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Effects of Filtered Air- and Bone-Conduction Sounds' Presentation in Mastication on Food Texture

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ABSTRACT

Food texture is an essential sensation for food palatability as taste and aroma, and the effect on solid foods is particularly important. Among food textures, crispness is one of the most popular food textures in various countries. Humans generally perceive force, bone-conduction sound, and air-conduction sound for texture perception through the senses of tactile and hearing. Due to the using multiple senses, food texture is a multimodal perception integrated with the multiple senses. This study focused on auditory presentation and investigated the effects of air-conduction and bone-conduction sounds on food texture through experiments with sound devices. We had participants evaluate three food textures of eight food samples. Low-pass and high-pass filters cut chewing sound components in high and low frequencies. The participants listened to the modulated sound in chewing and evaluated the food textures. We confirmed that the auditory presentation affected the texture of the thin snacks. Significantly, it weakened the crispness texture called Paripari by the low-pass filter.

Keywords: Food texture, Multimodal integration, Auditory presentation, Air- and bone-conduction sounds, Crispness

INTRODUCTION

Food texture is one of the perceptions in mastication as taste and aroma (Bourne, 2002). Regarding the contribution to the deliciousness of solid foods, food texture plays a more dominant role than the others (Matsumoto and Matsumoto, 1977; Pellegrino and Luckett, 2020). Hence, food companies need to develop new products with good food textures. Food texture is expressed by various descriptors such as crisp, crunchy, and crumbly. Besides, there are differences in the number of descriptors depending on the country (Bourne, 2002; Nishinari et al., 2008). The deliciousness between countries also has differences. However, some textures are commonly preferred as crispness (Szczesniak, 1971; Rohm, 1990; Luckett and Seo, 2015).

Taste buds and olfactory cells perceive taste and aroma on a one-to-one basis. On the other hand, food texture is perceived from mainly force sense in the periodontal membrane and hearing sense. The hearing sense has two conductive paths: air and bone paths. Their sounds are called air-conduction sounds and bone-conduction sounds. Due to the using multiple senses, food texture is a multimodal perception integrated with the multiple senses (Dacremont et al., 1991; Spence, 2015). This means that if one of the senses changes, the perceived texture of the food also changes.

Some studies confirmed that the change in food texture occurred to the change in biting and chewing sounds. Edmister and Vickers (1985) investigated the effects of sound on crispness in foods. They had their subjects evaluate the sounds by normal biting and chewing them and by only listening to the sounds of someone else eating them. Zampini and Spence (2004) reported that the amplification of high-frequency air-conduction sound enhanced the crispness of potato chips. There was a report of a device to feedback bone-conductive sound by changing the frequency of mastication sound (Koizumi et al., 2011). However, the dominance between frequency-modulated feedback air-conduction and bone-conduction sounds on Japanese texture descriptors has not been sufficiently investigated.

In this study, the dominance between air-conduction and bone-conduction sounds on food texture is verified through experiments with sound devices. We have participants evaluate three food textures and eight food samples. Low-pass and high-pass filters cut chewing sound components in high and low frequencies. The participants listen to the real-timely modulated sound and evaluate the food textures. Based on the sensory evaluation, the effects on food texture by air-conduction and bone-conduction sounds are revealed.

METHOD

Auditory Presentation

This study investigates the effects of auditory presentation on food texture. An experimental setup for auditory presentation is shown in Fig. 1. Participants wear an over-ear type headphone or an open-ear type earphone to hear air- or bone-conduction sounds, respectively. A microphone in front of a participant digitizes his chewing sound. A laptop computer modulates the sound data by a low-pass filter (LPF) or a high-pass filter (HPF) and outputs the filtered sound to the headphone or earphone. Therefore, participants hear their modulated chewing sounds in this experiment. The cut-off frequency of the LPF and HPF was 2093 Hz. The recording and filtering on the computer were performed by Python 3.11 and pyaudio 0.2.13.

Food Texture and Foods

For the evaluation of the effect of the auditory presentation, this study chose three texture descriptors; sakusaku, karikari, and paripari. Their definitions are shown in Table 1. Sound in chewing is dominant in these descriptors. People whose native language is Japanese can explain the difference between them. They also recognized the definitions in Table 1.

