Design of Syllabic Vibration Pattern for Incoming Notification on a Smartphone

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Abstract: We designed vibration patterns that notify a degree of urgency of an incoming message on a smartphone, a type of communication tool of the message and the sender' name, while the message is being received on the smartphone. The design assigns segmentations of the vibration to syllables of the words such as "twitter" or "LINE" and sender's surname. We propose that the patterns are easy-to-memorize and easy-to-discriminate because the vibration syllables imitate the syllabic sounds. Therefore, a user who senses and hears the vibrations can easily discriminate the information without looking at the smartphone screen. Discriminative correctness of the vibrations patterns was tested in a usability study with the smartphone in the user's hand or trouser pocket. For two degrees of urgency, six types of communication tools and six senders' names, the average correct answer rate was 78% in the hand and 34% in the pocket.

1 INTRODUCTION

Smartphone users receive so many notifications such as phone calls, messages, news, and application updates in their daily lives (Gallud et al., 2015, Okeke et al., 2018, Yoon et al., 2014). A survey conducted by Gallud et al. revealed that 69.3% participants received less than 50 notifications a day, and 9.7% of them received more than 100 notifications a day (Gallud et al., 2015). The survey also reported that each time a new notification was received, 44.7% participants checked their smartphones immediately.

Sound, vibration, visual notifications and a combination of the modalities are used in a smartphone notification. However, the visual or sound notifications force a user to look at or hear an incoming notification and is disabled when a phone is put on silent mode. Additionally, when a smartphone is in a bag or a trouser pocket, a user needs to pull it out to look at the visual notification. Typically, a visual or sound notification can disturb user's concentration while the user is performing a more important task with their smartphone.

In this study, we focus on a vibration notification of a smartphone because a vibration alert can inform an incoming event without any visual and/or sound alert if a user can touch a phone directly or indirectly through a bag's handle or harness. Haptic information involves kinematic control and evokes a subjective sense (Uchikawa, 2008). However, vibration notifications in current use can only inform the timing of an event and nearly nothing about the details of the event.

Thus, we designed patterns of vibrations to transmit information of an incoming event of a message when the message was being received. A pattern comprises three parts: urgency of message, type of message, and name of message sender. Degrees of the urgency help a user decide whether to check details of the message immediately or later. The type informs a user about a communication tool used to receive the message. The sender's name informs a user about who sent the message.

Our novel design approach assigns vibration duration and an interval between vibrations to syllables of communication tools and senders unlike previous patterns that used bit sequence (Yonezawa et al., 2013), Morse code (Ohta et al., 2010), or six-point Braille characters (Al-Qudah et al., 2014). The proposed approach allows a user to perceive vibration similar to the manner in which users perceive the sound of a name, and it is easy to make a short pattern with this strategy. Therefore, users can easily memorize the patterns and discriminate each one.

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We also evaluated discrimination correctness and usability of the patterns. This paper describes details of the design, the evaluation experiments, and the results, providing the following contributions.

- The average discrimination correctness of the vibration patterns about each of the six names of communication tools is 59%–86%.
- Users can discriminate the patterns not only through direct contact with their hand but also through indirect contact wherein the smartphone is within a bag held with the user's hand.
- Discriminating a vibration pattern of a sender's name that is similar to another senders' name is difficult. The highest correct answer rate of the names is over 70%, but the lowest rate is 30%.
- Participants answered that knowing the urgency and the order of the vibration patterns were useful.

2 BACKGROUND

2.1 Related Work

Jayant et al. developed V-Braille that is a way to haptically represent Braille characters on a smartphone using touch-screen and vibration (Jayant et al., 2010). The screen divided into six parts to mimic six dots in a single Braille cell. Experimental results shows that nine users (six deaf-blind, three blind) had a 90% accuracy rate. Five out of them were able to read a character in less than 10 seconds.

Azenkot et al. developed feedback methods called Wand, ScreenEdge and Pattern using vibration on a smartphone to provide turn-by-turn walking instructions to visual impairments (Azenkot et al., 2011). The Wand vibrates when the top of a phone is roughly pointing in a direction. The ScreenEdge vibrates when the user touches close to the edge corresponding to a direction. The Pattern vibrates for 1 to 4 pulses to indicate a direction. One pulse means "go forward," two pulses mean "turn right," three pulses mean "turn back," and four pulses mean "turn left."

