Exploring Haptic Feedback for Common Message Notification Between Intimate Couples with Smartwatches

John Brandon Graham-Knight
University of British Columbia (Okanagan)
Kelowna, BC
brandon.grahamknight@ubc.ca

Jon Michael Robert Corbett
University of British Columbia (Okanagan)
Kelowna, BC
joncorbett@live.ca

Patricia Lasserre
University of British Columbia (Okanagan)
Kelowna, BC
patricia.lasserre@ubc.ca

Hai-Ning Liang
Xi'an Jiaotong-Liverpool University
Suzhou, Jiangsu
haining.liang@xjtlu.edu.cn

Khalad Hasan
University of British Columbia (Okanagan)
Kelowna, BC
khalad.hasan@ubc.ca

ABSTRACT

In this paper, we explore haptic feedback for smartwatches (i.e., vibrations) as a means to transmit the conversational meaning of short text messages through a non-visual mode of communication between intimate people. The current use of smartwatch vibrations is limited to basic patterns to convey simple information such as notifying users on an incoming phone call or a text message. We envision the use of vibrations to notify commonly exchanged messages between intimate ones by providing discreet feedback on their wrist. This form of communication preserves the flow of users' primary activities without making them to look at the display, supporting unobtrusive interaction. We start our exploration by examining the common short text messages that intimate people, like couples, exchange in their daily life. We next investigate the vibration properties such as vibration duration and number of vibrations that are suitable to convey the meaning of these messages. We further examine users' accuracy of detecting and extracting the meaning of messages from vibrations where our results report an accuracy of 95% while perceiving the correct meanings. We conclude with design recommendations for using such vibrational feedback for communicating information with intimate partners.

CCS CONCEPTS

• **Human-centered computing** → **User studies**; *Haptic devices.*

KEYWORDS

Smartwatches; Text Messaging; Vibration; Haptic Feedback; Intimate Couples; Improved Communication;

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1 INTRODUCTION

Mobile and wearable devices (e.g., smartphones and smartwatches) are primarily designed to assist users to communicate with others. They offer different forms of communication channels such as text messaging, audio call, video call, and apps (e.g., messenger services) to allow people to communicate instantly and in personalized ways. People frequently use these channels to promote friendship within a group or continuing one-to-one connection with intimates ones such as their spouses or close friends. Consequently, these personal mobile technologies are facilitating improved social and interpersonal relationships by allowing users to send and receive information anytime, anywhere.

Text messaging has been shown to be one of the primary media for mobile communication used in personal relationships [27]. Researchers have shown that people tend to send text messages for a wide number of reasons, including asking questions, giving instructions, or sign-on and sign-off [13]. Along with text messages, non-visual modes of communication, such as vibration, have been shown to be effective to promote interpersonal communication [37] and improve intimacy in relationships [17, 33]. Vibration on wearable devices, such as smartwatches, offer always-available feedback channels in situations where users cannot take their eyes off their primary activity, such as while driving or giving a presentation. Though prior studies have shown promising results for improved communication with text and vibrations on mobile devices, there is no prior work studying smartwatch vibration properties such as duration or number of discrete vibrational pulses which are suitable for notifying the meaning and feelings of text messages between two people who have a close relationship to each other.

In this paper, we explore the use of smartwatch vibration as a mean of notifying commonly exchanged text messages between intimate partners. We used smartwatches as opposed to smartphones, as smartwatches provide similar functionalities as smartphones (e.g., receiving or replying to messages on the go) while proving more portable and are less likely to be in a pocket or placed on a table. Additionally, smartwatches are, in general, firmly attached to the body which helps users perceive haptic feedback more clearly and intensely than a smartphone.

Specifically, we investigated how to notify couples about frequently used "conversational meaning" without the need to engage in strictly verbal, visual, or textual communication. We focus on intimate couples as they communicate frequently via messages whose meaning is often repeated across encounters while sharing common aspects of the life or house management (i.e. "buy groceries" may be sent a few times a week). We envision that coding information with vibration would be extremely useful in many situations where accessing a smartphone is not possible (e.g., while driving, watching a movie in a theater, or attending a meeting).

The problem of realizing such vibration-based notifications has several dimensions such as two-way communications, the importance or urgency of the message and the need for replying or acknowledging the message. As an initial step towards leveraging vibrations for ease of communication between intimate people, we narrow down the problem to one-way communication, i.e., notification of common text messages received from a specific person (e.g., a partner) and focus on identifying vibration patterns that can effectively convey short-text messages.

We first conducted a study with a group of couples to find the commonly exchanged short text messages such as questions, requests and reminders during their daily conversation. We then explored suitable vibration parameters such as pulse duration and number of pulses that users can detect accurately. Based on these results, we developed a coding mechanism using vibration, which can be employed to transmit the meaning of messages to a recipient in a subtle, unobtrusive way. We conducted a second study examining how accurately users could extract the meaning of text messages (i.e., 'hi') and their categories (e.g., 'Greetings') from vibration patterns. Results showed 95% accuracy on detecting 8 text messages and their categories from vibration patterns.

Our contributions include: 1) An investigation of the common text messages that couples frequently send to each other; 2) an evaluation of vibrational properties on smartwatches that people can detect with high accuracy; and 3) an evaluation of vibration-to-text mappings that users can detect with a high accuracy.

2 RELATED WORK

Our work builds on the usage and benefits of text messages for everyday communication, which we review first. We then cover work in the area of vibration and conclude this section with a presentation of using vibrations for exchanging information, which is the core goal of our paper.

