any point in time without further contemplating the requirements for sending a touch. As a receiver it can be annoying to receive a touch when it is inconvenient. This annoyance when receiving mediated touches was initially identified in the self-test and the focus group and is confirmed in these user tests. However, it is unclear if any of the proposed solutions tackle this problem effectively.
In the voicemail mode, the spontaneous nature of touching disappeared. Although the feeling of receiving intrusive touches was also reduced, the lack of interactivity between the users remains. This could be solved by either using a status function or a snooze function.
For the snooze function, there is room for improvement. The light was not visible enough and therefore participants did not notice it enough. An alternative indicator could be for example warmth to signal a touch, but this can be difficult in a wearable. Especially if the wearable is worn outside in the summer, the addition of even more warmth could become unpleasant. Since users did not notice the warning, they were also not inclined to snooze the touch. To make this function work, things need to be altered. Firstly, there needs to be a warning sign that can be felt by the user, since the sleeve is not in the eye sight of the user a visual indicator is not suitable. Furthermore, the snooze time should be adaptable as well, such that users can choose how long they would like to snooze the touch. Another addition would be to let the users snooze the touch again if it is still not convenient.
Lastly, the status function received a lot of positive feedback and less negative feedback. There seemed to be more technical complaints in this mode than complaints on the mode itself. However, one participant mentioned that she did not like it whenever their partner was unavailable, it felt unwelcome. An alternative solution would be to add different levels of disturbance. Such that it is not only accept or reject, but there is also a possibility in between. It would be also possible to add a second level of communication where perhaps a reason would be given for the current level of the status. That way, the sender might feel less rejected if he or she knows why their partner does not want to receive a touch.

Overall, it is not possible to make a clear recommendation on which mode would be

most suitable in future devices. As can be seen in figure 11.1 in both the status mode and the voicemail mode there were less instances in which a user got disrupted during an important task. These modes have in common that there is a conscious choice on whether or not to receive a touch at that point in time. For the status mode, the user has the choice to turn off the ability to receive touches if they wish not to. In the voicemail mode the user has to specifically choose to receive the touches at that moment. Whereas in the normal and the snooze mode, the touch will be given eventually. During the snooze mode, the user has the option to delay the touch but in the end there is no option to decline a touch. This suggests that the choice on whether or not a touch can be received is an important aspect on the disruptive feeling of the mediated touch.

12.2 Urge to give a touch back

One participant mentioned that sending a touch was more disruptive than receiving a touch. This is an interesting statement that was not considered prior to the user tests. Sending a touch requires active attention in which one has to look at the device and depending on the mode perform one or more actions. In case of the status mode, the user has to look at the status of the other person before he or she can press the touch sensor. Whereas the normal mode only requires the sender to give a touch by pressing the touch sensor. Giving a touch also means directing the attention to the device and find the touch sensor with your finger. These actions can also be seen as disruptive. This becomes even more apparent when the need to response to a touch is added. Multiple participants mentioned that one reason for touching was to reply to the touch of the other person. This means that when a touch is received, it is not only played by a vibration motor but there is also a desire by the recipient to reply to this touch. This became also apparent when users ranked the statement:

"When I received a touch from my partner, I felt the need to give them a touch back". Nobody disagreed with this statement, one participants answered 'Neither agree nor disagree', 25 responses agreed to this statement and 14 responded with 'totally agree' .

One participant said: *For example, I was doing chores (the dishes) and couldn't send a touch back at the time. I did receive some touches while doing these chores and I did feel a little bad for not sending them back immediately.* This raises the question which of the two could be more intrusive; the touch itself or the need to actively reply to this touch. It could be that the touch itself is not what disrupts the user, but instead there is a need to reply and act on the touch that is given. Thus, the user feels the urge to react upon the touch with a reply (either another touch or a text message) and this reply is then what leads to the occurrence of an intrusive touch. This is in line with the proposed definition of intrusiveness from section 6.2, since the perception of the receiver is still leading. However, when it comes to considering the context of the receiver it might be the case the it is not dependent on what the receiver is doing but

to what extent the receiver can replay to the touch. If the recipient does not have the time or opportunity to reply to the touch, he or she might feel annoyed and thus the touch the recipient just experienced can become intrusive.

12.3 User expectations

None of the participants had any experience with a mediated touch device. Many of them were sceptical of these devices before the user test, stating that they could not imagine this would feel similar to a touch from your partner. This was not an expectation that was created intentionally by the researcher, instead it was observed when approaching participants for the user test. After the user test, most participants confessed that it was more fun than they had expected. They noted that it did feel like a new way of communicating with their partner and most of them added that it is an interesting alternative to sending text messages. However, it was also observed that the possibility of communicating via the mediated touch device was limited. Participants could not determine the intention of their partner when receiving a mediated touch. This is in contrast to different studies ([3], [37]) that were discussed in section 4.2, in which it was highlighted that emotions could be conveyed using mediated touch. However, in these studies different sorts of touch were used to convey different types of emotions. With this prototype only one sort of touch could be conveyed and thus it might be more difficult to determine the meaning behind the touch.

12.4 Evaluation of the prototype

In this section the sub question; "How to design a mediated touch device where the possibility for intrusiveness is diminished?" will be answered. The design process following the creation of the final prototype will be evaluated.

12.4.1 The design process

It was proposed that receiving a mediated touch at an inconvenient point in time could lead to a feeling of intrusiveness, where the mediated touch would disrupt the receiver. To this end, multiple solutions were proposed to see if they could remove the occurrence of intrusive mediated touches. Three solutions were integrated in a prototype to see if and to what extent they could reduce the intrusiveness of a mediated touch. Since the experience of the users was of great importance, the users were not only asked questions on the perceived intrusiveness but also on their general experience with these solutions.

Design and comfort of the sleeve
It was decided to create a sleeve, since this would not restrict users in their movement. There were also LED lights that displayed some information (depending on the mode) to the user. These LED lights were placed near the wrist such that they were easy

noticeable for the user. However, participants noted that looking at the lights was sometimes a distraction. They were not able to give a touch without looking at the device.
The design of the sleeve was comfortable, this was an important aspect since they were asked to wear the sleeve for multiple hours a day. The comfort of the sleeve might be improved by removing the velcro bands, since they can become uncomfortable. One alternative would be to use a corset set up, where a elastic wire is woven between both end sides. This would also make it easier to take it off and put in on.
Although there is a battery inside, the sleeve did not get too warm for users to wear. Currently, there are no breathing holes in the sleeve present. It might be comfortable for users to add small holes in the sleeve such that the skin is able to breath. This could be especially useful on warmer days and in situations where the user would take the sleeve outside as well.

12.4.2 Technical problems

As can be expected with a first user test, there were a wide range of technical problems. This meant that for some initial ideas other alternative solutions had to be implemented. Whilst other problems resulted in a decrease of user comfort. During each session, the researcher was always present such that participants could contact the researcher if anything was wrong with the devices.

Not functioning webserver
At first, it was decided to let users initialize a session by themselves via the web server of the ESP32. However, during initial tests it was found that this was not a reliable method. The web page of the web server would not always load and then the user was stuck, since they could not initialize a mode. It remained unclear why this was not consistent, but it meant that a different solution had to be found. In the end, the researcher had to initialize the sessions via the MQTT server. This took away the independence of the users, since they had to contact the researcher to initialize the sessions.

