Dependency of the Skin Temperature on the Threshold and the Quality of the Tactile Sensation

—A Basic Study for Tactile Aids—

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We have found that the tactile threshold and the quality of the sensation are greatly influenced by the skin temperature of a fingertip for both the vibratory and the non-vibratory stimulation. These findings are useful to design tactile aids using the combination of the above two stimulation.

Key Words : tactile aid, vibratory pattern, braille-like pattern, temperature, tactile display

1. Introduction

We have evaluated the difference between vibratory patterns and non-vibratory patterns to convey speech signals to the central nervous system in order to design an optimal tactile aid. We proposed a sweeping display method by which vibratory patterns swept on the fingertip surface like an electric news tape and proved that the display method using Braille-like patterns was useful to avoid fatigue and residual feeling during long time use¹⁾. However, the tactile threshold changed by the skin temperature of a fingertip and the subjects felt different quality of the tactile sensation depending on the skin temperature.

In this paper, we investigated how the tactile threshold and the quality of the sensation are influenced by the skin temperature of a fingertip for the basic study of tactile aids.

2. Experimental Setup and Method

A tactile stimulator matrix (2×4) was designed by using a Braille cell which could present non-vibratory convex patterns or vibratory patterns. A hemispheric plastic pin with 1 mm diameter was put on the stimulator to vertically stimulate the skin surface of a fingertip. A Braille cell consisted of 2×4 pins. As shown in Fig. 1, stimulation patterns, stimulation

amplitude and sweeping velocity were controlled by a computer through D/A converters. In this experiment, an index fingertip surface of right hand was put on stimulator pins as shown in Fig. 1. Each stimulation point was moved from right to left by computer control. Fig. 1 shows the following stimulation patterns: vibratory stimulation and a non-vibratory convex stimulation. Where the vibratory stimulation was 200 Hz, the envelope of each stimulation pattern was triangular as shown in Fig. 1.

As shown in Fig. 2, the Braille cell was put in a pyrostat to control the circumstance temperature and a Peltier element was set inside the pyrostat to control the temperature of the fingertip surface. A thermocouple was fixed under the skin surface to check the temperature of the fingertip during the experi-

Fig. 1 Arrangement of a tactile display on a fingertip and stimulating patterns

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Fig. 2 Experimental Setup

ment. An index finger was put on the Peltier element until the temperature of the fingertip reached the set temperature. The temperature was changed at the following 4 levels; 12, 22, 32, and 42°C. The temperature of the fingertip was monitored during the experiments. When the skin temperature shifted from the set temperature, the fingertip was put on the Peltier element again.

As the sweeping velocity increases, the detectability of the stimulation decreases. However, as the velocity decreases, the amount of information over time decreases although the detectability increases. From the view point of the above, 10 cm/sec was selected as the sweeping velocity. The sweeping velocity depends on the display time and distance between two pins. So, the display time becomes 20 msec in this case because the distance between two pins is 2 mm²⁾.

In the first experiment, the dependency of temperature on the threshold of the tactile sensation was measured using a swept vibratory point and a swept Braille-like convex point with a 20 msec duration. Subject adjustment was adopted as the measuring method and threshold was measured 10 times. The subjects were four normal adults whose ears were masked by white noise.

In the second experiment, how the quality of the tactile sense was influenced by the skin temperature was evaluated for both vibratory and convex stimulation. 50 vibratory stimulation and 50 convex stimulation were presented randomly. Then, the subjects

Fig. 3 Absolute threshold as a function of temperature

Fig. 4 Rate of how presented stimuli were felt like a vibration or a convex as a function of temperature

were asked to indicate which stimulation had been presented; vibratory or convex. The stimulation was 20 dB (Sensation Level: S. L.) with 20 msec and the data were obtained as a function of the skin temperature. The subjects and condition were the same as the first experiment.

3. Experimental Results and Discussion^{3)~7)}

Fig. 3 shows the average, minimum and maximum data for the four subjects in the first experiment. From the experimental results, it was found that the tactile threshold increased as the temperature decreased in the range of 42 to 12°C for both the convex stimulation and the vibratory stimulation. However, no threshold difference was found between the two stimuli.

Fig. 4 shows the average, minimum and maximum data for the four subjects in the second experiment. The horizontal axis indicates the skin temperature.

The vertical axis indicates the rates that the subjects recognized the presented stimulation as convex stimulation, in spite of the kind of stimulation. The black square shows the rates that the subjects could perceive convex stimulation correctly when convex stimulation were presented. The open circle shows the rates that the subjects could perceive vibratory stimulation correctly when vibratory stimulation were presented.

From the experimental results, the subjects could clearly discriminate the quality of both sensations produced by the vibratory and the convex stimulation in the temperature range of 22 to 32°C. However, the feeling for the vibratory stimulation became almost the same as for the convex stimulation when the skin temperature was 12°C.

It is considered that vibrotactile stimulation with a frequency of about 200 Hz is received by Pacinian corpuscles whose threshold is easily changed by the skin temperature compared with the other receptors. On the other hand, it is said that Braille-like convex patterns are received mainly by Merkel and Meissner cells which are located on the relatively shallow area under the skin surface according to the physiological findings. This may cause the receptors to be influenced by the skin temperature. This is one of the reasons why the threshold changed depending on the skin temperature for both the vibratory and the convex stimulation.

Furthermore, it is said that Meissner corpuscles are sensitive to a vibration with a frequency of 40 Hz. In our experiment, a 10 cm/sec sweeping velocity was used. This corresponds to about a frequency of about 40 Hz because the distance between the two stimulating pins was 2 mm. So, it was supposed that the vibratory stimulation activated Pacinian corpuscles and the convex stimulation activated Meissner corpuscles. The reason why the subjects could discriminate between the vibratory and convex stimuli in the

temperature range of 22 to 42°C is because the quality of tactile sense produced by Meissner corpuscles could be differentiated from the quality produced by Pacinian corpuscles.

It was concluded that the skin temperature below about 20°C was not adequate to convey the information through the tactile sense from the experimental results. It was anticipated that more information could be conveyed using the quality difference of the tactile sense by combining the vibratory and the convex stimulation if the skin temperature was beyond about 20°C.

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