2.1 Text Messages for Communication

Communication facilitated by digital devices has made it possible to share short conversations much more frequently - and usually several times throughout the day. Research of these brief types of text-based interactions has consistently found correlations to relationship satisfaction and connection between intimate partners is positively affected [3, 8, 15]. Though research directly related to the consequential effects of text messaging activity in romantic relationships is growing, it is a field of inquiry that can benefit from further investigation as the role(s) of text messaging behaviours change [26], especially with the development of new technologies and new forms of communication come into existence [12, 16].

Prior research categorized personal texting communications into broad functional categories such as basic contact (which includes appointments, greetings, and emotional support), sharing of general information, appeals, obligations, and declarations [2, 11], chatting, activity planning, communicating task coordinations, and other (which includes such things as jokes and greetings) [14, 34]. Similarly, in a study of text-type frequency and content classification, common message categories included: questions, rendezvous (immediate and ongoing), and rendezvous (near future), listed in descending order of the most frequently used [13]. These studies illustrate that text messaging plays a significant role in the communication of personal and romantic relationships, and has a dramatic impact on relationship satisfaction, and perceived similarity in content and relationship-commitment in relation to one's partner [26]. In contrast with other studies, we focus on exploring text messages that couples commonly exchanged between them.

2.2 Vibration and Human Physiology

Vibration is one of the modes to convey information (i.e., notification) on mobile devices. There have been many studies exploring detectable vibration frequency with Just Noticeable Differences (JNDs) [20]. Researchers showed that Pacinian corpuscles sense frequencies in the 300 - 840 Hz range, whereas Meissner corpuscles detect low frequencies up to 200 Hz. Mobile phones, generally, vibrate in the 130 Hz - 180 Hz range [20, 39]. These devices are commonly equipped with single actuator to present patterns by changing the vibration intensity over time, which in many cases limit users' experience. This can be further improved by incorporating several distinct actuators on the device [29]. Though smartwatches are, typically, more closely attached to users' skin than smartphones, Lim et al. [23] showed similar user performance in detecting vibrations with these devices. Additionally, vibration duration and number of vibrations have been examined on both smartphones [19] and customized wearable tactile display with multiple vibrator motors [21]. In our study, we explore the vibration duration and number of vibrations that users could detect with unmodified smartwatches which commonly include a single actuator.

2.3 Meaning through Vibration

Notable work has been done around the ability to convey meaning through vibrations. Researcher explored the use of vibrational pulses to convey urgency [30], notify drivers of danger when parking a vehicle [7], communicate activity progress in a smartwatch [6] or to convey various impressions to users [31]. Other work has centered around using vibrations for helping people with wayfinding. Researchers proposed different solutions such as vibrational gloves to navigate obstacle courses [40], belts to provide directional information with tactile senses [36]. Additionally, vibrational feedback has also been explored with mobile devices for wayfinding [28] and object selection [22]. In recent years, there has been an increased

Category	Examples Message
Questions	Do you want a ride? Need anything? What's for supper?
Request, Reminder	Can you check *something* for me? Can you grab *item name* on the way home?
Status update requests	Where are you? What are you doing? When are you coming home?
Status updates	On my way home, In a meeting, Busy now
Agreement, Disagreement	Yes, No, Ok, Sure, Sorry, Will do, Can't do that
Greetings	Hi, Hello, Welcome
Feeling, Affection	Love you, Miss you, Missing you, Thinking of you
Signon, Signoff	Good morning, Good night, Have a great day

Table 1: Commonly observed categories and examples text messages

interest in studying ubiquitous computing technologies and the potential of semiotic resources to transmit meaning through non-visual modes of communication [9]. Additionally, research projects such as Haptic Edge Display [18] attempt to convey meaning with a variety of novel mobile device augmentations, such as Dobson et al.'s [10] VibroBod which mixes vibration and temperature to aid or amplify affective feelings of empathy and/or mood.

3 THREE STUDIES

There has been notable work around using text messages for communication, vibration and human physiology, and applications of communicating meaning through vibration. There has also been substantial work exploring the common text messages that people send to others [1, 32, 35]. However, we are unaware of any previous work that employs vibrations to convey meaning of frequently sent text messages between couples. Therefore, we ran three studies to explore commonly exchanged short messages, suitable vibration parameters to present the messages, and evaluate the accuracy of extracting meaning of messages sent as vibration. Ethics approvals were in place prior to conducting the studies.

4 STUDY 1: COMMON SHORT TEXT MESSAGES BETWEEN COUPLES

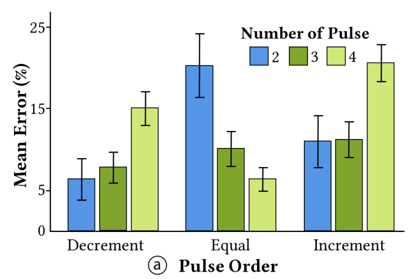
In this paper, we focus on the messages that intimate people (i.e., couples) commonly exchange in their daily life. In an attempt to gain insights into such messages, we conducted interview sessions with couples who use short text messages on smartphones on a regular basis for communicating with their partners. Though there are different types of channels for intimate communication such as text messages, images, videos, selfies, links etc, we only focus on short text messages as prior research showed that people prefer to keep their texts short [38].

4.1 Participants

22 participants (eleven 2-person couples, age range between 28 and 71) participated in the study. We only recruited participants who have been using smartphones for at least one year to send text messages for exchanging information with their respective partner. The participants were recruited from Canada.

