Stroking Stimuli to Ear Induces Pleasant Feelings while Listening to Sounds

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Abstract: We investigated whether stroking stimuli near the external auditory meatus while listening to sounds enhances pleasant feelings. Previous studies have demonstrated that vibratory stimuli manipulate emotions evoked by watching videos or listening to sounds; however, none have investigated the effects of stroking stimuli near the external auditory meatus through which vagus nerves extend. Participants were exposed to three types of sounds with and without the stroking stimuli to their ears, and selected one stimulus condition that induced intense feelings. When the sound stimuli were presented with the stroking stimuli to the ear, *joyful* and *pleasant* feelings were intensified, whereas *depressing* feelings weakened. Stroking stimulation of the outer ears in combination with sound stimulation was suggested to induce positive feelings.

Keywords: *Emotion, Natural sounds, Shampoo, Stroke*

1. INTRODUCTION

Emotional changes induced by sound and videos may influence the judgment of their values. Haptic stimuli to human bodies affect humans' emotions while experiencing audiovisual contents [1–10]. For example, vibrotactile stimuli, which are delivered through chairs to torsos are synchronized with movie soundtracks to improve emotional impressions [6, 7]. Vibratory stimuli are typically applied to torsos and the stimulation of ears is expected to cause effects similar to that of torsos [10].

Extant studies adopted vibratory stimuli which gave rise to arousing or unpleasant feelings [1–10]. Vibratory stimuli alone may not effectively induce pleasant and non-arousing feelings. Further, most studies selected torsos or hands to be stimulated but few studies investigated the external ears [10]. Vagus nerves that send the information of organs' states to the brain are also found in the outer ears. Thus, stimulation to the outer ears is linked to various physiological responses [11]. Hence, ear stimulation may become an alternative to torso stimulation and induce some emotional effects.

This study investigates the emotional effects of stroking stimulus to the external ear while listening to sounds. We adopted stroking stimuli unlike earlier studies. Stroking stimuli cause pleasant feelings when presented to arms [12], unlike vibratory stimuli. Hence, the stroking and vibratory stimuli to ears may have different emotional effects, which has yet to be studied. In the present experiment, a plastic tactile contactor placed at the ear was rotated by DC motors and presented stroking stimuli when participants were listening to sounds that could induce emotions. These included sounds of rain, storms, and shampooing. The findings of the present study will provide a basis for new emotional haptic interface designs.

2. METHODS

2.1 Apparatus

Figure 1 shows the appearance of the experimental apparatus. As a tactile stimulator, a resin rod fabricated by a 3D printer was used to stroke near the external acoustic meatus. The tip of the rod was spherical (12 mm in diameter) with a hemisphere (8 mm in diameter) attached to it. The shape and size were determined such that the external acoustic meatus could be stimulated without

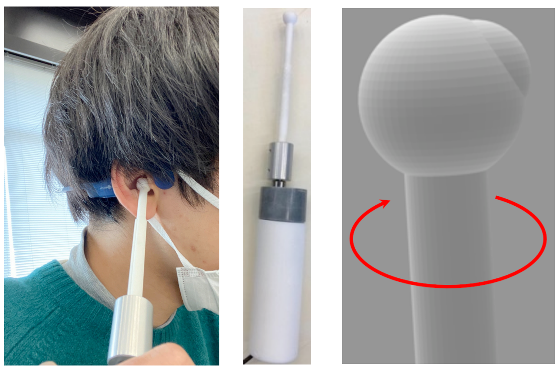

Figure 1: Experimental apparatus. Left) Experimental scene. Middle) Tactile stimulator for ear. Right) Tip of the ear stimulator.

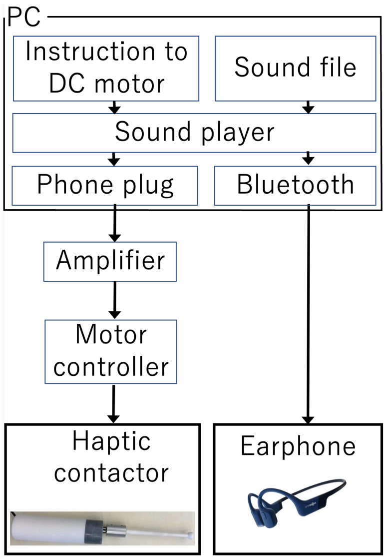

Figure 2: Configuration of apparatus

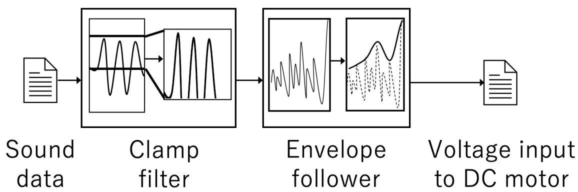

Figure 3: Voltage/speed instruction to DC motor generated from sound waves.

damaging it. The resin rod was connected to a DC geared motor (TG-47G-SG, Tsukasa Denko, Japan, reduction ratio: 50) via a coupling (Capricon MRG-20-6-8, Nabeya Bi-tech, Japan). The DC motor was given a speed command via a motor controller (SyRen 10, Dimension Engineering, USA).

