Impact of Sound Localization on Roughness Perception in Audio-tactile Cross-modal Effect

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I. Introduction

Cross-modal effects refer to phenomenon where the perception of one modality is influenced by stimuli from another modality [1]. Previous studies have demonstrated that sound can affect touch perception, giving rise to auditory-tactile cross-modal effect. For example, Jousmäki and Hari discovered the Parchment-skin illusion, where manipulating the frequency and level of sounds synchronous with hand rubbing altered the perceived roughness/moisture of the palmar skin [1]. However, most studies simply present sound through headphones, which just leads to a perception of sound inside the listener's head known as inside-of-head localization [2]. We aim to explore if outside-of-head localization, which includes the perception of sound direction and distance, has any impact on the cross-modal effect. Furthermore, previous studies have shown that the spatial position of stimuli can only affect tasks that require spatial responses [3]. In theory, roughness perception, which is not a spatial response, should not be affected by the position of auditory stimuli. Nevertheless, there are exceptions, such as the McGurk effect [4], which is not normally influenced by the position of sound but can be affected by attention to stimulus location. Therefore, we hypothesize that sound localization can affect audio-tactile cross-modal effect due to increased attention to auditory stimulus location.

II. Experiment

We conducted this experiment to investigate how sound localization affects audio-tactile cross-modal effect, particularly in the perception of surface roughness, based on previous research [1]. Tactile stimuli were provided by scraping three different sandpapers of varying roughness levels with a stainless steel rod ($\phi 4\,\mathrm{mm} \times 200\,\mathrm{mm}$). Auditory stimuli were presented via headphones and were combined with three conditions of sound localization (inside-of-head localization, outside-of-head localization, and outside-of-head localization moving in the opposite direction) and three types of sandpaper-scraping sound. 18 participants (11 males, 7 females, mean age = 27.56 years) were involved in the experiment. Participants sat on a chair and extend their arms through a belt fixed on a camera slider. They held the rod and moved their arm along with the slider to scrape the sandpaper in front of it (see Fig.1 Left). The slider was used to control the scraping speed and distance, with a sliding speed of 100 mm/s and a distance of 400 mm. The sandpaper was placed on an electronic scale to limit the pushing force. During each trial, participants were asked to wear an eye mask to eliminate the influence of visual cues. After each trial, they need to rate their perceived roughness level using a numerical magnitude estimation scale. A one-way ANOVA revealed that there was not a significant difference in perceived roughness level for P120 grit sandpapers among the three sound localization conditions, suggesting the study may not have fully reproduced the cross-modal effect (see Fig.1 Right). We further analysed the data from P60 and P400 grit sandpaper and found that a higher roughness level was perceived when listening to the P120 sound moving in the opposite direction for P60 grit sandpaper and when the P400 sound was localized inside the head for P400 grit sandpaper. Since the results are not consistent, the reason for these effects is currently unknown.

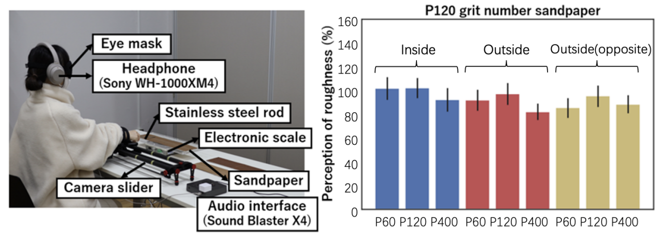

Fig. 1. Left: Experiment setup. Right: Participant ratings of perceived roughness levels for P120 sandpapers across nine auditory stimuli.

III. Future work

Preliminary results suggest that roughness perception may not be influenced by sound localization. However, there may have been a slight delay between when the slider began moving and when the audio started playing, which could contribute to the limitation in reproducing cross-modal effect. Additionally, some participants reported it is difficult to distinguish between inside-of-head and outside-of-head localization. For future work, we aim to address these problems and improve the experiment to create a more accurate cross-modal experience.

References

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