Study on Perception of Vibration Rhythms

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Abstract. In this study, we researched the way of designing the accessible vibration rhythms through experiments using the mouse-type tactile interface from the vibration perception and vibration memorability. Participants were twenty young individuals and fourteen older persons. First, the threshold of vibration duration and gaps between the duration were estimated statistically. As the result, some vibration rhythms were designed and evaluated the validity of the design factors. Further, the requirements for designing memorable vibration rhythms were considered. From the results, some requirements for designing perceivable and memorable vibration rhythms for older persons were found; however, it is required to clear the effect of vibration rhythm from the cognitive aspect through further research.

Keywords: tactile interface, vibration rhythm, accessibility.

1 Introduction

Almost of mobile devices include an actuator oscillating the mobile device and informing simple message to the user such as “You got a mail”. For presenting more or complex information by user interfaces, some ideas have been proposed and evaluated [1-3]. The feasibility studies successfully implemented a few rhythmical vibration patterns called “Tactons” into the proposed tactile interfaces using linear tactile actuators. Almost of the tactile interfaces proposed were used by wearing around the waist or attaching on the forearms or the wrists. On the other hand, most of the mobile devices include vibration motors with eccentric mass as the actuator oscillating the device. The wave form of the oscillation amplitudes generated by the vibration motor depends on the motor’s environment such as chassis of the mobile device, then the wave form is not a sine curve but complex waveform. Regarding the factors of the vibration patterns such as roughness and frequency were experimentally considered; however, the subjects or the participants were young individuals in common. The reason for investigating the young participants could be related to the tactile sensibilities. ISO 9241-910 [4], framework for tactile and haptic interaction, mentions that it is important to consider the age of potential users of tactile/haptic devices, since there is a considerable decline in haptic sensitivity with age. From this viewpoint, we assumed that to explore the tactile device’s usability for elderly persons should be required. As far as the vibration patterns are concerned, ISO 9241-910

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suggests that the perception of an event can be enhanced by a careful choice of patterns of oscillatory bursts. Thus, the vibration patterns should be perceptibility by a wide range of ages in order to improve the vibrating device's accessibility. Therefore, designing the vibration patterns for elderly people is considered in this study.

1.1 Vibration Perception

Vibration perception have been considered from physiological and medical viewpoints. For instance, the relation between vibration perception threshold and age, height, and etc. has been investigated using a biothesiometer [5]. The biothesiometer which is used for measuring large nerve fiber function of patients produce the varied amplitude of vibrations. As the results, the significant factor for vibration perception threshold was age rather than sex and etc.; therefore, it is assumed that the higher amplitude of vibration or the higher vibration velocity is perceptible in other parts of the older person's body such as palms. Hence the vibration velocity as described variable v in Fig. 1 should be as high as possible for the aged to perceive the vibration patterns.

On the other hand, a minimum perceptible duration of vibration (d) as well as a minimum perceptible gap (r) between vibration durations as shown in Fig.1 may change with not only the perceptive aspect of users but also the characteristics of vibration from the vibrating device. Therefore such the two thresholds (the minimums of d and r) for designing perceivable vibration patterns were measured using our custom tactile interface as described below in detail.

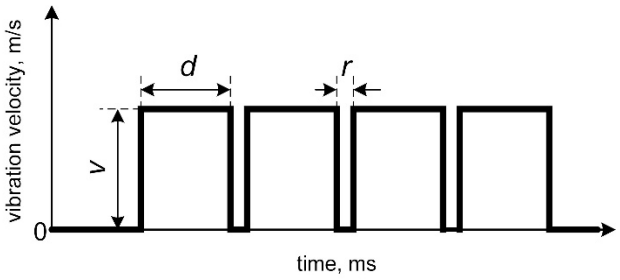


Fig. 1. Variables specifying vibration patterns

1.2 Memorability

If the elderly people are able to sense vibrations, the signal or information from the vibrations could be processed as well as young individuals. Although it is assumed that the memory ability among older adults varies with their individual, the sensed information could process at working memory. The model of working memory system is proposed by Baddeley and the system includes "visuospatial scratch-pad" and "articulatory loop" or "phonological loop" [6]. Although these systems are not for just tactile information, the tactual information could be processed based on higher-order non-tactual information [7]. In other words, the tactual information processing

could be related to the characteristics of vibration patterns such as images from the tactile rhythms rather than the characteristics of the oscillation within the vibration patterns. Further, the memorability could be prompted by the skill of catching vibration patterns such as musical skill. In this case, the memorability means ease of recalling the vibration patterns correctly. Therefore, to introduce the musical rhythm patterns into vibration patterns could be appropriate because the most people are familiar with music and songs regardless of age.

