Touch gestures in communicating emotional intention via vibrotactile stimulation

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ABSTRACT

Remote communication between people typically relies on audio and vision although current mobile devices are increasingly based on detecting different touch gestures such as swiping. These gestures could be adapted to interpersonal communication by using tactile technology capable of producing touch stimulation to a user’s hand. It has been suggested that such mediated social touch would allow for new forms of emotional communication. The aim was to study whether vibrotactile stimulation that imitates human touch can convey intended emotions from one person to another. For this purpose, devices were used that converted touch gestures of squeeze and finger touch to vibrotactile stimulation. When one user squeezed his device or touched it with finger(s), another user felt corresponding vibrotactile stimulation on her device via four vibrating actuators. In an experiment, participant dyads comprising a sender and receiver were to communicate variations in the affective dimensions of valence and arousal using the devices. The sender’s task was to create stimulation that would convey unpleasant, pleasant, relaxed, or aroused emotional intention to the receiver. Both the sender and receiver rated the stimulation using scales for valence and arousal so that the match between sender’s intended emotions and receiver’s interpretations could be measured. The results showed that squeeze was better at communicating unpleasant and aroused emotional intention, while finger touch was better at communicating pleasant and relaxed emotional intention. The results can be used in developing technology that enables people to communicate via touch by choosing touch gesture that matches the desired emotion.

Keywords

Haptics, mediated social touch, tactile communication, mobile devices, emotions, affective interaction

1. INTRODUCTION

Devices such as mobile phones have become pervasive in our daily lives. We tend to keep them within arm’s reach throughout the day to stay connected with people. Traditionally remote communication has relied on audio/video calls and text messages. Lately, however, the role of touch has become more active in interaction with mobile devices. Due to a technological shift towards touch sensitive displays, direct manipulation via different touch gestures has largely replaced physical keypads. The main purpose of gestures such as tapping and swiping has been to manipulate virtual buttons and other user interface elements. At the same time, these gestures remind
us of the ways humans touch each other. For example, patting and stroking that are used in interpersonal touch interaction (Hertenstein et al., 2006; Hertenstein et al., 2009) bear resemblance to tapping and swiping in terms of the type of physical contact. From this perspective, the possibility of introducing touch gestures as a remote communication modality seems intriguing. For example, one user could pat the screen of his mobile device to send a remote touch to another user.

Haans and IJsselsteijn (2006) defined mediated social touch as “the ability of one actor to touch another actor over a distance by means of tactile or kinesthetic feedback technology”. Tactile technology has been used in several studies as actuators such as vibration motors can be easily embedded in mobile and wearable devices (Bonanni et al., 2006; Chang et al., 2002; Hansson and Skog, 2001; Mueller et al., 2005; Park et al., 2011). It is possible to create different tactile sensations by varying the frequency, amplitude, duration, and rhythm of vibrotactile stimulation (Brewster and Brown, 2004). Although such stimulation is not capable of replicating forces of touch, tactile technology can imitate touch that moves on one’s skin. This is possible by driving several spatially distributed actuators in a sequence (Park et al., 2011; Rantala et al., 2011a; Rantala et al., 2011b; Wang et al., 2012). For example, Haans and IJsselsteijn (2009b) attached six vibrotactile actuators to one’s upper arm to imitate a stroking touch. The goal was to evaluate whether a mediated touch would increase people’s altruistic behavior and willingness to comply with a request similarly to real touch (i.e., Midas touch phenomenon). The results showed that touch-like qualities could be attributed to stimulation that imitated a stroking touch.

Research on imitating human touch has been largely motivated by the well-known relationship between touch and human emotions. Clynes (1977) observed that the use of touch and gestures varies depending on one’s emotional state. McDaniel and Andersen (1998) reported that people who touched each other in public settings were most often lovers or friends who had emotional ties. Jones and Yarbrough (1985) studied meanings of interpersonal touch by instructing participants to report touches that took place in daily interaction. The results indicated that people in close relationships used touch, among other things, to communicate positive emotions. This included touches that expressed support, appreciation, inclusion, sexual interest or intent, and affection. Moreover, Hertenstein et al. (2009) showed that also persons who did not know each other beforehand could communicate intended emotions using only touch. One participant was presented with a list of distinct emotions and asked to communicate them to another blindfolded participant by touching him/her as deemed appropriate. The results showed that anger, fear, disgust, love, gratitude, sympathy, happiness, and sadness were recognized with above chance accuracies. For example, anger was most commonly communicated with shaking, pushing, and squeezing, while love was communicated with touches such as hugging, patting, and stroking.
As real touch has been shown to be capable of conveying intended emotions, it has been assumed that touch mediated by means of vibrotactile technology would have a similar capability. Researchers have presented different device prototypes and proposed that mediated social touch would enable new forms of personal or intimate interaction (Bonanni et al., 2006; Brave and Dahley, 1997; Mueller et al., 2005; Park et al., 2011; Rovers and van Essen, 2004). However, as Haans and IJsselsteijn (2006) noted, “very few studies are available that report on empirical system validations beyond the level of anecdotal descriptions of user experiences”. For example, Bonanni et al. (2006) presented a wearable scarf designed for emotional touch therapy. Vibrotactile actuators attached to the scarf were used for imitating touch gestures of tap, press, stroke, and contact. Also, Park et al. (2011) proposed an affective interaction technique that was based on an array of vibrotactile actuators attached to the backside of a touch screen phone. The aim was to imitate touch gestures of pat, slap, pinch, stroke, kiss, and tickle. In a later study Park et al. (2012) evaluated the system in audio-tactile communication where pairs of users could use the prototypes as they saw fit during free-form phone calls. To the best of our knowledge, no systematic studies have investigated whether vibrotactile stimulation that imitates human touch can convey intended emotions between persons.

