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Texture-dependent effects of pseudo-chewing sound on perceived food texture and evoked feelings in response to nursing care foods

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A B S T R A C T

Because chewing sounds influence perceived food textures, unpleasant textures of texture-modified diets might be improved by chewing sound modulation. Additionally, since inhomogeneous food properties increase perceived sensory intensity, the effects of chewing sound modulation might depend on inhomogeneity. This study examined the influences of texture inhomogeneity on the effects of chewing sound modulation. Three kinds of nursing care foods in two food process types (minced-/puréed-like foods for inhomogeneous/homogeneous texture respectively) were used as sample foods. A pseudo-chewing sound presentation system, using electromyogram signals, was used to modulate chewing sounds. Thirty healthy elderly participants participated in the experiment. In two conditions with and without the pseudo-chewing sound, participants rated the taste, texture, and evoked feelings in response to sample foods. The results showed that inhomogeneity strongly influenced the perception of food texture. Regarding the effects of the pseudo-chewing sound, taste was less influenced, the perceived food texture tended to change in the minced-like foods, and evoked feelings changed in both food process types. Though there were some food-dependent differences in the effects of the pseudo-chewing sound, the presentation of the pseudo-chewing sounds was more effective in foods with an inhomogeneous texture. In addition, it was shown that the pseudo-chewing sound might have positively influenced feelings.

1. Introduction

The ability to chew and swallow deteriorates with age, which increases the risk of aspiration and can lead to asphyxia or pneumonia. To avoid aspiration, elderly individuals whose eating functions have declined can only eat foods with consistent textures (i.e., texture-modified diets; Curran & Groher, 1990; Garcia & Chambers, 2010; Martin, 1991; Pardoe, 1993; Steele et al., 2015). Although foods with modified physical properties can reduce the risk of aspiration, there is conflict between these foods and the foods that elderly individuals actually want. Losses of texture and visual appeal lead to issues of acceptability, causing dissatisfaction with these foods (Chadwick, Jolliiffe, Goldbart, & Burton, 2006; Colodny, 2005; Keller, Chambers, Niezgoda, & Duizer, 2012). Foods that are perceived as unpleasant decrease the appetite of the elderly, leading to reduction of food intake, and ultimately, malnutrition. Hence, eating pleasure recovery is necessary to increase appetite in these individuals.

Food appearance is an important factor to increase food intake (Piqueras-Fiszman & Spence, 2014; Wadhera & Capaldi-Phillips, 2014). As such, it is important to improve the visual appeal of puréed foods (Ettinger, Keller, & Duizer, 2014; Hotaling, 1992; Keller & Duizer, 2014; Martin, 1991). Molded puréed foods that were reformed into three-dimensional shapes were reported to be effective in increasing food intake (Cassens, Johnson, & Keelan, 1996; Germain, Dufresne, & Gray-Donald, 2006). Additionally, recent novel techniques have been developed to address this issue. For example, foods have been softened with an enzyme, while keeping the physical appearance intact (Sakamoto, Shibata, & Ishihara, 2006; Umene, Hayashi, Kato, & Masunaga, 2015), and foods have been produced via three-dimensional food printing technologies (Godoi, Prakash, & Bhandari, 2016; Lipton, Cutler, Nigi, Cohen, & Lipson, 2015). Though food appearance is important, it is not always enough. For instance, it has been reported that molded puréed foods were not acceptable because of disappointment in the

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different texture and flavor (Lepore, Sims, Gal, & Dahl, 2014; Stahlman et al., 2001; Stahlman, Garcia, Hakel, & Chambers, 2000). Further, it was reported that though visual appeal was desired, appearance did not have to be reformed or consistent with regular food, but rather that variety was needed (Keller & Duizer, 2014). Though we can create variations in taste and appearance, food texture must remain soft and monotonous to avoid aspiration. Food texture is one of several important sensory properties that constitute palatability (Delwiche, 2004; Kohyama, 2015; Szczesniak, 2002). Hence, if the perception of varied food textures can be delivered to the elderly, even if they are only capable of eating texture-modified diets, the food textures provided may contribute to a recovery of eating pleasure and appetite, and thus a potential increase in food intake.

Chewing sounds are associated with texture properties of food and influence the perception of food texture, especially the perception of crispness and crunchiness (Duizer, 2001; Saeleaw & Schleining, 2011; Spence, 2015; Vickers, 1982, 1985; C. Wilkinson, Dijksterhuis, & Minekus, 2000; Zampini & Spence, 2010). The effect of chewing sound modulation on crispness perception was first reported by Zampini and Spence (2004) and subsequently replicated by several researchers with both regular foods (Demattè et al., 2014; Koizumi, Tanaka, Uema, & Inami, 2013; Masuda & Okajima, 2011) and nursing care foods (Endo, Ino, & Fujisaki, 2016). In these studies, food textures related to several physical properties (e.g., crispness, stiffness, etc.) were perceived to be altered by chewing sound modulation. To modulate chewing sounds, the frequency profile of actual chewing sounds was changed or virtual chewing sounds were presented. For example, in a study using virtual chewing sounds, nursing care foods were perceived as stiffer and rougher with the presentation of crunchy virtual chewing sounds. Moreover, foods were perceived to have a greater number of ingredients. Therefore, chewing sound presentation is supposed to be a useful technique to help people on texture-modified diets to enjoy their food (Endo et al., 2016).

