Communicating Socio-Emotional Sentiment Through Haptic Messages

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***Abstract*— Touch plays an important social role in fostering and maintaining emotional communication in vital human relationships, but when close relations live apart for extended periods of time, this nonverbal channel is lost. We explore how a custom-built, low degree-of-freedom, wearable haptic display may mediate the encoding and decoding of a set of complex socio-emotional messages that is sent and received by strangers, intimate partners, and even the same individual a week later.**

I. INTRODUCTION

From infancy, touch plays a crucial role in forging critical emotional bonds and pro-social behaviours that persist over generations [1]. Strangers touch our elbow to politely indicate they need to get by; friends rub our shoulder to offer comfort; intimate partners withhold touch to communicate dissatisfaction or grasp our hand to implore forgiveness. Touch pressure, frequency, body location, even absence communicates nuanced details about emotional state [2], [3], [4].

Touch is a vital part of maintaining and advancing close relationships [5]. Simultaneously, there is a growing trend of long-distance relationships (LDR) [6] where partners, family members, and close friends are separated for extended time periods due to professional, academic, military, familial responsibilities, etc. Despite increasing interest in machine-mediated social touch, low degree-of-freedom (DoF), notification-style sensations cannot convey the communication range nor nuance of natural touch [7], [8]. Where long-distance is increasingly common [6], we consider how affectively interpreted vibrotactile patterns [9] can be personalized for conveying social touch. Can additional sensation parameters allow the encoding / decoding of nuanced touch on a low degree-of-freedom (DoF) wearable haptic device?

We explore three facets of machine-mediated social touch:

1) What messages do people wish to convey in an LDR? (Message Definition and Selection)
2) How might people design haptic sensations to communicate these messages? (Message Generation)
3) Can recipients of these haptic messages decode the complex root emotions? (Message Interpretation)

Here, we (1) outline the materials used including the custom-built haptic display that we designed to be worn on the inner forearm–a relatively large, touch-sensitive area of the body, natural for machine-mediated social touch [10]–and address the outcomes from a pilot to validate our device; (2) detail our three-phase study on $N_1 = 200$ online participants (Amazon Mechanical Turk), $N_2 = 10$ in-person dyad pairs, $N_3 = 10$ returning individuals, responding to the above three questions respectively and; (3) highlight a selection of interesting outcomes and discuss future work.

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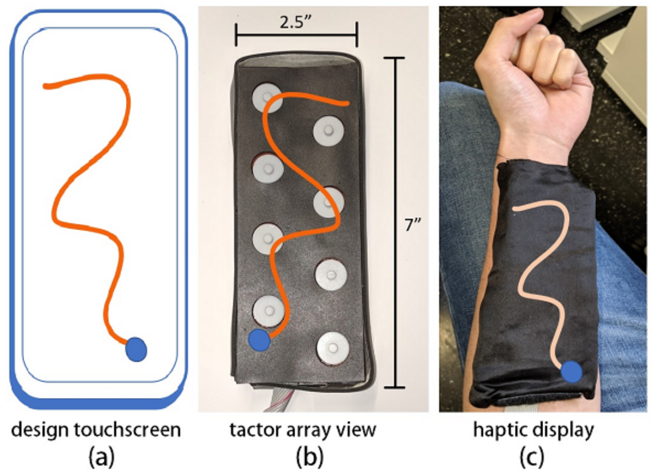

Fig. 1. Our custom build haptic device: (a) employs a touchscreen for sensation design; (b) consists of 8 tactors, modulated individually to render a continuous pattern (shown flipped on the contact side); and (c) displays the pattern as originally intended on the wearer.

II. MATERIALS AND PROCEDURE

We built a custom wearable haptic display (see Figure 1) for the inner forearm and conducted a small pilot to ensure that haptic patterns were discernible. Dyad pairs were given a set of 10 emotion-centric scenarios (selected from an online survey of people in LDRs) and one that they created. For each prompt, they described the embedded emotion and used a touchscreen control interface to convert it into a haptic sensation. Invited back at least a week later, they decoded the designs. We considered the interpretation accuracy by emotion—is an **anger** message more consistently recognized than a **calm** one?; and by relation-distance—how does recognition rate compare when we consider messages designed by our past *self*, our *close partner*, a *stranger*?

A. Computer-mediated Touch Device

The device consists of eight vibrotactors formed roughly in two rows, then encased in rubber and a silky fabric. A Motu 24Ao[1]audio interface modulates the signal between the channels such that a continuous haptic pattern is rendered across discrete tactor locations (Fig 1, modelled after tactile animation displays [11]).