Figure 2 shows the configuration of the apparatus. The command value to the DC motor was output from the earphone jack of the personal computer. It then passed through a non-inverting amplifier circuit using an operational amplifier and was input to the motor controller. The motor controller applied a pulse-width-modulation signal of up to 12 V to the DC motor. The voltage input to the DC motor was generated based on the waveform of the sound, as described in Section 2.3.

In addition to the tactile stimuli, the participants were presented with the sound stimuli. The sound stimuli were presented through bone-conducting earphones (Aeropex, Shokz, USA) via Bluetooth connection. We did not use inner ear or canal-type earphones because they would block the external acoustic meatus, where the stroking stimulus was applied.

2.2 Sound stimuli

We used the sounds of shampoo [13], rain [14], and winds in a storm [15] to evoke pleasant feelings. These sounds are expected to produce positive feelings including relaxation and stress-relief [16–18]. Each audio clip was 3 min long with a sampling frequency of 44100 Hz.

2.3 Stroking stimuli to ear

The plastic rod attached to the DC motor was rotated in response to the sound. Voltage commands to the DC motor were generated from the waveform of audio stimuli by the following process (Figure 3). First, the audio channel corresponding to the ear to be stroked was extracted from the two channels of the stereo audio. Second, the negative output voltage from a phone jack was removed and set to 0. Finally, the envelope of the waveform was extracted using the *envelope* function in Matlab (Mathworks, USA) with a peak mode of 1000. This peak interval value determines the smoothness of the envelope. When this value is small, the DC motor trembles slightly. When the peak interval is large, the DC motor rotates smoothly. This study did not aim to optimize the stroking stimulation, and the peak interval value was adjusted by the authors such that the stimulus felt comfortable.

2.4 Participants

Seven healthy participants (five males and two females) in their early 20s participated in the experiment. All participants had never experienced the apparatus and did not know the purpose of the experiment.

2.5 Procedures and tasks

Participants experienced two conditions in succession for each of the three types of sounds: In the first condition, only the sound was played; in the second condition, both the sound and tactile stimulus were played. For a given sound, the sound was first played for 3 min in one of the conditions, and after a 2 min interval, the sound was played for 3 min under the other condition. The order in which the two conditions and three types of sounds were presented were randomized. Participants were asked to close their eyes during the presentation of audio stimuli.

After experiencing an audio stimulus under the two conditions, participants chose the more applicable of the two conditions for eight emotional items (two-alternative task). The items measured were *arousing*, *sleepy*, *joyful*, *depressing*, *pleasant*, *unpleasant*, *relaxing*, and *scary* that were adapted from Russell's circumplex affect model [19].

2.6 Data analysis

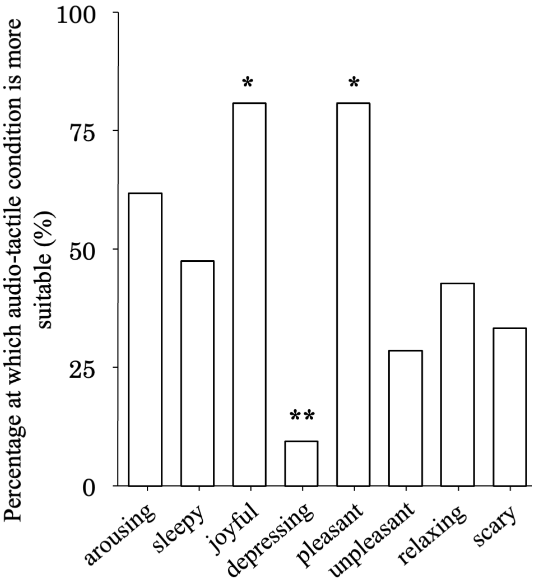

Figure 4: Proportion at which audio + tactile condition was selected as more suitable to each of the eight emotional words. * and ** mean that the proportions are significantly different from 0.5 (50%) at $p < 0.05$ and 0.01 with Bonferroni correction.

For each of the eight emotions, we calculated the percentage of participants who selected the audio-tactile stimulus condition. A binomial test was used to determine if each of the eight types of proportions was significantly different from the chance, i.e., 0.5 with Bonferroni correction of factor eight.

3. RESULTS

Figure 4 shows the proportions at which the audio-tactile condition was selected as more suitable for each feeling. For *joyful*, the audio-tactile condition was selected at 0.81 ($p < 0.05$). For *pleasant*, this proportion was 0.81 ($p < 0.05$). Conversely, the proportion for *depressing* was 0.10 ($p < 0.01$), suggesting that the audio-only condition felt more depressing. For other types of feelings, there were no significant differences between the two conditions.

4. DISCUSSION

Stroking near the external acoustic meatus resulted in stronger positive emotions such as *joyful* and *pleasant* and weaker negative emotions such as *depressing* compared to simply listening to the audio. Returning to Russell's circumplex model [19], *joyful* is an arousing and pleasant feeling in the circumplex model and *depressing* is a non-arousing and unpleasant feeling.

