Study on Control Method of Virtual Food Texture by Electrical Muscle Stimulation

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ABSTRACT

We propose Electric Food Texture System, which can present virtual food texture such as hardness and elasticity by electrical muscle stimulation (EMS) to the masseter muscle. In our previous study, we investigated the feasibility to detect user's bite with a photoreflector and that to construct database of food texture with electromyography sensors. In this paper, we investigated the feasibility to control virtual food texture by EMS. We conducted an experiment to reveal the relationship of the parameters of EMS and those of virtual food texture. The experimental results show that the higher strength of EMS is, the harder virtual food texture is, and the longer duration of EMS is, the more elastic virtual food texture is.

Author Keywords

food texture; electrical muscle stimulation; virtual reality

INTRODUCTION

Some previous studies proposed to present and change food texture by haptic technology for dining experiment improvement. There are two approaches, one is to use force feedback on user's teeth to change food texture directly [2], the other is to use cross modal sensation to change food texture indirectly [1, 3]. However, there are some limitations. The former approach has the limitations of scene; it cannot be used while users are eating real food because haptic actuators are put in their mouthes. The latter approach has the limitations of variety; it cannot control food texture of tender food like pasta because it doesn't make chewing sound.

Our motivation is to propose a novel method to present food texture for more widely used. In [4], we propose to use electrical muscle stimulation (EMS) to the masseter muscle. Pfeiffer, et al. showed EMS is useful to present hardness of virtual objects [6]. Therefore, we suppose that it is also useful to present food texture such as hardness and elasticity. In [4], we describe our proposal system; "Electric Food Texture System" as shown in Figure 1. The system is composed of "bite detection part", "food texture database", and "electric stimulation part". Virtual food texture is presented by EMS to the masseter muscle synchronizing with user's bite. We have investigated the feasibility to detect user's bite with a photoreflector and that to construct database of food texture with electromyography sensors. Thus, we describe the feasibility to control virtual food texture by EMS in this paper.

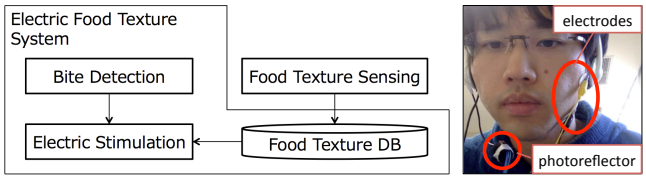

Figure 1. The architecture of Electric Food Texture System

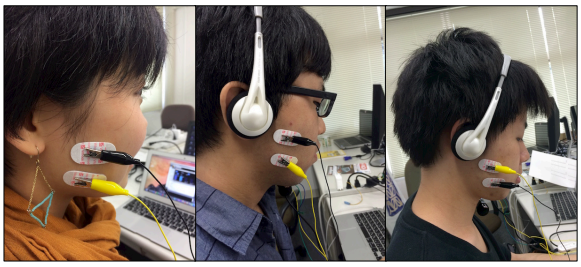

Figure 2. Electrodes are put on the masseter muscle

To control the parameters of virtual food texture such as hardness and elasticity, we have to investigate the relationship of those of EMS and those of virtual food texture. Based on texture profile analysis, our hypotheses are as follows [5].

1. The higher strength of EMS is, the harder virtual food texture is.

2. The longer duration of EMS is, the more elastic virtual food texture is.

We conducted an experiment to verify our hypotheses.