There are two general approaches to measuring communication of emotional intention. The differential theory of emotions suggests that human emotions can be seen as distinct categories (e.g., happiness, sadness, and anger) that have their specific motivational properties (Ekman, 1994; Izard, 1997). Bailenson et al. (2007) studied communication of distinct emotions using a joystick-like haptic device. One group of participants was given a list of seven emotions that were to be expressed by manipulating the device. Then, a second group of participants felt the recorded force stimulations and tried to recognize the intended emotions. The results showed that emotions were recognized with above chance accuracies. Smith and MacLean (2007) studied communication of distinct emotions using 1-degree-of-freedom haptic knobs. One participant was to communicate four intended emotions by moving his/her knob, while another participant attempted to recognize the emotions via a second knob. The participants were above chance when recognizing the emotions. While distinct emotions could be conveyed in both studies, it should be noted that the used devices are not applicable in mobile contexts due to their requirement of being attached to a table or other fixed structure.

Another approach is to work with the dimensional theory of emotions that maps emotions as combinations of two or more dimensions (Bradley and Lang, 1994; Russell, 1980; Russell et al., 1989). Bradley and Lang (1994) presented a three-dimensional affective space consisting of valence (from unpleasant to pleasant), arousal (from relaxed or calm to arousing), and dominance (from feeling of stimulus being in control to the feeling of user being in control). An established method to measure emotional reactions in relation to these dimensions is to use bipolar rating scales (Bradley and Lang, 1994; Schlosberg, 1954). Salminen et al. (2008) used the scales for measuring
emotional experiences evoked by vibrotactile stimulation. A friction-based fingertip stimulator presented different predefined stimuli to a participant’s index finger. After sensing a stimulus, the participant was to rate it using scales of valence, arousal, dominance, and approachability. The results showed statistically significant differences in the ratings of different stimuli even though the experiment included no interpersonal communication context. Also, the stimuli were not deliberately designed to evoke particular emotions. To adapt this methodology to studying communication of emotional intention between users, it would seem feasible to ask one user to intentionally create a stimulus that represents a particular position in the dimensional affective space. Then, rating scales could be used to measure whether another user can interpret the intended emotion based on the felt stimulus.

In our previous study we introduced a hand-held device that used vibrotactile stimulation to imitate different touch gestures (Rantala et al., 2011b). A user could manipulate the device by squeezing it, by stroking its touch sensitive top part, or by moving it (i.e., tilting or shaking). The gathered sensor data was converted into vibrotactile stimulation in real time. The stimulation was presented on user’s palm and fingers via four vibrotactile actuators located in the sides of the device. To imitate the three touch gestures, the stimulation was varied by intensity, duration, and actuator location. For example, moving one’s finger along the device’s top was represented by driving the actuators in a sequence to replicate the direction of finger movement. One participant at a time used the device in four example communication scenarios. The task was to communicate with an imaginary partner by creating vibrotactile stimulation suitable for the scenarios. The main finding was that the participants preferred squeezing and stroking to moving. One possible explanation for this was that when the participants squeezed the device or touched it with fingers, the device could be understood to be a metaphor of the communication partner. Moving the device, on the other hand, was more abstract.

Our current aim was to study whether vibrotactile stimulation that imitates squeeze and finger touch can convey intended emotions from one person to another. The devices introduced in our previous study were chosen for this purpose as they enabled converting touch gestures to vibrotactile stimulation (Rantala et al., 2011b). Participant dyads (i.e., sender and receiver) interacted in a laboratory setting using only the vibrotactile channel provided by the devices. When the sender squeezed one device or touched it with finger(s), the receiver felt corresponding vibrotactile stimulation on another device. The dimensions of valence and arousal were adopted for measuring communication of emotional intention. The sender’s task was to use the two touch gestures for creating vibrotactile stimulation that would communicate the opposite ends of valence and arousal to the receiver. In practice, the sender attempted to communicate that he/she felt unpleasant, pleasant, relaxed, or aroused. The receiver felt the created stimulation without knowing that the sender was attempting to communicate specific information (i.e., one of the four intended emotions). Then, both the sender and receiver evaluated the stimulation...
using rating scales for valence and arousal. These ratings were used for comparing the match between senders’ intended emotions and receivers’ interpretations.

2. METHODS

2.1. Participants

A total of 12 voluntary dyads (i.e., 24 participants) took part in the experiment (mean age 29.8, range 20-49 years). The dyads were either intimate couples or friends. On average, the participants had known each other for 4 years. All dyads were cross-gender (i.e., one male, one female) to avoid possible gender effects related to the interpretation of touch (Haans et al., 2007; Heslin et al., 1983). During the experiment participants were located in different laboratory rooms to ensure that the communication took place solely via the tactile modality. The participants signed consent forms and agreed on the use of video recordings for analysis. Each participant was compensated for the participation with a movie ticket.

2.2. Apparatus

A hand-held device (Figure 1) with dimensions of 13.5 × 5.5 × 3.5 cm (length × width × height) was given to both participants in a dyad. The device was designed to fit comfortably in hand so that a user could simultaneously provide touch input and sense vibrotactile output without having to change the grip from the device. For further details of the device, see Rantala et al. (2011b).