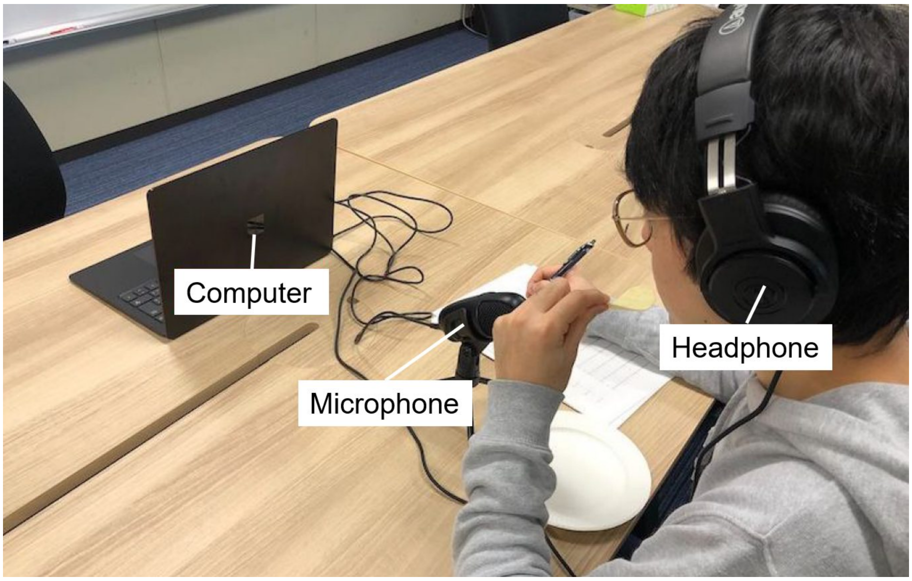


Figure 1: Experimental setup.

As samples including the food textures of the descriptors, this study chose eight commercially available foods; potato chips (Chipstar, Yamazaki-Biscuits Co., Ltd.), thin rice crackers (Seven premium usuyaki senbei, Hizatsukiseika Co., Ltd.), pretzel sticks (Pretz, Ezaki Glico Co., Ltd.), thin cookies (Moon light, Morinaga Co., Ltd.), sablés (Coconut sablé, Nissin Cisco Co., Ltd.), thick glutinous rice cracker (Teyaki arare, Shinko Seika Co., Ltd.), deep-fried dough snack (White karinto snacks, Natsume Seika Co., Ltd.), and fried stick of sweet potato (Imokenpi, Yokoyama Syokuhin Co., Ltd.). The samples are shown in Fig. 2. They are usually available in Japan. Hence, almost participants are used to eating them.

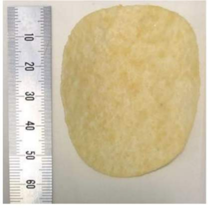
Table 1. Texture descriptors, their definitions in this study.

Descriptor	Definition
Sakusaku	Easily broken by biting with a weak force
Karikari	Short fracture with a relatively strong force in a mastication
Paripari	Breaking thin foods with a relatively high-frequency sound

Sensory Evaluation

Participants were eight students aged 22.9 ± 0.83 (mean ± standard deviation, male:female = 7:1). They bit and chewed each sample three times and marked the degrees of the three textures on the visual analog scale which had a scale from 0 to 100. The filter's conditions of the auditory presentation were three; no filter, high pass, and low pass. The device's conditions ware two; air and bone conduction. The participants evaluated three times for all conditions. This study was approved by the Ethics Committee of the Kobe

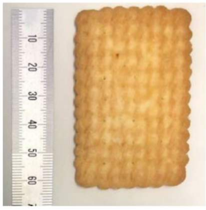
University Graduate School of System Informatics (No. R02-01) in accordance with the Helsinki Declaration. Written informed consent was obtained from all study participants. The sensory evaluation results were anonymized and converted into data so that individuals could not be identified. The statistical analysis of the results was carried out using MATLAB (R2022a, Mathworks, Inc, USA).


(a) Potato chip.


(b) Thin rice cracker.


(c) Pretzel stick.


(d) Thin cookie.


(e) Sablé.


(f) Thick glutinous rice cracker.


(g) Deep-fried dough snack.

