Universiteit Utrecht
Master Toegepaste Cognitieve Psychologie

THESIS

Communicating discrete emotions using mediated touch

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27.05.2014

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Abstract

Even though touch plays an important role in human communication, modern internet-communication focuses predominantly on visual and auditory interaction. In the current study, I raised the question whether mediated touch resembles real touch, and whether discrete emotions can be communicated using a haptic device. To induce emotions, we used picture arrays which were validated in an online study beforehand. In the main experiment we measured the percentage of correct identification of emotions in five different conditions, namely mediated, unmediated or no touch, splitting the first two up in visible or invisible touch. One participant would try to communicate a discrete emotion, while the other one tried to recognize this emotion. Participants would also see each other's facial expressions. For one of the mediated touch conditions, a set-up was made where the hands were projected on top of each other. We used questionnaires to obtain subjective measures of the perceived closeness and perceived ability to recognize emotions across different conditions. Results showed that although participants were able to communicate discrete emotions significantly above chance level, no significant improvements in communicating emotions were found for the different touch conditions. Results from the questionnaires after each condition showed that the condition with the projected haptic device made the mediated touch feel more real, but that real touch still made the contact feel closer than mediated touch. We may conclude that mediated touch does not improve recognition of discrete emotions compared to no touch, but that the contact was nevertheless perceived as more comforting than no touch.

* Kies voor één persoonsvorm waarin je het gehele verslag schrijft.

1. Introduction

The recent development of internet-based communication has created the opportunity for people to stay easily in contact with people who are geographically separated from them. Current communication devices rely predominantly on the visual and hearing senses, even though touch plays an important part in the communication of emotion too. The lack of touch in modern communication tools might be the reason that mediated communication feels less personal than face-to-face communication and, because of that, inferior to real communication (Haans & IJsselsteijn, 2006). In the current study, I investigated whether using a device that can transfer touch over the internet, in engineering terminology referred to as 'haptics' or 'mediated touch', might make mediated communication feel more personal and real, and whether emotions can be recognized better than when touch is not part of the communication.

1.1. Touch in the communication of emotion.

In many situations people have the opportunity to touch each other directly, but this is not always possible. Take for instance couples, family members or friends who are geographically separated from each other. They can see and speak to each other with any of the current online communication systems (e.g., Skype, FaceTime, Google Hangout, Adobe Connect), but miss the feeling of being able to touch each other. Another example is inpatient cancer treatment, where cancer patients with low immunity have to be isolated in hospitals and may be deprived of frequent human contact with the family, which can have some serious consequences (Cabibihan, Zheng, & Cher, 2012). Considering the importance of social touch in affective and social communication, the addition of touch to online communication would potentially be very useful.

Whereas facial and vocal displays of affect have been thoroughly researched in the communication of emotion (e.g., Banse & Scherer, 1996; Ekman & Oster, 1979; Russell, 1994), social touch has received relatively little attention. Nevertheless, touch plays a crucial part in the affective communication of humans (Field, 2010). For example, people may use touch in everyday face-to-face communication to add sincerity, weight or urgency to a conversation (Bailenson, Yee, Brave, Merget, & Koslow, 2007). Furthermore, touch can enhance the readiness to

empathize (Schirmer et al., 2011), affect the physical, emotional, social and spiritual wellbeing (Field, 2010), decelerate heartbeat and blood pressure (Drescher, Gantt, & Whitehead, 1980; Weiss, 1986), reduce anxiety (Weiss, 1990), increase trust (Bailenson et al., 2007) and lower pain and stress levels (Fishman, Turkheimer, & DeGood, 1995). It is interesting to add mediated touch to online communication, since touch might add an affective quality to human communication that facial and vocal communication alone cannot achieve.

1.2. Mediated touch

Although past research suggested that only positively valenced warmth and intimacy, or negatively valenced pain and discomfort could be communicated by touch (Hertenstein & Campos, 2001; Knapp & Hall, 1997), recent research has claimed that people can recognize a number of different discrete emotions reliably when touched. For example, Hertenstein, Keltner, App, Bulleit and Jaskolka (2006) separated two strangers using an opaque barrier, so they could not see each other, and could only touch each other through a hole in the barrier. One participant was instructed to convey different emotions by only touching the forearm of the other participant. The other person had to guess which emotion was being communicated. The results indicated that participants could decode anger, fear, disgust, love, gratitude and sympathy above chance levels, but were not able to recognize happiness, surprise, sadness, embarrassment, envy and pride. Bailenson et al. (2007) investigated whether emotions could also be recognized when communicated through digital touch. They did this by having participants generate several emotions by moving a joystick, after which other participants interacted with these recordings and attempted to recognize each emotion. Bailenson et al. also tested whether participants could communicate the emotions to one another via a normal handshake. They found that the emotions conveyed by the haptic device could be recognized with an accuracy of twice what would be expected by chance, although participants were more accurate when transferring the emotions via direct contact. These two studies illustrate that various emotions can be communicated via handshakes, even when these handshakes are mediated.

Several devices have been designed to realize a haptic stimulation over the internet, including for example the Frebble (Toet et al., 2013), Feelybean (Kontaris,

Harrison, Patsoule, Zhuang, & Slade, 2012), Lumitouch (Chang, Resner, Koerner, Wang, & Ishii, 2001) and HugMe (Cha, Eid, Barghout, Rahman, & El Saddik, 2009). Despite the differences between these devices, they all have in common that they aim to provide people with a sense of presence or connectedness with a distant other (Gaver, 2002; IJsselsteijn, van Baren, & van Lanen, 2003). Results from several studies show that the addition of a haptic device can increase the ratings of 'togetherness' on spatial tasks (Basdogan, Ho, Slater, & Shrinivasan, 1998). Furthermore, the addition of mediated touch to the telling of a story improved the feeling of connectedness to the storyteller (Wang, Quek, Tatar, The, & Cheok, 2012). But, will using these devices also improve the communication of emotions between one another?

