Stroking Stimuli to Ear Emotionally Affect Musical and Non-musical Sounds in a Different Way

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***Abstract*— Most extant studies that present haptic stimuli to the human body simultaneously with audiovisual contents for enhancing the emotional experience use vibration stimuli to the upper body. Vibratory stimuli largely induce arousal and do not lead to relaxing feelings. In our previous study, we investigated the emotional effects of presenting stroking stimuli to the external auditory meatus during listening to natural sounds that evoke relaxation. The results of the previous study suggested that the stroking stimuli to the external auditory meatus increased the joyfulness and pleasantness of the sounds. In this study, we investigated whether the emotional effects of the stroking stimuli could also be applied to classical music that induces relaxation. A user study involving twelve participants showed that, as in the previous study, the stroking stimuli enhanced pleasant feelings for non-musical sounds, whereas they enhanced unpleasant feelings for music. These findings help develop emotional haptic interfaces.**

I. INTRODUCTION

Haptic stimuli enhance viewers' emotions while experiencing emotionally evocative audiovisual contents [1], [2]. Vibration stimuli are typically used as haptic stimuli for such purposes. They largely induce arousal and do not lead to relaxing feelings.

In this study, we used stroking stimuli to the external auditory meatus for affecting emotions. Most studies selected torsos or hands for stimulation, but few studies have investigated the stimulation to external ears. The vagus nerves are located near the auditory meatus [3] and the mechanical stimulation to the outer ear give rise to various physiological responses including heart rate reduction [4]. Hence, ear stimulation may be an alternative to torso stimulation to induce emotional effects [5]. In addition, several studies have shown that stroking stimuli evoke pleasant or low-arousal emotions [6]. The stroking stimuli may have emotional effects different from vibratory stimuli when applied simultaneously with audiovisual contents.

We previously demonstrated that stroking stimuli to the auditory meatus made non-musical relaxing sounds felt more pleasant and joyful [5]. This study further examines the effects of the stroking stimuli to the ear on music. If the music is felt more pleasant and joyful because of the stroking stimuli to the ear, then it may lead to new emotional interfaces to enhance musical experiences.

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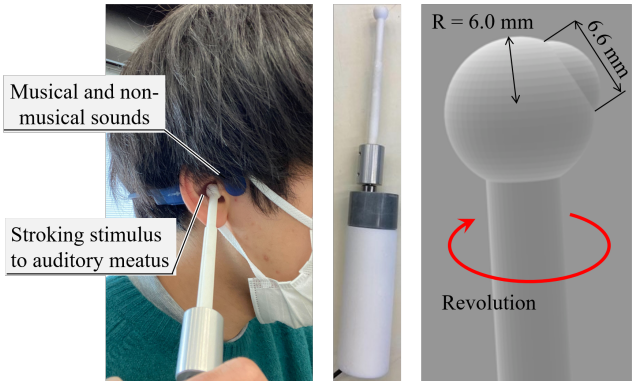

Fig. 1. Experimental apparatus. Left) Experimental scene. Middle) Tactile stimulator for ear. Right) Tip of the stimulator.

II. METHODS

A. Apparatus

The experimental setup is shown in Fig. 1, which was also used in the author's earlier study [5]. A resin rod was used for stroking the external acoustic meatus. The rod tip was spherical (12 mm in diameter) with a spherical nab of 6.6 mm. The resin rod was connected to a DC-geared motor (reduction ratio: 50). The DC motor was given a speed command via a motor controller (SyRen 10; Dimension Engineering LLC, OH). The speed command to the DC motor was generated based on the sound waveform described in Section C. The participants listened to sound stimuli through bone-conducting earphones (Aeropex, Shokz, TX).

B. Sound Stimuli

Four sounds, that were the sounds of shampoo and rain, classical music, and piano solo music, collected from Youtube (Google, LLC., CA) were used. In a preliminary questionnaire, these four sounds elicited pleasant and non-arousing feelings. In the preliminary session, twelve participants rated the pleasantness and arousal of eight sounds including these four sounds using nine-graded scales. These four sounds were rated more pleasant and less arousing than neutral on average.

C. Stroking Stimuli to Ear

The plastic rod attached to the DC motor rotated in synchronization with the volume of the presented sound stimulus. Voltage, that is the speed, commands to the DC motor were generated from the waveform of the audio stimuli in the following way. First, the audio channel corresponding

to the ear to be stroked was extracted from the two stereo audio channels. Subsequently, the absolute values of the sound output voltage were calculated. Hence, the DC motor continually rotated in one direction. Finally, the waveform envelope was computed using the envelope function in MATLAB (MathWorks, Inc., MA).

