"I'm Always Touched by Your Presence, Dear": Combining Mediated Social Touch with Morphologically Correct Visual Feedback

Antal Haans and Wijnand A. IJsselsteijn

Eindhoven University of Technology
{A.Haans, W.A.IJsselsteijn@tue.nl}

Abstract

Combining mediated social touch (interpersonal touch over a distance) with visual feedback allows people to both see and feel their interaction partner's touches. Combining touch with vision is expected to increase the transparency of the interface, as well as the user's sense of telepresence. We anticipated these positive effects of visual feedback to depend on the morphological congruence of the visuotactile stimulation. In our experiment, we compared two input media (the devices on which the touch acts are performed): a sensor-equipped mannequin, enabling a one-to-one mapping between seen and felt touch, and a touch screen displaying buttons. With morphologically congruent visual feedback participants demonstrated more physiological arousal, reported a higher sense of telepresence, and perceived of the mediated touches as more touch-like. These findings illustrate that morphologically congruent multisensory stimulation is important for transparency and telepresence, and that visual feedback, especially when morphologically correct, can improve mediated social touch.

Keywords – **Computer mediated communication, physical contact, mediated social touch, telepresence, personal space, physiological arousal**

1. Introduction

Touching is an important part of our social interaction repertoire. Despite the significance of touch, current communication devices rely predominantly on vision and hearing. In recent years, however, several designers and researchers have developed prototypes that allow for mediated social touch; enabling people to touch each other over a distance by means of haptic and tactile feedback technology. Examples of such prototypes are the inTouch [1], and the FootIO [2] (for a recent overview, see [3]). Designers of such systems conjecture that the addition of a haptic or tactile communication channel will enrich mediated interactions, and generally refer to the symbolic and intrinsic (e.g., recovery from stress) functions of social touch, as well as to the supposed intimate nature of addressing the skin. There are, however, several notable differences between a real touch and the tactile and haptic stimulation provided by the prototypes described earlier (also [4]). First, interpersonal touching requires people to be in very close proximity of each other, and thus involves a possible violation of a person's personal space (i.e., the culturally defined area around the body in which the presence of others is considered inappropriate; e.g., [5], [6]). The strong relation between touch and physical closeness makes the notion of "touch over a distance" somewhat of a paradox, especially when compared to the mediation of visual or auditory interaction, which by their nature are less dependent on physical proximity. Second, simulating the sensation or "feel" of a human touch is difficult and expensive, despite advancements in tactile and haptic display technologies (for an overview, see, e.g., [7], [8]). As a result, current prototypes rely on simple electromechanical actuators, such as vibration motors, which are a poor substitute for real physical contact (i.e., in terms of the qualitative experience or "feel").

To our knowledge, published work on prototypes that allow for mediated social touch have not yet considered to combine touch with vision, which would allow people to see, and at the same time feel, their interaction partner performing the touches (also [9]).[1] Combining touch with vision allows the central nervous system to extract real-time intermodal correlations, which is crucial in the design of transparent media technology [10]. Transparency is important, because when people "forget" about the interface, they are more likely to respond to the touches as if the mediating technology were not there [3]. They might thus perceive of the electromechanical stimulations as more natural or touch-like when combined with visual feedback. Moreover, by establishing reliable visuotactile correlations, a tactile sensation might be felt, not on the person's own body, but in the location in which the stimulation is seen (so-called distal-attribution [11]). This, in turn, is expected to facilitate people in developing a sense of telepresence: the impression of being physically there in the same location as the person initiating the touch [12]. Relevant in this respect, is a recent study by Lenggenhager and colleagues [13]. In their experiment, participants wore a head-mounted display through which they saw a virtual character standing with its back toward the participant. This virtual character was created by a real-time recording of a fake human figure (i.e., a mannequin). The experimenter stroked the backs of the participant and the mannequin in precise synchrony. The

[1] Interestingly, in the domain of internet-based adult toys (for which Ted Nelson coined the term teledildonics in the 1970s), there are several commercial systems available that take advantage of combining tactile stimulation with visual feedback.

