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The effect of a crunchy pseudo-chewing sound on perceived texture of softened foods

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HIGHLIGHTS

- A masseter EMG signal was delivered as a "crunchy" pseudo-chewing sound.
- Softened foods were evaluated as 'stiffer' in the EMG chewing sound condition.
- Physical food properties are more likely to be influenced by altered auditory input.
- A modified chewing sound presentation may help those on texture-modified diets.

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ABSTRACT

Elderly individuals whose ability to chew and swallow has declined are often restricted to unpleasant diets of very soft food, leading to a poor appetite. To address this problem, we aimed to investigate the influence of altered auditory input of chewing sounds on the perception of food texture. The modified chewing sound was reported to influence the perception of food texture in normal foods. We investigated whether the perceived sensations of nursing care foods could be altered by providing altered auditory feedback of chewing sounds, even if the actual food texture is dull. Chewing sounds were generated using electromyogram (EMG) of the masseter. When the frequency properties of the EMG signal are modified and it is heard as a sound, it resembles a "crunchy" sound, much like that emitted by chewing, for example, root vegetables (EMG chewing sound). Thirty healthy adults took part in the experiment. In two conditions (with/without the EMG chewing sound), participants rated the taste, texture and evoked feelings of five kinds of nursing care foods using two questionnaires. When the "crunchy" EMG chewing sound was present, participants were more likely to evaluate food as having the property of stiffness. Moreover, foods were perceived as rougher and to have a greater number of ingredients in the condition with the EMG chewing sound, and satisfaction and pleasantness were also greater. In conclusion, the "crunchy" pseudo-chewing sound could influence the perception of food texture, even if the actual "crunchy" oral sensation is lacking. Considering the effect of altered auditory feedback while chewing, we can suppose that such a tool would be a useful technique to help people on texture-modified diets to enjoy their food.

1. Introduction

The ability to chew and swallow deteriorates with age, which increases the risk of aspiration and can lead to asphyxia or pneumonia. In order to avoid aspiration – the breathing in of food – elderly individuals whose eating functions have declined can only eat soft food with a consistent texture [1–5]. However, these modified diets are not always pleasant and can result in a loss of appetite [6–9]. The principal aim of this investigation was thus to explore how dissatisfaction with food texture can be reduced. One possibility is altering the auditory feedback of the sounds made when eating.

Although we do not usually pay conscious attention to the sounds emitted when we chew food, chewing sounds can influence the perception of food texture, especially the perception of crispness and crunchiness (for reviews, [10–13]). For instance, Zampini et al. reported that the perception of crispness and staleness of potato chips can be altered by varying the loudness or frequency composition of the first bite sound [14]. The effect of sound modulation on crispness perception has been subsequently replicated by other researchers [15–17]. Thus, the perception of food texture involves not only oral sensation, but also auditory feedback. It might be therefore possible to alter people's experience of food texture via altered auditory feedback of chewing sounds, thereby

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ameliorating dissatisfaction with food texture in individuals who are obliged to follow restricted diets.

The effect of auditory modification on crispness perception in previous studies has been explained by the principle of crossmodal integration [18,19], whereby oral sensation and chewing sounds are said to be integrated unconsciously [13]. This model has been used to describe results in which there is no dissociation between the oral somatosensory and auditory sensations. However, the foods in texture-modified diets are very soft and so do not elicit the oral sensation of crispness or crunchiness when eaten; we therefore created a dissociation using altered auditory feedback of chewing sounds. In this way, our study aimed to investigate whether the modified chewing sound can influence the perception of food texture, even if the actual oral sensation is lacking. Although the principal aim of our investigation was to enhance the eating experience of elderly people obliged to follow texture-modified diets, it is important to first confirm an effect with normal subjects. The present study thus assessed the effect of modified chewing sound in healthy adults. In this report, we also propose a method that can provide a pseudo-chewing sound in a simple and practical way.

2. Materials and methods

2.1. Pseudo-chewing sound using EMG signals

The foods in texture-modified diets are very soft and do not emit crispy or crunchy chewing sounds. Therefore, it is impossible to alter the real chewing sound, and chewing sounds must be provided from outside the oral cavity, i.e., from an external source. Previous studies have detected mastication by monitoring real chewing sounds or jaw movements and playing pre-recorded chewing sounds [15,16,20]. However, because real chewing sounds are hardly emitted while eating foods from texture-modified diets, it is difficult to detect mastication from the real chewing sounds. Besides, jaw movements during mastication can also be mixed with those due to speech, which must therefore be distinguished in some sophisticated way [16]. Because the final goal of our study is to help elderly people obliged to follow texture-modified diets in their daily lives – and not in a laboratory setting – we decided to detect mastication in a simple way. To achieve this, we used the electromyogram (EMG) of the masseter muscle, an agonist of mastication whose contractions are synchronous with the closing of the mouth [21–23]. By monitoring the EMG of the masseter, it is possible to provide chewing sounds that are synchronous with chewing behavior, which is what differentiates the present study to previous research.