Sensitivity of touch sensors
The touch sensors of the sleeves were not always reliable. They were not always easy to press and sometimes users had to search where they needed to press before a touch was sent. This made sensing touches sometimes more tiresome than needed. If this was more reliable and less extensive, the sending of a touch would have been easier for a user. Furthermore, the left touch sensor appeared to be more sensitive to movement noise than the right touch sensor. The left sensor was used for amongst others the switching of one's status. This resulted sometimes in a situation where the status would change without the user specifically touching the sensor.

Using WiFi

One of the biggest obstacles at the start of each user test was to insert the right WiFi networks into the code. Since the ESP32 has to have a connection to the internet in order to work, this meant that for each participant the WiFi networks had to be initialized. This needed to be done prior to the start of the user test and participants were made aware that they needed to be connected to one of these WiFi networks throughout each session. The use of a hotspot via laptop or mobile phone was possible in certain cases, but not for everyone. This is because the ESP32 cannot connect to a 5 GHz network. Thus, if the mobile hotspot used a 5 GHz hotspot, the ESP32 was not able to connect. This meant that some users had to be home (or somewhere else with a stable WiFi connection) during each session. This also limited the users and meant that it sometimes was more difficult to plan a session. It would have been easier for the users if the ESP32 was connected with, for example one tablet provided by the researcher, and then users could use that tablet to connect to their hotspot or WiFi network. Then, users would be more flexible on when and where to use the prototype. As long as the tablet is near and in range of WiFi, they can go anywhere. Furthermore, in that case participants could add WiFi networks on the go by simply connecting the new networks to the tablet. For this user tests, participants were stuck with the WiFi networks they initially chose.

Initializing the mode

During many sessions it would happen that the LED lights turned pink, this meant that the ESP32 is not currently in any mode and no touches could be given or received. There were multiple reasons why this would happen, one of these reasons is that when the ESP32 restarts it does not go back into the previous mode but instead it will ask for a mode (signaling this with the pink lights). But on other occasions it would also happen that the lights suddenly turned pink. This might be because the ESP32 was out of WiFi range. However, it meant that users had to contact the researcher and the researcher had to initialize the specific mode again. Most of the times, simply initializing the mode again would be enough. However, sometimes this did not work and it meant that the user had to press the reset button on the ESP32. These situations could take away from the experience, since it often meant that users had to recheck their connection.

Feedback on whether touch was received

Users had feedback on whether their touch was send, the LED light would blink for a small second. However, this did not always guarantee that the other person received a touch. This left some users wondering on whether or not the other person had received their touch.

12.4.3 Touch sensation

The touch sensation, resembled by two vibration motors vibrating for a few seconds, is very simple and was also viewed by participants as not extensive enough. If the mediated touch would entail more details, such as a stroking pattern or a form of inflatable pressure, this could also lead to different results. In that case, the touch would take away more time and attention from the receiver and this could also lead to a disruptive feeling. For these sleeves, the touch was small and therefore it would also not disturb users easily.

12.5 Improvements for the modes

The proposed modes could be improved in a number of ways. Some of these improvements were put forward by the participants during the user test and will be discussed below.

Snooze mode
In the snooze mode it would be more suitable if the snooze time was adjustable. Some participants noted that the 3 minutes was not enough, whilst other thought it would be good enough in some situations but not in other situations. It was also proposed that the recipient should be able to snooze again if the touch is still not convenient. This could be implemented by giving a warning prior to the touch and then letting the user choose again if they wish to snooze or not. Furthermore, it would be interesting to have two options during the snooze phase; one could either snooze the touch or decline the touch altogether. In that case, a touch can also be declined if it is not convenient in the foreseeable future.

Status mode
For the status mode, different options were already proposed during the design process. Such as connecting the availability to the online calendar of the user or adding different stages for the unavailability (for example orange for 'rather not'). Furthermore, participants noted that although it was very useful to know the status of the other person, this also was inconvenient for others. It kept them occupied and wondering why the status of their partner was unavailable. One participant mentioned that whenever the status of his partner became unavailable, he was contemplating on what the other person was doing. This could be avoided by having an option to choose whether or not the status of the other is visible.

Voicemail mode
In the voicemail mode, participants were forced to play their voicemail at once. They did not know how many touches there were on the voicemail and how much time it would take to play this voicemail. This could be altered by informing the user how

many touches there are on the voicemail and when they were added to the voicemail. Then, the user could also choose how many they want to play at a time. It was also noted that one would not know how long the touch was waiting on the voicemail and how long their partner might be waiting for a reply. Some sort of time indication on when the touch was initially given would help inform the user.
In conclusion, it would be interesting to see how these solutions would fare if they could be customized by the user.

12.6 Combining solutions

At the beginning of the design process, it was already suggested that combining these solutions and letting the user choose their own solution would be the most ideal implementation. However, to be able to clearly compare each solution, they were implemented separately. This notion of combining solutions was also put forward by multiple participants. For example they mentioned that combining the voicemail with other options would be ideal. In the case of the status solution, one would be able to switch status and if the receiver is not available, the sender can still send a touch but this would then be send to their voicemail.
This could be done by using an app to set the user preferences. In this app, the user would be able to set their own preferences, where they are asked questions on how they would like the device to deal with situations in which they do not wish to receive a touch. This way, users can choose whether or not they want to display their status and whether or not they want to send a touch to the voicemail when it is inconvenient. It would be interesting to explore the possibilities of combining these solutions in future research work.

12.7 Limitations

Pool of participants
The user tests was done with 5 pairs of participants, this is a small sample size and therefore it is not possible to gain grounded quantitative results for statistical analysis. The pairs of participants each had different relationships meaning that it was not a controlled study. Ideally, such a device would be used with people who do not live near each other. This was the case for some pairs, but other pairs lived together and were only separated during the day. This could also lead to different results. The pairs who saw each other physically outside the sessions, may have had less desire to touch one another during the sessions.

Duration of user test
The duration of each session was 3 to 5 hours. This is a short time window to gain insight into the occurrences of intrusive touches. For example, it could be the case

that the participant was not doing anything in which the mediated touch would be disruptive and therefore they experienced this problem less in that specific session. On the other hand, it could be the case that only for one specific condition they were in a focused task such that they experienced that one condition differently than all the other conditions. Therefore, the results might be different if this study was done as a longitudinal study in which participants experienced each mode multiple times and for a longer period of time.

Choice of solutions
During the design process, different possible solutions were generated. Eventually, three solutions were implemented. However, the other solutions were eliminated based on theoretical criteria and design considerations. It could be that these other solutions were appreciated more by users than the solutions that were implemented in the end. A user test with many solutions could have been done to gain insight on the perspective of the users and which solutions they would find most suitable.

12.8 Future work

Not many studies have touched upon the possibility of intrusiveness in mediated touch, suggesting that a mediated touch might not always be wanted by the recipient. As a result, a lot of future research directions are possible. Some of these possibilities have been discussed throughout this report, whilst others will be elaborated below.

Grounded work into intrusiveness
Why and when does an intrusive touch occur and how different is this between people? It remains unclear to what extent this problem occurs in mediated touch and more research needs to be done to see how different devices elicit these feelings. Different sorts of touch will elicit different feelings within a user and this could also have an effect on the perceived intrusiveness. Research needs to be done to gain a clear understanding of the user needs for such a mediated touch device.