participant would thus feel the strokes on his or her body, while seeing the virtual character being stroked at the same time. After one minute of such visuotactile stimulations, many participants developed the vivid impression that the body they saw standing in front of them was actually their own, as if they were looking at themselves standing in the location of the virtual character (resembling telepresence).[2] Interestingly, no such illusion was elicited when the virtual "character" did not resemble the human body. Based on this finding, one can expect that the positive effects of combining mediated social touch with vision depend on the morphological congruency between the human body and the input medium on which the touch acts are performed.

1.1 Research Aims

In this study, we investigate the effect of combining touch with morphologically correct visual feedback on people's responses to mediated social touch. We expect that a morphologically congruent input medium, which resembles the human body and allows for a one-to-one mapping between seen and felt touch, will result in a more transparent interface than an incongruent input medium. This expectation is translated into four related hypotheses. Our first hypothesis states that seeing the touch acts being initiated on a morphologically congruent input medium will increase the perceived naturalness of the felt touches. Our second hypothesis states that with a morphologically congruent input medium, men will be more uncomfortable with a mediated touch by another man. This hypothesis is based on social psychological research in North America and North Western Europe which demonstrates that men generally dislike and avoid touching other men (for an overview, see, e.g., [15]). We test this hypothesis by means of both self-reports and the extent to which people experience physiological arousal in response to being touched (measured by means of Electrodermal Activity; EDA). Our third hypothesis states that people will report a higher sense of telepresence (i.e., "being there") with a morphologically congruent input medium. The measurement of EDA provides an interesting alternative means (next to self-reports) of tapping into the strength of a person's telepresence experience. As mentioned before, touching often involves the violation of another person's personal space. Such personal space violations are accompanied by increased physiological arousal [16]. If a person shows more signs of physiological arousal when the interaction partner, rather than keeping a respectable distance, moves very close toward the input medium, then this provides strong evidence that this person developed a vivid telepresence experience (since his or her personal space, then, must have extended into the remote environment). Since telepresence is expected to depend on the morphological congruence of the visual feedback, our fourth hypothesis states that the effect of the distance between the interaction partner and the input medium is expected to be larger with a morphologically congruent as compared to an incongruent input medium.

2. Methods

2.1 Participants

Our sample was drawn from the participant database of the JF Schouten School at Eindhoven University of Technology, Eindhoven, the Netherlands. Twenty-two persons, all free of medication use and known medical conditions, were invited to participate in the experiment. Two persons were excluded from the data set due to technical problems with the tactile display. Of the remaining 20 participants, the mean age was 35.0 (*SD* = 18.5; range 18 to 65 years); All participants were of Dutch nationality. All participants received a compensation of € 10.00.

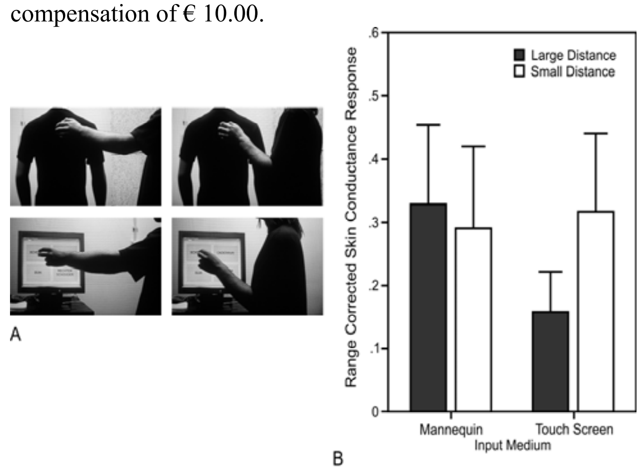

Fig. 1: Panel A depicts the visual stimuli for the four conditions. The images are video stills converted to grayscale. Rows depict the morphologically congruent (top) and incongruent visual feedback (bottom). Columns depict the far distance (left) and close distance touches (right). Panel B depicts the range-corrected skin conductance responses (SCR's) and corresponding 95% confidence intervals for the four experimental conditions.