In the field of emotional haptics, researchers often use vibration stimuli, with which arousing and unpleasant emotions are induced [1–10]. In contrast, the use of stroking stimuli in the present study led to arousing and pleasant feelings, suggesting that vibratory and stroking stimuli give rise to different types of feelings. In this study, we used only one type of tactile contactor and stimulus generation algorithm. In the future, we will optimize these factors to effectively evoke pleasant feelings. In addition, we used sounds that could induce pleasant feelings. It will be interesting to investigate how the stroking stimulus affects feelings evoked by unpleasant sounds.

5. CONCLUSION

Earlier researchers established the emotional effects of vibration stimuli presented to the torsos of human bodies. In contrast, we investigated the emotional effects of stroking stimuli presented to the external acoustic meatus while listening to sounds. The user study involving seven participants suggested that the stroking stimuli elicited positive feelings including *joyful* and *pleasant*, and suppressed negative feelings such as *depression*. Optimization and generalization of the stroking stimuli to the ear remain to be studied.

REFFERENCES

[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, 2023.

[2] I. Tara, S. Okamoto, Y. Akiyama and Y. Yamada; How important is the timing of vibrotactile stimuli for the excitation of an emotional response for audio-visual content?, IEEE Global Conference on Consumer Electronics, pp. 157–159, 2021.

[3] I. Tara, S. Okamoto, Y. Akiyama and Y. Yamada; Heightening fear response to horror video scenes by applying vibratory stimuli to upper bodies of viewers, IEEE 4th Global Conference on Life Sciences and Technologies, pp. 250–252, 2022.

[4] G. Karafotias, A. Teranishi, G. Korres, F. Eyssel, S. Copti and M. Eid; Intensifying Emotional Reactions via Tactile Gestures in Immersive Films, ACM Transactions on Multimedia Computing, Communications, and Applications, 13(3), pp. 1–17, 2017.

[5] S. Sakurai, T. Katsumura, T. Narumi, T. Tanikawa and M. Hirose; Evoking emotions in a story using tactile sensations as pseudo-body responses with contextual cues, International Conference on Human Interface and the Management of Information, pp. 241–250, 2014.
[6] F. Giroux, J. Boasen, S. Sénécal, M. Fredette, A. Tchanou, J. Ménard, M. Paquette and P. Léger; Haptic stimulation with high fidelity vibro-kinetic technology psychophysiologically enhances seated active music listening experience, Proceedings in IEEE World Haptics Conference, pp. 151–156, 2019.
[7] S. Merchel and M. Altinsoy; The Influence of Vibrations on Musical Experience, Journal of the Audio Engineering Society, 62(4), pp. 220–234, 2014.
[8] T. Makioka, S. Okamoto and I. Tara; Fear magnified by vibratory stimuli to the upper-body at predictive horror scenes, Proceedings of IEEE Global Conference on Consumer Electronics, 2022.
[9] H. Hasegawa, S. Okamoto, K. Ito and Y. Yamada; Affective vibrotactile stimuli: Relation between vibrotactile parameters and affective responses, International Journal of Affective Engineering, 18(4), pp. 171–180, 2019.
[10] S. Fukushima, K. Amou, A. Nakata and H. Kajimoto; Emotional Vibration: Enhancement of emotion using a Combination of Sound and Skin Sensation to the Pinna, The Virtual Reality Society of Japan, 19(4), pp. 467–476, 2014.
[11] A. R. Murray, L. Atkinson, M. K. Mahadi, S. A. Deuchars and J. Deuchars; The strange case of the ear and the heart: The auricular vagus nerve and its influence on cardiac control, Autonomic Neuroscience, 199, pp. 48–53, 2016.
[12] G. K. Essick, F. McGlone, C. Dancer, D. Fabricant, Y. Ragin, N. Phillips, T. Jones and S. Guest; Quantitative assessment of pleasant touch, Neuroscience & Biobehavioral Reviews, 34(2), pp. 192–203, 2010.
[13] https://www.youtube.com/watch?v=RCT8hGGnTjw
[14] https://www.youtube.com/watch?v=NNLIC0bMdPE
[15] https://www.youtube.com/watch?v=sGkh1W5cbH4
[16] M. Annerstedt, P. Jönsson, M. Wallergård, G. Johansson, B. Karlson, P. Grahn, Å. Hansen and P. Währborg; Inducing physiological stress recovery with sounds of nature in a virtual reality forest—Results from a pilot study, Physiology & Behavior, 118, pp. 240–250, 2013.
[17] R. S. Ulrich, R. F. Simons, B. D. Losito, E. Fiorito, M. A. Miles and M. Zelson; Stress recovery during exposure to natural and urban environments, Journal of Environmental Psychology, 11(3), pp. 201–230, 1991.
[18] P. McGeoch and R. Romke; How everyday sounds can trigger strong emotions: ASMR, misophonia and the feeling of wellbeing, Bioessays, 42(12), no. 2000099, 2020.
[19] A. Tseng, R. Bansal, J. Liu, A. J. Gerber, S. Goh, J. Posner, T. Colibazzi, M. Algermissen, I. Chiang, J. A. Russell, and B. S. Peterson; 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, 44, pp. 1332–1346, 2014.