Exploration of more solutions
Only three solutions have been proposed in this report, whilst many more solutions could be effective. Some solutions were proposed in an earlier stage but were eliminated due to the size of the project. For example, it would be possible to integrate a smart system that helps identify the ideal moment for a user to receive a touch. This could be linked to neurological features such as the heartrate of the user. By using neural networks and a feedback loop, the system can find the most opportune moments to give a touch. However, would this affect the interactive feeling of mediated touch? The user should have a choice in how the system deals with intrusive touches. To this end, a combination of different solutions can be implemented. The user answers a series of questions on how they would like the system to act and the system can then adapt

to the user's needs.

Mediated touch in daily life

A lot of research remains in the lab, meaning that the devices are evaluated in a lab setting. However, the lab setting is inherently different than how someone would use such a device in real life. More research needs to be done to see how users act around mediated touch in their daily life. A lot of users started this user test with some scepticism on mediated touch. After a few sessions, this changed and they started to like the idea more and more. This adaption phase needs to be taken into account when doing research with a mediated touch device.

Chapter 13
Conclusion

The purpose of this research was to explore the occurrence of intrusiveness in mediated touch and how this could be reduced. To this end, a series of solutions were proposed and these were narrowed down until three alternative solutions remained; a status function, a snooze button and a voicemail for touches. By designing a mediated touch device these three solutions could be compared to a normal mode, in which touches could be given back and forth without the option to opt out of a touch. This was implemented in a wearable sleeve which was then tested by five pairs of participants. The purpose of the user test was two folded, on the one side it was to gain insight into the occurrence of intrusive touches and how often a user would be disrupted by a mediated touch. On the other side, the user test was an exploratory test to see what users liked and disliked about these modes and how these could be improvement.
Results showed that users experienced some intrusive touches in one situation or another. In these cases, users received a touch but they would not have wanted to. There was no statistical difference in the occurrence of intrusive touches between these modes. This means that it is difficult to determine if one solution overcomes this problem more than the others. Participants seemed to prefer the status function over others. During both the status mode and the voicemail mode, users reported less interruption due to receiving a mediated touch. However, one drawback of the voicemail mode is that it removes the interactivity between users. This form of asynchronous communication was not appreciated by users, they missed spontaneous interaction. They liked the simplicity of the normal mode, but during this mode they also noted that receiving a mediated touch is sometimes inconvenient. A solution would be to combine all the previous solutions and let the user decide on how they want touches to be handled. This could be done by asking the user a series of questions (e.g. do you want the touch to be send to a voicemail if you are unavailable?) and adjusting the program based on the answers provided.

With this research, a new light was shone on intrusiveness within mediated touch. In this light, a mediated touch is not always convenient for the recipient and this is something that needs to be considered by design researchers. In prior research often the

assumption is made that receiving a mediated touch is always wanted. However, this research shows that this may not the case. There are more factors and possible solutions that could be used within mediated touch to reduce the possibility of an intrusive touch. To be able to investigate these aspects it remains important for researchers to not only test their prototype in a lab setting but also in a real life setting. It is in a real life setting that the possibility of an intrusive touch becomes more apparent.
The question then arises how and why an intrusive touch occurs. It was hypothesized that the touch itself would disrupt the user and direct their attention away from their current task to the mediated touch device. After the user tests an alternative explanation was put forward, in which the touch itself does not induce this intrusiveness but instead the need to answer the touch. Users feel the need to answer in one way or another to the mediated touch they receive. This action of giving another mediated touch could be what disrupts the user of their main task. When designing a mediated touch device, researchers need to take into account that not all touches are welcome. This is accurate in human social touch and also relevant in mediated social touch.

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Appendix A
One day using the Hey Bracelet

When the alarms goes at 08:15, A (my partner) wakes up, kisses me goodbye and goes to work. I get to sleep in a bit longer, but at 09:15 my alarm goes as well. When I get behind my laptop and put on the Hey Bracelet, I already have a message from A that he has problems connecting the Hey Bracelet. It appears that the battery is not fully charged and therefore it won't turn on. I advise him to put the bracelet on the charger and we can try it again in a few hours.
In the mean time, I start to work on my own things. After half an hour or so, I suddenly feel a squeeze from the Hey Bracelet. This feels surprising as I did not expect it to work already. I also feel the need to respond, so I press the bracelet, sending a squeeze back to let him know I received his touch. This results in a sort of back and forth game between me and A to see who can send the most touches, which was very amusing. After 20 minutes of touching back and forth, we both have to get back to our work. There was a short silence, which was good because the device does not have to be in the centre the whole time. When I was making my lunch, I feel the bracelet again, this gives me a good feeling because it is a reminder that A is thinking of me. I also feel the urge to give a touch back, to show that I am also thinking of him. It feels like it is almost a game, when the other person sends you a touch, you want to show that you are there and present and send a touch back. This goes back and forth between me and A throughout the day. When I sit down to have my lunch, A messages me that he has battery problems again, so I suggest that we can take a little break to charge the battery. Interestingly, his battery is almost empty whereas mine is still at 80%.
At 14:00, I have an important meeting and A knows this. A little before 2 o'clock, I feel the bracelet squeeze for a few times. I think this is A wishing me luck and letting me know that he thinks of me. This gives me a very good feeling, because I am already a bit nervous about the meeting and this calms me down. During the meeting, I want to let A know that it was going well, so I send him a touch to let him know I am still alive and kicking. However, what I did not take into account is that he probably also feels the need to touch back. Right after I sent him a touch, someone is asking me something in the meeting. This means that I have to shift my attention from the touching to the meeting. What I did not anticipate was that he also wants to touch me back. And I receive a touch as I am in the middle of my answer. This distracts me and my attention shifts back to the Hey bracelet. Although it is taking me out of my focus, I also feel a little giggle because it is nice to know that he responds. I am guessing he also knows that I am still in the meeting, because after that one touch I did not

receive anymore touches.
After the meeting, I decide to send him a few touches to let him know that I am done. To be sure that he knows that my meeting is finished, I am sending him a bunch of touches. This gives me a new idea on how we can experiment with the Hey Bracelet, how much touches can we send? I keep sending him touches and I notice that there is not really a limit on the amount of touches, but you have to wait a few seconds before you can send a new touch. The touch has to be received first by the other person and only then you can send a new one. Interestingly, he is also trying to send a lot of touches to me. When I attempt to send a touch by pressing the top of the Hey Bracelet, I feel the Hey Bracelet squeezing together. This gives me a weird feeling, because the palm of my hand also feels the touch that has been send. This is a fun game where we are testing the limits of the Hey bracelet, and it seems to react accurately to our touches.
A little before five o'clock, I get a few touches from A. He is about to leave work, so I am guessing he is telling me that he is going to be home soon. I send one last touch back. Although it is a really nice way to stay in touch with each other throughout the day, I cannot wait until he is home again.

Appendix B
Focus group results

In this appendix, the results of the first physical focus group will be presented. For each question, the responses of the participants were extracted. In the next section, these results will be interpreted.

B.1 "What do you think of the Hey bracelet?"

Starting, the question was asked how everyone feels about using the Hey bracelet and what they believe are the upsides and the downsides. Some participants mentioned that it is quite fun to give and receive touches, it is a nice way of communicating with your partner that does not only consist of texting. However, some problems were also identified. There were a lot of technical difficulties to install the bracelets and get it working for everyone, some bracelets even stopped working during the focus group. This often meant that the bracelet had to be rebooted to get it working again. Furthermore, some participants mentioned that using the Hey bracelet could be invasive:

"Your location is send to your partner, this makes it very invasive, it can become controlling"

"It can be controlling, if you don't get a touch back you wonder what is up"

It was also pointed out that there is a need for giving a touch back:

"If I send one touch and get nothing back then it is okay, but then I would touch again and if I get nothing back again then I would wonder if there is something up"

It was also pointed out by one participant that they preferred a text message, since then they were able to choose when and where they could read this message instead of being forced to undergo the touch at that point in time:

"I like the idea, but I prefer a message on my phone that I can check whenever I choose."