Although promising results were found in earlier studies (Bailenson et al., 2007; Cabibihan et al., 2012, Kontaris et al., 2012; Suhonen et al, 2012; Wang et al., 2012), some points of critique can be raised. For example, most of the work has focused on the design of haptic devices, and only a few studies are available that report on the empirical validations beyond the level of anecdotal descriptions of user experiences (Haans & IJsselsteijn, 2006). Furthermore, in most studies that tested whether emotions could be communicated using haptic devices, the task consisted of communicating instructed emotions, instead of communicating actual experienced emotions (Bailenson et al., 2007). Instead of forcing people to generate emotions on demand, it might be better to have participants really experience the emotions. Additionally, most studies examined mediated touch in isolation; that is, without input from the other senses. However, likely, a haptic system will eventually be used in combination with audio and vision. It would therefore be worthwhile to examine whether the addition of mediated touch to current online communication systems improves the communication (Bailenson et al., 2007).

Another point of critique was that mediated communication felt less personal than face-to-face communication (Haans & IJsselsteijn, 2006). One way to address this problem might be by making use of the synchronized combination of touch and vision, which can create a strong sense of bodily ownership (Armel & Ramachandran, 2003). It is long known that vision can be so powerful in relation to touch, that the touch experience itself undergoes a change, making an object actually feel the way it looks (Ramachandran & Rogers-Ramachandran, 1996; Rock & Victor,

1964). This dominance of vision over touch can be seen in the rubber hand illusion, where when someone watches a fake rubber hand tapped in synchrony with his own hidden hand, that person will start experiencing the rubber hand as part of its own body (Botvinick & Cohen, 1998). The crucial part for invoking a strong illusion seems to be that the visuo-tactile stimulation should be synchronized (Botvinick and Cohen, 1998; Slater, Perez-Marcos, Ehrsson, & Sanchez-Vives, 2008), and stronger effects are found if the rubber arm is aligned with the real arm (Pavani, Spence, & Driver, 2000). It is also possible to replace the rubber arm with a virtual arm, keeping in mind that the virtual arm should be perceived as connected to the rest of the body (Perez-Marcos, Sanchez-Vives, & Slater, 2012). Proper perceived alignment between touch and vision might be crucial for realistic affective mediated touch. That is, you feel what you see.

1.3. Research question

In this study I raised the following question: Can discrete emotions be communicated using mediated touch? This research question was divided into three different sub-questions:

1. How does mediated touch compare to unmediated touch?

The frequent use of online communication led to the design of haptic devices, considering that social touch plays an important part in the affective communication between people. However, simply assuming that the use of a haptic device will be similar to real touch might be a bit premature. Although touch is able to convey strong emotional feelings, currently there is little empirical evidence that this is also the case for mediated touch (Haans & IJsselsteijn, 2006). Since one of the main applications of mediated touch will be in the communication of emotions between geographically separated people, I investigated whether using mediated touch communicates emotions as well as using unmediated touch does.

2. Does mediated touch facilitate the communication of emotions with facial expressions?

The little research that has been done on communicating emotions via mediated touch has been done with touch in a vacuum; that is, the other participant could not be seen nor heard (Bailenson et al., 2007). Since mediated touch will be

used to improve online communication, it will be useful to find out whether the addition of mediated touch improves the communication of emotions in current online communication systems. Therefore, instead of using exclusively a haptic device to communicate emotions, I investigated whether the addition of mediated touch facilitates the communication of discrete emotions with facial expressions.

3. Will the co-occurrence of vision and touch make mediated touch seem more real?

Comments on other studies about mediated touch are that the communication might improve when the setting is more similar to real communication. I hypothesized that the device might be better at transferring emotions when it is set up in a way that seems like the participants are actually holding hands, making the contact with the other person as similar to face-to-face communication as possible.

1.4. Research approach and thesis outline

In the remainder of this thesis I will first discuss an online validation study, which consists of two parts. I conducted this validation study to make sure the picture sets used in the main experiment will actually invoke the intended emotions. Methods and results will be explained for both parts of the validation study, followed by a discussion. Second, the main experiment will be discussed. In the main experiment, different emotions would be elicited in one participant, while the other had to identify these emotions. The correct identification of emotions would be measured in five different conditions, containing either mediated, unmediated or no touch, while the first two are divided up further in visible and invisible touch. In addition to these measures, questionnaires would be done. I will conclude this thesis with a general discussion, where the results will be considered in light of the research question, together with suggestions for further research.

2. Study 1 – Inducing discrete emotions

A point of critique on earlier research was that people were forced to generate emotions on demand, which led to studying idealized, artificially constructed emotions, instead of actual experienced emotions (Bailenson et al., 2007). Therefore, instead of telling the participants what to feel, we wanted them to really experience the emotions, by inducing these with emotion eliciting pictures. Research showed that pictures are an adequate method to induce emotions in research settings (Codispoti, Bradley, & Lang, 2001; Smith, Löw, Bradley, & Lang, 2006). In the first study we validated picture arrays made based on previous research (Mikels, Fredrickson, Larkin, Lindberg, Maglio, & Reuter-Lorenz, 2005), to make sure these picture sets could consistently evoke the intended discrete emotion in the main experiment. This validation study consisted of two parts: First, several picture arrays for each emotion were made, and rated on emotion and strength in an online experiment. After that, the picture arrays that were less able to elicit the intended emotions were identified, and another online validation study was conducted make improved picture arrays.

2.1. Method

2.1.1. Participants

For the first part of this experiment seventeen participants were recruited online, ranging in age from 22 to 76 years. Four men (M = 30.0, *SD* = 12.0) and 13 women (M = 41.5, *SD* = 16.1) were tested. Most of the participants were Dutch, with the exception of one Spanish, one Belgian and one French woman. For the second part of this experiment another seven participants were recruited online. They ranged in age from 21 to 62 years, and included four women (M = 22.0, *SD* = 1.2) and three men (M = 35.3, *SD* = 23.1). All of them were Dutch.

2.1.2. Materials

We used the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2005), a set of standardized emotion eliciting color photographs, as a basis for this study. The choice of using such a picture database was based on their facilitation of comparison of results across different studies (Bradley & Lang, 2007),

their clear evocative ability (Codispoti et al., 2001; Smith et al., 2006), cross-cultural consistency (Bradley & Lang, 2007), and ease to edit and manipulate.

