Warm Ear Stroke to Make Sounds More Pleasant and Sleepy

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***Abstract*—We investigated the effect of stroking stimulation near the external auditory meatus, where vagus nerves exist, on emotions while listening to sounds to induce pleasant feelings. In our previous study, we demonstrated that such stimuli amplified the pleasant and arousing feelings evoked by pleasant sounds. This study additionally investigated the effects of warming stroking contactor. In a user study involving ten participants, a comparison of stroking stimuli with and without warming showed that the warm stimulation increased subjectively reported pleasantness and sleepiness, and decreased arousal. These findings help develop emotionally-appealing products in consumer electronics.**

***Index Terms*—emotion, vagus verves, relaxation**

I. Introduction

Simultaneous presentation of audiovisual contents, such as movies and music, and haptic stimuli to the body enhances the participant's emotional experiences (e.g. [1]–[5]). For example, when an upper body vibration was applied while viewing a horror scene, the participants felt greater fear than when no vibration was applied [1]. Vibration stimuli tend to make the emotions evoked by audiovisual contents more arousing and unpleasant. In contrast, stroking stimuli to auditory meatus enhance pleasant and joyful feelings caused by pleasant audio stimuli including the sounds of rain and winds [6]. In order to induce less arousing or more sleepy feelings, in this study, we investigate the effect of warm stroking stimuli to auditory meatus.

Warm temperature stimuli to the human body, such as neck, decrease subjective and physiological arousal, leading to relaxation [7]. There are many examples of combining audiovisual and thermal stimuli to manipulate feelings evoked by audiovisual stimuli (e.g., [8], [9]). In many previous studies, pleasant feelings were enhanced by warm stimuli. In some cases [8], [9], warm stimuli enhanced arousal during video and image viewing.

This gap of the effects of warm stimuli on arousal between earlier studies may originate from the differences in body parts warmed in those studies. In some studies such as [8], [9], the warm stimuli were presented to the palm or abdomen. Warming of the ear may have the same effects as warming of the neck, i.e., causing relaxation.

In this study, we compare subjectively reported feelings including pleasantness and sleepiness between with and without warming when pleasant sounds such as rain, winds, and shampoo are played with auditory stroking stimuli. Thus far, the effects of warm stroking contactor for auditory meatus has not been investigated, and this study will add a positive aspect to the literature in consumer electronics.

Fig. 1. Experimental apparatus. Left) Experimental scene. Middle) Tactile stimulator for ear. Right) Rod retained in temperature-controlled water.

II. Methods

A. Apparatus

Fig. 1 shows the experimental apparatus. A similar apparatus was used in a previous research [6]. A 3D-printed plastic rod was used as a contactor for presenting frictional stimuli to the external auditory meatus. The tip of the rod was spherical (12 mm in diameter) with a smaller hemisphere, of which diameter was 8 mm. The plastic rod was fixed to a DC geared motor with a reduction ratio of 50. The speed of the DC motor was controlled to be proportional to the transient volume of the sound by using a motor controller (SyRen 10, Dimension Engineering Llc., OH). Two cups filled with water of different temperatures were used to control the temperature of the rod. In one cup, the water temperature was the room level ranging 20–25°C. In another cup, the water was warmed at 42–43°C. A temperature controller (TXN-200AL, As One Corp., Japan) was used to retain this range. The rod was immersed in the cup for more than 1 min long.

Along with the tactile stimuli, sound stimuli were presented to the participants through bone-conduction earphones (Aeropex, Shokz, TX). This type of earphones did not plug up ears, and allowed the participants to contact the rod at their auditory meatus.

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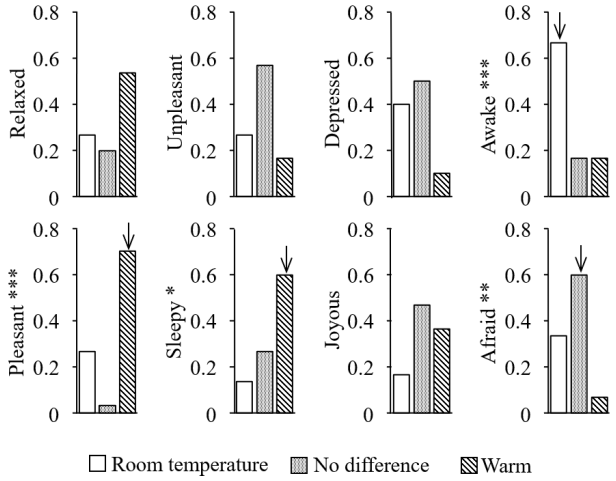

Fig. 2. Proportion of participants who selected each of the three options as most suitable for each adjective. *, **, and *** mean that three proportions are unequal to the chance, i.e., 0.33 with Bonferroni adjustment of factor eight, at $p < 0.05$, 0.01, and 0.001. The down arrow exhibits the largest residuals among the three options.

B. Procedures and tasks

Before the main experiments, the participant adjusted a force to contact the stimulator to the external auditory meatus such that the motion of the rod could be recognized. During the adjustment, the motor was continuously revolved.