2.2.1. Input Sensors and Vibrotactile Actuators

The touch gestures were detected by using two types of sensors: force sensing resistors and a capacitive touchpad. Four force sensing resistors (FSR) from Interlink electronics were mounted inside buttons located in the sides of the device (Figure 1a). The FSRs were activated once a user squeezed the buttons. Each of the four FSRs reported separate values. The custom-built capacitive touchpad was located underneath the device’s flat top surface (Figure 1b). The touchpad consisted of 15 touch-sensitive regions that enabled touch interaction with one or more fingers at the same time. The sensors were sampled with a frequency of 100 Hz.
Figure 1. Side view of the device with a white illustration of the button borders (a). Top view of the device with an illustration of the capacitive touchpad and its 15 touch-sensitive regions (b).

Vibrotactile feedback was created using four Minebea Linear Vibration Motor actuators (LVM8, Matsushita Electric Industrial Co., Japan) that were located inside the buttons (Figure 1a). The buttons were separated from the rest of the device body in an attempt to isolate vibration to the four specific locations. The actuators were driven using an audio signal of 160 Hz mixed sine wave that was previously found to be optimal in terms of hand sensitivity and minimal resonance sound (Rantala et al., 2011b).

In order to measure how accurately users could localize vibration from the different actuators, a separate localization study was conducted with 9 participants. These participants did not take part in the actual experiment. The participants were presented with 10 different stimulation patterns and asked to indicate which one they felt (see Rantala et al., 2011a for a more detailed description of the procedure). There were three types of stimulation patterns: positional patterns vibrated a single actuator, linear patterns vibrated two actuators at a time to present directions (i.e., left, right, forward, and backward), and circular patterns vibrated all four actuators in a sequence (i.e., clockwise and counter-clockwise). The results showed that positional, linear, and circular patterns were recognized correctly with mean accuracies of 72, 46, and 74 % (when chance level was 10 %).

2.2.2. Technical Setup

The device was connected to an interface box via HDMI (Figure 2). This connection transferred sensor data from the device, and audio output signals to the device. The interface box was connected to a PC via serial connection. Pure Data (PD) audio synthesizer software read data from the serial connection and generated audio output that was fed back to the interface box using an external Gigaport HD USB sound card and four 3.5 mm plugs. PD was also used for logging sensor data. A TCP/IP connection transferred data between the two laboratory rooms. Identical experimental setups were used in both rooms.
2.2.3. Transferring Touch Input to Vibrotactile Stimulation

Transferring the characteristics of touch gestures into vibrotactile stimulation was based on two principles. First, the intensity of touch input (i.e., pressure level of squeezing the buttons or amount of capacitive contact with the touchpad) was conveyed by varying the amplitude of the mixed sine wave. Second, the spatiality of touch input (i.e., squeezing only certain buttons or touching only part of the touchpad) was presented by driving actuators closest to the touch location.

Each of the four squeeze sensors in the buttons reported values between 0 and 150. This corresponded to force levels ranging approximately from 1.6 to 7 N. The threshold level of 1.6 N was set to ignore light squeezing needed to hold the device in hand. The values of the 15 touch-sensitive regions were used for calculating four combined values with the same range of 0-150. For example, combined value for the front left part of the touchpad was calculated by adding up values of six regions (Figure 1b, grey regions). The resulting four input quarters (i.e., front left, front right, rear left, and rear right) were mapped to their corresponding actuators. In practice, squeezing the front left button or touching the front left part of the touchpad vibrated the front left actuator. Alternatively, touching the center of the touchpad as in Figure 3b would activate all four actuators.

Linear mapping was used between the sensor input values and amplitude levels of the actuators. Thus, the more intense the touch input, the higher the resulting stimulation amplitude. The highest possible amplitude level was same for both touch gestures.
2.3. Procedure

First the laboratory and conditions were introduced to each dyad. Then, the participants were explained that the purpose of the study was to send and receive vibrotactile stimulation. The roles of sending and receiving stimulation were balanced between genders within the 12 dyads. The same roles were used throughout the experiment. The participants were then guided to separate laboratory rooms. The experiment was divided into familiarization, training, and test sessions. The sessions were followed by a post-experimental interview. Conducting the experiment took approximately 50 minutes per dyad.

2.3.1. Familiarization Session

The purpose of the familiarization session was to let participants try how the device responded to touch. The participants were allowed to use approximately two minutes to familiarize themselves with the two touch gestures. The device was held in the hand that the participants would normally use for holding mobile devices (right hand for 20 out of 24 participants). The participants were advised to grip the device so that all the four buttons would be in contact with palm or fingers. They were instructed to use one hand in squeeze and both hands in finger touch (see Figure 3). Vibrotactile stimulation was created instantaneously when a squeeze or finger touch was sensed. During the familiarization session the participants felt only stimulation created by their own interaction. Thus, they could neither sense the other participant’s touches nor create any common tactile vocabulary. Noise-blocking headphones were used to ensure that audio created by the actuators was not perceived.