Ohta et al. proposed the method of text communication by tactile sensation (called Tachifon) (Ohta et al., 2010). It conveys text information in the form of Morse or modified Braille signals using the vibration for users with visual and hearing impairment. They assessed communication efficiency of Tachifon and found a high level of correct message recognition over 96%.

Yonezawa et al. proposed Vineteraction that leveraged combination of vibrator and accelerometer to send information from a smart device to another device (Yonezawa et al., 2013). The system encodes each character of a string to "0" that means stopping vibration and "1" that means generating vibration. Results of evaluation for accuracy show that all the smartphone achieves almost 100 % of accuracy of information transferring.

Exler et al. hypothesized that there was a correlation between the perceptibility of a notification depending on its notification type (ringtone, vibration and LED) and the smartphone position (on a table, in a trouser front pocket and in a backpack) (Exler et al., 2017). The ringtone was standard sound "Tejat" for about 250 ms. The vibration was a pattern of 300 ms off, 400 ms on, 300ms off and again 400 ms on. The LED blinked for 500 ms in green and stays off for 500 ms. The results show that vibration and ringtone are perceived best at all positions, and that users felt that vibration is most pleasant than the ringtone due to habit, lower obtrusiveness, lower disturbance, and lower distraction.

Kokkonis et al. explored how visually impaired people can take advantage of vibro-tactile interaction in order to distinguish colours, objects or specific areas on the touch screen (Kokkonis et al., 2019). Different vibration patterns were proposed and assigned to each of eight colours. The evaluation tests revealed that the vibration time should be shorter than 300 ms and the idle time should be shorter than 400 ms. The period time for the vibration pattern should be shorter than 600 ms.

Al-Qudah et al. developed a method for presenting the six-point Braille characters on mobile devices that feature tactile feedback (Al-Qudah et al., 2014). The eight various combination of raised and lowered points of the three-point column are encoded with a single pattern of vibration. The proposed method significantly reduces the average reading time and the average power consumption.

2.2 Motivation

Simple combination of vibration and pause as described above cannot represent meaningful pattern. Moreover, vibration patterns based on ASCII code or Morse code can represent several meaningful vibrations but it is difficult for a user to memorize and recognize the meaning of them because there is no direct relationship between the patterns and the characters or words that are expressed by the patterns, and the patterns can become so long.

We propose a method to assign vibration segmentations to syllables of a word. The method can make direct syllabic relationship between the vibrations and the words. Also, length of a pattern made by the method can become shorter than that made by ASCII or Morse code. For example, when a vibration pattern of "mail" in Japanese is represented by Morse code method, the pattern consists of "– . . . – . – – . – – . – – ." (each dot(.) means a short vibration and each dash(–) means long vibration.). On the other hand, when the word is represented by our method, the pattern consists of "– ." (described in the next section in detail), which is shorter than that of Morse and is simple.

3 DESIGN OF VIBRATION PATTERNS

This section describes our proposed design of vibration patterns to notify a smartphone user of a degree of urgency of an incoming received message (or a tele-phone call), a communication type (including telephone), and a message sender (or a telephone caller). Vibrations of a pattern are segmented and presented in the order of urgency, communication type and sender because we consider that users who sense and hear the vibrations may want to be notified of this information in that order. In our design, the time interval among the three segmentations is 800 ms, the segmentations last for 5–9 s, and the number of vibrations per pattern is less than 18. We believe that these numbers ensure that a user has no problem perceiving the information in a notification because humans can perceive as many as eight vibrotactile stimuli at a single site and at a rate of five per second (Lederman, 1991). However, we cannot control the frequency of the vibration because it depends on a specification of a vibrating motor of a receiving phone. Additionally, our current design excludes the simultaneous presentation of multiple vibration notifications.

3.1 Patterns for Degrees of Urgency

Because Gallud et al. reported that 43.9% of participants responded a notification after receiving it depends on the urgency (Gallud et al., 2015), we assigned the first vibration pattern to urgency of notification.