4.2 Procedure

We coordinated interview sessions with the participants. Interviews were employed to minimize the noisy responses typical of surveys and questionnaires; interviews also alleviate low response rates, ensuring a well distributed sampling. At the beginning of the session, one co-author provided general information about the study to the participants. Next, the co-author asked the participants to review their own messages and write the commonly and frequently exchanged short messages with their partners. Participants could paraphrase, as a few communicate in their native, non-English, language. We collected a total of 207 messages. Only text messages were reviewed, as these were the form of communication most pertinent to our intended application. While this potentially allows filtering, we believe that the intention to prove commonality and identify categories in frequent messages was satisfied. We did not focus on non-textual communications (e.g., images, emojis) as they might be associated with context of the messages, however this could be a potential future work. Each session took roughly twenty minutes.



Original Pulse → Perceived Pulse	Error (in %)
0.2 → 0.3	21%
0.2 → 0.4	3%
0.3 → 0.2	23%
0.3 → 0.4	23%
0.4 → 0.2	4%
0.4 → 0.3	26%

ⓑ

Figure 1: (a) Mean error rates. Error bar±1 S.E. and (b) Original pulses, users perception of the pulse and corresponding error rate

4.3 Results

Two co-authors separately analyzed participants' responses by grouping the messages into categories. Once completed, they came together, sorted their categories and merged their data tables together. Table 1 shows common message categories and example messages that we found from the study.

Our results revealed that many short text messages contain a range of questions (16% messages, examples: 'Do you want a ride?', 'What's for supper?') and requests and reminders (15%, e.g., 'can you check [something] for me?'). We also found that couples use text messages requesting updates on their partner's status (17%, e.g.,'Where are you?', 'What are you doing?'). In response, they commonly reply with their current status (17%, e.g., 'On my way home', 'In a meeting').

Results also revealed that 13% of the text messages were exchanged in response to questions, commonly with an agreement or disagreement statement. These messages contain short texts such as 'Yes', 'No' or 'Ok'. We also found that 10% of the messages are sent to express some form of feeling or affection between partners. Example messages include 'Love you', 'Miss you' or even expressions of anger, 'What's wrong with you'. Couples also exchange sing-on/sign-off (3%) and greeting messages (8%) that are generally interchanged at the start (e.g., 'Good morning', 'Hi') or the end of a day or a conversation ('Goodnight', 'Bye').

4.4 Summary

Our findings confirmed that the types of messages that are exchanged among couples can be compared with other existing studies on text messages. For instance, Faulkner et al. [13] revealed that people commonly use messages for questions, instructions, reminders, jokes, sign-ons, sign-offs and information sharing purposes. We also observed similar results with an additional set of messages expressing emotion or affection which are more common among intimate people. Grinter et al. [14] showed that teenagers (i.e., 15-16 years old) tend to text for chatting, coordinating and planning. However, we found less messages in these categories, and it warrants further investigations in age-gender-relationship based text message analysis.

5 STUDY 2: SMARTWATCH VIBRATION PROPERTIES

In this session, we examined different smartwatch vibration properties that can be used to represent a short text message category and possibly the message itself.

5.1 Design

We designed this study to explore vibration properties that users can detect while they are wearing a smartwatch on their wrist. There are many properties of vibration such as duration of vibration, number of vibrations, vibration intensity, and vibration direction. We only focused on the first two properties as a prior study [21] showed that intensity is the most difficult property to distinguish. Additionally, most commercial smartwatches do not support intensity- or directionally-variant vibration. As we were only interested in exploring vibration properties on unmodified smartwatches, we excluded these properties from our study. We included *Pulse Duration* which is defined by the duration of vibration; we used vibrations that are 0.2, 0.3, 0.4 seconds long. Similar values are also explored in previous research for mobile devices [19] and customized wristband [21]. We also varied the *Number of Pulses*, which is defined as the number of discrete vibrations; we used 2, 3 and 4 vibrations in this study.

We created a set of vibration patterns combining the pulse duration and number of pulses, with a 0.5 seconds time gap between two consecutive vibrations (Figure 2). For both 2 and 3 pulses, we used repeated pulse duration and non-repeated pulse duration (Figure 2a row 4-9). As it is not possible to generate non-repeated pulse duration for a 4-pulse pattern (with three pulse durations), we repeated a 0.3-second pulse twice. We also decided not to put 0.3-second pulse twice together in the pattern to generate a non-repetitive sequence within a pattern. Consequently, we came up with 27 unique patterns with 3 *Pulse Duration* and 3 *Number of Pulse* as shown in Figure 2a. All these patterns include either an increment (e.g., 0.2, 0.3), an equal (e.g., 0.2, 0.2) or a decrement (i.e., 0.4, 0.3) order with their neighbour pulses; notably, (0.2, 0.4) and (0.4, 0.2) neighbours were excluded. Accordingly, we had 18 increment, 18 equal, and 18 decrement orders for each 2-, 3- and 4-pulse patterns.

5.2 Participants and Apparatus

We recruited 12 participants (age between 27 and 45) from Canada. Two participants had prior experience using a smartwatch. All participants had experience with smartphones and vibration for notifications. We used an LG G Watch R to conduct the study. The smartwatch was connected to a node.js application via Wi-Fi. The server was used to send vibration patterns, one at a time, to the smartwatch.

5.3 Procedure

Participants were first provided with the smartwatch and asked to place it on the wrist on which they feel most comfortable wearing it. During the experiment, vibrational pulse sequences were sent to the smartwatch, one pulse pattern at time. Once the participant detected a vibrational pulse pattern, they were instructed to describe to the co-author the characteristics of that vibration sequence verbally (e.g., saying "0.3, 0.3, 0.3" or "0.2, 0.3, 0.4" or) as shown in Figure 2b and 2c. The co-author recorded the participants' responses and repeated these steps until the trial had finished. Note that no visual cue was provided on the smartwatch during the experiment.

