Improving the Palatability of Nursing Care Food Using a Pseudo-chewing Sound Generated by an EMG Signal

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Abstract. Elderly individuals whose eating functions have declined can only eat unpleasant foods with very soft textures. If more varied food textures could be delivered, the pleasure derived from eating could be improved. We tried to influence the perception of food texture using a pseudo-chewing sound. The sound was synchronized with mastication using the electromyogram (EMG) of the masseter. Coincidentally, when the EMG is heard as a sound, it is similar to the "crunchy" sound emitted by root vegetables. We investigated whether the perceived texture of nursing care food would change in subjects exposed to the EMG chewing sound. Elderly participants evaluated the textures of nursing care foods. When the EMG chewing sound was provided, they were more likely to evaluate a food as chewy. In addition, several scores related to the pleasure of eating were also increased. These results demonstrate the possibility of improving the palatability of texture-modified diets.

Keywords: Texture-modified care food · Chewing sound · Electromyography · Elderly · Meal support

1 Introduction

Although we use vision to obtain information about the palatability of dishes, such as their color and appearance, oral sensation and audition predominate once food is taken into the mouth. Although we do not usually pay attention to the sounds emitted when we chew food, these sounds can influence the perception of food texture [1, 2]. Here we describe the development of a meal support technology for elderly individuals that exploits these chewing sounds.

With aging, the ability to chew and swallow deteriorates, and the risk of aspiration becomes higher, potentially leading to asphyxia or pneumonia. Consequently, elderly individuals whose eating functions have declined can only eat food with very soft textures. Because food texture makes an important contribution to palatability [3, 4], unpleasant food texture decreases quality of life (QOL) of the elderly [5, 6]. Hence, if varied food textures could be delivered to the elderly even when they are only capable of eating texture-modified diets, the pleasure derived from eating and QOL related to meals will be improved.

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However, it is difficult to change the physical properties of food in order to cause people to experience various food textures. Therefore, novel apparatuses have been developed that directly stimulate oral sensation. A “food simulator” has been used to generate virtual chewiness by controlling the biting force of the device [7], and a “straw-like user interface” has been used to generate a virtual drinking sensation by controlling air pressure and vibration [8]. The aim of these apparatuses was to virtually simulate sensations, and they were not intended for use at mealtimes. Importantly, to enhance their effectiveness, these apparatuses provided the corresponding sounds simultaneously.

Changes in chewing sounds influence the perception of food texture. Zampini et al. reported that the perception of the crispness and staleness of potato chips can be altered by varying the loudness and/or frequency composition of the biting sound [9], and these findings were subsequently replicated by other researchers [10]. Thus, food texture is a complex sense that is composed of audition as well as oral sensation. Therefore, it might be possible to make people experience varied food textures by changing chewing sounds, even if the actual texture of a food is dull.

In this study, we tried to influence the perception of food texture by modifying the chewing sound. Previous studies investigated the relationship between biting or chewing sounds and the texture of crispy or crunchy foods. However, the target foods in this study were very soft and barely emitted chewing sounds. Therefore, chewing sounds had to be artificially generated. We developed a technique for presentation of a pseudo-chewing sound generated from the electromyogram (EMG) of the masseter muscle. Using this technique, we investigated whether the perceived textures or impressions of nursing care foods were altered when accompanied by an artificially generated pseudo-chewing sound.

2 Methods

2.1 Generating of Pseudo-chewing Sound

Because texture-modified care foods are very soft and barely emit sounds when chewed, chewing sounds must be provided from an external source that is synchronized with chewing behavior. To achieve this synchrony, we used the EMG of the masseter muscle, an agonist of mastication whose contractions are synchronous with the closing of the mouth. By monitoring the EMG of the masseter, chewing sounds can be provided that are synchronous with chewing behavior. Because the amplitude of the EMG signal correlates with chewing strength, the chewing sound can be provided at an appropriate intensity. Moreover, because the EMG is an electrical waveform, it can be readily interpreted as a sound. Coincidentally, the sound of the myoelectric waveform is similar to the chewing sound emitted by crunchy root vegetables. Therefore, by feeding back the EMG signal as sound, we can provide a “crunchy” chewing sound with high verisimilitude (EMG chewing sound).