Because information on degree of urgency is nonverbal, the degrees are distinguished by the number of vibrations in a pattern. We set the number of degrees of urgency to two: high and neutral. Table 1 explains the number of vibrations in each degree. In table 1, each dot means a vibration over a period of 80 ms. The time interval between vibrations is 100 ms. In our design, the number of vibrations for high urgency is double that of neutral urgency because the more vibrations in the pattern, the more a user feels the urgency.

Table 1: Vibration pattern for notifying urgency.

Degree of urgency	Pattern of vibrations	Duration time of each dot (.) [ms]
Neutral	. . .	80
High	. . . . . .	80

3.2 Patterns for Communication Type

After urgency, the system notifies users concerning communication type. It is important for a user to know the type of communication that generated the phone message in order to consider degree of priority for response to a message or phone call. For instance, many people give phone calls higher priority than emails.

Our design informs six types of communication tools that are widely used by smartphone users in Japan: telephone, email, LINE app (LINE, 2020), Facebook, Twitter, and others. They are described by the white paper information and communications in Japan as widely used tools (Ministry of internal affairs and communications, 2016). Table 2 lists the five named tools (plus "Others") and shows each of their vibration patterns. These patterns are made up of syllables, which are sequenced units of speech sounds typically consisting of a vowel and a consonant (Kubozono, 1998). For instance, because "twitter" is pronounced "Tu-Wi-Tter" in Japanese, the vibration pattern is ". . –," of which the dot (.) means a short vibration, and the dash (–) means a long vibration. However, the pattern of syllables of "LINE (La-I-N)" is ". . ." is the same as "telephone (De-N-Wa in

Table 2: Vibration patterns for different tools.

Communication tool	Pattern of vibrations	Duration of each dot (.) [ms]	Duration of each dash (–) [ms]
Telephone (De-N-Wa)	– –	NA	1000
Mail	– .	200	500
LINE	. . .	200	NA
Facebook	– . . .	200	400
Twitter	. . –	100	500
Others (So-No-Ta)	–	NA	500

Japanese)" and "others (So-No-Ta in Japanese)." Therefore, we assigned "– –" to De-N-Wa and "–" to So-No-Ta as easy to memorize and distinguishable patterns, although they are not syllables. Note that the terms of the vibrations are adjusted to term of syllables as pronounced by Japanese. The time between vibrations is 100 ms.

3.3 Patterns for Surname of Sender

Lastly, the system notifies a user regarding the name of the caller when a telephone is used for the communication or of the sender when another communication tool is used.

Because a name is verbal information, vibrations are assigned according to the syllables in the name. However, it is difficult to distinguish individual names by using only syllables because there are many surnames that have the same number of syllables (two to four) in Japanese. For example, "Suzuki," "Tanaka," and "Satou" have three syllables with Japanese pronunciation. Therefore, we proposed a method to assign vibration duration time to a consonant and assign time interval between vibrations to a vowel of Japanese alphabet pronunciation. Otherwise, it would be impossible to assign individual vibration patterns to the 46 characters of the Japanese alphabet.

The differences in assigned vibration durations and intervals between vibrations using our method are shown in Tables 3 and 4. Each consonant is assigned a non-overlapping vibration duration time in multiples of 100 ms, increasing from 'A' to 'W' (see Table 3). On the other hand, as shown in Table 4, each vowel is assigned a separate interval time (between vibrations that represent consonants) as a multiple of 100 ms, increasing from 'a' to 'o'. For instance, "ToYoTa" is converted to patterns representing three syllables: a 400-ms vibration (T) followed by a 500-ms interval (o), then an 800-ms vibration (Y) followed by a 500-ms interval (o) and then a 400-ms vibration (T) followed by a 100-ms interval (a).

Table 3: Vibration duration for surname consonant (in Japanese alphabetical order).

Japanese consonant	Duration of vibration [ms]
A	100
K	200
S	300
T	400
N	500
H	600
M	700
Y	800
R	900
W	1000

Table 4: Interval between vibrations for surname vowel (in Japanese alphabetical order).