Furthermore, they also mention that they could be startled by the bracelet when they re-

ceive a touch that they do not expect:

"If you are close to each other you feel each other closeness and you are not surprised by the touch, this startles me. You are then projecting this to the person that touches you, but that is not fair"

"When I am home alone reading and suddenly the bracelet goes off, that would be very annoying"

These problems perfectly introduced the second part of the focus group, in which they were asked to identify these problematic situations and think about how they would solve these problems.

B.2 "How would you solve these problems?"

One of the participants suggested that it would be interesting if there was a voice coming out of the device, warning you prior to the touch. However, this sparked some discussion in the group, with other participants saying the following:

"That depends, not if you are in a meeting or something"

"I think a voice would be taking it too far, the idea is that this is different than calling or texting"

Someone suggested that prompting each other with certain lights would be a good idea, since lights can be less intrusive than sound. Furthermore, it was noted that one should not have to explain why they do not want to receive a touch, this could be invasive as well.
When asking how they would feel if they received a touch during an important meeting, they all agreed that this would be annoying and they would be distracted. For a solution, the following ideas were put forward:

"I would use a light to show whether I am busy"

"Maybe with icons, 'stop' when I am busy"

"If you would send the other a touch, but the other is busy, you get a light or message back saying that it is not possible"

When asking how they would feel if the device was connected to their online calendar, everyone agreed this could be valuable but the other person should not be able to see what they had marked in their calendar. Earlier it was mentioned that tracking your location could be invasive and this is the same for sharing your calendar.

B.3 "What would be the worst thing that could happen whilst being touched?"

This sparked different viewing points, where some participants were practical and mentioned that it is not good in unsafe situations, other were more psychological and thought about their worst feelings:

"If you are driving a car and you would get distracted"

"If you would have a device and use it with someone, and then it would suddenly stop and then you are even more lonely because you don't have that anymore"

"In my own private moments, for example on the couch when I want to have time for myself"

"When you are waiting for it for a long time and nothing happens"

B.4 "Any closing thoughts?"

Lastly, everyone was asked whether they had any other thoughts with regards to mediated touch. They pointed out that the Hey bracelet is limited to the sort of touching that can be given and they would want more sorts of touching. Furthermore, the prior thoughts on working with lights were again highlighted. It was pointed out by a participant that they liked the Hey bracelet, but they wondered if this would still be enjoyable if they could not see each other.

Appendix C
User scenarios

Introduction:
Anna and David are in a long distance relationship, Anna lives in the Netherlands, whereas David lives in France. They see each other once every month and every day they call each other via the phone or via Skype. However, they would like to try a new form of connecting where they do not have to talk or text all the time. They would like to try a social touch device, where they can administer touches to one another via a bracelet.

Scenario 1: Office - Focused work
David is at work in his office. He is working on a task which requires a high mental workload and therefore he should not be distracted. Right in the middle of working, he receives a mediated touch from Anna. As a result, he loses focus and becomes distracted by the touch and he becomes frustrated because he now has to regain focus.

Scenario 2: Home - While reading a book
David is home after a long day at work, all he wants to do now is to sit on the coach and read a book in silence. He forgets the world around him and is lost in his book, at that point he is startled by the bracelet, it is a mediated touch from Anna. Whilst it is nice to know that Anna is thinking about him, it was not a good moment for a touch because David would have liked to not be distracted while reading a book.

Scenario 3 - Gym - Exercising
David is at the gym busy lifting weights. While focussed on lifting these weights, he receives a mediated touch. This is inconvenient because he needs to focus on his muscles and using them correctly. The mediated touch tickles slightly and distracts him from exercising.

Scenario 4 - School - during an exam
Anna is in the middle of taking an exam. It is very quit in the exam hall, when all of the sudden Anna receives a mediated touch. This startles her and the people around her. The supervisors even question whether she isn't cheating because of the mediated touch bracelet.

Scenario 5; Office - in a meeting
David is working at the office and has a meeting with the whole team. During the meeting,

David has to give a pitch regarding his topic. While he is giving the presentation, he receives a touch from the bracelet. The noise is quite loud and distracting. As a result, not only David is distracted and does not know what to say next, but everyone is able to hear the bracelet. David feels embarrassed and distracted, because now everyone has heard the bracelet.

Scenario 6 - Office - Talking with colleagues
David is talking with a colleague whilst he is receiving a mediated touch. He wants to keep the touch private, but because the vibration is quite loud the colleague notices the touch and starts asking what it is.

Scenario 7: Funeral
David is at a funeral. He is sitting in the audience whilst someone else is giving a speech. He receives a touch from the bracelet, the noise is so loud that people around him can hear it. They look at him with annoyance.

Scenario 8 - In a car- driving
David is driving in a car and there is a lot of traffic, so he needs to remain focussed on what is happening around him. He receives a mediated touch while driving, and he is distracted by the touch. He becomes frustrated because this is not a good time for him.

Scenario 9 - Home - focus task
David is at home working with great concentration on repairing his game console. He is soldering two parts together, which requires a lot of focus and precision. Right at that moment he receives a mediated touch from Anna. As a result, his hand is out of balance.

Scenario 10 - Zoo/vet - while holding an animal
David is holding a cat while the vet is examining the cat. At that point David receives a mediated touch and the bracelet vibrates intensely. The cat startles because it also feels the vibration and scratches David.

Scenario 11 - Home - emotional phone call
David is at home on the phone with his grandmother, they are having an emotional phone call since she is telling him that she is sick. David feels very sad and at that moment he receives a mediated touch. Although it is nice to be touched, it is not a convenient time because David wants to give all his attention to his grandmother.

Scenario 12 - Home - watching a movie
David is watching an emotional movie, he is very emotionally invested in the movie and totally focused on what is happening on the screen. Suddenly he receives a mediated touch. He is startled by this touch and lost his attention in the movie

Scenario 13 - Kissenger device
David is in a busy park, he wants to send Anna a kiss via the Kissenger to wish her good luck. But since it is such a public place, he finds it awkward to give her a kiss.

Scenario 14 - Bracelet with a loud feedback sound
David wants to give a mediated touch by touching his bracelet. However, he is in a busy office space. The bracelet gives a loud feedback noise and David cannot give a mediated touch without drawing attention to himself. He does not want others to know he is sending the touch.

Scenario 15 - Mediated touch where you need to touch yourself
David is on a busy train. He wants to send a mediated touch, but this needs to be done by touching a body part of his own. Since he is cramped between different strangers, he does not want to accidentally touch them instead of himself.