We repeated 27 unique pulse patterns 3 times and randomized across participants. Each participant was give 81 pulse patterns in total. Practice trials, where a set of random pulses were sent and the description provided by the participant were confirmed or corrected by the co-author, were given to the participants before running the main session. These practice sessions continued until the participant expressed comfort with the method of testing. With practice trials and breaks, the experiment lasted for approximately 30 minutes.

5.4 Results

Friedman tests with Wilcoxon tests were used for post-hoc pairwise comparisons to analyze error rate. Post-hoc pairwise comparisons were Bonferroni adjusted. We first examined the data to explore how well users could recognized the *Pulse orders* (Decrement, Equal and Increment) and the *Number of Pulses* (2, 3 and 4). Interestingly, we did not observe any error in detecting the number of pulses in a pattern. All the participants successfully detected the correct number of pulses in each trial (i.e., either 2, 3 or 4 pulse). Thus, we marked a trial as an error trial once participants provided incorrect answers on the order of the pulse (e.g., instead of Decrement order, they detected Increment order). We calculated the error rate by counting the number of times that participants provided incorrect answers for pulse orders and then divided by the total number of

#	2-Pulse Pattern	3-Pulse Pattern	4-Pulse Pattern
1	0.2, 0.2	0.2, 0.2, 0.2	0.2, 0.2, 0.2, 0.2
2	0.3, 0.3	0.3, 0.3, 0.3	0.3, 0.3, 0.3, 0.3
3	0.4, 0.4	0.4, 0.4, 0.4	0.4, 0.4, 0.4, 0.4
4	0.2, 0.3	0.2, 0.3, 0.4	0.2, 0.3, 0.4, 0.3
5	0.2, 0.4	0.2, 0.4, 0.3	0.3, 0.2, 0.3, 0.4
6	0.3, 0.2	0.3, 0.2, 0.4	0.3, 0.2, 0.4, 0.3
7	0.3, 0.4	0.3, 0.4, 0.2	0.3, 0.4, 0.2, 0.3
8	0.4, 0.2	0.4, 0.2, 0.3	0.3, 0.4, 0.3, 0.2
9	0.4, 0.3	0.4, 0.3, 0.2	0.4, 0.3, 0.2, 0.3

a

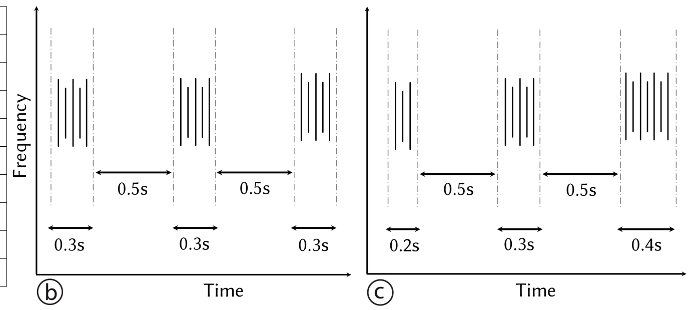


Figure 2: (a) 2, 3 and 4 pulse patterns that we tested in Study 2. Vibration patterns: 3 pulse pattern with (b) 0.3s-0.3s-0.3s and (c) 0.2s-0.3s-0.4s pulse duration

answers. We observed an overall error rate of 12%. Figure 1a shows the mean error rates.

We found that *Number of Pulses* had no effect on error rate (χ^2 (2,N=12) = 4.31, p = 0.12) and observed 13%, 10% and 14% errors across 2, 3 and 4 pulses, respectively. We found significant differences in *Pulse Order* (χ^2 (2,N=12) = 10.4, $p < 0.05$). The mean error rate was: 11% (Decrement), 10% (Equal), and 14% (Increment). Post-hoc Wilcoxon tests showed significant differences between the Increment and Equal, and between the Increment and Decrement orders.

We observed an interesting interplay between *Pulse Order* and *Number of Pulses* (Figure 1a). When 2 pulses with equal duration were used (e.g., 0.2s, 0.2s), participants were more prone to error (i.e., 20%) in identifying the correct answer. This error rate decreased rapidly when a higher number of pulses were used (10% and 6% for 3 and 4 pulses respectively) as the additional pulses provided a greater opportunity to perceive the pattern. On the contrary, for increment and decrement pulse orders, the error rates increased with the number of pulses. This is because participants answered incorrectly when a 0.3s pulse was included in the pulse sequence (Figure 1b).

We also asked participants to provide their preference on *Pulse Order* and *Number of Pulses*. All the participants preferred 4-pulse over 2- or 3-pulse patterns. They expressed that having more pulses helped them to understand the patterns better. Additionally, they mentioned that it is easier to detect pulses especially when their duration differs by more than 0.1s (e.g., 0.2s and 0.4s).

5.5 Summary

Our results indicate that error rates increase significantly when using equal pulse orders with two pulses (i.e., 0.2, 0.2). Thus, we decided to use this vibration pattern for the next study. Additionally, 93% of error trials were recorded when a 0.3s vibration is included in the pattern. Participants also expressed that it was hard for them to detect a pulse pattern when there was a 0.3s pulse included in the pattern. Consequently, in our next study, we decided to exclude this 0.3s vibration from our study design.

6 STUDY 3: RECOGNITION OF MEANING THROUGH VIBRATION

Study 1 results showed the frequent short text messages that intimate people commonly exchange and Study 2 informed us on the vibrations and patterns that people can detect with high accuracy. Based on these results, we next conducted a study examining how well users could recognize a text message and a category from a vibration pattern.