Interestingly, the EMG signal is an electrical waveform that can be readily interpreted as a sound. The principal frequency range of the surface EMG is up to several hundred Hertz [24–26], and therefore does not contain the high-frequency components present in crispy and crunchy sounds [27–31]. However, the frequency range of 125 Hz to 1250 Hz was extracted as the first principal component of air-conducted crispy, crunchy, and crackly sounds [29], where the frequency range of the EMG sound overlaps. In fact, the EMG sound was close to the crunchy sound emitted by hard moist foods (e.g. root vegetables). Thus, we could use the EMG signal as an external sound source of crunchy chewing sound.

In addition to onset and offset synchrony with chewing, using the EMG signal as chewing sounds provides two practical merits. The first is that, other than individual calibration to each user to accurately detect jaw movements, no adjustment is necessary to set up the system. The second is that speech movements have less of an effect on the modified chewing sound. Because the amplitude of presented chewing sound changes depending on the intensity of the masseter activity, and the masseter activity during speech is smaller than that during mastication [32,33], a chewing sound evoked by speech movements is hardly emitted.

As shown in Fig. 1, the EMG was recorded using surface electrodes. A pair of bipolar Ag/AgCl surface electrodes 5 mm in diameter was attached to the skin overlying the right masseter. One electrode was located over the maximum distended muscle belly, which was determined by palpation, and the other was attached parallel to the direction of muscle fibers with an inter-electrode distance of 20 mm; a ground electrode was attached to the forehead. Myoelectric signals were amplified (BioAmp FE132, AD Instruments) with a low-pass filter (LPF) at 5 kHz and a high-pass filter (HPF) at 10 Hz, and recorded at a sampling rate of 10 kHz (PowerLab8/35, AD Instruments).

The analog output voltage of the amplifier was sent to a mixer/graphic equalizer (ZMX124 FX USB, ALTO Professional). To reduce noise, the input signal was filtered with a HPF at 75 Hz (18 dB/oct) and high-frequency attenuation over 12 kHz (−15 dB). In order to match the frequency characteristics to the first principal component of the real chewing sound, the amplitudes of each frequency band were adjusted using the function of the graphic equalizer with one-octave resolution: frequencies <125 Hz and over 2 kHz were attenuated by

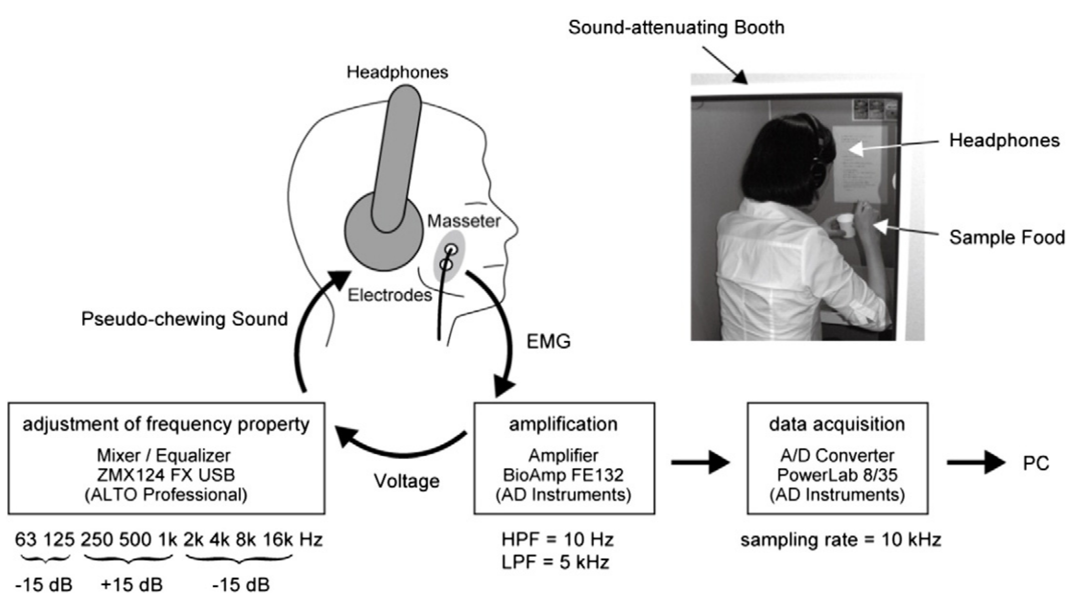

Fig. 1. EMG chewing sound presentation system and experimental setup. The EMG signal of the masseter was fed back to headphones through an amplifier and graphic equalizer to provide a pseudo-chewing sound. The EMG signal was also recorded by a personal computer for further analysis. Experiments were conducted in a sound-attenuating booth.