1.3 Vibration Rhythm

Although the vibration patterns has been expressed using musical note in previous tactile studies, the musical rhythm or musical sound have used in mobile devices such as phone ringing. However, temporal gaps among the notes is necessary in order to express the rhythm by the vibration as shown in Fig. 2 and the duration of the gaps should be as short as possible for taking no account of the gap, and then it is possible to consider that the vibration rhythm is in order. Thus the duration of the gap should be determined according to the minimum perceptible gap so that musical rhythms are made into vibration patterns and we called the vibration patterns made from the musical rhythms is called “vibration rhythms”.

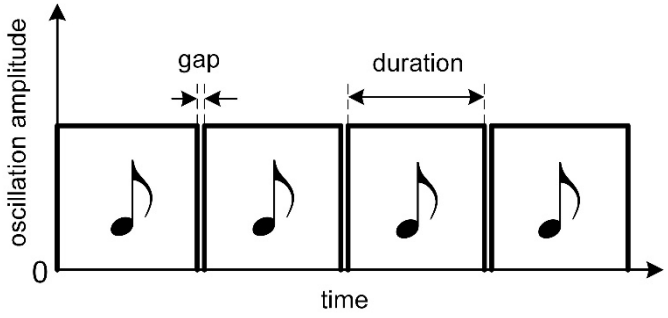


Fig. 2. Factors of a vibration rhythm

As described above, we assumed the requirements for designing the vibration rhythm in order to utilize as a way of presenting information by the vibrating device. Hence the minimum perceptible duration and the minimum perceptible gap of young individuals and older persons were measured. Further, the memorability for the young and the older persons was also investigated through the experiment.

2 Designing of the Vibration Mouse

From our previous studies, there are Japanese senior citizens who are aversion to high-tech gizmos [8]. Thus it is preferable to touch the tactile interface for the older people rather than to wear or to attach the tactile interface on their body part. Accordingly, we made a mouse-type tactile interface with a little familiar computer mouse for the Japanese senior citizens. The system of the tactile interface we made

was simple and made of a vibration motor and the computer mouse (DELL USB mouse) as shown in Fig. 3. We called such mouse-type tactile interface "vibration mouse". The vibration motor in the vibration mouse rotated within a range of 0.3 - 0.7 V and oscillate the vibration mouse. The power voltage for activating the vibration motor was controlled using a high-precision analog I/O terminal (CONTEC AIO-160802AY-USB) and a personal computer (DELL Vostro 1500) running Windows 7 Professional Japanese edition. In other words, the voltage applied to the vibration motor was controlled by the I/O terminal with our custom software. The wave form of the amplitude of vibration on the top of the vibration mouse was not a sine curve but very rough. The resonant frequency of the amplitude of vibration was ranging from 74 to 116 Hz in accordance with the voltage applied to the vibration motor in the vibration mouse. In addition, the vibration mouse functioned also as the computer mouse with two buttons and a scroll wheel.

Fig. 3. Vibration mouse presenting vibration rhythm

3 Measuring Two Thresholds for Designing Perceivable Vibration Rhythm

To measure the minimum perceptible duration and the minimum perceptible gap, we conducted an experiment using the vibration mouse.

3.1 Method

The participants were ten male and ten female young individuals and six male and eight female older persons. The young ranged from 18 to 22 years of age (mean = 20.1, SD = 1.1) and the elderly persons ranged from 65 to 85 years of age (mean = 73.8, SD = 5.7). The participants touched the vibration mouse with their palm as if they were using a computer mouse on a desk and tried to count and to answer the number of vibration durations within the presented vibration patterns. The vibration velocity was 2.3 m/s which is the producible maximum vibration velocity by the

vibration mouse. The two thresholds for designing vibration rhythm was determined in the following way.