2.2 Experimental Design

The experiment consisted of two sessions. In each session, the participants were remotely touched by another person (a confederate of the experimenter). At the same time, the participants could see the confederate performing the touches on an input medium through a television screen, which displayed a real-time recording of the confederate's actions. A two (Morphologically Congruent vs. Incongruent input medium) by two (Large vs. Small Distance to input medium) repeated-measures experiment was conducted. In the "Mannequin" session, participants could see the confederate performing the touches on a human-like input medium (i.e., a mannequin; see Fig. 1A). This input medium was congruent with the morphology of the human body not only in appearance, but also the mapping between seen and felt touch. In the "Touch Screen" session, the human-like

[2] The process in which a foreign object is categorized by the central nervous system as a part of the body is called self-attribution. For a discussion on the relation between self-attribution and telepresence, see [14].

input medium was replaced by a set of buttons, each corresponding to a body location (displayed on a touch screen; see Fig. 1A). This input medium was incongruent with the human body both in appearance and in the mapping of felt and seen touch. The order of the Mannequin and Touch Screen sessions was counterbalanced across participants. In both sessions, participants received eight mediated touches (four body locations by two distances from the interface). For the Large Distance touches, the confederate would touch the mannequin or touch screen while keeping the largest possible distance between himself and the input medium (see Fig. 1A). For the Small Distance touches, the confederate would step up towards the input medium before initiating the touches (thereby clearly violating the social norms with respect to personal space, should such space have extended to the remote location). The order of the touches was counterbalanced across participants. For each participant, however, the same order was used in the Mannequin and Touch Screen session.

2.3 Stimuli and Apparatus

Tactile stimulation was provided through a neoprene vest equipped with vibration motors (similar to [17]). Series of 8 actuators were located at the stomach, 16 at the upper-back, and 12 at the lower back region. Two actuators were placed on the right shoulder. The Morphologically Congruent input medium consisted of a male mannequin equipped with reed contacts (i.e., an electrical switch operated by applying a magnetic field). The position of the reed contacts were matched to the position of the actuators in the vest, with each reed contact connected to one actuator. Small magnets were attached to the confederate's fingers. By bringing a magnet near a reed contact, the contact would close and the corresponding vibration motor was actuated. Mediated touches to the stomach and lower and upper back were given by stroking the magnet over the reed contacts on the mannequin. Mediated touches to the participant's shoulder were given by briefly touching the reed contacts on the shoulder of the mannequin, thereby resembling a tap rather than a stroke. Touches to the stomach were done with the right hand, but all other touches were done with the left hand. Since the reed contacts on the mannequin were matched to the position of the actuators in the vest, the mannequin input medium allowed for a one-to-one mapping between seen and felt touch for both body location and direction of touch.

The Morphologically Incongruent input medium consisted of a touch screen on which four buttons were displayed, each of which corresponded to one of the four body locations (see Fig. 1A). The buttons were labeled with the name of the body part they represented. Each time the confederate briefly pressed a button on the touch-screen, the software actuated the corresponding vibration motors to either produce a stroke (i.e., for the stomach, lower, and upper back) or a tap (i.e., for the shoulder). The hardware and software used for controlling the actuators with the touch screen were similar to that used by Rovers and Van Essen [2]. The buttons were always pressed with the left hand. The confederate was trained extensively to match the duration of the mediated touches in the Mannequin session with those in the Touch Screen session. The room in which the experiment was conducted was divided in two sections by means of a black curtain. One section housed the mannequin and touch-screen input media, as well as a digital camera that recorded the confederate's actions. In the other section of the room, a 21 inch television screen was placed at face height. During the sessions, the participant stood facing the television screen at a distance of approximately 1.50 meters. The television was connected to the camera standing in the other section of the room, allowing the participant to watch, in real-time, the confederate's actions on the input medium. To avoid that participants could see their own reflection in the television screen during the sessions, lights were switched off in this section of the laboratory room.