2.3.2. Training Session

A training session with two trials was held to introduce the experimental procedure. In the beginning of the first trial the sender was given a slip of paper that stated the first touch gesture to be used. In the training phase the
sender’s task was to create vibrotactile stimulation without any particular emotional intention. The sender could sense stimulation on his/her own device while manipulating it. When the sender was ready to create stimulation, tactile channel was enabled also on the receiver’s device. The sender then repeated the touch interaction once. At this point identical stimulation was felt on both devices with the exception that the sender was actively manipulating the device whereas the receiver was holding his/her device passively. The stimulation was followed by rating scales (as described in section 2.3.4). The second training trial with the other touch gesture followed the same procedure.

2.3.3. Test Session

The test session proceeded similarly to the training session with the exception that the sender was instructed to create stimulation that would communicate the opposite ends of valence (i.e., unpleasant or pleasant) and arousal (i.e., relaxed or aroused) to the receiver. Only one dimension was varied at a time. For example, the sender’s instruction was to “tell the other that you feel yourself relaxed”. The receiver was not aware of the sender’s task. The test session consisted of 2 × 4 trials (touch gesture × emotional intention) that were presented in a randomized order.

2.3.4. Subjective Ratings

In the end of each trial both participants rated the felt stimulation using scales for valence and arousal. Although the sender’s task was to vary the emotional intention only on one dimension (i.e., primary dimension), ratings were asked also for the other dimension (i.e., secondary dimension) so that the stimulation could be positioned to the two-dimensional affective space. Nine-point bipolar rating scales varying between -4 and +4 were used.

The sender’s instructions for rating the arousal of created stimulation were as follows: “if you feel that the created message was relaxing, choose a number between -1 and -4 depending on how relaxing the message was” and “if you feel that the created message was arousing, choose a number between +1 and +4 depending on how arousing the message was”. The same wording was used for valence by substituting “relaxing” and “arousing” with “unpleasant” and “pleasant”, respectively.

The receiver’s corresponding instructions for rating felt stimulation were as follows: “if you think that the sender felt relaxed, choose a number between -1 and -4 depending on how relaxed the sender felt” and “if you think that the sender felt aroused, choose a number between +1 and +4 depending on how aroused the sender felt”. Again, similar wording was used for valence. The sender’s task of communicating one of the four intended emotions was
not disclosed to the receiver in order to elicit ratings that would not be guided by a predefined set of possible meanings. Thus, the receiver could also choose the midpoint of a scale (i.e., 0) in case the stimulation was perceived, for example, neither unpleasant nor pleasant.

2.3.5. Post-Experimental Questionnaire and Interviews

Once the experimental tasks were finished, the sender was asked to choose which touch gesture he/she would have used for expressing each emotional intention if given a choice. At the same time, the receiver was briefed on the sender’s task of communicating the four intended emotions. Before revealing that the sender tried to convey each emotional intention with both touch gestures, the receiver had to judge which touch gestures he/she expected the sender used. Also, both the sender and receiver were asked whether they could imagine using such a touch communication system for sending SMS-like touch messages or enhancing phone conversations.

Finally, the participants were encouraged to comment on the experiment and prototype devices in a non-structured interview. For example, they were asked how they perceived the two touch gestures and how easy or difficult it was to communicate using the devices.

2.4. Data Analysis

2.4.1. Subjective Ratings

We were interested in measuring whether the participant role, emotional intention, or touch gesture affected participants’ ratings of felt stimulation. For this purpose, the participants’ primary ratings were analyzed using repeated measures mixed-model analysis of variance (ANOVA). If the sphericity assumption of the data was violated, Greenhouse-Geisser corrected degrees of freedom were used to validate the F statistic. Pairwise Bonferroni corrected t-tests were used for post-hoc pairwise comparisons.

Also, to get an overall success rate of communication, receivers’ primary ratings were categorized as correct or incorrect based on the bipolarity of valence and arousal scales. For example, if the intended emotion to be communicated was relaxed, receivers’ arousal ratings between -1 and -4 counted as correct. Neutral ratings (i.e., 0) were always counted as incorrect.
2.4.2. Parameters of Vibrotactile Stimulation

To understand whether the assigned emotional intention or used touch gesture had an effect on created vibrotactile stimulation, the mean intensity and spatiality of stimulation were analyzed. Repeated measures analysis of variance (ANOVA) was conducted for this purpose.

Mean intensity was the mean amplitude value of the four input quarters. Mean spatiality was measured using the number of peak actuator changes in stimulation. A peak actuator change was registered when one of the input quarters gained the highest input value for at least 150 milliseconds. For example, moving one’s finger in a circular manner between the touchpad quarters would result in several peak actuator changes and high spatiality value. Data of one participant dyad was excluded from the parameter analysis as an outlier because the mean duration of the created stimulation was 8.4 times longer as compared to the other dyads.

2.4.3. Observations and Post-Experimental Interviews

Senders’ touch interaction in each trial was coded from video using the following parameters: number of rehearsed touches, time used for choosing a touch, number of repeating sequences in a touch, used touch type, direction of touch, and intensity of touch.

Post-experimental interviews were first transcribed from video recordings. Individual interview comments were then grouped into categories using thematic coding. Section 3.5 is organized based on these categories. Comments that best represented the participants’ general view or pointed out important challenges were included in the results section. The quotes were translated from Finnish to English. Analysis of the video recordings was conducted by one coder.