6.1 Design

As intimate people send a diverse set of messages to their partner, it is difficult for them, and people in general, to remember all messages that can be mapped to vibration patterns due to memory limitations. Additionally, there is evidence that people can store and recall 7 ± 2 items without continuing to repeat the items until it is committed to memory [24]. Consequently, we focus on exploring user performance in terms of recognizing a set of messages and its categories from vibration patterns

We included the following *Message Representation* styles - Four message categories: Questions, Request, Reminder, Request for Status Update, and four messages: 'Hi' (Greetings), 'Love you' (Affection), 'Yes' (Agreement), 'Good Morning' (Signon). We do acknowledge that there might be other choices (e.g., using only eight categories or eight messages), we used a combination of both in this study. As the results from Study 2 indicate users' preference towards using 3- and 4-pulse patterns, we used them to map to text messages as shown in Figure 3a. We applied 4-pulse vibration patterns to randomly map the text messages and 3-pulse patterns for a message category. For instance, (0.4s, 0.4s, 0.4s, 0.4s) vibration was used to represent 'Love you' (all 0.4s) where (0.2s, 0.2s, 0.2s) was used for 'Status Update'. Repetitive similar sequences, (e.g., 0.4,0.2,0.4,0.2), were used to facilitate recall of the text messages.

6.2 Procedure

We recruited 16 participants, whose ages ranged between 25 and 69, from Canada. All the participants reported that they had been using smartphones for at least one year. The apparatus used was the same as in Study 2.

Pattern	Category/Text
0.4,0.4,0.4,0.4	Love you
0.4,0.2,0.4,0.2	Yes
0.2,0.2,0.2,0.2	Hi
0.2,0.2,0.4,0.4	Good Morning
0.2,0.2,0.2	Status update
0.4,0.4,0.4	Request status update
0.2,0.2,0.4	Question
0.4,0.4,0.2	Reminder

ⓐ

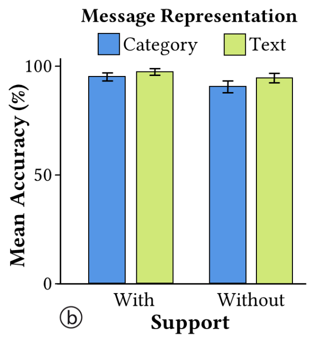


Figure 3: (a) Pattern-to-Category and Pattern-to-Text message mappings and (b) Mean accuracy across *Message Representation* and *Support Type*. Error bar±1 S.E.

6.3 Procedure

We aimed to explore whether participants can detect commonly used short messages conveyed by vibrations. Rather than inviting couples at the same time, we invited one participant at a time to explore how accurately they could extract meaning of messages in a scenario when they receive messages from their partner. We used a similar procedure as in Study 2, where participants were first asked to wear the smartwatch on their wrist on which it felt most comfortable. One co-author used the Node.js server to send a vibration pattern to the smartwatch. They were asked to notify the co-author when they felt a vibration sequence. Once they notified the co-author, they were asked about the characteristics of that vibration pattern and the corresponding message or category name.

Category choice was driven by the study 1 results; we selected the top four categories with most text messages and four randomly from the remaining four categories. Participants were provided with a paper support describing the mappings from vibration to meaning; this helped to foster building their spatial memory on the pattern-to-text and pattern-to-category mappings. A few practice trials were performed for each participant before the actual experiment, with and without *Support*, describing the mappings; this helped to ensure participants understood the tasks. These practice sessions continued until the participant expressed comfort with the method of testing.

We randomized and repeated 8 vibration pattern-to-text mappings 4 times, and presented these to the participants. For the first two repetitions, participants were permitted to reference the paper showing the associated mappings. This support was removed for the last two repetitions, and participants were asked to recall the message/category of the presented vibration. With practice trials and breaks, the study lasted for approximately 30 minutes.

6.4 Results

We were interested in analyzing error rates, as defined by the number of trials with incorrect answers divided by the number of total trials. In this study, we collected 512 trials from the participants. We found that out of 512 trials, participants answered 484 trials (95%) correctly (Figure 3b).

We found neither *Message Representation* (χ^2 = 0.7, p = 0.78) style nor *Support* (χ^2 = 3.0, p = 0.08) influenced the accuracy (Wilcoxon tests). Results indicated that the accuracy degraded slightly, but not significantly, when the paper support was removed (from 96% to 92%, with and without paper support, respectively). The accuracy drops between 0% and 9% for messages and 0% to 16% for message categories when the support was removed. We also observed that participants were more accurate associating the text message with 4-pulse vibrations (96%) than message categories with a 3-pulse vibration (93%). Results revealed 95% accuracy for 'Love you', 95% for 'Yes', 94% for 'Hi', 100% for 'Good Morning', 94% for 'Status update, 92% for 'Request Status update', 94% for 'Question' and 92% for 'Reminder'.

6.5 Summary

As expected, with paper support, participants were more accurate finding the correct correlation of pattern to message. This approach mostly relies on recognizing the vibration patterns whereas the other approach (i.e., without support) depends on both recognition and recall. Similar trends were observed in [4] where item recognition was reported easier and more accurate than item recall due to the availability of additional visual cues. We observed that the mean accuracy does not significantly decrease after removing the paper support. Our results also revealed that interpreting specific text messages with vibration is more accurate than identifying a message category. This is primarily due to the pattern-to-text message mapping with more vibrations (i.e., four pulses) that we used in our study.