2.4 Procedure

Participants were invited to the laboratory to evaluate a multimodal communication device together with another person. This other person was a male confederate of the experimenter. The confederate was casually dressed in a manner appropriate for a young man of his age (21 years). At their arrival, participants were asked to wash their hands with soap and water. Next, the experimenter assisted the participants with putting on the tactile vest, and asked him to wear disposable earplugs to block background noise. Meanwhile the experimenter prepared the electrodes for the measurement of EDA by filling the cavities with electrolyte gel. The electrodes were attached to the fingers of the participant's non-dominant hand by means of hook-and-loop fastener straps. The electrodes remained attached to the participant's fingers throughout the two experimental sessions. After the electrodes were attached, the participant was asked to stand in front of the television screen, and the experimenter connected the tactile vest to either the Mannequin or the Touch Screen input medium. Next, the experimenter gave the participant one mediated touch to the upper back to familiarize him with the tactile stimulation.

At the start of each of the experimental sessions (one with the mannequin and one with the touch screen as the input medium), the participant was instructed to pay attention to the touches he saw and felt. Next, the experimenter would turn on the camera, enabling the participant to see both the input medium and the confederate through the television screen (see Fig. 1A). The experimenter monitored the participant's EDA on a computer screen for signs of SCR's not related to the mediated touches (i.e., non-specific SCR's). For this purpose, a high pass filter of 0.05 Hz was applied to the absolute EDA signal. By applying such a filter, the EDA signal centers around 0 micro Siemens (μS) when no SCR is in progress. When the relative EDA was zero, the experimenter would signal the confederate to initiate a mediated touch. After the last mediated touch, the participant completed a questionnaire. The second session, with the other input medium, proceeded in a similar manner as the first.

2.5 Measures

Electrodermal Activity (EDA) was measured as skin conductance changes by means of the BIOPAC MP100 system (BIOPAC Systems Inc., Santa Barbara, California, USA) and the BIOPAC GSR100B amplifier, which applies a constant voltage of 0.5 volt over two Ag-AgCl electrodes (TSD103A) prepared with electrolyte gel (Signa Gel; a multipurpose electrolyte by Parker). The electrodes were attached to the volar surfaces of the distal phalanges of the index and middle fingers of the participant's non-dominant hand by means of hook-and-loop fastener straps. A waiting period of at least five minutes ensured that the electrolyte interacted sufficiently with the participant's skin. The sensitivity (i.e., the gain) was set to the highest value that the individual's skin conductance level allowed. The GSR100B amplifier was set to DC with the low-pass filter at 1 Hz. Absolute skin conductance was recorded in micro Siemens (μS) with 500 samples per second. Any skin conductance response (SCR) starting within five seconds after the initiation of a mediated touch was considered to be a response to that stimulus. If no response occurred within these five seconds, a value of 0 μS was given as a person's SCR to that stimulus. In case there were two (stacked) responses starting within the five second time frame, the average SCR was calculated. A range correction was applied to the SCR data before analysis, as suggested by Lykken and Venables [18] (also [19]). For this range correction, each SCR was divided by the highest SCR observed for that particular individual. For each person, the average of the range-corrected SCR's in each experimental condition was used in the analyses. Due to various reasons, we did not obtain reliable measures of EDA for two out of 20 participants.

Unpleasantness of being touched by the interaction partner was assessed by means of four self-report items, such as "How pleasant or unpleasant was it to be touched by the other person"?[3] Participants could respond on a five-point scale with labels ranging from, for example, "pleasant" (coded with a 0), through "neutral" (coded with a 2), to "unpleasant" (coded with a 4). The mean score across these four items was used in the analyses. The reliability (Cronbach's alpha) of this aggregated Unpleasantness measure was α = .74 in the Mannequin, and α = .83 in the Touch Screen condition. There were no missing responses.