The principal frequency range of the surface EMG is up to several hundred Hz [11], and thus does not contain the high-frequency components included in crispy and crunchy sounds [12, 13]. However, based on a principal component analysis of crispy, crunchy, and crackly sounds, the frequency range from 125 Hz to 1250 Hz was extracted as the first principal component of air-conducted chewing sounds [13]. Ultimately, we used the frequency range from 250 Hz to 1 kHz of EMG signal to generate the pseudo-chewing sound. The EMG chewing sound was similar to the crunchy sound of hard moist foods, although it did not contain the frequency components that characterize crispness, crunchiness, and crackliness.

As shown in Fig. 1, the EMG was recorded using surface electrodes. A pair of bipolar Ag/AgCl surface electrodes was attached to the skin overlying the right and left masseters with an inter-electrode distance of 20 mm, while a ground electrode was also attached to the forehead. The EMG signals were amplified (BioAmp FE132, AD Instruments), with a low-pass filter at 5 kHz and a high-pass filter at 10 Hz, then recorded at a sampling rate of 10 kHz (PowerLab8/35, AD Instruments). The masseter with the higher amplitude was used to generate the chewing sound. The analog output voltage of the masseter EMG signal was sent to a mixer/graphic equalizer (ZMX124 FX USB, ALTO Professional). The amplitudes of each frequency bands were adjusted using the function of the graphic equalizer with one-octave resolution. The adjustment was performed by setting the frequency range less than 125 Hz and over 2 kHz to the minimum level (−15 dB) and the frequency range between 250 Hz and 1 kHz to the maximum level (+15 dB). The EMG chewing sound was delivered via headphones. The frequency characteristics of the EMG and the EMG sound during clenching are shown in Fig. 2.

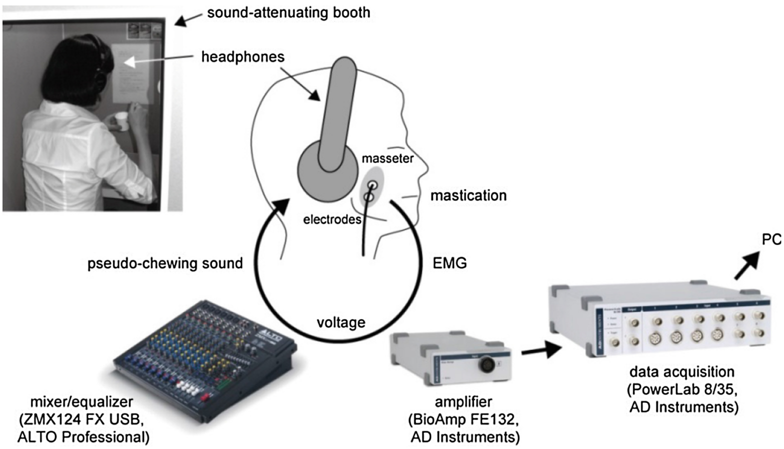

Fig. 1. Experimental setup

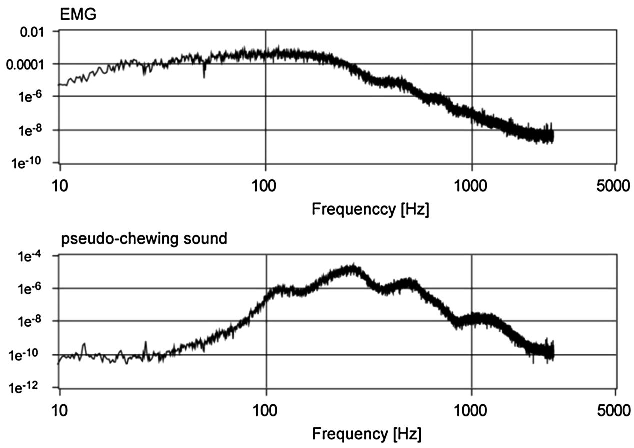

Fig. 2. Frequency characteristics of EMG and pseudo-chewing sound

2.2 Participants and Sample Foods

Ten healthy elderly participants (five male and five female, age range 66–74 years, [70 ± 3 years]) without signs of oromandibular and auditory diseases took part in the experiment. These participants usually ate normal foods, and did not eat texture-modified diets for their daily meals. They gave informed consent after receiving a full explanation of the study. The ethics committee for human experimentation at the National Institute of Advanced Industrial Science and Technology approved the experimental procedures.