However, the foods used in the preceding experiments were hard or had inhomogeneous food texture (NOT puréed foods). The issue of acceptability for texture-modified diets is mostly related to puréed foods, which are very soft and have a homogeneous texture (Chadwick et al., 2006; Colodny, 2005; Keller et al., 2012). Thus, the effects of chewing sounds on softened foods with homogeneous texture require investigation. If foods have inhomogeneous properties, the perceived sensory intensity is reported to increase, including sweetness (Holm, Wendin, & Hermansson, 2009; Mosca, van de Velde, Bult, van Boekel, & Stieger, 2010), saltiness (Noort, Bult, Stieger, & Hamer, 2010), fat-related sensory attributes (Mosca, Rocha, Sala, van de Velde, & Stieger, 2012), and aroma (Nakao, Ishihara, Nakauma, & Funami, 2013). These findings suggest that inhomogeneous texture might enhance the effects of chewing sounds on perceived food texture and chewing sound modulation might be ineffective on texture perception in puréed foods. In this study, we examined the influences of texture homogeneity on the effects of chewing sounds.

2. Materials and methods

2.1. Participants and sample foods

Thirty elderly participants (15 male and 15 female, age range 66–75 years, mean 70 ± 3 [SD] years) took part in the experiment. Though eleven participants used a partial denture, all participants were free from pain and dysfunctions in the oromandibular region and had no difficulty in hearing chewing sounds by self-assessment. Though the principal aim of our study is to enhance the eating experience of elderly people obliged to follow texture-modified diets, the present study assessed the effects of chewing sounds in healthy elderly people. The experiment was approved by the institutional review board of the National Institute of Advanced Industrial Science and Technology (AIST), was conducted in accordance with the Declaration of Helsinki, and all participants provided informed consent.

Six commercially available nursing care foods were used as sample foods: three kinds of Japanese foods in two food process types (minced-like and puréed-like, which are slightly different from so-called minced and puréed foods; Asahimatsu Foods, Japan; Fig. 1, Table 1). The difference between the two process types was homogeneity, where vegetables in the minced-like foods were finely chopped around 5 mm, and all ingredients in the puréed-like foods were mushed. In both process types, all ingredients had been cooked until very soft.

2.2. Presentation of pseudo-chewing sound

The sample foods were very soft and did not emit crispy or crunchy chewing sounds. Therefore, chewing sounds must be provided from an external source. To present chewing sounds, we developed a pseudo-chewing sound presentation system, where the electromyogram (EMG) signal from the masseter was directly fed back as a sound (Endo et al., 2016). This system produces the EMG signal in an audible format as the pseudo-chewing sound (EMG chewing sound). Therefore, the pseudo-chewing sound can be presented synchronously with the onset and offset of jaw closing during mastication. Further, because the amplitude of the EMG signal correlates with the chewing force, the pseudo-chewing sound can be varied proportionally to the chewing strength. The details of the system are described in our previous report (Endo et al., 2016). The outline of the system is explained below.

Fig. 2 shows a schematic diagram of the pseudo-chewing sound presentation system. The EMG was recorded using surface electrodes, which were attached to the skin overlying the right and left masseters (either side of the masseter was used). Myoelectric signals were amplified (BioAmp FE132, AD Instruments) and recorded (PowerLab8/35, AD Instruments). The analog output voltage of the amplifier (EMG signal) was sent to a mixer/graphic equalizer (ZMX124 FX USB, ALTO Professional). To make the EMG chewing sound similar to an actual chewing sound, the amplitudes of each frequency band were adjusted using the function of the graphic equalizer with one-octave resolution: frequencies less than 125 Hz and over 2 kHz were attenuated by −15 dB, and frequencies of 250 Hz and 1 kHz were amplified by +15 dB. The EMG chewing sound was delivered via headphones (MDR-NC60, Sony). The EMG chewing sound mimics the crunchy sound emitted by hard moist foods (e.g. root vegetables; as ascertained by the subjective impression of the experimenters). Ultimately, we could deliver a "crunchy" pseudo-chewing sound synchronously to the chewing behavior by directly feeding back the altered EMG signal.

2.3. Questionnaires

Two questionnaires that were used in our previous study were used (Endo et al., 2016). Questionnaire 1 was for material-property rating, and a set of 18 adjective pairs were used (Table 2). For convenience, the adjectives were divided into three groups: adjectives related to taste; adjectives related to texture; and adjectives related to evoked feelings. Participants used seven-point scales to rate how well these adjectives applied to each of the food stimuli. Questionnaire 2 was for general impressions of the eating experience. A set of four questions was used to measure more general impressions of the eating experience (Table 3). As in Questionnaire 1, seven-point scales were used, but evaluations