Appendix D
Mindmap

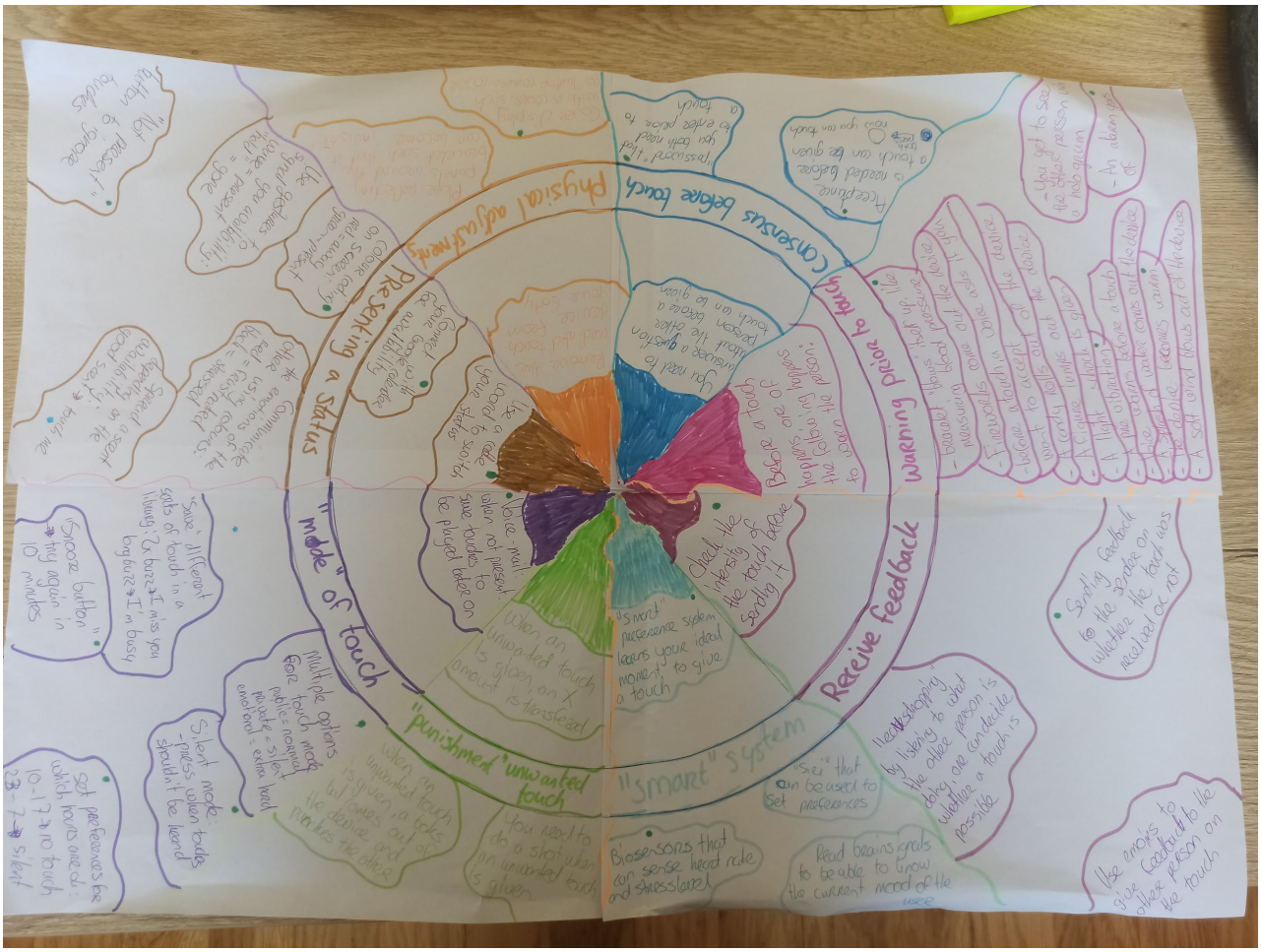


Figure D.1: Mindmap containing the solutions

Appendix E

Table with solutions

Nr.	Category	Solution	Realistic?	Good idea?	Why?
1	Receive feedback	Check intensity of touch before sending it	Yes	Maybe	Does not really solve intrusiveness on its own, can be a good add on to warn senders about the intensity of the touch
2	Receive feedback	'Eavesdropping'; by listening to the noise of the other person, the sender can decide whether or not to send a touch	No	No	You do not want a device that constantly listens. Could be used to measure decibel, but what does the data mean? Does a lot of noise mean that you cannot disturb? Or that you can?
3	Receive feedback	Send feedback to the sender whether a touch was received	Yes	No	Does not solve intrusiveness, but can be used to get rid of feeling that sender is unheard
4	Receive feedback	Use emojis to send feedback to the sender on how the touch was received	Yes	No	Lets the users communicate and give feedback on how a touch was received, but maybe it lacks context; if you receive an angry emoji then what do you do with it?
5	'Smart' system	'Smart' preference system that learns you ideal moment to give a touch	No	Yes	Would be interesting to learn for each person what their ideal moment of touching is. Switching statussen and such could be tiresome to do manually. Difficult to determine what kind of data needs to be gathered
6	'Smart' system	Biosensors that can sense heart rate/stress level	Yes	Maybe	Similar data gathering as smart watches. But how do you interpret data? In what situations is a touch wanted?
7	'Smart' system	Voice control that can be used to set personal preferences	Yes	No	Can be used to reduce screen time/interaction with the device. But it does not really solve the intrusiveness problem.
8	'Smart' system	Read brain signals for the mood of the user	No	Maybe	It is difficult to read brain signals in a wearable device and perhaps too invasive. But it is interesting to see

					what kind of brain signals could signal a good moment of touch
9	‘Punishment’ unwanted touch	When an unwanted touch is given, some money is transferred from sender to recipient	Yes	No	Users might not give any touches because they are scared that it is perceived as unwanted.
10	‘Punishment’ unwanted touch	Sender needs to do a shot when an unwanted touch is given	Yes	No	Users might not give any touches because they are scared that it is perceived as unwanted.
11	‘Punishment’ unwanted touch	When an unwanted touch is given, the sender is slapped with a boxing hand	No	No	Users might not give any touches because they are scared that it is perceived as unwanted.
12	‘Mode of touch’	Voicemail → when you are not present the touch is stored to be played later	Yes	Yes	Asynchronous communication. That way, the sender can send touches whenever they want but the receiver does not need to receive it immediately.
13	‘Mode of touch’	Multiple options for touch mode; public, private, silent	Yes	Maybe	It makes it less noticable when you are in a public space and you can choose how you want to experience the touch
14	‘Mode of touch’	Silent mode; press button for more silent touch; less vibration	Yes	Maybe	Is a silent touch mode still seen as intrusive? Then it might not be useful
15	‘Mode of touch’	Set preferences for which hours are ok for touching; 10-17 not ok, 17-24 ok	Yes	Maybe	Good idea to set moments when absolutely no touch is allowed. But what about the moments in between?
16	‘Mode of touch’	‘Snooze button’ → try again in x minutes	Yes	Yes	Same principle as snoozing alarm. But you need a warning prior to the touch, so you will not experience the touch if you snoozed
17	‘Mode of touch’	Save different sorts of	Yes	Maybe	If you are already giving a touch, then it might not add

