How important is the timing of vibrotactile stimuli for the excitation of an emotional response for audio-visual content?

Ibuki Tara, Shogo Okamoto, Yasuhiro Akiyama, and Yoji Yamada

***Abstract*—In this study, we investigated the effect of the timing of vibrotactile stimuli in the context of audio-visual content, on feeling of viewers. We used videos of figure skating performances, and vibrotactile stimuli were supplied to the upper body of the viewer using voicecoil motors, according to the jump scenes in the videos. The increase in skin conductance of the palm in response to the experience was measured, and the experimental participants scored their level of excitement with a questionnaire. We performed experiments under conditions with and without the vibrotactile stimuli. For the vibrotactile conditions, the timing of the vibrotactile stimuli was varied by 200 ms. The increases in the skin conductance and the questionnaire scores in the vibrotactile conditions were significantly high compared to those in the non-vibrotactile condition. However, the timing of the vibrotactile stimuli had no marked effect on these values.**

I. Introduction

Vibrotactile stimuli can induce various emotional responses [1]–[4] and have been used to enhance the quality of experience using audio-visual content, such as video games and movies [5]–[7]. In these studies, physiological indices, such as heart rate and skin conductance, were measured, and questionnaires were used to record subject impressions. Previous studies investigated the effect of vibration frequency of the vibrotactile stimuli and the spatiotemporal patterns of vibrators on the quality of experience. However, the effect of the timing of vibrotactile stimuli has not been thoroughly investigated. Thus, in this study, we investigated the effect of the timing of vibrotactile stimuli on the quality of viewer experience of audio-visual content.

The vibrotactile stimuli were presented to the upper bodies of participants at five intervals according to the various sections of the audio-visual content. We measured the skin conductance of the palm and employed a questionnaire for evaluating subjective impressions. We verified the effect of the timing by testing the increase in skin conductance and evaluating the scores obtained from the questionnaire.

II. Experiment

A. Audio-visual and vibrotactile stimuli

We selected six videos of figure skating performances for the audio-visual content. All six videos were of different skaters, each of which started at the entry of the performer and ended after the first jump and lasted approximately a minute.

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All the authors are with the Department of Mechanical Systems Engineering, Nagoya University, Japan. Shogo Okamoto is also with the Department of Computer Sciences, Tokyo Metropolitan University.

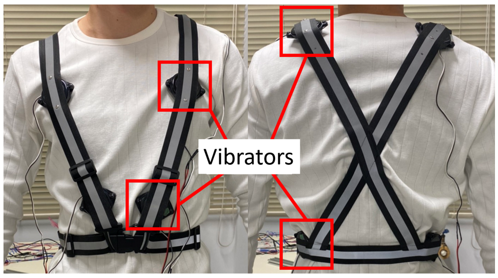

Fig. 1. Vibrotactile vest with eight high-fidelity voicecoil motors [8].

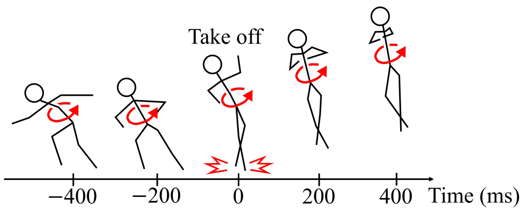

Fig. 2. Five levels of the timing of vibrotactile stimuli.

We used voicecoil motors (Vp408, Acouve Lab., Japan) for the vibrotactile stimuli. A vest was used to attach the voicecoil motors to the left and right sides of the shoulders, chest, abdomen, and waist of the participants. The vibration frequency was maintained at 70 Hz, and the amplitude was modulated along a triangle wave. The amplitude reached the peak over 640 ms after the onset and decreased linearly for another 640 ms. All the voicecoil motors were driven at the same time. The stimulation was presented once according to the jump scene in each video.

We experimented under six conditions of vibrotactile stimuli. In one condition, the vibrotactile stimuli were not presented, and in the other conditions, the timing of the vibrotactile stimuli was varied across five levels. We considered the reference stimulus to be the moment when the peak vibration amplitude coincided with the moment when the feet of the skater took off from the ground. We also selected four timings of the vibrotactile stimuli that shifted by 200 ms from the reference level, as shown in Fig. 2. The order of the videos and combinations of the video and vibrotactile stimuli conditions were randomized for each participant.