Although the pictures in the IAPS were originally rated in terms of the dimensions of pleasure (valence) and arousal, some research has been done on the categorical classification of the IAPS (Barke, Stahl, & Kröner-Herwig, 2011; Jackson Davis et al, 1995; Libkuman, Otani, Lern, Viger, & Novak, 2007; Mikels et al., 2005). We decided to use the basic emotions proposed by Ekman and Oster (1979), but to leave out surprise, because it can be argued that surprise may better be explained as a cognitive state rather than an emotion (Oatley & Johnson-Laird, 1987; Ortony & Turner, 1990; Ortony, Clore, & Foss, 1987), and because surprise seemed almost impossible to consistently induce in earlier studies anyway (Bailenson et al., 2007; Barke et al, 2011; Jackson Davis et al, 1995; Libkuman et al., 2007).

Based on the study by Mikels et al. (2005) a selection was made of 15 pictures per emotion (anger, disgust, fear, happiness and sadness). These were divided into three arrays, each containing five pictures of the same emotion.

In the second part of the validation study I used the previously obtained results to improve the picture arrays. While the IAPS consists of more than 1000 pictures, previous picture arrays were made based on the article by Mikels et al. (2005), who only tested a subset of 390 pictures. To improve the "anger" and "fear" subsets, more pictures of anger or fear eliciting subjects from the IAPS were added to the list of previously chosen pictures. In addition to the already established selection of 15 pictures per emotion, another 15 pictures per emotion were added. Ten "happy" pictures were added so people would not notice that only two emotions were tested.

2.1.3. Procedure

The experiment was done online. Participants received a link from where they could go directly to the experiment webpages. The experimental webpage started with a welcome screen, explaining why the experiment was conducted and with the question whether they promised to participate seriously. After that some demographic information was obtained and additional information about the experiment was given.

For the first part of the experiment the different picture arrays were shown randomly. After each array participants could indicate which emotion they felt, and

how strongly they felt it on a scale from one to ten. It was stressed that it was important to indicate which emotion they felt, not what they saw in the picture. If they did not feel any emotion, they could also indicate 'None of these emotions'.

Before each array 10 'neutral' pictures of the IAPS were shown, followed by a black picture to indicate that the emotional picture array was starting. The pictures were originally normed and rated by being shown for six seconds (Bradley & Lang, 2007), so we decided to hold on to this presentation time. This made each picture set 30 seconds long. Each neutral image was shown for two seconds, thus letting participants return to a neutral emotional state in 20 seconds.

For the second part of the study, instead of combining the pictures into arrays, each picture was presented separately so they could be rated individually. This way, it could be made sure each single picture elicited the intended emotion, before combining them into new arrays. Each picture was shown for six seconds, after which participants were asked to indicate which emotion they felt and how strongly they felt that emotion. After all picture arrays were shown participants were thanked for their time and given contact information if they would like to learn more about the study. The first study took about 15 minutes, the second around 20 minutes.

2.2. Results

The percentages of 'correct' responses per picture array for the first part of the study are shown in Table 1. The results indicated that the picture arrays with happy, disgusting and sad emotional pictures all had 81 percent or more correct responses. That is, when the pictures were meant to induce happiness, at least 81% of the participants indicated that they felt happy. Anger and Fear on the other hand had between 41% and 59% correct responses. Binomial tests were performed to see if the frequencies of correct responses were significantly higher than what could be expected by chance (20%). This was the case for all emotions (p values between .038 and .000).

Even though the Anger and Fear picture arrays were identified significantly better than chance, the percentages of correct identification of emotions were lower than on other emotions; at least 41% of the responses were incorrect, compared to the at most 19% incorrect responses on other emotions.

Table 1.

Percentage of 'correct' responses on every picture array, and the mean indicated strength of the induced emotion.

	Array 1		Array 2		Array 3	
Emotion	Correct (%)	Strength	Correct (%)	Strength	Correct (%)	Strength
Anger	53**	7.8	59**	7.5	41*	6.9
Disgust	94**	8.3	89**	7.8	94**	7.4
Fear	44*	8.1	47**	6.3	53**	7.2
Happiness	81**	6.0	94**	6.4	95**	7.1
Sadness	83**	5.2	94**	6.0	89**	6.6

Binomial tests; **p<.01, *p<.05.

To make better picture arrays, a second experiment was conducted to find pictures that induced anger and fear more consistently. For each separate picture the percentages of correct answers were calculated, and the pictures with the highest percentage of correct answers were evenly distributed over three sets of pictures, as can be seen in Table 2. Fear eliciting pictures that had at least 50 percent of correct responses were identified. In contrary, few pictures were able to consistently evoke anger in the participants; only five pictures were found that were able to elicit anger in at least half of the participants

Table 2.

New arrays anger and fear eliciting pictures, with the IAPS number and percentages of correct responses.

	Array 1		Array 2		Array 3	
Emotion	Number	Correct (%)	Number	Correct (%)	Number	Correct (%)
Anger	6312	60	9150	50	6550	50
	9424	33	2691	50	6315	50
	2751	33	2688	33	6350	25
	9427	17	9940	17	2345	25
Fear	1201	80	6263	75	1200	75
	2811	67	6231	67	6250	67
	8475	50	1525	60	1932	60
	1300	50	1304	50	6260	50

2.3. Discussion

Results showed that emotions were appropriately and reliably induced. Fear and anger scored lower percentages of correct responses, and even after the second part of the study anger was still hard to elicit consistently. Of the thirty pictures tested for this emotion, only five of them were able to elicit anger in at least half of the participants. This might be because anger is an emotional state associated with feeling injured or offended (Kalat & Shiota, 2011). The internal cause of this emotion might make it harder to elicit with just pictures or film clips. Research on emotion elicitation showed that eliciting anger is difficult using films (Phillipot, 1993; Gross & Levenson, 1995), which seemed also to be the case with pictures (Mikels et al., 2005).