		touch in a library; 2x buzz; i'm busy			much to communicate more with this touch. One is already interrupted by the touch, saying that the other one is busy or misses you might not add anything
18	Warning prior to touch	Device 'blows itself up' (air pressure)	Yes	Maybe	It resembles someone grabbing your arm, that could be interesting. But it can also be even more intrusive if the receiver cannot stop the action
19	Warning prior to touch	Fireworks come out of the device	No	No	It will startle the receiver, intrusiveness increases
20	Warning prior to touch	Before a touch, a voice asks if you want to accept the touch	Yes	Maybe	The voice can still induce intrusiveness, but it is a good idea to ask receiver if they want to experience the touch
21	Warning prior to touch	Candy rolls out of the device	Yes	No	Gives receiver wrong incentive to experience the touch
22	Warning prior to touch	A figure jumps out of the device	Yes	No	It will startle the receiver, intrusiveness increases
23	Warning prior to touch	A light electric shock is given	No	No	It will startle the receiver, intrusiveness increases
24	Warning prior to touch	A pre vibration prior to touch	Yes	Yes	If it is tiny enough it does not have to be intrusive. But receiver should not feel like pre vibration is part of the touch
25	Warning prior to touch	Voice warns for incoming touch	Yes	Maybe	If it is only a warning and no rejection is implemented then it is not useful. Then the warning will become the intrusive part
26	Warning prior to touch	Splash of water comes out of the device	No	No	It will startle the receiver, intrusiveness increases
27	Warning prior to touch	Device becomes warm	Yes	Yes	Warmth has more resemblance to human touch. But how much warmth and how to get rid off warmth after a

					touch? The receiver should be able to turn it off as well
28	Warning prior to touch	A soft wind blows out of the device	Yes	No	If it is a bracelet then it is difficult to position the breeze such that the receiver will notice it. Will it add anything?
29	Warning prior to touch	You get to see the other person via a hologram when touching	No	Maybe	This would be more a combination of video calling and using mediated touch. Does not really solve intrusiveness
30	Warning prior to touch	An alarm goes off before a touch	Yes	No	It will startle the receiver, intrusiveness increases
31	Consensus before touch	Mutual acceptance is need prior to giving a touch	Yes	Yes	Might reduce the fun for the sender, since they have to wait before sending. But, if both accept then both agree that a touch can be sent.
32	Consensus before touch	‘Password’ that you both need to enter to give and receive a touch	Yes	Maybe	Could be tiresome to enter a password everytime. Reduces the idea of giving a quick touch
33	Consensus before touch	You need to answer a personal question about the other before giving a touch	Yes	No	Too much effort to give a touch, reduces the idea of giving a quick touch
34	Physical adjustments	Remove mediated touch from your body	Yes	Yes	Current solution for most mediated touch devices; physically remove it from your arm
35	Physical adjustments	Place reflecting panels on device such that it becomes ‘invisible’ when no touch should be given	No	Maybe	Could be interesting to see if you still feel it even if you cannot see it properly. Bu can also give an eerie feeling.
36	Physical adjustments	Cover the display when no touch should be given; no distraction	Yes	Maybe	If there is a large display with lights then it can be good to cover this up, then you cannot get distracted by the lights.
37	Presenting a	Use code word to switch	Yes	Maybe	Using voice controls is quick and is saves you from

	status	status			redirecting your eyes to a screen. But is is also sensitive to errors and background noise.
38	Presenting a status	Connect to your online calendar for availability	Yes	Yes	Might be too invasive if the other person can view your calendar as well. But it is useful such that one does not have to switch availability manually all the time.
39	Presenting a status	Color coding status on screen; red=busy	Yes	Yes	Useful to know if the other person is available or not. Maybe more than two colours? Or only available/unavailable?
40	Presenting a status	Communicating the emotions of the other person using colors	Yes	No	Might not solve the intrusiveness problem. Can be good to know how the other person feels such that you know how to react
41	Presenting a status	Spread a sent depending on availability; nice scent = touch me	No	No	Too invasive. Also difficult to determine what is a ‘good’ scent and how to get rid off the scent once a touch is given
42	Presenting a status	‘Not present button’ to ignore incoming touches	Yes	Yes	Simplified version of status, where you only press a button to show you do not want to receive touches
43	Presenting a status	Use gestures to signal availability; waving = not present	No	Maybe	Reduces screen time. But difficult to implement

Appendix F
Solutions

These solutions were extracted from the table with initial solutions and explored further:

1. Check the intensity of a touch before sending it
2. Biosensors that can measure heart rate/ stress level
3. Voicemail, a touch is stored and is only played whenever the recipient 'plays' the voicemail
4. Silent mode; press button for more silent touch; less vibration
5. Multiple options for touch mode; public, private, silent. In which public generates a more present touch whereas the silent mode generates a small touch.
6. Set preferences for certain hours of the day during which a touch can or cannot be given
7. Snooze button, if a touch is not wanted at that moment it can be given again in x minutes.
8. Save different sorts of touches in a library; 2x buzz; i'm busy
9. Device inflates prior to an incoming touch
10. Before a touch is given, a voice asks if you want to accept the touch or not
11. A pre vibration prior to touch
12. Voice warns for incoming touch
13. Device becomes warm prior to a touch
14. Mutual acceptance is need prior to giving a touch, both users need to press a button to initiate the possibility for a touch
15. 'Password' that both users need to enter to give and receive a touch
16. Remove mediated touch from your body
17. Cover the display when no touch should be given; no distraction by the device
18. Use a code word with voice activation to switch status
19. Connect to your online calendar for availability
20. Use color coding on screen to show availability
21. 'Not present button' which can be pressed to ignore incoming touches

Appendix G
Protocols

C1: Voicemail; save touches to a voicemail which can be played whenever the received chooses

1. Alice wants to send a touch to Bob
2. Alice touches her device such that a touch is send
3. Bob does not receive this touch immediately
4. The LED button for a voicemail will change color; indicating there is a voicemail waiting for Bob
5. If Bob is ready to receive a touch, he can press the voicemail button to receive all the touches that are waiting

C2: A small vibration will warn the user of the incoming touch

1. Alice wants to send a touch to Bob
2. Alice touches her device
3. The touch is send from the device of Alice to the device of Bob
4. The device of Bob will start to vibrate slightly, vibration will increase
5. After the vibration is increased, the touch will be given.

C3: Warmth of device increases to warn user for incoming touch

1. Alice wants to send a touch to Bob
2. Alice touches her device
3. The touch is send from the device of Alice to the device of Bob
4. The device of Bob will increase in warmth slowly

5. After the warmth is increased enough, a touch will be given.

C4: Connect with a calendar and status screen

1. The status of Alice is determined by using the online calendar of Alice
2. When putting an item in the agenda a disturbance level can be added;
   (a) Level 0; touches can be given freely
   (b) Level 1; Touches cannot be given during this event
   (c) Maybe some in between levels? For example; only long touches, max amount of touches per event, no repeating touches etc.
3. If an item is in the calendar of Alice, her status will be switched to red.
4. Bob will see the status of Alice, which will be either red or green

Appendix H
Instruction and troubleshooting guide

Instruction guide user test - mediated touch

Thanks again for your participation in my user test! In this guide, I will explain everything about the device and how you can use it. Remember that safety is most important. The device contains a battery and if you feel that the battery is getting hot or something else does not feel right, you should take off the device immediately! If, at any point during the user test, you have any questions or something is happening with the device, you can send a message or give me a call!

Once your 4 sessions are complete, I will make an appointment to collect the devices again. If you have any other feedback, remarks or thoughts on the experiment you are more than welcome to share them with me!

Kind regards,
Marieke van Doorn

Before the experiment can begin:
We will discuss suitable start and end times for the experiment for both you and your partner. 15 minutes before the start of the session, you will receive a reminder text message that your session is about to start and with some instructions on initializing the session. Once your session is ended, you will also receive a message that you can take off the device.