Japanese vowel	Time interval [ms]
a	100
i	200
u	300
e	400
o	500

3.4 Implementation

We used Android Studio (Android Studio, 2020) to develop an application for an Android smartphone (Google Nexus 4) that generates vibration patterns for urgency, communication type and sender's name. We used the Vibrator class of the Android Application Programming Interface to implement the vibration patterns. Additionally, we used an application to collect answers from participants in experiments (as described in the next section).

4 EXPERIMENTS

We ran two experiments to assess the correctness of discrimination of vibration patterns for communication type and sender surname (as described above) when participants sense and hear the vibration of a smartphone without seeing its display screen. Since the vibration patterns related to the degree of urgency are simple and the number of types is small, it was expected that the correct answer rate would be higher than the vibrations related to communication type or sender surname, so the experiment of the urgency was omitted.

4.1 Communication Type

We conducted an experiment to assess factors affecting the correctness of the smartphone user's discrimination among vibration patterns for six communication types (Table 2) and three common smartphone locations (in a hand, in a bag, or in a trouser pocket) (Figure 1). The dependent variables were percentage of types identified correctly and time for response to a pattern. We used a within-subject experimental design. Six right-handed participants aged 21–23 years old took part in this experiment.

4.1.1 Environment

We used an Android smartphone (Google Nexus 4) to actuate vibration and a laptop computer for participants to answer one of the six communication types. The phone was connected to the computer via WiFi. A participant sat a chair that was about 20 cm from a table where the computer was located, sensed a vibration pattern, and selected communication type that he or she thought. This experiment was conducted in a silent laboratory room.

We assessed common smartphone locations as one type of experimental condition. For the in-hand condition, a participant held the smartphone in his or her preferred hand and kept his or her elbow on the table (Figure 1a). After sensing vibration in the hand, the participant selected the vibration pattern from a list of the types by using the other hand to tap the button on the phone's screen. For the in-bag condition, a participant sitting in the chair used his or her non-preferred hand to hold the handles of a bag that contained the phone and that was on the floor (Figure 1b). After sensing vibration through the handles, the participant selected the vibration pattern from the list of the types by using the preferred hand to click the selected button on the laptop screen. For the in-pocket condition (Figure 1c), a standing participant had the phone in his or her right rear trouser pocket (We had asked him or her to wear tight pants, such as skinny jeans.). After sensing vibration, the participant selected a type on the computer screen.

(a)

(b)

(c)

Figure 1: Smartphone's locations: (a) on a preferred hand, (b) in a bag, and (c) in a trouser pocket.

4.1.2 Procedure

There were two blocks in the experiment. The first block was unexplained the design approach of the patterns and the second block was explained it. In the first block, the participants memorized the vibration patterns for communication types, but the experimenter did not explain the design approach that assigned short or long vibration to syllables of a name. Therefore, participants needed to memorize the patterns without knowing the reason behind the patterns. In contrast, in the second block, participants memorized the patterns again after the experimenter informed them the approach. We hypothesized that correct answer rate in the second block would higher than that in the first block because we expected that it would be easier for participants to memorize the patterns with the explanation about the design than those without the explanation.

The experimental procedure used in the blocks were the same, with the exception of the prior explanation about the design. In the training phase, first, a participant held the smartphone and memorized each vibration pattern by sensing it five times while using acoustic earmuffs to cut off sounds from the vibrations. Then the experimenter asked the participant whether he or she had been able to memorize all the patterns. If he or she could not memorize some part of them, the experimenter instructed him or her to sense and memorize the patterns five times again in order for sufficient training. Then the participant trained to sense a vibration pattern and select its type of a list of the types twice to each pattern at random (i.e., 12 trials) as experimental task practice while holding the phone in his or her hand.

In the performing phase, the participant performed the experimental task to sense vibration patterns and select a type five times for each communication type randomly for each of the three phone locations. Therefore, the number of all trials was 90 (30 trials × 3 locations) for each participant (within-subjects design). Finally, participants filled out a questionnaire about the degree to which the felt vibrations were easy to sense and easy to memorize.

In the second block, the experimenter explained the design approach of the patterns to the same participant. The procedure was similar to the first one after that.

