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Vibration Device for Electric Wheelchairs Providing Tactile Feedback on the Type and Direction of Nearby Objects

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I. Introduction

Electric wheelchairs are essential welfare equipment for maintaining and improving the quality of life for the elderly and individuals with mobility difficulties. However, most electric wheelchair accidents in Japan involve people aged 65 and older [1]. Accidents can be prevented if users are able to detect their surroundings at an early stage. In addition to the natural decline in vision and hearing associated with aging, elderly individuals face difficulties in outdoor environments due to direct sunlight and noise, which hinder their ability to communicate visually and audibly. Therefore, we focused on the vibrotactile sensation in the palm, which is less susceptible to age-related functional decline [2] and environmental factors. A previous study confirmed that vibrotactile apparent motion can be used to recognize vehicles approaching from the left and right with high accuracy [3]. In this study, we introduced a new approach to investigate whether approaching objects (e.g., passenger vehicles, motorcycles, bicycles, and pedestrians) could be recognized by varying the frequency of the vibrotactile stimulus, in addition to its direction.

II. Tactile Stimulations

An image of the function of the vibration device is shown in Figure 1. Electric wheelchair users identify the type of object through the presentation of the vibration device, based on differences in vibration frequency and envelopes, and determine the direction of the object through tactile apparent motion.

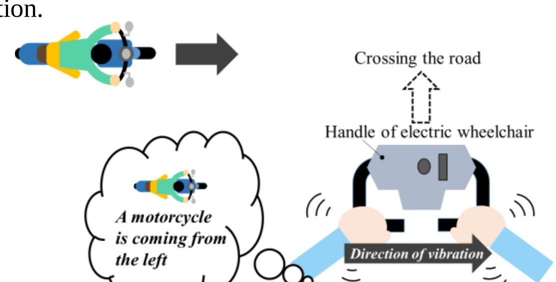
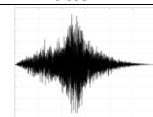
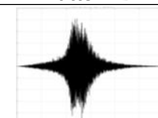
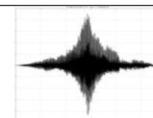
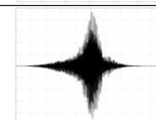
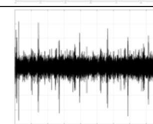
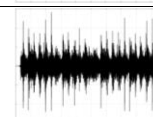
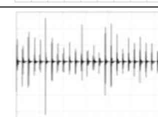


Figure 1. Image of the function of the vibration device

A. *Presenting the type of objects using different frequencies and envelopes*

To recognize an approaching object, users receive vibration stimuli with varying frequencies and envelopes from vibration motors. The vibration motor is a device with a variable frequency. Eight different sound waves were used to represent approaching objects (passenger vehicles, motorcycles, bicycles, and pedestrians), as listed in Table 1.

TABLE I. Sound Waves

Objects	Pattern A	Pattern B
Passenger vehicle		
Motorcycle		
Bicycle		
Pedestrian		

B. *Presenting the direction of objects using vibrotactile apparent motion*

To recognize the direction of an approaching object, users receive vibration stimuli that create tactile apparent motion. Tactile apparent motion is an illusory phenomenon in which motion is perceived from the preceding stimulus toward the posterior stimulus by applying a time difference between two or more points on the skin. Because audio files were used, the tactile apparent motion was achieved by using the stereo effect of the audio to move the sound left and right.

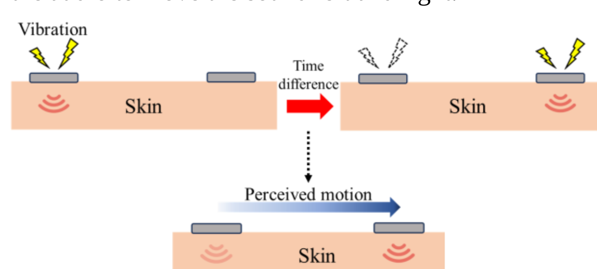


Figure 2. Tactile apparent motion

III. Experiments

A. *Participants*

The participants in the experiment were 10 healthy male and female students, aged 18–21 years. The experiments were

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reviewed and approved by the Research Ethics Committee of the Arakawa Campus at the Tokyo Metropolitan College of Industrial Technology. Informed consent was obtained from all participants.

B. *Experimental apparatus*

The experimental apparatus and the dimensions of the vibration device are shown in Figures 3 and 4. The apparatus consisted of a grip made from poly-lactic acid material produced by a 3D printer, with two vibration devices (*Foster Electric Company, ACOUSTICHAPTIC*), one located at the center of each handle. Stereo sound was played from PC software (*Apple, GarageBand*), and the vibration motor was controlled via a D/A converter (*FX-AUDIO, FX-01J TYPE-A*) and stereo power amplifier (*FX-AUDIO, FX202A/FX-36A PRO*). Resonance was minimized by placing a 5 mm thick urethane foam between the handle and the desk.