Three kinds of commercially available nursing care foods were used as sample foods (Table 1). All of the sample foods contain several kinds of foodstuff that are cut into small particles and cooked until they are very soft. Consequently, they barely emit a chewing sound. They are classified into categories 2 and 3 of UDF (Universal Design Food) category, which are defined by the Japan Care Food Conference based on care recipients' ability to bite and swallow foods. UDF category 2 foods "can be broken up using the gums", whereas foods in category 3 "can be broken up by the tongue" (http://www.udf.jp/).

2.3 Questionnaire

A set of 16 adjective pairs were used for the experiment, most of which were selected by referring to previous literature [14–17]. For convenience, we first divided the adjectives used for material property ratings into three groups. The first group contained adjectives related to taste (Table 2a); the second, adjectives related to food texture (Table 2b); and the third, adjectives related to perceived feelings and other topics (Table 2c).

Participant used seven-point scales to rate how well these words applied to each of the stimuli. In the analysis of material properties, "1" was assigned to the first adjective in each pair, and "7" to the second. The seven degrees of evaluation were: (1) very much, (2) considerably, (3) somewhat, (4) neither, (5) somewhat, (6) considerably, and (7) very much.

Table 1. Nursing care foods used in the experiment

Food No.	Description of food (*Name in Japanese*)	UDF category	Product maker
1	Spicy fried and boiled vegetables (*Go-shu-yasai-no-kinpira-ni*)	3	WAKODO
2	Pumpkin simmered with minced chicken (*Kabocha-no-tori-soboro-ni*)	3	WAKODO
3	Japanese radish simmered with minced chicken (*Daikon-no-tori-soboro-an*)	2	Kewpie

Table 2. Words selected for material property rating

a. Taste	
	light taste – heavy taste
	stale taste – fresh taste
	simple taste – complex taste
	unpalatable – palatable
b. Food Texture	
	soft – hard
	dry – moist
	not chewy – chewy
	smooth – rough
	fewer ingredients – more ingredients
	bad texture – good texture
c. Perceived Feelings	
	unexciting – exciting
	less involved dining experience – more involved dining experience
	diminishes appetite – arouses appetite
	unable to masticate regularly – able to masticate regularly
	unpleasant – pleasant
	sound/food combination is unnatural – sound/food combination is natural

Questions were originally presented in Japanese – here translated into English.

The participants evaluated how perception changed in the condition with EMG sound compared with the without-sound condition, and then filled out the questionnaire after the two sound conditions were completed.

2.4 Procedure

The experiments were conducted in a sound-attenuating booth. The sound pressure level depended on the amplitude of the individual EMG signal. Therefore, to adjust the sound pressure level, a mastication evaluation gum (Masticatory Performance Evaluating Gum XYLITOL, Lotte) was used. Each participant was instructed to adjust the sound pressure to a comfortable level while they chewed the gum. In the without-sound condition, no EMG sound was fed back to the participant.

Six trials were carried out (three kinds of sample foods × two sound conditions), and each trial was performed once. The order of sample foods was random. The two sound conditions for each food were carried out sequentially. Half of the participants began in the with-sound condition, and the other half began in the without-sound condition.

In each trial, the participant was informed of the food name and sound condition in advance. Because the purpose of this experiment was to examine the influences of the chewing sound, the participants were instructed to chew more than ten times on the side where the EMG signal was being received. No restriction was imposed on the timing of swallowing, provided that mastication was performed over ten times. The task of participants was to rate the sensations and impressions described in the questionnaire. The participants filled out the questionnaire when the two sound conditions for each food were completed.