7 DISCUSSION AND DESIGN RECOMMENDATIONS

In this paper, we explore how to bring two ideas together which have yet to be explored: intimate communication and vibrational messaging. We conduct three studies examining frequent text messages that intimate couples exchange, vibration properties that users can detect, and accuracy on communicating text message meanings through vibration. Results of our studies show that people have the ability to identify text messages and their categories through smartwatch vibrations. Our results also showed that users' performance varies in their perception of vibration patterns which could be further refined by mixing different pulse durations and/or number of vibrations. Based on the results, we offer the following recommendations for designing vibration-based intimate communication:

- *Avoid vibration durations that are too close to each other*: We observed that participants performed the vibration-identity task with greater accuracy when at least one of the pulses was significantly different from the rest (i.e., 0.2s, 0.4s combination). Thus, we suggest creating vibration patterns that avoid durations that are too close to each other (i.e., 0.2s, 0.3s combinations).
- *Use a long and similar pulse duration*: Our Study 1 results suggest a possible trade-off between the number of pulses and pulse order with which a user recognizes a vibration pattern. Accordingly, we suggest designing long vibration patterns with a similar pulse duration (i.e., 0.2, 0.2, 0.2, 0.2).

- *Recognition and recall of the Vibrations*: Our results revealed that the additional support (e.g., a paper showing the mapping) helps users to recall meaning of vibration patterns with accuracy. We suggest using a combination of recognition and recall strategies to help users retrieve a text message or category from memory. Designers could start with providing information or visual cues on the assigned mappings that can then be removed as results begin to show no significant degrade in users' recall after removing the support.
- *Age-gender-relationship consideration*: Our results provide initial insights into the variations of text messages based on ages and relationships. For instance, [14] showed that teenagers tend to text for chatting, coordinating and planning. However, we found fewer messages in these categories for couples, and more in expressions of emotions. Therefore, designers should consider age-gender-relationship factors for any text-based communication.

8 LIMITATIONS AND FUTURE WORK

In this paper, we have presented the results of two studies that represent initial steps to develop our understanding on how to enable users who are familiar with each other to send messages using the vibrations of smartwatches. Although the results show a positive case for their use, there are some limitations of our work.

All studies were conducted in Canada with persons living there. Diversity was fostered by including people of various ages and backgrounds. Since all participants are currently living in a Western culture, we would be wary of generalizing the common-message study results to different cultures. Exploring culturally dependent differences in frequently used messages between intimate partners would be a challenging, but a very useful direction for future work. Although the number of participants in our studies is of similar or bigger size of experiments reported in HCI papers (e.g., 12 is the most common number of participants in experiments in CHI'12 papers [5]), more participants from a more diverse culture and background could help shed further light on our findings and help us uncover other patterns.

This paper shows that smartwatch-enabled vibrational communication of meaning is technically feasible and practically promising. However, there are limitations to these studies which prohibit conclusions about usability and usefulness of such a solution on a daily basis. Firstly, we conducted all studies in an environment where all the participants were seated and focused. Secondly, we conducted Study 3 with pre-defined mappings of vibration patterns and text messages; this study did not include participants' partners as it sought only to examine how accurately participants can recognize and recall messages from vibrations, which we show that they can do accurately.

We believe that future work should focus on whether users can manage receiving vibrational information in a context-of-use study (e.g., walking instead of sitting) and/or when users' hands are occupied with other tasks (e.g., carrying a shopping bag) [25] that affect a user's perception, efficacy, and usage patterns of this type of communication. Ideally, this should be a longitudinal study which would allow users time to become familiar with the technology; the study would examine usability, user satisfaction and desire in employing such a solution. The mapping of messages in such a study should be user-defined, as opposed to the herein explored pre-defined mappings; this would facilitate multiple user groups (i.e. couples, family members, and friends) and relationship statuses (e.g., couple, single, married). This would help further our understanding of this way of communication for multiple user types.

We acknowledge that identifying the upper limit of performance demands further study of strategies for improving memory recognition and recall. The current study proves the viability of using vibration for message exchange among users. We could further explore the upper limits by several techniques like: (1) combining multiple pulse patterns (e.g. 4-pulse then 3-pulse, where the first could be used to represent a category and the second for message under the category); (2) using "user-defined" mappings to accommodate more vibration-to-text messages; (3) leveraging techniques to improve long term memory (e.g., mnemonic device). We plan and invite other researchers to undertake this work in the future.

9 CONCLUSION

In this paper, we explored the potential of a non-verbal and non-visual means of communicating short text messages through vibrations on smartwatches between users who are intimate to one another. We showed that users can reliably identify vibratory pulses of two distinct lengths (e.g., 0.2s and 0.4s). When a third or fourth pulse is introduced, users' ability to distinguish a pattern depends on the new pulse's properties (e.g., pulse length). We also revealed that users can interpret messages communicated through a vibration sequence with relatively high accuracy. Further work on vibrotactile communication mediated through technology could be used to notify messages between intimate couples aiming to support healthy interpersonal communication.