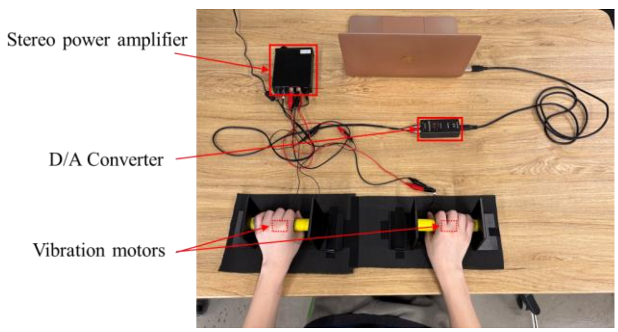

Figure 3. Experimental apparatus

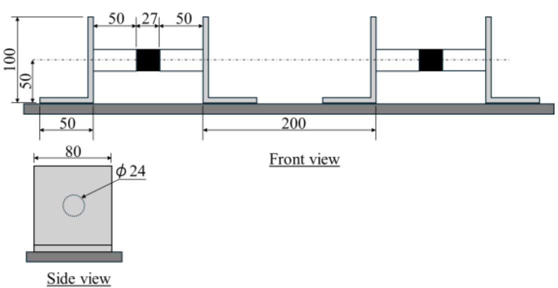

Figure 4. Dimensions of vibration device

C. *Procedure*

Before conducting the experiment, subjects were presented with all the vibration patterns listed in Table 1 as a pre-study. They responded by marking on a response sheet the type of approaching object and the direction from which it was approaching. The experimental conditions included 8 different vibration stimuli, each presented from both the left and right directions across two trials, resulting in 32 vibrations presented to the participants at random. The percentage of correct responses was then analyzed. Vibration stimuli were presented until the subject provided a response. During the experiment, subjects wore headphones playing white noise to eliminate the influence of external sounds.

IV. Result and Discussion

The correct response rate for recognizing the type of objects is shown in Figure 5. The figure shows that the percentage of correct responses for pedestrians was 100%. The ease of recognizing pedestrian sounds is due to the perceptible waveform peaks and the long duration between these peaks. For bicycles, Bicycle B had a higher percentage of correct responses because the waveform in Table 1 shows that the number of clear peaks is greater than in Bicycle A. However, the percentage of correct responses for passenger vehicles and Motorcycle B was low. All incorrect responses for Motorcycle B were misidentified as passenger vehicles, and 88.9% of incorrect responses for passenger vehicles were misidentified as motorcycles. This suggests that most participants recognized passenger vehicles or motorbikes with engines. For the left and right directions, the correct response rates were 100%, which aligns with the findings of previous studies.

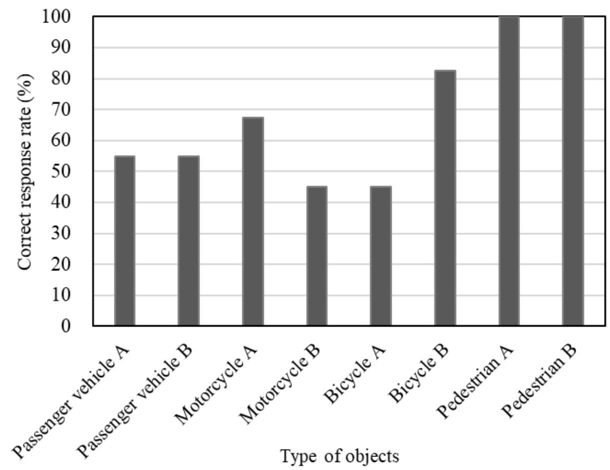

Figure 5. Correct response rate

V. Conclusion and Future Works

This study showed that approaching objects could be recognized by varying the frequency of the vibrotactile stimulus. It was also found that vibrations with easily perceptible waveform peaks, such as those from pedestrians and bicycles, are more easily recognized. In the next study, we will conduct detailed subjective evaluations and frequency analyses of vibrations, along with comparisons between subjective response and physical properties using a Kansei engineering approach. As the range of expression through vibration increases, we expect participants to recognize a wider range of object types and states.

References

[1] National Police Agency, "The accident of electric wheelchairs - The reality of recent road accidents", https://www.npa.go.jp/koutsuu/kikaku12/shi_04jikojittai.pdf, accessed March 7, 2025 (in Japanese)

[2] R. Katzman and R.D. Jerry, "The Neurology of aging, Japanese edition", Translated by T.Mizutani, Nishimura-shoten, Niigata, Japan, 1986, pp.24-27. (in Japanese)

[3] H. Ookawara and T. Furuya, Study on methods of alerting with vibrotactile stimuli during road crossing for electric wheelchair users, The Japanese Journal of Ergonomics, vol. 60, 2024 p. 2F5-5. (in Japanese).