3. Study 2 – Communicating emotions with mediated and unmediated touch

To answer the question whether mediated touch resembles real touch, and whether it is able to communicate discrete emotions, a lab experiment was conducted. In addition to squeezing each other's (mediated) hand, participants could see each other's facial expressions. This way we could investigate whether using mediated touch improves the communication of emotions with current online communication tools.

3.1. Method

3.1.1. Participants

Twenty participants were recruited at the TU Delft and via Facebook. Sixteen of them were rewarded with a book voucher of €10, the remaining four worked at the university and did not receive a compensation. The participants ranged in age from 16 to 42 years, and consisted of 12 woman (M = 22.7, *SD* = 4.3) and eighth men (M = 25.0, *SD* = 7.3). Participants had different nationalities: Two of them were Chinese, one Spanish, one Surinamese, one Romanian, one French, one Indonesian, one Hispanic-American and 12 were Dutch. All of them were right-handed, with the exception of one who was ambidextrous. Two participants signed up alone and were partnered with someone they did not know, two participant couples were life partners, and the rest of them were acquainted. Informed consent was obtained for all participants, and the experiment was done in agreement with the Declaration of Helsinki, Dutch Law and local ethical regulations.

3.1.2. Materials

To transfer mediated touch a device designed by Holland Haptics called a Frebble was used (see Figure 1). The Frebble is a battery powered force-feedback device, that when squeezed delivers a vibrating pulse on the hand palm of the person holding the other Frebble. The Frebble held by the sender was attached to a pink rubber glove stuffed with cotton balls (see Figure 2), which was taped to the table. The Frebble held by the receiver was not attached to anything. To capture the faces of the participants two Logitech HD Pro C920 webcams were used, attached on two LG television screens with a resolution of 1920x1080, placed at 65 cm distance from the head. To capture the arm a Logitech HD C525 webcam was used,

Figure 1. The Frebble

Figure 2. The Frebble attached to the rubber glove

placed at 82 cm distance above the table. A Dell Precision T3600 computer running on Windows 8.1 was used to show these webcam images and picture sets. The webcam images were shown in a custom-made webpage viewed in Google Chrome. To project the hand a Projectiondesign projector with a resolution of 1400 x 1050 was installed 123 cm above the table. A styrofoam table of 92 cm by 51 cm by 9.5 cm was made to cover the hand of the receiver.

3.1.3. Procedure

The experiment took place in a lab at the Faculty of Electrical Engineering, Mathematics and Computer Science at the Delft University of Technology. No other people than the two participants and the experimenter were in the room at the time of the experiment. Both participants received an experiment pack including information about the study, instructions, contact information, an informed consent form, a questionnaire to obtain some demographic data, questionnaires for during the study and a questionnaire for after the study.

The experiment was a 2 ("Visible touch" vs. "Invisible touch") by 3 ("Mediated touch" vs. "Real touch" vs. "No touch") within-subjects design. Since in the "No touch" condition no hands would be seen, no distinction between visibility and invisibility was made here, which made a total of five within-subject conditions (see Table 3). For the "Real touch" condition the hands would be hold on the table of the receiver. In the visible "Real touch" condition the receiver could see both hands, while in the

Table. 3

The different conditions with the way of touch and the visibility of their own hand holding the other hand.

		Touch	
Visibility	Mediated	Real	None
Visible	A1	B1	X
Invisible	A2	B2	C

invisible "Real touch" condition their hands would be covered. To make the touch 'visible' in the visible "Mediated touch" condition, the senders Frebble-holding hand was projected on top of the receivers hand, while the receiver would hold his Frebble exactly underneath the rubber glove. The webcam image of the senders face was real life sized, and adjusted so the projected underarm seemed attached to the upper arm (see Figure 3A & 3B). In this way, the communication seemed considerably more like face-to-face communication than when only a haptic device was used.

The screen of the receiver contained only a webcam image of the senders face. Depending on the condition the receiver would also see the projected Frebble or the real hands. The screen of the sender was divided up in two parts, showing the emotional picture arrays on the left side, and a video image showing the other participant on the right side.

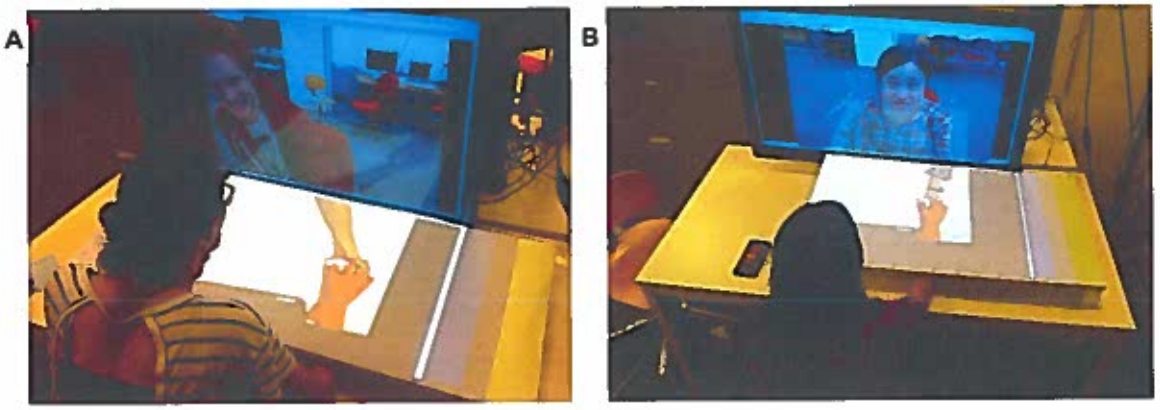

Figure 3A & 3B. The Frebble-holding hand of the sender is attached to a rubber glove, which is projected on top of the hand of the receiver.

The 15 picture arrays established in the validation study were divided into three different sets; each set included picture arrays for each emotion. Before each picture array the name of the emotion was already shown to the participant to make the induced emotion even less ambiguous. Each picture array was preceded by eight neutral pictures, shown for 1,5 seconds per picture, which allowed for a 12 seconds timespan to return to a neutral emotional state. To counter fatigue, the presentation time of each picture was reduced to 4 seconds per emotional picture. Earlier research showed that presenting the pictures for 500ms elicited similar affective reactions as with pictures that were presented for six seconds (Codispoti, Bradley, & Lang, 2001). In addition to that, Bradley & Lang (2007) also showed that single pictures shown for six seconds were already sufficient to induce intended emotions. Since each emotional state would last for 16 or 20 seconds in our study, the shortened presentation time would not hurt the induction of emotions.