3. RESULTS

3.1. Subjective Ratings

3.1.1. Primary and Secondary Ratings in the Affective Space

To get an overall view of how the senders and receivers rated vibrotactile stimulation with different emotional intention, the primary and secondary ratings were positioned to the two-dimensional affective space (Russell, 1980). In Figure 4, a short arrow between mean ratings indicates that the match between senders’ intended emotions and receivers’ interpretations was good. In contrast, longer arrows indicate a poorer match.
Figure 4. Mean primary and secondary ratings for unpleasant, pleasant, relaxed, and aroused emotional intention positioned in the affective space by touch gestures of squeeze (a) and finger touch (b).

The senders’ mean ratings show that the senders based their ratings mainly on the instructed emotional intention. Stimulation with unpleasant intention fell in the unpleasant–arousing quadrant of the affective space regardless of the touch gesture (see Figures 4a and 4b). Stimulation with aroused emotional intention, on the other hand, fell in the pleasant–arousing quadrant. Stimulations with pleasant and relaxed emotional intention were considered to be practically the same as both fell in the pleasant–relaxed quadrant.

On the contrary, the receivers’ mean ratings show that the interpretations of vibrotactile stimulation varied depending on the used touch gesture. Squeeze was interpreted predominantly as unpleasant and arousing (see Figure 4a), while finger touch was interpreted mainly as pleasant (see Figure 4b). Comparing the match between senders and receivers shows that when squeeze was used only stimulation with unpleasant emotional intention was placed to the same affective quadrant by both dyad members. In terms of finger touch, stimulation with aroused, relaxed, and unpleasant emotional intention was placed to the same affective quadrants by both dyad members.
Overall, the receivers’ mean ratings were located closer to the center of the affective space than the senders’ mean ratings. Thus, the receivers interpreted the emotionality of vibrotactile stimulation to be somewhat weaker as compared to the senders.

3.1.2. Primary Ratings of Valence

For the primary ratings of valence (Figure 5), a three-way $2 \times 2 \times 2$ (participant role $\times$ touch gesture $\times$ emotional intention) mixed-model ANOVA showed statistically significant main effects of touch gesture ($F_{1,22} = 6.6, p < 0.05$) and emotional intention ($F_{1,22} = 52.8, p < 0.001$). In addition, there were significant interactions between touch gesture and participant role ($F_{1,22} = 7.8, p < 0.05$) and emotional intention and participant role ($F_{1,22} = 44.3, p < 0.001$).

Two one-way ANOVAs were conducted to analyze the interaction between emotional intention and participant role. The ANOVAs showed that the interaction was caused by the fact that emotional intention had a significant effect on senders’ ratings ($F_{1,11} = 76.9, p < 0.001$), but not on receivers’ ratings. Post-hoc pairwise comparison showed that the senders rated stimulation with pleasant emotional intention as significantly more pleasant than stimulation with unpleasant emotional intention ($MD = 4.8, p < 0.01$).

Also, two one-way ANOVAs were conducted to analyze the interaction between touch gesture and participant role. The ANOVAs showed that the interaction was due to the fact that touch gesture had a significant effect on receivers’ ratings ($F_{1,11} = 8.3, p < 0.05$), but not on senders’ ratings. Post-hoc pairwise comparisons showed that the receivers rated stimulation created with finger touch as significantly more pleasant than stimulation created with squeeze ($MD = 1.9, p < 0.05$).

The mean success rates of communicating valence varied between 17 and 75% when chance level was 50% (Figure 5). The success rates indicate cases where the senders’ and receivers’ ratings were on the same side of the dimension.
3.1.3. Primary Ratings of Arousal

For the primary ratings of arousal (Figure 6), a three-way $2 \times 2 \times 2$ (participant role $\times$ touch gesture $\times$ emotional intention) mixed-model ANOVA showed statistically significant main effects of touch gesture ($F_{1,22} = 24.1, p < 0.001$) and emotional intention ($F_{1,22} = 131.8, p < 0.001$). In addition, there was a significant interaction between participant role, touch gesture, and emotional intention ($F_{1,22} = 5.1, p < 0.05$).

To analyze the three-way interaction, two separate mixed-model ANOVAs were conducted. A two-way $2 \times 2$ (participant role $\times$ emotional intention) ANOVA showed a significant main effect of emotional intention ($F_{1,22} = 166.9, p < 0.001$) and significant interaction between participant role and emotional intention ($F_{1,22} = 29.8, p < 0.001$). Moreover, a two-way $2 \times 2$ (participant role $\times$ touch gesture) ANOVA showed a significant main effect of touch gesture ($F_{1,22} = 24.0, p < 0.001$) and significant interaction between participant role and touch gesture ($F_{1,22} = 13.0, p < 0.01$).

To analyze the two-way interaction between emotional intention and participant role, two one-way ANOVAs were conducted. The ANOVAs showed that the interaction was due to the fact that although emotional intention had a significant effect on both senders’ ratings ($F_{1,11} = 332.8, p < 0.001$) and receivers’ ratings ($F_{1,11} = 11.6, p < 0.01$), the effect was greater on senders’ ratings. Post-hoc pairwise comparisons showed that stimulation with aroused emotional intention was rated as significantly more arousing than stimulation with relaxed emotional intention by senders ($MD = 5.5, p < 0.001$) and receivers ($MD = 2.0, p < 0.01$).

To analyze the two-way interaction between touch gesture and participant role, two one-way ANOVAs were conducted. The ANOVAs showed that the interaction was caused by the fact that touch gesture had a significant
effect on receivers’ ratings \((F_{1,22} = 24.8, p < 0.001)\), but not on senders’ ratings. Post-hoc pairwise comparison showed that the receivers rated stimulation created with squeeze as significantly more arousing than stimulation created with finger touch \((MD = 1.6, p < 0.001)\).