[1]https://motu.com/products/avb/24ai-24ao

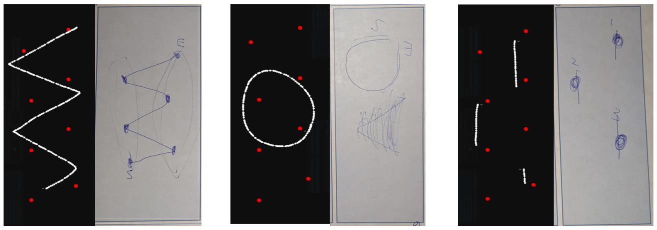

Fig. 2. A comparison of the test design (L) and a participant interpretation (R) from each of the three images above. Each continuous segment is labelled with the order of playback.

Participants designing haptic messages manipulated six engineering parameters in order to achieve the desired sensation: the waveform's amplitude, frequency, brush size (large brush meant a larger surface area was stimulated), diffusion type (where linear was the slowest delta between brush centre and border; and exponential being fastest), as well as the x-y coordinates of the 2D drawing surface plus the time-variations of strokes. Designers could record a message, play it back, and edit the sensation (including speeding up or slowing down).

B. Device Validation

To verify that participants perceived the haptic display as expected, we conducted a small pilot, $N = 6$, of three metrics (repetition and order counter-balanced): do people reliably discern the (1) discontinuous pieces? (2) direction of motion?; and (3) overall 2D shape of the sensation?

After a sandbox session with the device (to reduce novelty), we played 8 pre-recorded haptic sensations and asked participants to use pen and paper, drawing what they felt. They explicitly marked direction, order of discontinuous segments, and the representative 2D space to indicate the experience on their arm (example in Fig 2). All participants successfully distinguished (dis)continuities and the intended direction of the sensation. Participants were not as good at recognizing the full shape, particularly when playback was set at more pleasant low-frequency vibrations; at less preferred higher frequencies, shape was better recognized but described as "buzzy and annoying" (P3).

C. Message Definition and Selection

We used Amazon Mechanical Turk to recruit $N = 200$ participants to find emotions common and authentic to the LDR experience. All were currently, or had been, in an LDR for at least 2 years and answered an online survey about what they cared to communicate. We chose 10 emotions that we embedded in contextual scenarios to act as prompts for message designers (task described in Section II-D) in order to better simulate how communication organically arises; Table I shows three illustrative examples.

D. Message Generation

We recruited $N = 10$ dyad pairs (20 individuals) who were in close relationships, all of whom were currently co-habitating. In the 1-hr session, dyads were given some

TABLE I
EXAMPLE EMOTIONS AND THE SCENARIO PROMPTS FOR MSG DESIGN

Emotion	Scenario or Message Prompt
anger	*Your partner has done something careless that has set off a sequence of inconveniences and you are frustrated that this has happened, again.*
calm	*You've just had a relaxing massage and you think your partner should try it too.*
excited	*You've just received big news you were hoping for! You want your partner to know you want to celebrate together.*

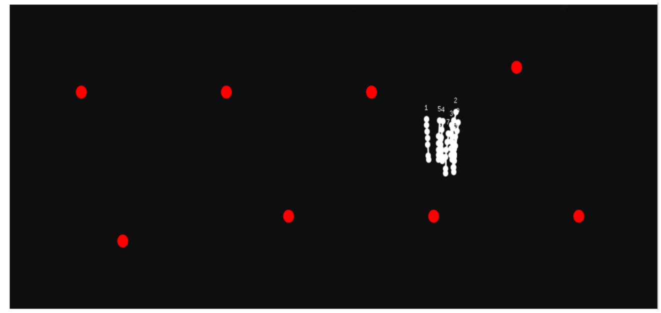

Fig. 3. P6a designed an **excited** message using 7 short, disconnected, high-frequency segments in quick succession. It's describe as "... *an excited poking, which I already do to her*". The red dots indicate the relative physical centre of the vibrotactors on the associated haptic display; spacing irregularities are unintentional but necessarily reflected in positional measurements.

time to play around and send messages to one another (reducing novelty effects) and we ran a number of the device validation pilot patterns (verifying that participants reliably felt the haptic sensations). Then the dyad was separated; each individual had their own experiment room and experimenter where they were asked to design a set of messages directed to their partner using the custom device. For each message, designers were asked to describe the emotions that the scenarios evoked for them–to verify that they were aligned on the intended emotional content. If they did not key in on emotion synonyms, the resulting design was thrown out. To 'draw' the design, participants could quickly adjust the waveform's frequency, amplitude, diffusion pattern, and rendering speed on a touchscreen interface. If they had any trouble, or if they only wanted to draw the 2D design (see sample in Figure 3, the experimenter would step in and adjust the parameters, letting the designer dictate changes to the haptic sensation until they were satisfied with the effect. We also allowed re-starting. Once participants had designed as many of the message prompts as they could in the allotted time, they were asked to design a message of their choice intended for their partner and describe the emotions or meaning they associated with it.