The experiment was done in pairs. After the participants filled in the informed consent form and demographic information forms, one participant was asked to take place on the Senders table, the other on the Receivers table. After the first five conditions they switched places, so each would participate in all five conditions either as Sender and Receiver. By constructing a 5x5 balanced Latin Square, the order of conditions and picture sets were completely counterbalanced across the experiment.

The Sender would see each emotional picture array, and tried to transmit this emotion with facial expressions and, depending on the condition, by using his hand or the Frebble. They were instructed not to exaggerate their facial expressions, but that it was not necessary to keep a straight face. The participants were not allowed to talk to each other. After each emotion the sender could indicate which emotion they felt and how strong they felt this emotion. The Receiver had to decode the emotion and indicate which and how strong the transferred emotion was. Both the sender and receiver could also indicate 'None of these', if they did not experience any emotion. A beeping sound was heard every time an emotion started, a double beep when the picture array ended.

After each condition both participants filled in a short questionnaire, with questions on the mediated touch and on how close they felt to the other participant (see Appendix A & B). The questions could be rated using 5-point Likert scales,

ranging from 'Not at all' to 'Very much'. At the end of the experiment a final questionnaire was filled in to rank the conditions on different aspects and with space to leave further comments (see Appendix C). They were given time to ask questions and talk about what they thought of the experiment.

3.2. Results

In this section we will first look at how well emotions were induced in the sender and how accurate each emotion was recognized by the receivers. Second, we will see whether there were any differences in the identification of emotions between different conditions. Finally, the answers on the questionnaires were averaged and compared for every condition.

3.2.1. Differences between emotions

On average the emotions were correctly induced in the sender in 90.2% of all trials, as measured by the emotion the sender reported after each picture set. The distribution of reported emotions by the sender is shown in Table 4, together with the average strength they reported for each emotion. As can be seen, not all senders reported the intended emotion; some felt another emotion than the picture was supposed to elicit. To see if the intended emotions were significantly reported more than chance (20%), a Binomial test was performed. All emotions were correctly induced significantly higher than chance ($p < .01$).

Table 4.

Percentages of experienced emotion by the sender at every picture set and their average strength.

	Sender							Strength	
Picture Set	Anger	Disgust	Fear	Happiness	Sadness	None	Total	M	*SD*
Anger	82**	3	1	0	7	7	100	6.0	2.4
Disgust	0	97**	0	1	1	1	100	7.3	2.2
Fear	0	0	77**	6	0	17	100	5.1	2.5
Happiness	0	0	0	98**	0	2	100	5.9	1.9
Sadness	1	1	0	0	97**	1	100	5.4	1.9

Binomial tests; ***p<.01*

Table 5.

Percentages of the reported emotions by the receiver by every experienced emotion by the sender.

	Receiver						
Sender	Anger	Disgust	Fear	Happiness	Sadness	None	Total
Anger	53**	6	11	1	22	7	100
Disgust	5	75**	1	3	13	3	100
Fear	10	10	42**	8	16	14	100
Happiness	0	2	4	82**	3	9	100
Sadness	11	4	11	4	49**	21	100

Binomial tests; $^{**}p<.01$

The percentages of accurate responses from the receiver are shown in Table 5, together with the distribution of responses over the other emotions. The response was defined as correct when the receiver reported the same emotions as the sender. Participants recognized the intended emotions with an average accuracy of 58.3%. Binomial tests were performed to see if the intended emotions were recognized significantly more often than chance, which was indeed the case for all emotions ($p < .01$). The trials where the sender reported to experience none of the emotions were left out.

3.2.2. Differences between conditions.

The number of correct answers per participant per condition was counted, based on whether the receiver and the sender both reported the same emotion. We decided to use the emotions reported by the sender instead of the emotion the picture was intended to elicit, since those were the emotions that would be communicated to the receiver. On average the highest amount of correct answers were given in the "Visible Mediated touch" condition (M = 3.2, *SD* = .3), followed by "Invisible Mediated touch" (M = 3.0, *SD* = .3) "Invisible Real touch" (M = 3.0, *SD* = .3), "Visible Real touch" (M = 2.9, *SD* = .3), and "No touch" (M = 2.9, *SD* = .3). To create a full factorial design, the control condition was doubled and used as both visible and invisible "No touch" condition, since no division could be made here. A 2x3 repeated-measures ANOVA with Visibility and Touch as factors revealed there was no main effect for Visibility ($F(1,19) = .043$, $p = .837$, $\eta_p^2 = .002$) nor for Touch

($F(2,38) = .428$, $p = .655$, $\eta_p^2 = .022$) on correct identification of emotions by the receivers. There was no interaction effect either.

3.2.3. Strength

To see whether the receivers were able to recognize the elicited strength by the sender, we looked at if the overall strength the emotions elicited in the sender was correlated with the strength the receiver reported to perceive. The incorrectly recognized emotions were left out. A significant correlation between elicited emotion in the sender and perceived emotion by the receiver was found, $r(99) = .325$, $p = .001$. If we divide these up per condition, we see that only in the "Invisible Real touch" condition the felt and perceived strength was significantly correlated ($r(20) = .562$, $p = .010$), but not in the other conditions.

To test if there were differences in the communicated strength per condition, the average strength perceived by the receiver per condition was calculated. The incorrectly recognized emotions were left out. On average the perceived strength was highest for the "No touch" condition (M = 6.3, *SD* = 2.0), followed by "Visible Real Touch" (M = 6.2, *SD* = 1.6), "Invisible Real Touch" (M = 5.9, *SD* = 1.6), "Visible Mediated touch" (M = 5.6, *SD* = 1.9) and "Invisible Mediated touch" (M = 5.5, *SD* = 2.3). A 2x3 ANOVA with Touch and Visibility as factors was performed. Mauchly's test indicated that for Touch the assumption of sphericity had been violated ($\chi^2(2) = 11.6$, $p = .003$), therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon = .66$). No main effects of Visibility ($F(1,18) = .335$, $p = .570$, $\eta_p^2 = .018$) nor Touch ($F(1.329,23.922) = 1.987$, $p = .169$, $\eta_p^2 = .099$) on perceived strength were found.