The mean success rates of communicating arousal varied between 50 and 83 % when chance level was 50 % (Figure 6).

![Mean primary ratings of arousal, S.E.M.s, and success rates of communication for stimulation with relaxed and aroused emotional intention.](image)

**Figure 6.** Mean primary ratings of arousal, S.E.M.s, and success rates of communication for stimulation with relaxed and aroused emotional intention.

### 3.2. Parameters of Vibrotactile Stimulation

#### 3.2.1. Intensity

For the mean intensity (Figure 7), a two-way 2 × 4 (touch gesture × emotional intention) ANOVA showed statistically significant main effects of emotional intention \((F_{3,30} = 5.9, p < 0.01)\) and touch gesture \((F_{1,10} = 11.6, p < 0.01)\). Furthermore, there was a significant interaction between the main effects \((F_{3,30} = 3.7, p < 0.05)\).

To analyze the interaction between emotional intention and touch gesture, two one-way ANOVAs were conducted. The ANOVAs showed significant effects of emotional intention \((F_{1,21} = 25.1, p < 0.001)\) and touch gesture \((F_{1,43} = 18.0, p < 0.001)\). Post-hoc pairwise comparisons showed that stimulation with unpleasant emotional intention had significantly higher mean intensity than stimulation with relaxed \((MD = 26.8, p < 0.05)\) and pleasant \((MD = 30.1, p \leq 0.001)\) emotional intention. Also, stimulation created with squeeze had significantly higher mean intensity than stimulation created with finger touch \((MD = 20.0, p < 0.001)\).
3.2.2. Spatiality

For the mean spatiality (Figure 8), a two-way $2 \times 4$ (touch gesture $\times$ emotional intention) ANOVA showed a statistically significant main effect of touch gesture ($F_{1,10} = 13.4, p < 0.01$). There was also a significant interaction between the main effects ($F_{3,30} = 3.2, p < 0.05$).

To analyze the interaction between touch gesture and emotional intention, two separate one-way ANOVAs were conducted. The ANOVAs showed a significant effect of touch gesture ($F_{1,43} = 20.1, p < 0.001$). Post-hoc pairwise comparisons showed that stimulation created with finger touch had significantly more spatial variation than stimulation created with squeeze ($MD = 5.1, p < 0.001$).

3.3. Observations on Touch Gestures

The senders used four different ways to manipulate the device when creating stimulation with finger touch: index finger only (31 % of finger touch gestures), index and middle fingers (31 %), index, middle, and ring fingers (19 %), or thumb (10 %).
In addition, finger touch elicited different use strategies that can be categorized into separate touch gestures (Figure 9). First, the participants moved one or more fingers on the device’s top in a continuous manner (46 % of finger touch gestures). These stroking or sweeping touches were used mainly when creating stimulation with pleasant and relaxed emotional intention. Second, patting or tapping was used for creating stimulation that consisted of multiple touches (40 %). These touches were most often used when creating stimulation with aroused and unpleasant emotional intention. Third, during spot touches the participants touched the device only once without moving finger(s) on the surface (14 %).

![Figure 9. Observed finger touch gestures by emotional intention.](image)

Variations in squeeze interaction were more unnoticeable and subtle. In majority of squeeze gestures the participants squeezed all four buttons at the same time.

### 3.4. Preferred Touch Gestures

The results of touch gesture preferences showed that if given a choice, both the senders (Figure 10) and receivers (Figure 11) would have used finger touch mainly in communicating pleasant and relaxed emotional intention. Squeeze, on the contrary, would have been the dominant gesture in communicating unpleasant emotional intention. In terms of aroused emotional intention the preferences were more divided.

![Figure 10. Touch gestures the senders would have preferred to use for communicating the emotional intention.](image)
3.5. Post-Experimental Interviews

3.5.1. Touch Gestures

Several participants commented that squeeze was easier to use than finger touch. One participant said that “squeezing had in a way less interaction [with the device] and because of that one did not need to think of the use (sender, male, 22)”. Another participant felt that squeeze was less laborious to use. It was also commented that especially aroused intention was easier to communicate with squeeze.

On the other hand, some participants felt that finger touch was more precise than squeeze. One participant commented that “with finger touch you could adjust the applied force better (sender, male, 23)”. The vibration response of squeeze was noted to be more imprecise and vague. According to the comments, the impreciseness of squeeze might have depended on the applied force. One of the participants pointed out that gentle squeezing resulted in irregular vibration but with more force controlling became easier.

3.5.2. Communication Partner

Several participants felt that the communication partner had an effect on how vibrotactile stimulation was used and perceived. One of the receivers commented that “if some stranger would have been sending the messages, I definitely would not have thought it as stroking and the messages would have been more neutral (receiver, female, 20)”. Similarly, one of the receivers considered it strange to use stroking with a friend. According to one participant “the communication partner should be someone really familiar, a friend that I see at least once a week (receiver, female, 49)”.

Contrary to other comments, friends in one dyad noted that they did not pay attention to the communication partner as much as they had presumed. Instead, the sender concentrated on the instructed emotional intention,
while the receiver focused solely on the felt vibration. The dyad suspected that in a more naturalistic setting the partner would play a more significant role.