4.1.3 Result

Average correct answer rates of all of the participants in the two blocks for discriminating the six communication types given three different phone locations are shown in Figures 2 and 3. As shown on Figure 2, the rates were from 59% to 86% in without-explanation condition, and the rates were from 69% to 78% in with-explanation condition. There was a significant difference across the phone locations but not among the communication types (two-way ANOVA, $p < 0.05$). Additionally, there was no interaction between communication type and phone-location factors. We found significant differences between in-hand and in-pocket locations and between in-bag and in-pocket locations by performing multiple comparisons ($p < 0.05$). We found the correct answer rate of the in-pocket condition was significantly lower than those of the in-hand and in-bag conditions.

Average response times of all of the all participants in the two blocks for discriminating communication types and phone locations are shown in Figures 4 and 5. There were significant differences among the communication types and across the phone locations but no interaction between type and location (two-way ANOVA, $p < 0.05$). By performing multiple comparisons ($p < 0.05$), we found significant differences between in-hand and in-pocket locations and between in-bag and in-pocket locations. Overall, the response time in the in-pocket condition was longer than those in the other locations. Also, there were significant differences between "mail" and "Twitter" and between "mail" and "telephone (De-N-Wa)."

A summary of participants' responses to the questionnaire about vibration patterns are shown in Table 5. We found that most of them answered that it was easy to sense the vibration patterns for in-hand and in-bag conditions but hard to sense for the in-pocket condition.

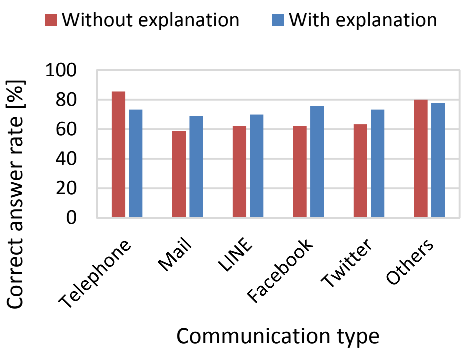

Figure 2: Average correct answer rate of each of the communication types in presence or absence of the explanation.

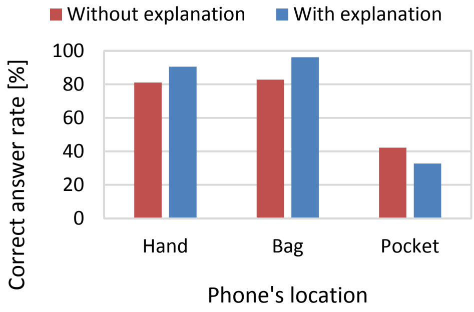

Figure 3: Average correct answer rate of each of the locations in presence or absence of the explanation.

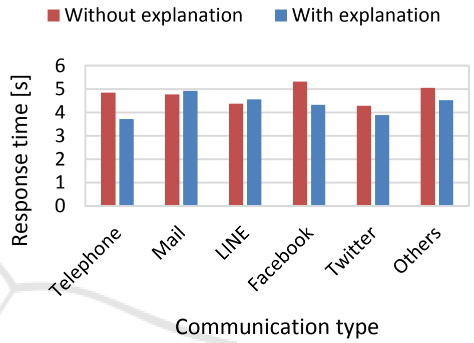

Figure 4: Average response time of each of the communication types in presence or absence of the explanation.

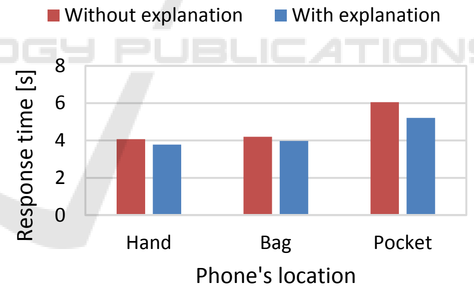

Figure 5: Average response time of each of the location in presence or absence of the explanation.

Table 5: Number of answers about sensitivity of the vibrations.