3.2.4. Other factors

It might be possible that of each participant couple, the second participant scored higher on the correct identification of emotions than the first one. Since the second participant had already been the sender, they already knew which emotions were induced and what to expect. To test if there were differences between the two groups an independent samples T-test was performed. We found that participants who were receiver after they had been sender performed significantly better

(M = 17.2, *SD* = 4.0) than the ones that started as receiver (M = 12.3, *SD* = 3.8), $t(28) = 3.194$, $p = .003$.

Another factor that might influence the scores were the picture sets. It might be possible that one of the sets elicited stronger emotions, which could influence the data. A 3x1 repeated measures ANOVA with Picture set as a factor revealed no significant effect, $F(2, 496)=.040$, $p = .961$.

To check whether the non-significant results were due to a lack of statistical power, I did a post hoc power analysis using G*power (Erdfelder, Lang, & Buchner, 2007), with power (1 - β) set at 0.80, α = .05, and using the achieved effect size of $\eta_p^2 = .020$. This showed us that sample sizes would have to increase up to N = 88 in order for the correct identification of emotions to reach a statistical significance at the .05 level.

3.2.5. Questionnaire data

Average responses on questionnaires are shown in Table 6. We wanted to find out if the addition of a projected hand would make the mediated touch seem more like real touch. A one-way repeated measures ANOVA with Visibility as factor revealed significant differences for the "Visible Mediated touch" condition over the

Table 6.

Average response on questionnaires on a 5-point Likert scale.

	Questions	A1	A2	B1	B2	C
Receiver	Did the projected arm feel like your real arm?	2.7				
	Did the Frebble feel like part of your real hand?	2.8*	2.3			
	Did the Frebble feel as an extension of your arm?	2.9*	2.3			
	Did the Frebble feel similar to a real hand squeeze?	2.2	2.0			
	How close did you feel to the other person?	3.2**	2.5	4.1**	3.6**	2.3
	How well do you think you recognized the emotions?	3	2.7	3.3	2.9	3
Sender	Did the Frebble feel similar to squeezing a real hand?	2.2				
	How close did you feel to the other person?	2.7		3.6**		2.1
	How well do you think the other recognized your emotions?	3.2		3.7**		3.1
	Did you feel comforted by the presence of the other?	3.1**		3.4**		2.0

*p<.05, **p<.01 (compared to the control condition).

"Invisible Mediated touch" condition on the questions if the Frebble felt like part of the real hand ($F(1,19) = 5.487$, $p = .030$, $\eta_p^2 = .224$) and if the Frebble felt as an extension of the arm ($F(1,19) = 7.120$, $p = .015$, $\eta_p^2 = .273$). No significant results were found for the question whether it felt similar to a real hand squeeze, $F(1,19) = .379$, $p = .545$, $\eta_p^2 = .020$.

For the responses of the receivers, we did a one-way repeated-measures ANOVA with Condition as factor, instead of a 2x3 repeated measures ANOVA. This way we obtained measures of each separate condition compared to the other, instead of the combined effects of different Touch and Visibility conditions. A main effect for Condition on perceived closeness was found, $F(4,76) = 15.001$, $p = .000$, $\eta_p^2 = .441$. Significant effects of "Visible Mediated touch" ($p = .007$), "Visible Real touch" ($p = .000$) and "Invisible Real touch" ($p = .000$) over the "No Touch" control condition were found. Here as well a significant effect of "Visible Mediated touch" over "Invisible Mediated touch" was found ($p = .019$). Significant results for "Visible Real touch" over both mediated touch conditions were found ($p = .005$ for "Visible Mediated touch", $p = .000$ for "Invisible Mediated touch"). No significant results between the real touch conditions ($p = .058$), nor for the "Invisible Mediated touch" over the "No touch" condition ($p = .507$) were found. No main effects for how well the receivers thought they recognized the emotions were found, $F(4,76) = 1.772$, $p = .143$, $\eta_p^2 = .211$.

For the results of the sender the visible and invisible conditions were averaged with each other, since the sender would not see the projection nor the hands in neither of the conditions. A one-way repeated-measures ANOVA with Touch as factor, revealed a main effect for Touch on closeness, $F(2,36) = 15.610$, $p = .000$, $\eta_p^2 = .587$. A significant effect of "Real touch" compared to "Mediated touch" ($p = .000$) and "No touch" ($p = .000$) was found. Between the "Mediated touch" and the "No touch" condition no significant interaction was found ($p = .567$). Main effects of Touch were found for how well the senders thought the emotions were recognized, $F(2,38) = 6.391$, $p = .004$, $\eta_p^2 = .252$. Here too, significant results for "Real touch" over "Mediated touch" ($p = .006$) and "No touch" ($p = .003$) were found, without significant effects for the "Mediated touch" over "No touch" ($p = .439$). Main effects for Touch on how comforted the senders felt were found ($F(2,38) = 35.906$, $p = .000$, $\eta_p^2 = .654$), with significant effects of "Mediated touch" ($p = .000$) and "Real touch"

Table 7.

Average ranking of the five conditions on the final questionnaire.

	Question		
Rank	Closest to the other	Resembles Face-to-Face communication	Recognition of emotions
1st	B1	B1	B1
2nd	A1	B2	B2
3rd	B2	A1	C
4th	A2	C	A1
5th	C	A2	A2

(p = .000) compared to the "No touch" condition. No significant differences between "Mediated touch" and "Real touch" were found here (p = .083).

After all conditions were finished we had asked the participants to rank the conditions on a few different aspects, shown in Table 7. Finally, the question was asked if they thought the Frebble would add something to online communication, and in what ways. The average result fell in the middle of the Likert-scale. Comments were that the Frebble might add something when you are in a long distance relationship and need some comfort, and that it helps to make you feel closer to the other, but that it might work better if the device were able to convey smaller gestures too.