E. Message Interpretation

All original dyad members designed a common set of messages and had messages designed specifically for them by a close relation. $N = 10$ individuals returned for the 30-min evaluation study where participants had a set of haptic messages played for them (without the visual cue from the designing phase). They were asked to describe the emotions that were evoked when experiencing the message and then select the scenario prompt they thought to represent the sensation. The messages they were feeling were designed by one of themselves, their dyad partner, or a stranger and played back in random order. Finally, they were asked to interpret the unprompted message that their partner chose to design specifically for them. During this phase, participants could ask to play a message back as many times as needed.

III. Outcomes and Discussion

In the Message Interpretation phase, participants recognized the emotion at 20% accuracy overall, roughly double that of chance (≈ 10%). Nearly all (8/10) of the emotional messages were recognized at above chance. Notably, **attention** was the highest performer of our pre-determined messages, 45%, with **anger** and **calm** tied for next best at 23%. The worst, by far, were the **excited** messages at 2.5%. But perhaps the most interesting outcome was that 64% of the 'participant's choice' haptic messages were described accurately by recipients (based on designer's affect tags).

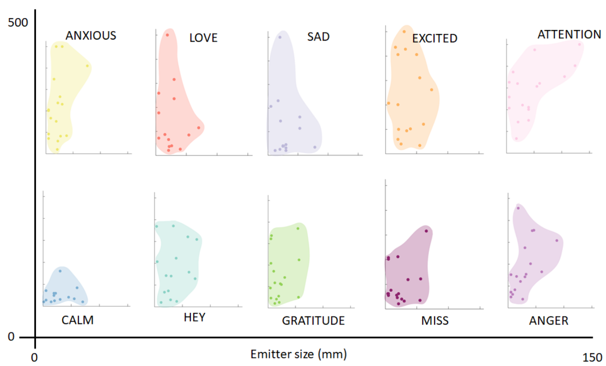

Fig. 4. Comparing emotion messages' design parameters, here frequency by brush size.

We looked at parameters that participants mentioned were haptically salient. Figure 4 depicts how emotion messages were designed by low vs high frequency vibrations and brush size. We see that for this parameter set, emotions like **calm** has a very constrained design space with every design being of low frequency-small brush size pair; **excited**, however, has a large spread that has a lot of overlap with messages like **anxious** and **love**. This kind of design analysis highlights where universal patterns emerge in how people expect emotions to be represented haptically.

We hypothesized that the closer the relationship between message sender and recipient, the higher the recognition rate. This turned out to be the case with the closest relationship–sender and recipient is the same person–recognizing emotions at 28% accuracy; close partners at 21%; and strangers at 16%. But a more nuanced outcome emerges when we further breakdown by message emotion. Figure 5 shows that our relationship hypothesis is not true across all emotions. Interestingly, while our partner can recognize our **angry** messages, we may not recognize our own!

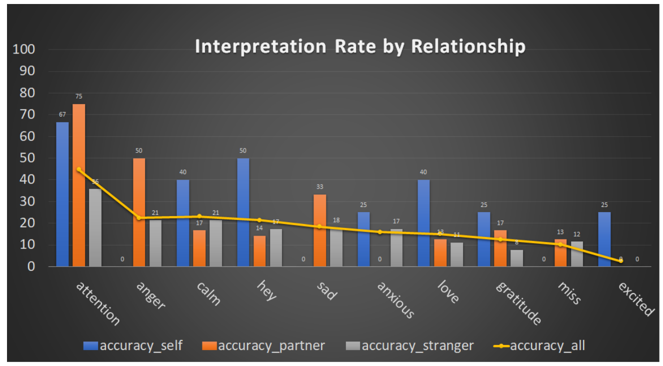

Fig. 5. Recognition of emotional haptic messages broken down by sender-recipient relationship.

IV. Future Work

We will expand on our exploration of how the design factors influence haptic emotion design (brush size, frequency, volume, 2D spread and density, discontinuity count) and build a machine learning model of the haptic sensations based on these parameters. It would be curious to explore whether there is something unique in how recipients then decode the emotions by comparing machine and human recognition rate. We are excited to demonstrate the viability of haptics in machine-mediated communication as a vehicle for conveying the important but subtly nuanced emotional content that we project so naturally in person.

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