Question	Presence or absence of explanation	Very hard	Hard	Neither	Easy	Very easy
Ease of memorization of vibration patterns	without	0	1	1	4	0
	with	0	2	0	1	3
Sensitivity of in-hand vibration	without	0	0	0	2	4
	with	0	0	0	1	5
Sensitivity of in-bag vibration	without	0	0	1	2	3
	with	0	1	0	2	3
Sensitivity of in-pocket vibration	without	5	1	0	0	0
	with	6	0	0	0	0

4.1.4 Discussions

We conclude that users can sense a syllabic vibration patterns for in-hand and in-bag conditions and correctly discriminate the six patterns because people would usually use a hand to touch a smartphone or to hold a bag and because mechanoreceptors such as Meissner's corpuscle for vibration perception are distributed densely in the hand (Uchikawa, 2008). In contrast, users can hardly sense in-pocket vibrations through trousers, because the fabric of which separates the in-pocket phone from more direct sensory perception, and the density of the Meissner corpuscles on hip is lower than that on hand.

Our hypothesis that users could memorize the syllabic vibration patterns more easily after having the design explained to them was not validated. We find that it is difficult for users to discriminate similar patterns such as LINE (. . .) and mail (– .) regardless of whether they know the design approach. On the other hand, their response time is shorter after such explanations.

4.2 Names of Senders

We conducted a validation experiment to assess correctness of users' discrimination among vibration patterns for six senders' surnames when a smartphone that vibrates is in a hand or in a trouser pocket. Factors for this experiment are vibration pattern, smartphone location, and sound-insulation. The number of levels for the vibration pattern factor is six. We used the typical Japanese three-syllable names "I-to-u," "Su-zu-ki," "Ta-na-ka," "Sa-to-u," "Ka-to-u" and "Yo-shi-da." The number of levels for the phone-location factor is two: in-hand and in-pocket. The in-bag condition was not included because its correct answer rate was the same as or greater than that of the in-hand condition, as discussed above. The number of levels for the sound-insulation factor, added to assess correctness differences between only-vibration and vibration-with-sound conditions, is two: using or not using acoustic earmuffs. Therefore, we assessed four experimental conditions (two location and two sound conditions), and the dependent variables were percentage of names answered correctly and time for response to a pattern.

We used a within-subject experimental design. Five right-handed participants 21–22 years old took part in this experiment. Experimental environment for this experiment was the same as discussed in the previous section.

4.2.1 Procedure

First, the experimenter explained the design method (Tables 3 and 4) to a participant and demonstrated the vibration patterns for a participant. Then, the participant confirmed the vibration by holding a smartphone in his or her hand without putting on the acoustic earmuffs. The participant sensed the vibration pattern for each surname twice at random as a training phase. After that, the participant did it five times for each pattern at random and answered the sender's name that the vibration pattern meant for each condition as a performing phase. Finally, the participant was interviewed concerning the understandability of the patterns.

4.2.2 Result

Average correct answer rates of all of the participants for all six surnames and all conditions are shown in Figure 6. Average correct answer rates of all participants for the sound-insulation and phone-location factors are shown in Figures 7a and 7b. As shown on Figure 6, the highest correct answer rate was over 70% (Suzuki and Yoshida), but the lowest rate was 30% (Satou). We found significant differences among the surnames, between using and not using acoustic earmuffs and between in-hand and in-pocket conditions (three-way ANOVA $p < 0.05$). By performing multiple comparisons ($p < 0.05$), we found significant differences between "Katou" and "Yoshida," between "Satou" and "Suzuki," and between "Satou" and "Yoshida." Results of "Suzuki"

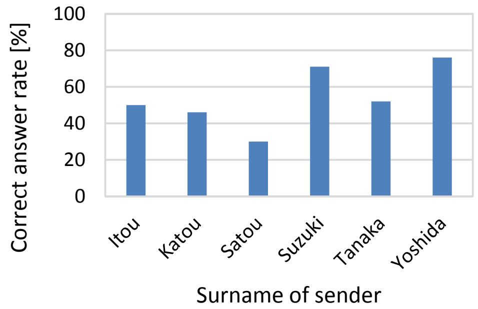

Figure 6: Average correct answer rate of each of the surnames.