3.5.3. Possible Use Scenarios

Out of 24 participants, 15 said that they could imagine sending and receiving touch-only messages. According to the participants touch messages could be used in places where one cannot use other modalities for interacting with a communication device (e.g., work settings). Also, messages could be felt afterwards similarly to reading SMS messages. The comments indicated that touch messages alone would not be suited to abstract or complex communication. Instead, it was suggested that touch could be used for conveying simple information. One participant commented that “it could be used for communicating momentary feelings like with Twitter ... if I got an enthusiastic touch message during the day, I would ask later at home what the message meant (receiver, male, 36)

Furthermore, 15 out of 24 participants said that they could imagine sending and receiving touch information during a phone call. One participant suggested that touch could be used for adding presence and awareness to a phone conversation. She stated that “in face-to-face conversation you can nod to show that you are listening ... if there was a way to express that you are listening [using touch during a call] (sender, female, 29)”. Another participant was more skeptical of the need of a touch channel during conversation as she felt that the information could as well be communicated verbally.

4. DISCUSSION

Our results showed that the match between senders’ intended emotions and receivers’ interpretations depended on the used touch gesture. In general, the senders thought that both touch gestures would perform equally well in communicating the intended emotions. The receivers, on the other hand, interpreted felt stimulation differently depending on the used touch gesture. The receivers’ ratings indicated that squeeze was more suitable for communicating unpleasant and aroused emotional intention, while finger touch was more suitable for communicating pleasant and relaxed intention. This distinction between the gestures can also be seen when looking at the mean success rates of communication. Overall, the dyads communicated variations in valence and arousal successfully in 48 and 69 % of trials, respectively (chance level 50 %). It is noteworthy that the success rate of communicating valence was practically the same as chance level. However, when leaving out the gestures that provided a poorer match, the mean success rates for valence and arousal were 75 and 79 %, respectively.
Thus, the senders and receivers agreed on the emotionality of mediated touch in roughly three cases out of four when suitable touch gesture was used.

Analysis of the vibrotactile stimulation showed that the receivers’ distinctive emotional interpretations of squeeze and finger touch could be due to differences in stimulation parameters. Stimulation created with squeeze had significantly higher mean intensity than that created with finger touch. Also, squeeze was interpreted mainly as unpleasant and arousing. This is in line with the work of Salminen et al. (2009) who showed that vibrotactile stimuli with high amplitude (i.e., intensity) were rated as more unpleasant and arousing than stimuli with lower amplitudes. It seems that this effect exists also when tactile stimulation is used to communicate emotional intention between two persons. Another main result of the stimulation parameter analysis was that stimulation created with finger touch had significantly more spatial variation than that created with squeeze. For example, when communicating pleasant intention, the mean intensities between touch gestures were comparable (see Figure 7), but stimulation created with finger touch had more spatial variation (see Figure 8). Consequently, the receivers interpreted stimulation created with finger touch as more pleasant and relaxed. It could be that the receivers perceived moving stimulation as more natural or tickling than constant stimulation with less spatial variation.

The differences in vibrotactile stimulation between squeeze and finger touch may be explained by looking at how touch gestures were converted to tactile representations. In our previous study we observed that applied pressure tends to distribute evenly when squeezing an object in one’s hand (Rantala et al., 2011b). Similarly, in the current study the senders often squeezed several buttons at the same time and, thus, created vibrotactile stimulation with low mean spatiality. On the contrary, the two-handed interaction of finger touch provided more precise spatial control that enabled touch sequences activating only certain actuators (e.g., a stroke that moved along the device’s top). This suggests that some spatial characteristics of squeeze and finger touch could be converted to vibrotactile stimulation despite the rather simple four-actuator output. Our approach of sensing real-time touch input differed from earlier studies that utilized predefined stimulation patterns for imitating interpersonal touch (Bonanni et al., 2006; Haans and IJsselsteijn, 2009b; Park et al., 2011). Moreover, as discussed above, squeeze and finger touch evoked different emotional interpretations in the participants who received mediated touch. Taken together, some evidence was found suggesting that physical touch gestures could convey different emotional intention in remote communication.

The results of preferred touch gestures showed that if given a choice, the dyads would have communicated intended emotions using particular touch gestures. In general, the preferences were in line with the success rates of communication. That is, the majority of senders and receivers would have chosen squeeze for communicating
unpleasant emotional intention, while finger touch was preferred for conveying pleasant and relaxed emotional intention. In terms of aroused emotional intention the distinction was not equally clear. This was possibly reflected in the success rates of communication as aroused emotional intention was communicated at above chance rates with both gestures (see Figure 6). The dyad members provided their preferences independently, and they were not aware of the success rates of communication. A possible explanation for the preferences might be that the participants opted for touch gestures they would have chosen to use in non-mediated (real) touch communication. Another possible explanation is that the participants perceived the difference in stimulation between the touch gestures and therefore associated particular stimulation parameters with different emotional intention. From the perspective of practical communication applications, the relationship between participant preferences and successfulness of communication is encouraging as it suggests that after a relatively short use people could select the more suitable touch gesture depending on their communication needs.