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REFERENCES

[1] Robert E Beasley. 2009. Short Message Service (SMS) Texting Symbols: A Functional Analysis of 10,000 Cellular Phone Text Messages. *The Reading Matrix* 9, 2 (2009).
[2] Klaus Brinker. 2005. *Linguistische textanalyse.* E. Schmidt.
[3] Jane D Brown. 2006. Emerging Adults in a Media-Saturated World. In *Emerging adults in America: Coming of age in the 21st century.* American Psychological Association, 279–299. https://doi.org/10.1037/11381-012
[4] Raluca Budiu. 2014. Memory Recognition and Recall in User Interfaces. https://www.nngroup.com/articles/recognition-and-recall/. [Online: Last accessed 31-January-2020].
[5] Kelly Caine. 2016. Local Standards for Sample Size at CHI. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems (CHI '16).* ACM, NY, USA, 981–992. https://doi.org/10.1145/2858036.2858498
[6] Jessica R. Cauchard, Janette L. Cheng, Thomas Pietrzak, and James A. Landay. 2016. ActiVibe: Design and Evaluation of Vibrations for Progress Monitoring. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems (CHI '16).* ACM, New York, NY, USA, 3261 – 3271. https://doi.org/10.1145/2858036.2858046
[7] Tanemichi Chiba, Hiroto Uesaka, and Michael A Wiegand. 2009. Parking Aid Notification by Vibration. US Patent App. 12/072,218.
[8] Sarah M. Coyne, Laura Stockdale, Dean Busby, Bethany Iverson, and David M. Grant. [n.d.]. "I luv u :)!": A Descriptive Study of the Media Use of Individuals in Romantic Relationships. *Family Relations* 60, 2 ([n. d.]), 150–162. https://doi.org/10.1111/j.1741-3729.2010.00639.x

[9] Emilia Djonov and Theo Van Leeuwen. 2011. The Semiotics of Texture: From Tactile to Visual. *Visual Communication* 10, 4 (2011), 541–564. https://doi.org/10.1177/1470357211415786

[10] Kelly Dobson, danah boyd, Wendy Ju, Judith Donath, and Hiroshi Ishii. 2001. Creating Visceral Personal and Social Interactions in Mediated Spaces. In *CHI '01 Extended Abstracts on Human Factors in Computing Systems (CHI EA '01)*. ACM, New York, NY, USA, 151–152. https://doi.org/10.1145/634067.634160

[11] Nicola Döring. 2002. 1 Bread, Sausage, 5 Bags of Apples ILY-Communicative Functions of Text Messages (SMS). *Zeitschrift für Medienpsychologie* 14, 3 (2002), 118–128.

[12] Nicole C Duke. 2018. How Social Media Influences Our Romantic Relationships. (2018). https://digitalcommons.whitworth.edu/sirc/2018/ps2/12/ Spokane Intercollegiate Research Conference.

[13] Xristine Faulkner and Fintan Culwin. 2005. When Fingers Do the Talking: A Study of Text Messaging. *Interacting with Computers* 17, 2 (2005), 167–185. https://doi.org/10.1016/j.intcom.2004.11.002

[14] Rebecca Grinter and Margery Eldridge. 2003. Wan2tlk? Everyday Text Messaging. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '03)*. ACM, New York, NY, USA, 441–448. https://doi.org/10.1145/642611.642688

[15] Khalad Hasan, Debajyoti Mondal, David Ahlström, and Carman Neustaedter. 2020. An Exploration of Rules and Tools for Family Members to Limit Co-Located Smartphone Usage. In *Proceedings of the 11th Augmented Human International Conference (AH '20)*. Association for Computing Machinery, New York, NY, USA, Article 7, 8 pages. https://doi.org/10.1145/3396339.3396364

[16] Marc Hassenzahl, Stephanie Heidecker, Kai Eckoldt, Sarah Diefenbach, and Uwe Hillmann. 2012. All You Need is Love: Current Strategies of Mediating Intimate Relationships through Technology. *ACM Transactions on Computer-Human Interaction* 19, 4, Article Article 30 (Dec. 2012), 19 pages. https://doi.org/10.1145/2395131.2395137

[17] James M. Honeycutt. 2009. Symbolic Interdependence, Imagined Interaction, and Relationship Quality. *Imagination, Cognition and Personality* 28, 4 (2009), 303–320. https://doi.org/10.2190/IC.28.4.b

[18] Sungjune Jang, Lawrence H. Kim, Kesler Tanner, Hiroshi Ishii, and Sean Follmer. 2016. Haptic Edge Display for Mobile Tactile Interaction. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems (CHI '16)*. ACM, New York, NY, USA, 3706–3716. https://doi.org/10.1145/2858036.2858264

[19] Takanori Komatsu, Kazuki Kobayashi, Seiji Yamada, Kotaro Funakoshi, and Mikio Nakano. 2018. Vibrational Artificial Subtle Expressions: Conveying System's Confidence Level to Users by Means of Smartphone Vibration. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems (CHI '18)*. ACM, New York, NY, USA, Article Paper 478, 9 pages. https://doi.org/10.1145/3173574.3174052

[20] Heow Pueh Lee and Siak Piang Lim. 2014. Comparative studies of perceived vibration strength for commercial mobile phones. *Applied Ergonomics* 45, 3 (2014), 807 – 810. https://doi.org/10.1016/j.apergo.2013.07.006

[21] Seungyon "Claire" Lee and Thad Starner. 2010. BuzzWear: Alert Perception in Wearable Tactile Displays on the Wrist. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '10)*. ACM, NY, USA, 433–442. https://doi.org/10.1145/1753326.1753392

[22] Yi-Chi Liao, Yen-Chiu Chen, Liwei Chan, and Bing-Yu Chen. 2017. Dwell+: Multi-Level Mode Selection Using Vibrotactile Cues. In *Proceedings of the 30th Annual ACM Symposium on User Interface Software and Technology (UIST '17)*. ACM, New York, NY, USA, 5–16. https://doi.org/10.1145/3126594.3126627

[23] Hyunchul Lim, YoonKyong Cho, Wonjong Rhee, and Bongwon Suh. 2015. Vi-Bros: Tactile Feedback for Indoor Navigation with a Smartphone and a Smartwatch. In *Proceedings of the 33rd Annual ACM Conference Extended Abstracts on Human Factors in Computing Systems (CHI EA '15)*. ACM, NY, USA, 2115–2120. https://doi.org/10.1145/2702613.2732811

[24] George A Miller. 1956. The Magical Number Seven, Plus or Minus Two: Some Limits on Our Capacity for Processing information. *Psychological review* 63, 2 (1956), 81.