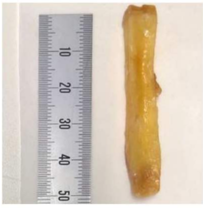
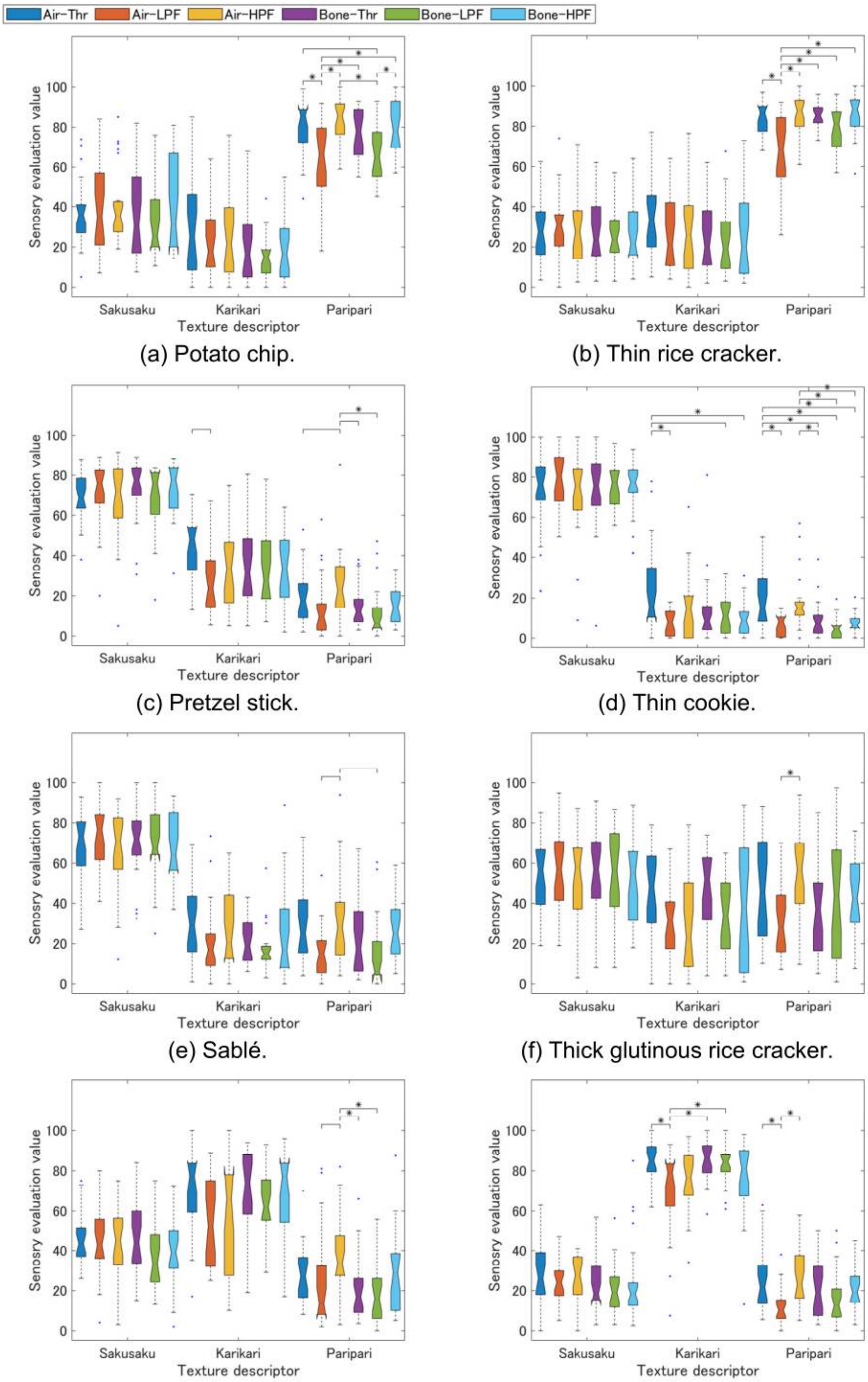

(h) Fried stick of sweet potato.

Figure 2: Snack food samples.

RESULT AND DISCUSSION

The sensory evaluation results are shown in Fig. 3, which includes significant differences between two conditions of a texture descriptor calculated by Tukey's honestly significant difference test. Samples (a) and (b) had higher paripari than the others. Sakusaku was high for samples (c), (d), and (e), and karikari was high for samples (g) and (h). Sample (f) had middle values in the three descriptors.

In the results, sakusaku had no significant difference between the low-pass or high-pass filter and the air- or bone-conduction sound. On the other hand, low-pass filtered sound decreased the evaluation values of karikari and paripari of most samples by the air-conduction sound. These results suggest that sakusaku tends to be influenced by the perception of force than air- and bone-conduction sounds. Although karikari and paripari were affected by both sounds, paripari is more sensitive to the frequency of air-conduction sounds like potato chips and thin rice crackers. The tendency of potato chips' results is coincident with that of an earlier study (Zampini and Spence, 2004). The effects of the low- and high-pass filters in bone-conduction sound were small. This study used the same cut-off frequency for air- and bone-conduction sounds. In the next step, the filter frequency for bone-conduction sound should be chosen to fit the characteristics of human hearing.



(a) Potato chip.

(b) Thin rice cracker.

(c) Pretzel stick.

(d) Thin cookie.

(e) Sablé.

(f) Thick glutinous rice cracker.

(g) Deep-fried dough snack.

(h) Fried stick of sweet potato.

Figure 3: Box plots of eight samples in sensory evaluation. The notch's center of each box shows the median. The upper and lower lines in each box represent the 75th and 25th percentiles, the maximum and minimum values in the whiskers represent the maximum and minimum values for non-outlier data, and the dots represent outliers. Brackets with and without '*' mean the significant differences of $p < 0.01$ and $p < 0.05$ in the texture descriptors, respectively.

CONCLUSION

This study investigated the effects of air- and bone-conduction sounds for the three Japanese descriptors through the experiment with sound devices. In the eight samples used in the experiments, we confirmed that the auditory presentation affected the texture of the thin snacks. It especially weakened Paripari by the low-pass filter.

In future works, we study the effects of different frequencies on food texture.

ACKNOWLEDGMENT

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