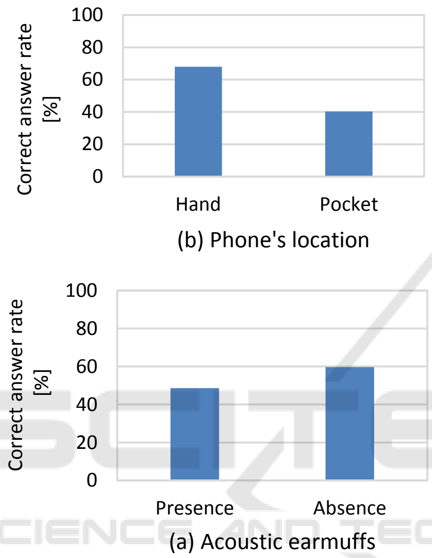

Figure 7: Average correct answer rate (a) with or without the acoustic earmuffs and (b) by each of the location.

and "Yoshida" were more correct (Figure 6) and their response times were shorter (Figure 8a) than those of the four others. Notably, most participants correctly answered "Yoshida" in the first representation of the pattern because the vibration pattern for "Yoshida" is very different from those for the other surnames. Additionally, some of the participants said that it was difficult to discriminate between "Itou," "Satou" and "Katou" because their voice patterns are similar, and their vibration patterns are also similar.

For all of the participants, response times for all six surnames and all conditions are shown in Figure 8a, and for the sound-insulation factor, in Figure 8b. We found a significant difference between using and not using acoustic earmuffs: Participants could determine a name vibration pattern more quickly without putting on acoustic earmuffs.

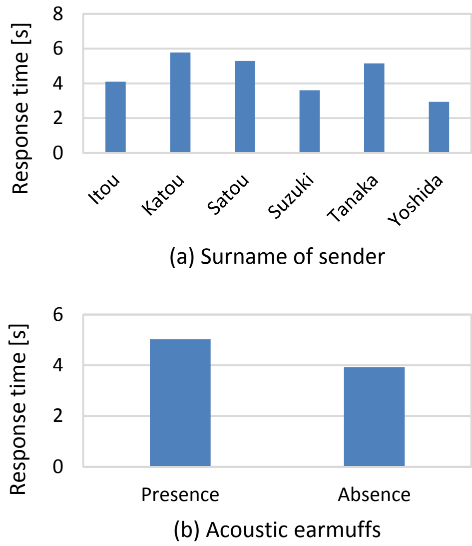

Figure 8: Average response time of (a) each of the surnames and (b) with or without use of the acoustic earmuffs.

4.2.3 Discussions

We conclude that it is difficult for a user to sense the specific syllabic vibration patterns used in our approach for a particular name. We found it especially difficult for them to discriminate between similar name patterns, although it was not difficult to identify the characteristic pattern.
We also found that the participants relied on not only vibration but also sound of vibration to discriminate each vibration pattern.

5 EVALUATION

We conducted an experiment to evaluate summative usability of our proposed syllabic vibration patterns consisting of three kinds of notifications: a degree of urgency, a communication type and a sender's name. Factors for this experiment are phone's location and sound-insulation. Levels for the phone-location factor are in-hand, in-trouser-pocket during standing. Levels of the sound-insulation factor are putting on acoustic earmuffs and without them. Dependent variables are percentage of patterns answered correctly and time for response to a pattern.

We used a within-subject experimental design. Five right-handed participants 21–22 years old took part in this experiment. Experimental environment for this experiment was the same as described in the previous chapter.

5.1 Procedure

First, the experimenter explained the design method described above to a participant and demonstrated the vibration patterns for the participant. Then, as a training phase, the participant confirmed vibration patterns five times by holding a smartphone on his or her hand without putting on the acoustic earmuffs. Each of the patterns included three segmentations is combined and ordered randomly. After sensing the sequential three segmentations, the participant answered content of each segmentation as soon as possible.

After that, as a performing phase, the participant performed the task 10 times in each condition. The number of conditions is four that means combinations of two phone's locations and with or without the earmuffs. After performing all trials, the participant was interviewed concerning understandability of the patterns.