[25] Alexander Ng, Stephen A. Brewster, and John H. Williamson. 2014. Investigating the Effects of Encumbrance on One- and Two- Handed Interactions with Mobile Devices. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '14)*. ACM, NY, USA, 1981–1990. https://doi.org/10.1145/2556288.2557312

[26] Jonathan Ohadi, Brandon Brown, Leora Trub, and Lisa Rosenthal. 2018. I Just Text to Say I Love You. *Comput. Hum. Behav.* 78, C (Jan. 2018), 126–132. https://doi.org/10.1016/j.chb.2017.08.048

[27] Jonathan Pettigrew. 2009. Text Messaging and Connectedness Within Close Interpersonal Relationships. *Marriage & Family Review* 45, 6-8 (2009), 697–716. https://doi.org/10.1080/01494920903224269

[28] Martin Pielot, Benjamin Poppinga, and Susanne Boll. 2010. PocketNavigator: Vibro-Tactile Waypoint Navigation for Everyday Mobile Devices. In *Proceedings of the 12th International Conference on Human Computer Interaction with Mobile Devices and Services (MobileHCI '10)*. ACM, New York, NY, USA, 423–426. https://doi.org/10.1145/1851600.1851696

[29] Alireza Sahami, Paul Holleis, Albrecht Schmidt, and Jonna Häkkilä. 2008. Rich Tactile Output on Mobile Devices. In *Proceedings of the European Conference on Ambient Intelligence (AmI '08)*. Springer-Verlag, Berlin, Heidelberg, 210–221. https://doi.org/10.1007/978-3-540-89617-3_14

[30] Bahador Saket, Chrisnawan Prasojo, Yongfeng Huang, and Shengdong Zhao. 2013. Designing an Effective Vibration-Based Notification Interface for Mobile Phones. In *Proceedings of the 2013 Conference on Computer Supported Cooperative Work (CSCW '13)*. ACM, New York, NY, USA, 149–1504. https://doi.org/10.1145/2441776.2441946

[31] Shota Shiraga, Yuichiro Kinoshita, and Kentaro Go. 2016. Designing Smartphone Feedback Based on Vibration Impression. In *Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems (CHI EA '16)*. ACM, New York, NY, USA, 3190–3196. https://doi.org/10.1145/2851581.2892430

[32] Anita Smith and Kipling D Williams. 2004. RU there? Ostracism by Cell Phone Text Messages. *Group dynamics: Theory, research, and practice* 8, 4 (2004), 291. https://doi.org/10.1037/1089-2699.8.4.291

[33] Timothy D. Stephen. 1984. A Symbolic Exchange Framework for the Development of Intimate Relationships. *Human Relations* 37, 5 (1984), 393–408. https://doi.org/10.1177/001872678403700503

[34] Caroline Tagg. 2009. *A Corpus Linguistics Study of SMS Text Messaging*. Ph.D. Dissertation. University of Birmingham.

[35] Mike Thelwall, Kevan Buckley, Georgios Paltoglou, Di Cai, and Arvid Kappas. 2010. Sentiment Strength Detection in Short Informal Text. *J. Am. Soc. Inf. Sci. Technol.* 61, 12 (Dec. 2010), 2544–2558.

[36] Koji Tsukada and Michiaki Yasumura. 2004. ActiveBelt: Belt-Type Wearable Tactile Display for Directional Navigation. In *UbiComp 2004: Ubiquitous Computing*, Nigel Davies, Elizabeth D. Mynatt, and Itiro Siio (Eds.). Springer Berlin Heidelberg, Berlin, Heidelberg, 384–399.

[37] Frank Vetere, Martin R. Gibbs, Jesper Kjeldskov, Steve Howard, Florian "Floyd" Mueller, Sonja Pedell, Karen Mecoles, and Marcus Bunyan. 2005. Mediating Intimacy: Designing Technologies to Support Strong-Tie Relationships. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '05)*. ACM, New York, NY, USA, 471–480. https://doi.org/10.1145/1054972.1055038

[38] Daniel T. Wagner, Daniel R. Thomas, Alastair R. Beresford, and Andrew Rice. 2015. Device Analyzer: A Privacy-Aware Platform to Support Research on the Android Ecosystem. In *Proceedings of the 8th ACM Conference on Security & Privacy in Wireless and Mobile Networks (WiSec '15)*. ACM, New York, NY, USA, Article Article 34, 2 pages. https://doi.org/10.1145/2766498.2774992

[39] Jinho Yim, Rohae Myung, and Byongjun Lee. 2007. The Mobile Phone's Optimal Vibration Frequency in Mobile Environments. In *Usability and Internationalization. HCI and Culture*, Nuray Aykin (Ed.). Springer Berlin Heidelberg, Berlin, Heidelberg, 646–652.

[40] John S. Zelek, Sam Bromley, Daniel Asmar, and David Thompson. 2003. A Haptic Glove as a Tactile-Vision Sensory Substitution for Wayfinding. *Journal of Visual Impairment & Blindness* 97, 10 (2003), 621–632. https://doi.org/10.1177/0145482X0309701007