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Study on the Perception of Non-linguistic Information in Speech through Tactile Stimulation

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Hearing impairment is accompanied by reduced frequency selectivity and decreased temporal resolution in the auditory system. As a result, speech communication becomes difficult, which can consequently lead to a decline in quality of life (QoL). To address this issue, technologies that compensate for auditory function are required. Alternatively, technologies that substitute auditory function using other sensory modalities (auditory substitution) are needed. Tactile receptors are widely distributed over the body surface. Moreover, like hearing, the tactile modality can extract information from vibrations. Therefore, using tactile modality for auditory substitution has potential. Representative examples of tactile-based auditory substitution are Braille and Tactile Vocoder. These approaches are effective for conveying linguistic information. However, challenges remain in transmitting non-linguistic information such as emotion and urgency. Smooth speech communication requires more than linguistic information alone. Non-linguistic information, such as emotion and urgency, is also important. Hence, realizing tactile-based auditory substitution that can convey non-linguistic information is expected to contribute to improving QoL.

To examine acoustic features effective for perceiving non-linguistic information, findings from auditory perception are referenced. In hearing, temporal amplitude envelope (TAE) information of speech serves as a primary cue. In particular, amplitude-modulation components below 16 Hz are considered important for perceiving emotion and urgency. Meanwhile, the tactile modality is also capable of perceiving envelope components of vibratory stimuli. Based on these findings, temporal amplitude envelope (TAE) information of speech may be utilized as a cue through tactile modulation perception. If so, tactile perception of non-linguistic information in speech may be achievable.

The purpose of this study is to clarify the feasibility of perceiving non-linguistic information in speech through tactile stimulation. To link basic tactile characteristics with outcomes of tactile perception of non-linguistic speech information, three aspects were investigated in a stepwise manner: (i) tactile sensitivity, (ii) modulation perception characteristics in tactile, and (iii) perception of non-linguistic information using speech sounds presented as tactile stimuli.

First, tactile detection thresholds were measured. Tactile sensitivity varies substantially depending on the presentation sites and the type of stimulus. Threshold measurement was required for two reasons. The first reason

was to clarify site-dependent differences in sensitivity. The second reason was to obtain reference levels for setting stimulus intensity in subsequent experiments. In this experiment, 30 Hz, 250 Hz, and 1 kHz sinusoidal vibrations and white noise were used as stimuli. The presentation sites were the cheek and the palm.

Next, the temporal modulation transfer function (TMTF) was measured as a characteristic of tactile modulation perception. To discuss whether TAE can be exploited as a cue, it is necessary to determine the modulation-frequency range to which the tactile modality is sensitive. The TMTF represents modulation detection thresholds as a function of modulation frequency under a specific carrier condition. In this experiment, amplitude-modulated stimuli were generated using 30 Hz, 250 Hz, and 1 kHz sinusoidal carriers and a white-noise carrier. The presentation sites were the cheek and the palm. Based on these results, tactile amplitude-modulation perception characteristics were clarified.

Finally, emotion perception and urgency perception experiments were conducted. The stimuli were original speech and noise-vocoded speech (NVS). In the emotion-perception experiment, speech samples expressing five emotions (Neutral, Joy, Cold anger, Sadness, and Hot anger) were used. Participants Participants selected one of the five emotions they perceived. Agreement rates between the stimulus labels and participants' responses, as well as misclassification rates, were evaluated. In the urgency perception experiment, speech samples representing four levels of urgency were used. The evaluations were conducted using Scheffe's method of paired comparisons. The primary information shared by original speech and NVS is TAE. Therefore, if perceptual outcomes are similar between the two stimuli under tactile presentation, such similarity would support the hypothesis that TAE functions as a cue for perceiving non-linguistic information.

The results revealed the following findings:

1. Tactile detection thresholds were lower at the palm than at the cheek, indicating substantial site-dependent differences.

2. TMTF of tactile exhibited a bandpass-like shape, and modulation components roughly below 32 Hz were perceivable.

3. Within the same stimulation site, emotion and urgency perceptions were similar between original speech and NVS.

4. Emotion and urgency perceptions differed between the palm and the cheek.

The ability to perceive envelope components below 32 Hz in amplitude-modulated tactile stimuli, together with the similarity of emotion and urgency perception between original speech and NVS, suggests that TAE shared by original speech and NVS may have contributed to the perception of non-linguistic information. In conclusion, the feasibility of perceiving non-linguistic information in speech through tactile stimulation can be stated.