3.3. General discussion

Current mediated communication only uses visual and auditory interaction, even though social touch has proven to be crucial for affective communication. To answer the question whether mediated touch is able to communicate discrete emotions, we conducted an experiment with two independent variables (Touch and Visibility), to see if emotions were better identified when adding touch to facial expressions. Responses were measured by counting the amount of correctly identified emotions per condition, and by taking questionnaires after each condition. Results showed no significant improvement of identifying emotions across different conditions. Responses on questionnaires showed that the projection of the Frebble-holding hand made the mediated touch considerably more real, but that real touch still scored better than mediated touch.

We asked ourselves the following question: Can discrete emotions be communicated through mediated touch? To answer this, we divided this general question up in three sub questions, which will be answered below. In section 3.3.1 we will look at if mediated touch compares to unmediated touch. After that, we will see whether the addition of mediated touch facilitates the communication of emotions with facial expressions. Then, we will look whether the co-occurrence of vision and touch makes the mediated touch feel more real. After that we will integrate these answers to give an answer to the general research question. Then, we will look at the implications of this study and we will give some suggestions for future work. Finally, I will end with a general conclusion.

3.3.1. How does mediated touch compare to unmediated touch?

We found no significant differences in the communication of emotions between mediated and unmediated touch. Other research methods might need to be used to get a better view of the relation between mediated and unmediated touch. Comments by participants were that the longer they hold the Frebble, the more real it felt because it warmed up, although an improvement might be if the device was able to convey smaller touch gestures too. This might make it more like real hand holding, which might be a step towards a smaller gap between mediated and unmediated touch. In addition this, several other devices could be tested to see if these show different response patterns. It might be possible that other types of touch might be more able to communicate emotions than squeezing each other's hand.

If we look at the responses on questionnaires, we can see that perceived closeness by both the receiver and the sender is significantly higher for unmediated touch than mediated touch. This result is not illogical, seeing that participants were holding each other's real hand in the unmediated touch condition, which is warmer and more sensitive to small gestures than the mediated touch device.

No significant differences for how comforted the sender felt were found. This is in contrast to a study done by Cabibihan et al. (2012), who showed improved comfort (measured by decreases in heart rate after experiencing a sad event) for either mediated as unmediated touch, with better results for unmediated touch. One reason for this difference might be that they only induced sadness with a sad video-clip for five minutes, while we induced five different emotions for shorter periods of time.

Sadness might also be one of the emotions where the need for comfort is highest. If we did questionnaires on perceived comfort after each emotion, we might possibly have found an effect of touch on comfort for sadness.

In the final rankings both unmediated touch conditions were ranked higher than mediated touch on the perceived recognition of emotions and on how much it resembled face to face contact. These results are in line with earlier findings by Bailenson et al. (2007), who found better results for real touch over mediated touch. We can conclude that unmediated touch is superior to mediated touch on a couple of different aspects.

3.3.2. Does the addition of mediated touch facilitate the communication of emotions with facial expressions?

Although both mediated touch conditions scored higher on the identification of emotions than the control condition, no significant differences were found. This contradicts the study done by Bailenson et al. (2007), who did find a significant effect of communicating discrete emotions using mediated touch over no touch. Since touch was tested in isolation in that study, one of the reasons the communication of emotions did not improve with mediated touch in our study, might be that the facial expressions were so strong, that most emotions could be correctly identified by using only the seen facial expressions. This made the possible added effect of mediated touch so small it made it almost impossible to find a significant effect. The power analysis suggested that a much bigger sample size was needed to find significant results for an effect of this size.

Both mediated touch conditions ranked higher in closeness on the final questionnaire, and the sender felt significantly more comforted by the presence of the other using mediated touch than with no touch. These facts are in line with an earlier mentioned study by Cabibihan et al. (2011), who found increased comfort of mediated touch over no touch. Remarkable is that the no touch condition ranked higher in the perceived recognition of emotions than both mediated touch conditions. One of the reasons for this might be that when interacting with the Frebble, the attention is divided between the device and the screen, while in the no touch condition all attention could be focused on the facial expressions. Some participants

commented that they found the device distracting sometimes, and made them look at their hands instead of the screen.

As we can see, the addition of mediated touch to facial expressions does not improve the ability to identify discrete emotions. It does make people feel closer to each other in some situations, and might be a good way to comfort a distant other.

3.3.3. Will the co-occurrence of vision and touch make the mediated touch seem more real?

Although visible mediated touch scored higher on the recognition of emotions than invisible mediated touch, no significant improvement of visibility of the arm was found for recognition of emotions. Responses on questionnaires indicated that the visible Frebble condition made the Frebble feel significantly more as part of the real hand and as an extension of the arm than the invisible Frebble condition. This finding is important, since assimilating the device with the own body is a huge step towards improving the mediated touch experience. Instead of solely focusing on designing different devices, it might be extremely useful to also pay attention to the set-up it can be used in. It might be expanded further by changing the projection for a virtual hand, which might be an easier set-up to use at home. Research already showed that the rubber hand illusion could be translated to a virtual hand illusion (Padilla et al., 2010; Slater, Perez-Marcos, Ehrsson, & Sanchez-Vives, 2008). Using information from these studies, a simpler set-up with a virtual hand could be made for the use at home.

Significantly better results for projected Frebble on perceived closeness over either the invisible Frebble condition as on the no touch condition were found. In the final rankings the visible Frebble scored higher on all conditions than the invisible Frebble. In addition to this, almost all participants commented that they really enjoyed the condition with the projected hand, and that it seemed incredibly real. These findings implicate that improving the set-up instead of only paying attention to the device might be a good starting point to a more realistic way to use mediated touch.

3.3.4. Can discrete emotions be communicated using mediated touch?

This main research question can be answered with "no"; I did not find indication in the data that would support this hypothesis. Even though the discrete emotions were correctly induced and identified in most of the trials, we did not find

any significant effects between the different touch conditions. The power analysis suggested that a sample size of 88 participants was needed to find significant results for an effect of the size obtained in this study.