In the main session, the participant experienced two temperature conditions for each of the three sounds that were the sounds of rain, winds, and shampoo. In one condition, the rod was immersed in water at room temperature. In the other condition, the rod was immersed in water at 42–43°C. For a given sound, participants experienced both conditions for 30 s each with the interval of 45 s. The order of the audio clips and temperature conditions were randomized. The participants closed their eyes during the presentation of the stimuli.

After the participant listened to each sound with the stroking stimuli at the auditory meatus under the two temperature conditions, for each of the eight quesionnaire items, they selected a suitable one among three options: the room temperature condition, warm condition, or no difference between two conditions. The questionnaire items were *awake*, *sleepy*, *joyful*, *derpressed*, *pleasant*, *unpleasant*, *relaxed*, and *afraid* referring to Russell's circumplex model [10].

C. Participants

Ten university students (seven males and three females) unaware of the study objectives participated in the experiment after providing a written informed consent.

D. Data analysis

Participants' answers for all the sounds were pooled and the proportions of selection for each option, i.e., warm temperature, room temperature, and no difference, were calculated. For each of the eight emotions, a chi-square test for goodness-of-fit with Bonferroni correction of factor eight was used to determine whether the frequencies of the three options differed from chance levels (0.33).

III. Results

Fig. 2 shows the proportions of three options selected in the questionnaire for each of the eight emotions. For *awake*, the proportions of the three conditions were unequal ($\chi^2 = 15.0$, $p < 0.001$) and the room temperature condition was selected most. For *pleasant* ($\chi^2 = 20.6$, $p < 0.001$) and *sleepy* ($\chi^2 = 10.4$, $p < 0.05$), the proportions were also unequal, and the warm condition was selected most. For *afraid*, the most participants answered that the two conditions were not different ($\chi^2 = 12.8$, $p < 0.01$). For the other adjective attributes, we did not find any differences in the proportions among the three options.

IV. Discussion

The participants judged the warm stimuli as more sleepy and the room-temperature stimuli as more awake. Sleepy and awake or arousing feelings are considered as opposite [10]. Hence, the thermal stimuli suppressed arousal feelings.

In terms of *pleasant*, the warm condition was selected most, suggesting that the warm stimuli enhanced the pleasantness of the sounds. For *unpleasant*, which is the opposite of *pleasant*, the two types of stimuli were not felt differently. This may be because the sounds used in this study were largely pleasant, and the use of the tactile stimuli did not affect unpleasantness.

V. Conclusion

We focused on the effects of stroking stimuli to the external auditory meatus using a warm ear contactor, whereas the effect of auditory stroking stimuli were demonstrated in an earlier study [6]. Further, most earlier studies employed vibratory stimuli to torsi and hands. The use of warm contactor made pleasant sounds feel more pleasant and sleepy (or less arousing) than that at the room temperature. In the future, we will investigate the most effective temperature of the rod and install a temperature control function to the stroking rod.

References

[1] I. Tara, S. Okamoto, Y. Akiyama, and H. Ozeki, "Timing of vibratory stimuli to the upper body for enhancing fear and excitement of audio-visual content," *International Journal of Affective Engineering*, vol. 22, no. 2, pp. 105–113, 2023.

[2] T. Makioka, S. Okamoto, and I. Tara, "Fear magnified by vibratory stimuli to the upper-body at predictive horror scenes," in *2022 IEEE 11th Global Conference on Consumer Electronics*, pp. 570–572, 2022.

[3] Y. Kosuge, Y. Ogura, and S. Okamoto, "Vibration to upper body manipulates joyful experience while viewing emotional scenes," in *2023 IEEE 12th Global Conference on Consumer Electronics*, 2023.

[4] M. Kim, S. Lee, and S. Choi, "Saliency-driven real-time video-to-tactile translation," *IEEE transactions on haptics*, vol. 7, no. 3, pp. 394–404, 2013.

[5] H. Hasegawa, S. Okamoto, K. Ito, and Y. Yamada, "Affective vibrotactile stimuli: relation between vibrotactile parameters and affective responses," *International Journal of Affective Engineering*, vol. 18, no. 4, pp. 171–180, 2019.

[6] Y. Goto and S. Okamoto, "Stroking stimuli to ear induces pleasant feelings while listening to sounds," pp. AM–1B–3, 2023.

[7] K. Kato, "Changes in autonomic nerve activity and pleasure-displeasure during hot compresses to the posterior region of the neck," *Journal of Japan Society of Nursing Research*, vol. 34, no. 2, pp. 39–48, 2011.

[8] S. Greiner, J.-N. Antons, and I. Wechsung, "Emotional responses to thermally augmented audiovisual stimuli," in *Seventh International Workshop on Quality of Multimedia Experience*, pp. 1–6, 2015.
[9] G. Wilson and S. A. Brewster, "Multi-moji: Combining thermal, vibrotactile & visual stimuli to expand the affective range of feedback," in *CHI Conference on Human Factors in Computing Systems*, pp. 1743–1755, 2017.
[10] A. Tseng, R. Bansal, J. Liu, A. J. Gerber, S. Goh, J. Posner, T. Colibazzi, M. Algermissen, I.-C. Chiang, J. A. Russell, *et al.*, "Using the circumplex model of affect to study valence and arousal ratings of emotional faces by children and adults with autism spectrum disorders," *Journal of Autism and Developmental Disorders*, vol. 44, pp. 1332–1346, 2014.