When you receive your text message, you can turn the device out of sleep mode by pressing the RIGHT touch sensor for a few seconds. This will boot up the system again, and after a few seconds, both lights will turn pink (starting up can take some time). If this does not happen after a minute or so, you can press the reset button.
If the led lights are pink, this means that you are connected to the wifi and I can see your device. When both devices are online, I will initiate your mode and your session. When the pink lights turn off, the mode has been initialized and you can start sending touches. I will also send you a reminder message if both modes are initialized. At the end of this page, there is a short description of each mode, such that you know what to expect. But I encourage you to test them out for yourself!

ORDER OF THE MODES:

- Session 1:
    - START TIME: _____
    - END TIME: _____
- Session 2:
    - START TIME: _____
    - END TIME: _____
- Session 3:
    - START TIME: _____
    - END TIME: _____
- Session 4:
    - START TIME: _____
    - END TIME: _____

<u>The end of each session:</u>
When it is time to end the session, you will receive a text message indicating that you can take off the device. Consequently, you are asked to fill in the questionnaire. It is advised that you fill in the questionnaire immediately after the end of each session. Then, you can charge the device. I will put the device into sleep mode. If the pink lights are off, this means that your device is into sleep mode. If something does not work correctly, feel free to send me a message!

<u>Filling in the questionnaire:</u>
Use the following link to fill in the questionnaire, or scan the QR code

Sleeve number: _____

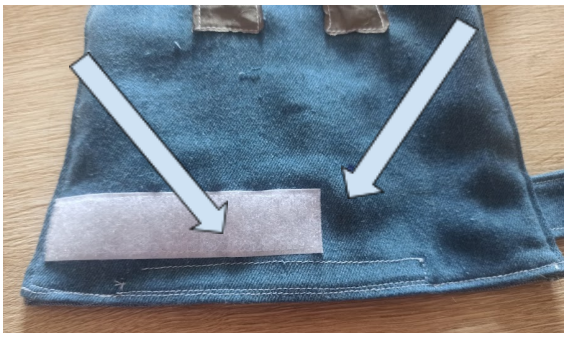
Pair number: _____

Charging the battery and sleep mode:

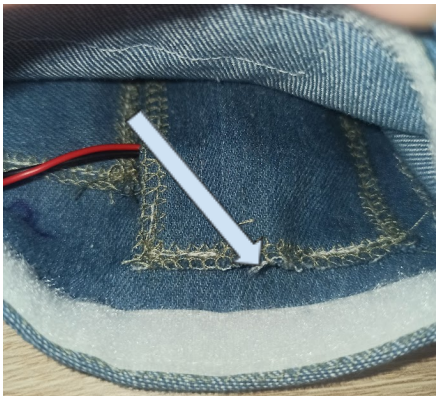
Once the session has ended and you have completed the questionnaire, it is also important to charge the battery for the session the next day. Therefore, you need to plug in the attached USB-cable into a charging device, such as your laptop. It is recommended to charge the battery for a minimum of 4 hours. It is also recommended to charge the battery for an hour or so before the sessions starts, if this is possible.

How to charge the battery:
Unfortunately, it was not possible to attach a cable to the microcontroller. This means that you need to plug it in yourself. This is done by following these steps:

1. Open the velcro (klittenband) at the top of the sleeve (this is the widest part, near your elbow)

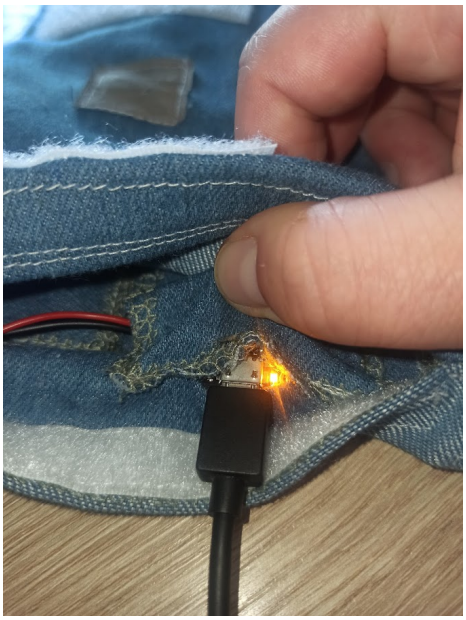


2. You will see a pouch with a small opening



3. Pull back the top of the opening with your fingers (I know this is delicate work) and the micro USB port will appear.

4. Put the cable into the USB port



5. Attach the other side of the cable to a charging device, such as your laptop.
6. Once the battery is charged, you can gently pull the cable out of the micro USB port and close the pouch again.

Explanation of each mode:

In each mode, the layout of the touch sensors are the same. The RIGHT touch sensor is used to give a touch. If your touch is sent to your partner, the right LED light will react. The LEFT touch sensor can be used to either change your status, snooze the touch or play your voicemail.

To get an idea of what is happening during each mode, an explanation is provided below:

Status mode:

During this mode, you can indicate your status to your partner. If you do not wish to receive touches, you can change your status. Your partner can see your current status as indicated by the LED lights.

Green: Available, you can receive touches
Red: Unavailable, you cannot receive a touch from your partner

Changing status:
You can indicate your status using the LEFT touch sensor. If you do not want to be touched, you press the touch sensor and you will see that your status will change to red, stating that you are not available. Touching the sensor again, will change the led to green, indicating that you are available.

Snooze mode:

In this mode, when your partner gives you a touch you will be prompted with the LED light which will blink for 5 seconds. If you do not want to be touched, you can touch the LEFT touch sensor. The touch will be snoozed and will be repeated after 3 minutes. If you do nothing, you will receive the touch.

Voicemail:

During this mode, you will not immediately receive the touch. When your partner sends a touch to you, your LED light will turn on, indicating that there is a touch ‘waiting’ for you. If you want to receive the touch, you press the LEFT touch sensor and you will receive the touches that are waiting for you. This means that there could also be multiple touches waiting.

Normal:

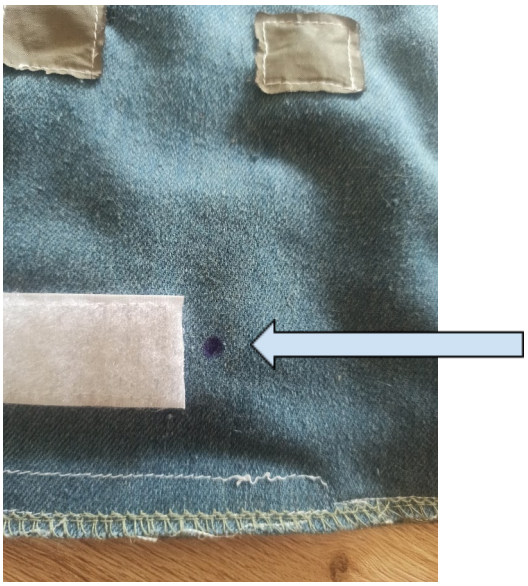
In the normal mode, you will simply send touches back and forth between you and your partner. If you send a touch, your partner will receive it and vice versa.

FREQUENTLY ASKED QUESTIONS AND TROUBLESHOOTING GUIDE

I think my device stopped working, what can I do?

You can try to reset the device, if this does not work then you should send me a message. If you believe that your device is not working, you can also send a message to your partner such that they know what is going on.

Reset the device:
There is a small reset button on the microcontroller which can be found on the round marking at the top of the sleeve (see picture). You might need to feel around a little bit, but you will find it there. You can press this button to restart the device. Once pressed it is advised to wait a minute such that the device can start again. Once the device is reset, the lights should turn pink again. If this is the case, it means that you have an internet connection and I can re-enter your mode.