The perceived naturalness of the mediated touches was assessed by means of four self-report items, such as "To what extent were the touches of a mechanical, or a human-like, nature"? Participants could respond on a five-point scale with labels ranging from, for example, "mechanical" (coded with a 0), through "neutral" (coded with a 2), to " human-like" (coded with a 4). The mean score across these four items was used in the analyses. The reliability (Cronbach's alpha) of this aggregated Naturalness measure was α = .93 in the Mannequin, and α =.84 in the Touch Screen condition. There were no missing responses.

[3] Due to space limitations, we did not include a complete description of all items. They, however, can be obtained from the first author.

Telepresence was measured, retrospectively, by means of four self-report items. These self-reports were written in the form of statements regarding the experience of "being there", such as "Sometimes, it felt as if the other person was standing closely beside me". These statements were based on existing presence questionnaires (e.g., [20]). Participants could respond on a five-point scale with labels ranging from "disagree" (coded with a 0), through "neutral" (coded with a 2), to "agree" (coded with a 4). The mean score across these five items was used in the analyses. The reliability (Cronbach's alpha) of this aggregated Telepresence measure was α = .64 in the Mannequin, and α = .73 in the Touch Screen condition. There were no missing responses.

3. Results

The average range-corrected SCR's for the four experimental conditions are depicted in Figure 1B. With these SCR's as the dependent variable, we performed a two (Morphologically Congruent vs. Morphologically Incongruent input medium) by two (Large vs. Small Distance to the input medium) repeated-measures ANOVA. Assumptions of normality and sphericity were met. We found a significant effect of Morphological Congruence on the size of people's SCR's, with $F(1, 15) = 5.1$, $p = .04$, and partial η^2 = 25.4%. As expected, participants reacted more strongly to the mediated touches when they saw the mannequin being touched rather than the touch screen. We also found a significant effect of the Distance between the confederate
and the input medium, with $F(1, 15) = 8.1$, $p = .01$, and partial η^2 = 64.1%. Again as expected, the smaller the distance to the interface, the more strongly the participant responded to the mediated touches. In addition, we found a significant Morphological Congruence by Distance interaction, with $F(1, 15) = 5.1$, $p = .04$, and partial η^2 = 2.5%. Contrary to our expectations, however, the effect of Distance was larger for the Morphologically Incongruent input medium (i.e., the touch screen) as compared to the Morphologically Congruent medium (i.e., the mannequin). Additional simple effects analyses revealed a significant effect of Morphological Congruence for the Large Distance touches, with $F(1, 15) = 9.2$, and $p < .01$, but not for the Small Distance touches, with $F(1, 15) = 0.2$, and $p = .71$.

Average self-reported unpleasantness of being touched was $M = 1.6$ ($SD = 0.8$) in the Mannequin, and $M = 1.5$ ($SD = 0.9$) in the Touch Screen session. Using a paired-sample *t*-test, we did not find a significant difference between the Morphologically Congruent input medium (i.e., the mannequin) and the Morphologically Incongruent medium (i.e., the touch screen), with $t(19) = .35$ and $p = .73$. Additionally, we explored the correlations between self-reported unpleasantness and SCR's. We found a marginally significant correlation between self-reported unpleasantness and SCR's in the Mannequin session, with $r = .44$ and $p = .09$. Further exploration revealed that self-reported unpleasantness correlated significantly with SCR's in response to touches made from a large distance, with $r = .56$ and $p = .03$, but not with SCR's in response to touches made from a short distance, with $r = .13$ and $p = .64$. In contrast, there were no significant correlations between self-reported unpleasantness and the various SCR's in the Touch Screen session, with $r \leq .20$ with $p \geq .45$.