First, the vibration patterns which included three vibration durations and the respective gaps (r as described in Fig. 1) of each were presented to the participants. Each of the gaps was randomly selected from 200, 400, 500, 700, 800, and 1000 milliseconds. The duration time (d as described in Fig. 1) presenting to the participant was decreased from 300 milliseconds in increments of 5, 10, or 50 milliseconds based on the participant's responses and answers. The vibration pattern was presented repeatedly on demand until the participant answer orally the number of vibration duration included in the vibration pattern. The threshold of vibration duration was determined by whether the participant's answer was right or wrong.

Second, the threshold of gap between vibration duration was investigated in a manner similar to the first trial. However, in this trial, the each vibration pattern included three gaps among four vibration durations and the each duration was randomly selected from 200, 400, 500, 700, 800, and 1000 milliseconds. The gap (r as described in Fig. 1) was decreased from 300 milliseconds in increments of 5, 10, or 50 milliseconds based on the participant's responses and answers.

3.2 Results

As the results of the two trials, two thresholds of respective participants were determined according to age-groups. Further, we tried to estimate the thresholds statistically based on the result of young and elderly participants' threshold. The result of the threshold of vibration duration is shown on the left-hand side of Fig.4 and threshold of gap between vibrations is on the right-hand side. The error bars as described in Fig. 4 indicates two-sided 95% confidence intervals.

Although the all vibration patterns presented to the participants in the trials were not rhythmical but just like random patterns, Fig. 4 shows the thresholds by the young

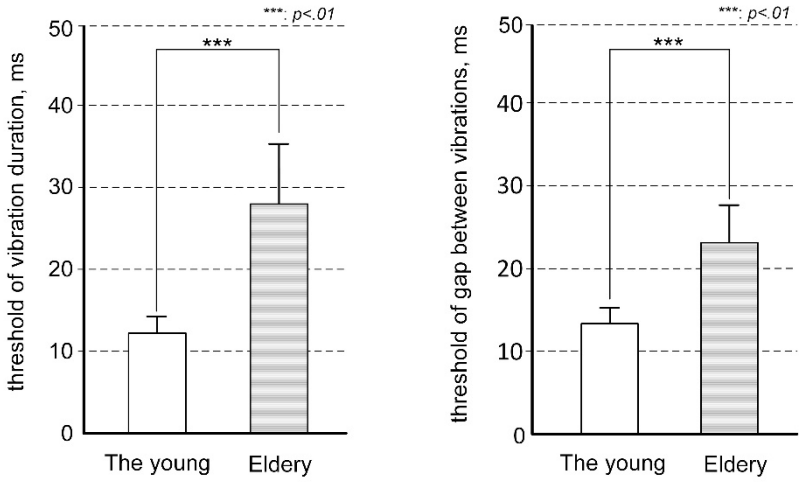


Fig. 4. Estimated thresholds of vibration rhythm by the results of two trials by the participants

and by the elderly differ significantly. Therefore, it is assumed the vibration rhythm for older persons should be slower-paced; however, two older participants said that it was difficult to count the number of vibration durations with concentrating on insensible vibration. As the two thresholds of the two older participants tended to be higher than the others' (around 50 milliseconds), the two thresholds could be affected by the cognitive characteristics of the respective participants.

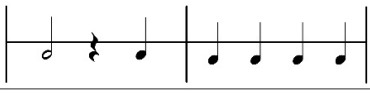
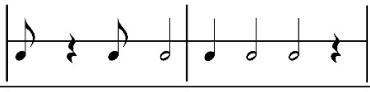
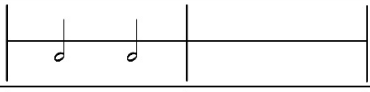
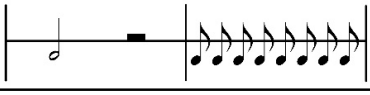
Considering the distributions of the thresholds by each age-group as shown in Fig. 4, it is appropriate to determine that the minimum vibration duration included in the vibration rhythm is 50 milliseconds in round figures; therefore, the shortest musical note in the vibration rhythm such as sixteenth note in the vibration rhythm should be represented by vibration duration for 50 milliseconds and then the duration of eighth note is 100 milliseconds. However, the threshold of gap should be estimated lower for aforementioned reason and the threshold for elderly could be assumed lower if the stimuli for the participants were vibration rhythms instead of the vibration patterns. Therefore, we assumed the threshold of the gap is 20 milliseconds in round figures and tried to design the vibration rhythm as described below.