I need to take off the device, should I inform my partner?
If it is for a short period of time, it is not necessary to inform your partner. However, if you suddenly cannot continue for the rest of the session then it is good to inform your partner and me as well. We can discuss together if it is necessary to reschedule the session. In some modes, the device will still work properly even if it is taken off temporarily. For example, in the status mode you can set your status to unavailable and then take off the device.

What can I do whilst wearing the device?
You can continue doing your daily work, for example studying. You can also walk around with the device and perform chores such as folding laundry or watching a movie on the couch. If the device is connected to the hotspot of your mobile phone, you could go outside with it. However,

if it is not connected to wifi then it will use your data plan instead. Take that into consideration, and whether you have data available for this.

Keep in mind that the device needs wifi to function, so if you are out of range or your wifi malfunctions then you should inform your partner.

What can I NOT do whilst wearing the device?
You cannot do any workouts or intense activities where you will move your arms heavily. It is also not advised to wear the device while biking or driving a car (because I do not want to be responsible for any accidents).
Furthermore, the sleeve should also NOT come in contact with water. That means that showering whilst wearing the device is not recommended but also doing the dishes is not a good idea.

If you are unsure on whether you can wear the device during a certain activity, please feel free to send me a message!

I forgot to fill in the questionnaire, is that a problem?
I will check after each session whether the questionnaire is filled in correctly, if this is not the case I will send you a reminder. So no worries, you cannot forget it!

I made a mistake when filling in the questionnaire, how can I fix this?
You can inform me of the faulty questionnaire and your starting time. Then I can delete this questionnaire from the database and you can fill it in again!

I feel unsafe wearing the device, what should I do?
If you do not feel comfortable wearing the device, you can take it off at any point during the sessions! If you do not wish to continue with the user test, you can send me a message and we will stop the test. That is totally fine, safety comes always first.

I think the device is getting hot, what do I do?
Take it off! Then, you can send me a message and we can figure out what the problem is.

The lights of my device are white, what does this mean?
Your device cannot connect to the internet. Check whether your wifi is connected.

My device does not work, what can I do?
Usually this means that there is a problem with the battery. You can charge the device and then see if it starts working again.

Appendix I
Consent Form

Consent form experiment "intrusiveness mediated touch"

The University of Twente and the Department of EEMCS support the practice of protecting research participants' rights. Accordingly, this project was reviewed and approved by an Institutional Ethical Board. The information in this consent form is provided so that you can decide whether you wish to participate in our study. It is important that you understand that your participation is considered voluntary. This means that even if you agree to participate you are free to withdraw from the experiment at any time, without penalty.

The aim of this study is to diminish the possibility for intrusiveness as caused by a mediated touch. To this end, you will be part of an experiment in which different solutions for this intrusiveness will be examined. Mediated touch is the ability of touching someone over a distance through a haptic device. This research will be carried out as part of my master thesis at the University of Twente.

During the study, you will be wearing a prototype sleeve around your arm that is able to give and receive a mediated touch. You will be using the prototype throughout the day following your normal activities. You can take of the prototype at any time during the experiment and you can withdraw your consent at any time during the experiment. A more detailed description on the set up of the session can be found in the brochure.

At the end of each session, you will be asked a series of questions through an online survey. In this survey you can share your experiences with the prototype. Furthermore, the data that is sent between your prototype and the prototype of your partner will be recorded, this data is limited to when a touch is send between the two parties. The data will be stored according to the GDPR guidelines for at most five years (until June 2027). At the end of the experiment, when the prototype will be collected again, your data will be anonymized such that it cannot be traced back to you. This experiment poses no known risks to your health. If you have any questions not addressed by this consent form, please do not hesitate to ask. If you want to talk about this study with an independent person, contact the Ethics Committee of EWI.

Declaration of consent (please tick each checkbox if you consent)

- ◯ **1.** I have read and understood the study information dated [DD/MM/YYYY], or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction.
- ◯ **2**. I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason.
- ◯ **3.** I understand that my data is stored for research purposes as described above, and can be stored until June 2027

_____ _____

Name and signature participant Date

_____ _____

Name and signature researcher Date

Appendix J
Qualtrics questionnaire

Block 6

What is your sleeve number (see instruction guide)?

- ○ Sleeve 1
- ○ Sleeve 2

What is your pair number?

Default Question Block

How strongly do you agree with the following statements:

	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
I was worried that using the sleeve would make my partner uncomfortable	○	○	○	○	○
Using the sleeve with my partner made me uncomfortable	○	○	○	○	○
Sometimes I received a touch, but I would not have wanted to	○	○	○	○	○
I wanted to give my partner a touch, but I did not because I was afraid they would not like it	○	○	○	○	○
I would not use the sleeve in public because it made me feel uncomfortable	○	○	○	○	○
I got disrupted during an important task because I received a touch from my partner	○	○	○	○	○
I experienced one or more incoming touches as unwanted	○	○	○	○	○

How strongly do you agree with the following statements:

	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
I would have enjoyed the same touch more if it was given in real life	○	○	○	○	○
I would have enjoyed the sleeve more if I was able to see my partner	○	○	○	○	○
I enjoyed this way of communicating with my partner	○	○	○	○	○

What were the reasons you would send a touch to your partner? You can mention multiple reasons. For example; emotional support, fun etc.

How strongly do you agree with the following statements:

	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
I considered what my partner was doing before sending a touch	○	○	○	○	○
I enjoyed receiving touches from my partner	○	○	○	○	○
I felt closer to my partner when I received a touch from him/her	○	○	○	○	○
I enjoyed sending touches to my partner	○	○	○	○	○
When I received a touch from my partner, I felt the need to give them a touch back	○	○	○	○	○

How often did you communicate with your partner throughout the day by phone calls or text message?

- ○ We did not communicate with each other via phone calls/text messages
- ○ Only one or two text messages/phone calls
- ○ A few text message/phone calls
- ○ A lot of text messages/phone calls

What were you doing whilst giving/receiving touches?

- ☐ Working/studying
- ☐ Doing chores
- ☐ Watching TV
- ☐ Gaming
- ☐ _____ Other:

Block 1

Which mode did you do today?

- ○ Voicemail
- ○ Normal
- ○ Status
- ○ Snooze

What did you like about the snooze function? You can name as many aspects as you like

What did you dislike about the snooze function? You can name as many aspects as you like

How strongly do you agree with the following statements:

	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
I wanted to snooze but I saw too late that my partner sent me a touch	○	○	○	○	○
It would have been easier if I could have denied the touch as well	○	○	○	○	○

Block 2

What did you like about the voicemail function? You can name as many aspects as you like

What did you dislike about the voicemail function? You can name as many aspects as you like

Block 3

What did you like about the normal function? You can name as many aspects as you like

What did you dislike about the normal function?You can name as many aspects as you like

Block 4

What did you like about the status function? You can name as many aspects as you like

What did you dislike about the status function? You can name as many aspects as you like

How strongly do you agree with the following statements:

	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
It was useful to know whether my partner was available or not	○	○	○	○	○

	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
I sometimes forgot to switch my status	○	○	○	○	○
I got annoyed with my partner when they were unavailable but I wanted to give them a touch anyway	○	○	○	○	○

Block 5

Do you have any other remarks or suggestions you would like to share?

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