The average perceived naturalness of the mediated touches was $M = 1.2$ ($SD = 1.0$) in the Mannequin, and $M = 0.8$ ($SD = 0.9$) in the Touch Screen session. Since self-reported naturalness was found not to be normally distributed, the non-parametric Wilcoxon signed-ranks test was performed to investigate the effect of morphological congruence on perceived naturalness of the mediated touches. Although the touches were perceived of as relatively unnatural in both sessions, our participants reported, as expected, a higher perceived naturalness in the Morphologically Congruent (i.e., the Mannequin session) as compared to the Morphologically Incongruent conditions (i.e., the touch screen session), with $Z(\mathrm{N} = 20) = 2$, and $p = .046$.

Average self-reported telepresence was $M = 1.2$ ($SD = 1.0$) in the Mannequin session, and $M = 0.8$ ($SD = 0.9$) in the Touch Screen session. Although our participants' experience of telepresence was rather uncompelling, a paired-sample *t*-test demonstrated that participants, as expected, reported a higher degree of telepresence in Morphologically Congruent (i.e., the Mannequin session) as compared to the Morphologically Incongruent condition (i.e., the Touch Screen session), with $t(19) = 2.6$ and $p = .02$.

4. Discussion

With a sample of only 20 participants, we were able to support most of our hypotheses regarding the effects of combining mediated social touch with morphologically congruent visual feedback. As we expected, our participants reported a higher sense of telepresence with the morphologically congruent (i.e., the mannequin) as compared the incongruent input medium (i.e., the touch screen). In addition, participants perceived the same electromechanical stimulation (by means of vibration motors) as more natural when they saw the mannequin being touched rather than the touch screen. Although we did not find a statistically significant difference in our participants' self-reports with respect to the unpleasantness of being touched by another male person, the EDA measurements demonstrated that participants showed significantly more physiological arousal when touches were combined with morphologically correct visual feedback (see Fig. 1B).

When the confederate, rather than maintaining an arm's length distance, moved very close toward the input medium before initiating a touch, our participants demonstrated more physiological arousal (see Fig. 1B). We anticipated such an effect of distance on arousal, only if participants would come to regard of the space around the input medium as their own personal space. However, contrary to our expectations, the effect of distance on physiological arousal was found to be largest in the Touch Screen session in which telepresence is less likely to occur (see Fig. 1B). One explanation for this unexpected finding is that the mere observation of the confederate moving toward the input medium might have affected a person's physiological arousal, thereby confounding with the SCR's to the small distance touches. The SCR's to small distance touches thus might not reflect an increase in physiological arousal in response to being touched, but the SCR's to large distance touches probably did. This is supported by two findings. First, SCR's were related with self-reported unpleasantness, but only for the large distance touches in the Mannequin session. Secondly, the observed main effect of morphological congruency was due to differences in SCR's to large distance touches only.

There were two notable limitations to the present study. First, our experimental setup involved an actual interaction between two persons (the participant and the confederate). Although this setup allowed for a more ecologically valid experimental situation, we could not ensure that the visuotactile stimuli were perfectly similar across sessions and participants. Our findings should therefore be confirmed with pre-recorded stimuli. With pre-recorded stimuli, the touch act can also be isolated from the interaction partner's movement toward the input medium, thereby eliminating the possible artifact of movement in the measurement of EDA. Second, our experimental setup consisted of relatively simple media technologies, such as a standard television screen, which might have constrained our participants in developing a vivid sense of telepresence. More immersive technology might thus produce stronger effects.

Despite these limitations, our experiment demonstrates that combining touch and vision can alleviate, at least partially, the limitations of current mediated social touch devices. Visual feedback, if morphologically correct, makes the mediating technology more transparent. As a result, mediated touches by means of electromechanical actuators are perceived of as more natural and touch-like. Moreover, by increasing a person's sense of telepresence, combining mediated touch with morphologically correct visual feedback can bridge, at least psychologically, the geographical distance between interaction partners. This, in turn, might aid in restoring the inevitable immediacy that marks natural unmediated physical contact.

5. Acknowledgements

The authors thank Dylan Schouten for assisting as a confederate, and Martin Boschman for assisting with the laboratory setup. Financial support from the EC through the PASION project (IST-6-27654) is gratefully acknowledged.

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