EXPERIMENT

Setup

A medical electrical stimulator (Digitimer, D185) is used for EMS. This stimulator can control the voltage of electric stimulation. The square wave whose pulse width is 0.05 ms. The trigger signal is sent from Arduino which is connected to bite detection part to control frequency and duration of electric stimulation. The strength of electric stimulation is controlled by pulse frequency modulation; the higher frequency is, the stronger electric stimulation is. Following safety standards

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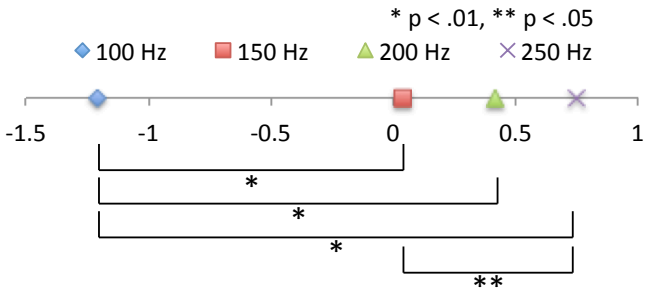

Figure 3. The Scheffe's pairwise comparison result of hardness

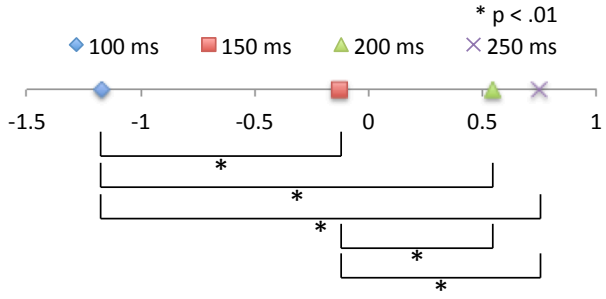

Figure 4. The Scheffe's pairwise comparison result of elasticity

(JIS T 0601-2-10), the voltage is less than 20 V and the current is less than 10 mA. We use small electrodes (Nihon Kohden, F-150S) whose size is 18 $\times$ 36 mm to stimulate only the masseter muscle. They are put on the right masseter muscle. The calibration is conducted to decide the positions of them for each subject. The positions are shown in Figure 2.

Procedure

5 males and 1 female (20s - 30s) participated in this experiment. First, we investigated the relationship of frequency and hardness. The duration is fixed at 150 ms. The frequency is set as 100,150, 200, or 250 Hz. The procedure is as follows.

1. The frequency of EMS is chosen randomly from 100 Hz to 250 Hz as 1st stimulation. Subjects move their jaws 5 times and the electric stimulation is presented for each bite when the mouth is closing.
2. The different frequency of EMS is chosen as 2nd stimulation. They move their jaws 5 times and the electric stimulation is presented for each bite when the mouth is closing.
3. Subjects are asked to rate in which stimulation they feel harder food texture using Scheffe's pairwise comparison whose rating scale is 7-point.

Each subject tried 6 combinations of 1st and 2nd stimulation. Next, we investigated the relationship of duration and elasticity. The frequency is fixed at 150 Hz. The duration is set as 100, 150, 200, or 250 ms. The procedure is the same as the investigation of hardness.

Results

The result of hardness is shown in Figure 3 and that of elasticity is shown in Figure 4. In Figure 3, the higher frequency is, the harder virtual food texture is. Frequency has a main effect ($F(3, 15) = 33.3, p < .01$) and there are significant difference between 100 - 150 Hz ($p < .01$), 100 - 200 Hz ($p < .01$), 100 - 250 Hz ($p < .01$), and 150 - 250 Hz ($p < .05$) by multiple comparisons. In Figure 4, the longer duration is, the more elastic virtual food texture is. Duration has a main effect ($F(3, 15) = 54.5, p < .01$) and there are significant difference between 100 - 150 ms ($p < .01$), 100 - 200 ms ($p < .01$), 100 - 250 ms ($p < .01$), 150 - 200 ms ($p < .01$), and 150 - 250 ms ($p < .01$) by multiple comparisons. These results suggest that hardness of virtual food texture can be controlled by strength of EMS and that of elasticity can be controlled by duration of EMS.

CONCLUSION

We propose to present EMS to the masseter muscle for virtual food texture. In this paper, we investigated the relationship of the parameters of EMS and those of virtual food texture. The experimental results show that the higher strength of EMS is, the harder virtual food texture is, and the longer duration of EMS is, the more elastic virtual food texture is. In future works, we will propose applications such as virtual dining experience and augmented dining experience.

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