5.2 Result

5.2.1 Correct Answer Rate

Average correct answer rates from urgency to communication type (two segmentations) and from urgency to sender (three segmentations) of all of the participants and all conditions are shown in Figure 9. There were significantly differences between phone's locations and between using and not using acoustic earmuffs (two-way ANOVA, $p < 0.05$). As shown on Figure 9, because the correctness rate of three segmentations in in-pocket and using-earmuff condition was 0%, we found it was almost impossible to discriminate them with only vibration in a pocket. In contrast, the correctness rate of three segmentations in in-hand and not-using-earmuff condition was 78%, and the correctness rate of two segmentations in the same condition was 98%. Therefore, we found that it was sufficiently usable to notify two-degree urgency and one of six communication types when a user could sense the vibration patterns, and it was important to use vibration with the vibration sounds.

5.2.2 Response Time

Average response times from urgency to communication type (two segmentations) and from urgency to sender (three segmentations) of all of the participants and all condition are shown in Figure 10. There was significantly difference between in-hand and in-pocket conditions, and there was no

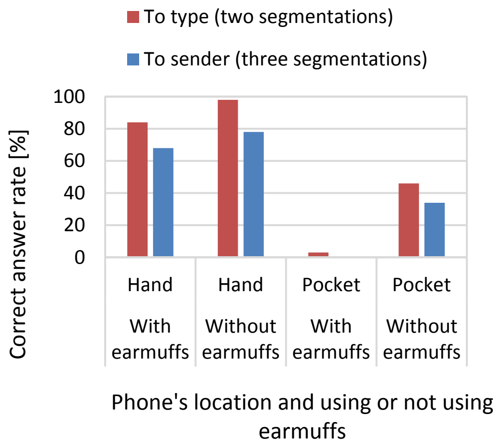

Figure 9: Average correct answer rate of sequential vibration patters in each of the condition.

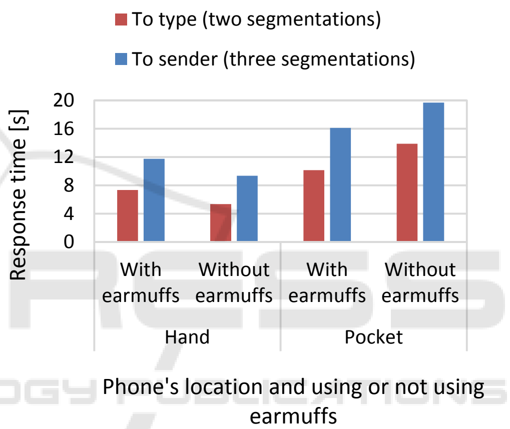

Figure 10: Average response time of sequential vibration patters in each of the condition.

significantly difference between using and not using earmuffs (two-way ANOVA, $p < 0.05$). We found that the difference between the presence and absence of the sounds had no effect on the response time.

5.3 Discussions

We found that it was easy to discriminate two degree of urgency, it was possible to discriminate each communication type, and it was difficult to discriminate each sender's name of the sequential vibration patterns. Therefore, we argue that a vibration pattern for urgency and communication type can provide a smartphone user with adequate information for making a decision whether to check the message immediately or later without looking at the smartphone screen. However, the vibration patterns of senders' names need further improvement from discrimination correctness.

From the results of the interviews, we also found that the 800 ms for time interval was so short to distinguish delimited timing and discriminate content of a vibration pattern. We will change the time to 1000 ms and evaluate it. Moreover, we plan to redesign the interval being dynamically changed with fitting user's habituation of the vibration patterns.

6 CONCLUSIONS

We designed syllabic vibration patterns to notify urgency of an incoming message that being received, communication type of the message and sender's name of the message on a smartphone in order to reduce the number of looking at the smartphone screen directly. Then, we conducted the experiments to validate discrimination correctness of the patterns and evaluate usability of them. We conclude that the design to use syllabic vibration is useful to memorize and remember the patterns and to discriminate each pattern via a hand directly and indirectly because the vibrations are like sounds of the words which are presented syllabic vibration. However, we also conclude that the design to assign syllabic vibration and interval to a sender's name makes it difficult for a user to discriminate each sender's name because of a number of names and the similar vibration patterns.

We propose that a smartphone user can reduce the number of looking at the smartphone screen to check a notification and can determine whether to confirm content of the message immediately or later by sensing and/or hearing our proposed vibration patterns. Additionally, we suggest that the design can deter smartphone use while walking.

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