4 Memorability of Vibration Rhythm

4.1 Designing Vibration Rhythms for Older Persons

The results from previous trials suggested that the vibration duration should be over 50 milliseconds; however, it is preferable for older persons to perceive the

Table 1. Evaluated seven vibration patterns

Pattern	Vibration rhythms represented by musical note
A	
B	
C	
D	
F	
G	
H	

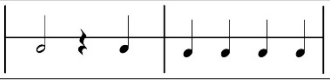
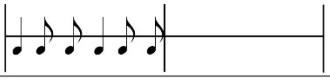
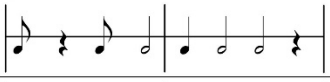
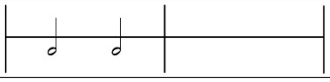
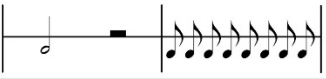
slower-paced vibration rhythms. Therefore, we let 50 milliseconds was the length of sixteenth notes and designed the seven vibration rhythms using eighth, quarter, and half notes or rests as described in Table 1. In other words, the length of shortest vibration duration in the vibration rhythms we designed was 100 milliseconds. In addition, we let 20 milliseconds was the length of the gaps in the vibration rhythms.

4.2 Evaluation of the Vibration Rhythm from Memorability

In this experimentl evaluation, the seven vibration rhythms we made were evaluated from the memorability through experiment as described below. In the experiment, the vibration rhythms was presented in order from the pattern-A to H as shown in Table 1 and the participant perceived the vibration rhythms using the vibration mouse. The vibration velocity was 2.3 m/s as well as the former experiment. The respective vibration rhythms were presented repeatedly on demand until the participant recalled and represented the vibration rhythm or gave up the trial. The way of answering the perceived vibration rhythms was describing using a simple code. However, a few elderly participants struggled to write using the code and their performances made it more difficult to recall and to represent the vibration rhythms. Thus, the way of answering for the elderly group was to sing the recalled vibration rhythm and the same researcher judged whether the sung rhythm by elderly was right or not.

As the results of trials, the percentages of the participants who were able to recall and to answer the correct vibration rhythm were indicated in Table 2.

Table 2. Evaluated seven vibration patterns

		Percentages of the participants recalling accurately	
Pattern	Vibration rhythms represented by musical note	The young	Elderly
A		40	13
B		5	6
C		35	50
D		0	0
F		69	44
G		85	100
H		5	13

Although the percentages of participants recalling and answering the vibration rhythm accurately differed between the young and elderly participants, the percentages by pattern-A, C, F, and G were higher than by pattern-B, D, and H regardless of the participant's ages. In this regard, the vibration duration and the gap based on the previous research were valid for elderly participants; however, there were many elderly participants who were not able to recall the number of vibration duration in the rhythm accurately. Thus the vibration rhythm including many vibration duration became a vague rhythm for older persons. Meanwhile the reason of low percentages of young participants recalling accurately was because it was difficult to describe the vibration rhythm especially specifying the rests. From these results, the requirements of designing accessible vibration rhythms assume as the followings:

- Many music notes are not included;
- Varied music notes are not included;
- The same music notes are not used repeatedly.

Considering the perception of vibration rhythm, the two elderly participants whose thresholds of gap is 50 milliseconds were able to recognize the vibration rhythms including 20 milliseconds' gaps. This result indicated that the rhythm could prompt the vibration perception of elderly participants; therefore, using the vibration rhythms for tactile interface was valid.

5 Conclusion

In this study, we researched the way of designing the accessible vibration rhythms through experiments using the mouse-type tactile interface. From the results, some requirements and guidelines for designing accessible vibration rhythm for older persons were found; however, it is required to clear the effect of vibration rhythm from the cognitive aspect through further research.

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