It is possible that because not all emotions could be consistently induced on every trial, communicated emotions were not always strong enough. We expected that anger and fear benefited most from the use of (mediated) touch, since a study by Hertensteijn et al. (2006) indicated that out of more than twenty coded tactile displays, hand squeezing belonged to the first two for these emotions. Unfortunately, these two emotions also pertained to the bottom two of induced and recognized emotions in our study. To evoke anger and fear more consistently other methods might be used, for example recalling anger-evoking personal memories (Engebretson, Sirota, Niaura, Edwards, & Brown, 1999) or seeing fear-eliciting video-clips (Kalat & Shiota, 2011). When these emotions are more consistently induced, they might benefit considerably from mediated touch.

3.3.5. Implications study

Even though we could not prove that discrete emotions could be communicated using mediated touch, we did find some interesting answers in the questionnaire data. It must be kept in mind that questionnaires should be used with careful consideration because of their subjective nature. On the other side, experiencing emotions is mainly subjective, wherefore questionnaires make an adequate research method to measure emotions. We found that the participants seemed to feel closer to one another and more comforted in the mediated touch conditions than in the control condition. The possibility to be able to comfort a distant other is at least an equally important goal of mediated touch as is the communication of emotions.

Another important finding is that the addition of a projected hand seemed to improve the mediated touch considerably. This might be expanded further by changing the projection for a virtual hand, which might be an easier set-up to use at home. This finding is important, since instead of exclusively focusing on designing different devices, it might be necessary to also pay attention to the set-up it can be used in.

* 't is niet zo dat emoties in mediated touch niet worden overgebracht, maar dat mediated touch 'niets toevoegt aan' het herkennen van emoties.

3.3.6. Suggestions further research

One of the main target groups for haptic devices are couples in long-distance relationships, since these will benefit considerably from being able to touch each other when they are not able to do this in person. More research with people who are in a romantic relationship could be done. They will also be more used to holding each other's hand, and might feel more comfortable doing that than strangers or platonic friends. On the other hand, in the study conducted by Hertenstein et al. (2005), strangers were able to accurately decode a number of different emotions by touch. In this study we only tested two romantically involved couples, hence not much about their results can be said. They did announce to be very enthusiastic on the possibilities such a device could mean for them, and indicated they would buy it when available on the market.

We did also find an unexpected discrepancy in results for the order in which the participants were sender or receiver. In future research it might be desirable to switch places per condition, or tell them more about the experiment beforehand. The reason we did not do that in this experiment is because we did not want the participants to be able to calculate which emotions were not shown yet.

It might be useful to conduct a study that focuses more on perceived closeness and comfort, and that measures this with other methods than questionnaires. Even though we found significant results on various questions, there is always the chance with a lot of questions that a few will appear to be significant. On the other hand, results on questions that measured more or less the same seemed to be fairly consistent.

We can conclude that we were not able to prove that discrete emotions could be communicated using mediated touch, although some interesting answers were found in the questionnaire data. These give possibilities for further research on mediated touch.

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Appendix A. Questionnaires Sender

Questionnaire after condition A1 & A2 – Set… **Sender**

Did the Frebble feel similar to squeezing a real hand?

O O O O O
Not at all A bit Very Much

How close did you feel to the other person?

O O O O O
Not at all A bit Very Much

How well do you think the other participant recognized your emotions?

O O O O O
Not at all A bit Very Much

Did you feel comforted by the presence of the other?

O O O O O
Not at all A bit Very Much

Further comments:

Questionnaire after condition B1, B2 & C – Set... **Sender**

How close did you feel to the other person?

O O O O O

Not at all A bit Very Much

How well do you think the other participant recognized your emotions?

O O O O O

Not at all A bit Very Much

Did you feel comforted by the presence of the other?

O O O O O

Not at all A bit Very Much

Further comments:

Appendix B. Questionnaires Receiver.

Questionnaire after condition A1 – Set... **Receiver**

About the Frebble

Did the Frebble feel like part of your real hand?

O O O O O

Not at all A bit Very Much

Did the Frebble feel as an extension of your arm?

O O O O O

Not at all A bit Very Much

Did the projected arm feel like your real arm?

O O O O O

Not at all A bit Very Much

Did it feel similar to a real hand squeeze?

O O O O O

Not at all A bit Very Much

General

How close did you feel to the other person?

O O O O O

Not at all A bit Very Much

How well do you think you recognized the emotions?

O O O O O

Not at all A bit Very Much

Further comments:

Questionnaire after condition A2 – Set... **Receiver**

About the Frebble

Did the Frebble feel like part of your real hand?

O O O O O

Not at all A bit Very Much

Did the Frebble feel as an extension of your arm?

O O O O O

Not at all A bit Very Much

Did it feel similar to a real hand squeeze?

O O O O O

Not at all A bit Very Much

General

How close did you feel to the other person?

O O O O O

Not at all A bit Very Much

How well do you think you recognized the emotions?

O O O O O

Not at all A bit Very Much

Further comments:

Questionnaire after condition B1, B2 & C – Set... **Receiver**

General

How close did you feel to the other person?

O O O O O

Not at all A bit Very Much

How well do you think you recognized the emotions?

O O O O O

Not at all A bit Very Much

Further comments:

Appendix C. Final Questionnaire

Questionnaire after the whole experiment

Can you rank in which condition you felt closest to the other participant? 1 is for the condition where you felt closest, 5 for the one you felt less close:

Frebble + Projected Hands ...
Frebble + Invisible Hands ...
Real Hands – Visible ...
Real Hands – Invisible ...
Just Face ...

Can you rank which condition felt the most like normal face-to-face communication? 1 is for most, 5 is for least:

Frebble + Projected Hands ...
Frebble + Invisible Hands ...
Real Hands – Visible ...
Real Hands – Invisible ...
Just Face ...

In which condition you think you recognized most of the emotions accurately? 1 is for most accurate, 5 for least accurate:

Frebble + Projected Hands ...
Frebble + Invisible Hands ...
Real Hands – Visible ...
Real Hands – Invisible ...
Just Face ...

Do you think the Frebble can add something to online communication?

O O O O O

Not at all A bit Very Much

In what ways?

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