Certain similarities could be identified between our findings and prior research on communicating emotional intention via non-mediated touch. In a study by Hertenstein et al. (2009) cross-gender dyads used non-mediated squeeze most commonly for expressing anger and fear. If these two distinct emotions are mapped to the dimensional affective space (Russell, 1980), they fall in the unpleasant–aroused quadrant similarly to the receivers’ interpretations of mediated squeeze in our study. In terms of finger touch, our video observations showed that the interaction could be divided into three touch gestures of stroke, pat, and spot touch. The ones used most frequently by the senders were stroke and pat. In non-mediated communication, these touch gestures were used most commonly for expressing positive emotions of love, sympathy, and gratitude (Hertenstein et al., 2009). Since in our study mediated stroke and pat conveyed mainly positive valence, it would seem plausible that there could be similarities between the ways people use and perceive non-mediated and mediated touch. Some indication of this was also seen in our interview results. The participants commented that mediated touch would be appropriate mainly in close relationships as has been shown to be the case with real touch (McDaniel and Andersen, 1998). It is important, however, to note that we did not directly compare mediated and non-mediated touch in our study. Therefore, these similarities should be interpreted with caution.

There were some limitations in our study. First, similarly to previous empirical studies on mediated social touch (Bailenson et al., 2007; Smith and MacLean, 2007), our work investigated mainly communication of intended emotions rather than felt emotions. That is, the senders were asked to deliberately create stimulation with specific emotional intention. While it has been suggested that these “on demand” emotions might be the type that is used mostly during HCI (Bailenson et al., 2007), further work is needed to establish possible differences between our results and settings where participants have emotional experiences during communication (e.g., watch an emotional film). Likewise, encoding and decoding the meaning of vibrotactile stimulation required cognitive
processing from the participants unlike real touch that is immediate and seldom planned. Wang et al. (2010) proposed that the immediacy of mediated touch could be improved by including contextualizing information channels to communication (e.g., audio). Second, as Haans and IJsselsteijn (2009a) noted, vibrotactile stimulation is a crude substitute for physical touch. It is apparent that vibrotactile technology stimulating the user’s skin cannot reproduce properties such as contact pressure, rubbing, or tugging. Alternative approaches include, for example, armbands for representing physical squeeze (Suhonen et al., 2012; Wang et al., 2010; Wang et al., 2012). On the other hand, our results can be seen as a hint of the powerfulness of touch as a communication medium. Certain similarities between the use of mediated and real touch were identified despite the rather simple sensing and actuation technology. Third, the prototype device had a unique form factor that was designed to afford various types of tactile interaction. While this form differed from devices such as phones, the same touch gestures could be adapted to other platforms. Researchers have presented phone prototypes with multiple vibrotactile actuators (Park et al., 2011; Yatani and Truong, 2009), while squeeze and finger touch could be sensed via force sensing resistors (Stewart et al., 2010) and touch screens. Fourth, we recruited only participants in close relationships as most physical touch communication takes place between acquaintances (McDaniel and Andersen, 1998). Even mediated touch communication between strangers can cause discomfort (Smith and MacLean, 2007) and, thus, no strangers were included. It is likely that the current results are not directly transferable to strangers. Lastly, analysis of interview data was conducted by one coder. In future studies the use of several coders is recommended so that inter-rater reliability could be established.

When looking at our findings from a wider perspective, certain implications can be identified for future development of touch communication applications. Squeezing as an interaction type could be applicable when thoughts of unpleasant and arousing information are desired. Conversely, spatial movement using one’s fingers could evoke more pleasant and relaxed thoughts in the communication partner. We envision that such interaction could be useful, for example, in adding physical closeness to communication by sending a gentle stroke to one’s companion. In addition, touch could be used to substitute other communication modalities in contexts where calling or texting is not appropriate (e.g., squeeze a device to send a touch message during a work meeting). In case such a touch communication channel would be introduced to practical use, privacy and ethical issues should be considered. As noted by Heikkinen et al. (2009), touch is a private way to communicate and users should have control over who can send touch messages to them. Also, while our current focus was on unimodal touch communication, in practice mediated touch would likely be used with other modalities. Addition of visual (Haans and IJsselsteijn, 2009a) and auditory (Wang et al., 2012) information has been shown to affect perception of tactile stimulation. Moreover, Park et al. (2012) observed that participants did not prefer to use mediated touch when the mood of discussion was negative in order to avoid making the other person angrier or more irritated.
In summary, our study showed that squeeze and finger touch evoked different emotional interpretations in the persons who received mediated touch. Using the dimensional frame of reference and rating scales seemed to be a feasible way to start measuring users’ subjective interpretations of emotional touch communication. An alternative method to proceed would be to measure lower level reactions (e.g., pupil size variation or facial electromyography). Such measurements might prove useful in tracing immediate and involuntary emotional reactions to mediated touch. From the viewpoint of HCI research, our study proposed an interaction method that was motivated by physical touch interaction. The fact that users were able to mediate touch sensations using common physical gestures can be seen as an attempt to add spontaneity and naturalness to remote communication. In some sense, the device held in one’s hand could be understood to be an embodiment of the communication partner. Lastly, our work relates to prior research in the field of haptics where researchers have mostly measured communication of emotional intention via non-mobile feedback devices (Bailenson et al., 2007; Smith and MacLean, 2007) or presented tactile communication prototypes along with pilot studies or informal evaluations (Bonanni et al., 2006; Hansson and Skog, 2001; Mueller et al., 2005; Park et al., 2011). Our aim was to combine these approaches and empirically measure the emotionality of touch mediated via tactile technology. Evidence was found indicating that touch has potential to convey emotional information between humans even in mediated form. It is our hope that the present findings encourage researchers to further pursue the concept of mediated touch.

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