3 Results

The results of the subjective evaluation of each food are shown in Fig. 3. Although there were some food-dependent differences, several questionnaire items revealed similar changes regardless of the identity of the food. Figure 4 shows the averaged score of all sample foods. When the EMG chewing sound was provided, participants were more likely to evaluate a food as having the property of chewiness (“not chewy – chewy”). In addition, they were more likely to feel that they were engaged in an actual eating experience (“less involved dining experience – more involved dining experience”). The scores were also higher for several questionnaire items related to the pleasure of eating. Thus, overall, the perceptions of food texture and the subjects’ feelings about their eating experience were improved.

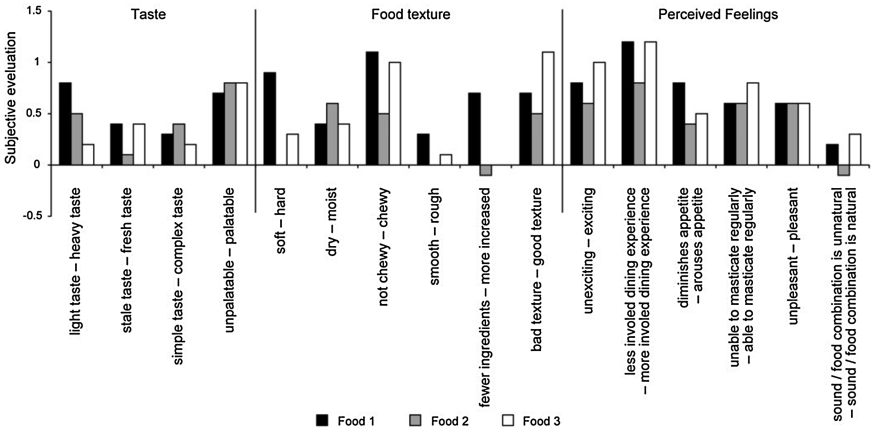

Fig. 3. Results of subjective evaluations of each food

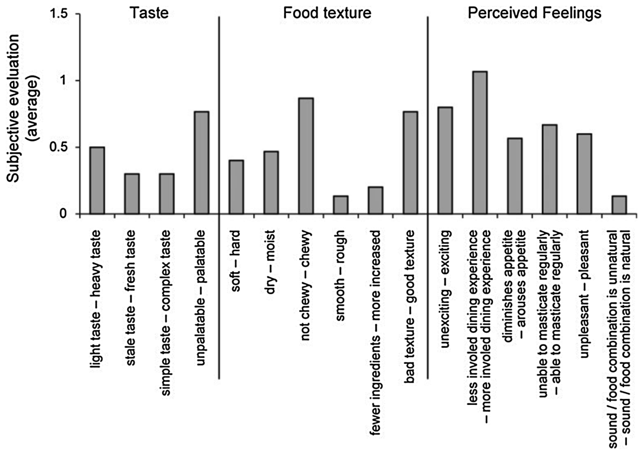

Fig. 4. Averages of subjective evaluations of all foods

4 Discussion

In this study, we found that a "crunchy" pseudo-chewing sound influenced the perceived texture and other properties of food. When the pseudo-chewing sound was provided, participants were more likely to evaluate a food as chewy. Consistent with this, previous work showed that crispy and crunchy food properties can be evaluated based on sound [18, 19]. In addition, perceived crispness is affected by the frequency components and loudness of the sound [9, 10]. Considering the effects inherent to crispy and crunchy sounds, it is plausible that the participants perceived crispness or crunchiness in response to the pseudo-chewing sound even when the sample foods were soft. In addition, several scores related to the pleasure of eating were also increased.

If elderly people who are only capable of eating texture-modified diets could be induced to experience varied food textures associated with positive impressions, then the quality and pleasure of their meals should be improved, potentially increasing their food intake and improving their nutritional condition. In future work, we will continue to investigate the relationship between chewing sounds and perceived food properties.

Sound can be processed in the background without consuming many attentional resources, and the sound presentation in our system is realized by a simple apparatus (Fig. 1) that could easily be miniaturized. Thus, the pseudo-chewing sound is considered to be a useful technique for improving the palatability of texture-modified diets.

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