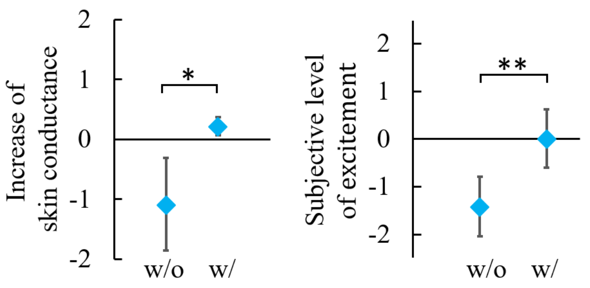

Fig. 3. Mean and standard error of skin conductance and questionnaire scores for conditions with and without vibrotactile stimuli. * and ** indicate a significant difference at $p < 0.05$ and 0.01, respectively.

B. Record of the level of excitement

We measured the skin conductance on the palms of the participants and used it as an indicator of emotions. The skin conductance varies according to sweating from arousal emotions such as excitement and anger. The skin conductance generally starts rising within 1 to 2 s after the onset of the stimulus, reaches the peak within 1 to 2 s, and then gradually decreases. Participants scored their level of excitement at the jump scene on a nine-grade scale questionnaire.

C. Participants

Seven male university students who were unaware of the study objectives participated in the experiments.

D. Experimental tasks

The participants experienced the audio-visual content combined with the vibrotactile stimuli at various timings, as well as at one instance without the vibrotactile stimuli. After each video, they recorded their subjective impressions on the nine-grade scale.

E. Analysis

We used the increases in the skin conductance from its onset of the rising to the peak and the questionnaire scores for the analysis. These values were standardized (z-valued) for each participant. The increase in the skin conductance and questionnaire scores were compared between the aforementioned conditions using t-tests. In this test, we compared the mean values of the five vibrotactile conditions and those of the non-vibrotactile condition. In addition, we verified the effect of the timing of the vibrotactile stimuli by comparing the changes in skin conductance and questionnaire scores under the five timing conditions using t-tests with Bonferroni correction.

III. Results

There was a moderate correlation between the increases in the skin conductance and questionnaire scores ($r = 0.41$, $p = 0.0066$). Fig. 3 compares the mean of the skin conductance and questionnaire scores between the conditions with and without vibrotactile stimuli. The vibrotactile stimuli significantly increased the skin conductance and resulted in higher questionnaire scores. Fig. 4 shows the changes in the skin conductance and questionnaire scores for the five timing conditions, and no significant differences were observed for both values. Almost all participants reported that the level of excitement was subject to change based on different timings of the vibrotactile stimuli; however, the most effective timing for the videos varied between individuals.

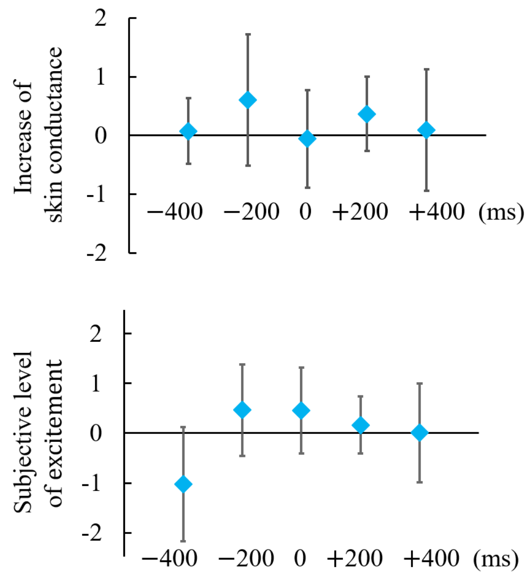

Fig. 4. Mean and standard error of skin conductance and questionnaire scores for different timings of the vibrotactile stimuli. No significant differences were observed between any two timings.

IV. Conclusion

The vibrotactile stimuli increased skin conductance and also bore higher questionnaire scores when the participants were made to watch the figure skating videos. Therefore the quality of audio-visual contents can be enhanced by vibrotactile stimuli. However, there were no significant differences between these values for the five timing conditions of the vibrotactile stimuli. It suggests that the timing of vibrotactile stimuli might not be related to the quality of audio-visual contents so much. Furthermore, we intend to experiment with different types of videos to derive more general conclusions about the effect of the timing.

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