D. Participants

Twelve healthy participants in their early 20s participated in the experiment after providing written informed consent. None of the participants knew the purpose of the experiment.

E. Procedures

The participants experienced two conditions in succession for each of the four types of sounds. In one condition, only the sound was played. In another condition, both the sound and stroking stimulus were played. Each sound lasted 30 s in each condition. The two conditions were experimented with the interval of 1 min. The order in which the two conditions and four sounds were presented was randomized.

After the presentations of the individual sound under the two conditions, the participants selected the more applicable condition for each of eight emotional adjectives adapted from [7] in a two-alternative forced-choice task. The adjective items were awake, sleepy, joyful, depressed, pleasant, unpleasant, relaxed, and afraid.

F. Data Analysis

We calculated the proportions of the audio + stroking stimuli conditions selected for each of the music and non-music sound groups. We pooled the results of the questionnaires for the shampoo and rain sounds as non-music group, and those for the piano and classical music as the music group. For each of the two sound groups, a binomial test was applied to investigate whether the proportions at which the audio + stroking stimuli condition was selected significantly for each of the eight emotional items. For this purpose, the proportions were compared with the chance level, that is 0.5, with Bonferroni correction of factor eight.

III. RESULTS

Fig. 2 shows the proportions, at which the audio + stroking stimuli condition was selected for each of the eight items for each sound groups. The non-musical sounds were judged as more relaxing ($z = 2.86$, $p = 0.0043 < 0.05/8$) and pleasant ($z = 2.86$, $p = 0.0043 < 0.05/8$) due to the stroking stimuli. Further, the non-musical sounds tended less unpleasant ($z = -2.04$, $p = 0.041 > 0.05/8$) and depressing ($z = -2.04$, $p = 0.041 > 0.05/8$) with the stroking stimuli. The musical sounds tended to be more unpleasant ($z = 2.45$, $p = 0.014 > 0.05/8$) with the stroking stimuli.

IV. DISCUSSION

All sounds used in this study, the sounds of shampoo and rain as non-musical sounds and classical music and piano solo music as the musical sounds, were felt pleasant and low-arousing. However, the effects of the stroking stimuli differed between the two groups. The stroking stimuli altered the non-music sounds to more relaxing and pleasant. The stroking stimuli to the external auditory meatus elicited pleasant feelings as well as stroking at other sites, including the arm [6]. Further, similar to a previous study on mechanical stimulation to the ear [4], a relaxation effect was observed in our setting. However, the stroking stimuli did not enhance the relaxing and pleasant feelings of the music. Stroking stimuli generate frictional sounds with the characteristics of pink noise. Natural sounds such as shampoo and rain typically share such characteristics wheres music does not. The frictional sounds might have deterred the music and did not lead to expected relaxing effects.

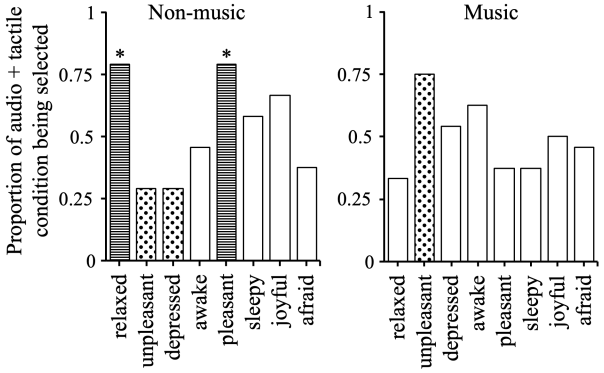

Fig. 2. Proportions at which the audio + stroking condition was selected as more suitable than the audio-only condition to each of the eight emotional attributes. Non-music sounds include the sounds of shampoo and rain. Music sounds include the piano and classical music. Each patterned bar with horizontal stripes and with polka dots are significantly greater than 0.5 at $p < 0.01$ and 0.05, respectively, without Bonferroni correction. * indicates significant difference from the chance, i.e., 0.5 at $p < 0.05$ with Bonferroni correction.

V. CONCLUSIONS

With stroking stimuli to the external auditory meatus, pleasant feelings increased while listening to the non-musical sounds. In contrast, the musical sounds were felt more unpleasant because of the stroking stimuli.

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