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Poster

Controlling the Distribution of Salty Taste Intensity on the Tongue Using Extraoral Galvanic Taste Stimulation

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Abstract

Galvanic taste stimulation (GTS) alters taste intensity by applying a weak electric current around the oral cavity. Previous studies on GTS have captured the overall trend of taste changes in the oral cavity produced by GTS. However, it is not well known whether the potentiating or inhibitory effects of GTS result in a spatial gradient of taste perception in the oral cavity. Therefore, in this study, we examined the possibility of spatially selective modulation of taste intensity produced in the oral cavity by GTS. The results suggested that it is possible to present the intensity gradient of the perceived taste in the front-back and left-right directions, depending on the arrangement of the electrodes. These results are expected to contribute to the presentation of taste changes that are close to the actual eating and drinking experience, and to the provision of a new taste experience in which the taste is perceived as it moves through the oral cavity.

1. Introduction

Galvanic taste stimulation (GTS) is utilized as a taste presentation method in virtual reality and human-computer interaction, whereby a weak electric current is applied around the oral cavity to change the perceived intensity of the taste sensation. Previous research on GTS showed that an anodal electric stimulation with an anode near the tongue enhances the salty taste sensation [NAR*21], while a cathodal electric stimulation with a cathode near the tongue suppresses salty taste stimulation [HF09]. Nakamura et al. also showed that anodal electrical simulation alone presents unique 'electric taste' near the anode when the electric stimulation with multiple electrodes was applied from the outside the oral cavity [NMA21]. These studies have captured the overall trend of taste changes in the oral cavity produced by GTS. However, it is not well known whether the potentiating or inhibitory effects of GTS result in a spatial gradient of taste perception in the oral cavity. Therefore, in this study, we examined the possibility of spatially selective modulation of taste intensity produced in the oral cavity by GTS. Especially, in light of these studies, we investigate whether the spatial distribution of salty taste intensity can be controlled by multi-electrode electrical stimulation with NaCl solution in the mouth. Generally, it is known that GTS with the anode near the mouth enhances taste, while the cathode suppresses it. Therefore, we hypothesized that the salty taste near the anode is enhanced, and the salty taste near the cathode is suppressed.

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2. Method

We have developed a custom-built electrical circuit that can apply a constant current to any pairs of electrodes simultaneously (Figure 1). The current value and stimulation time were controlled using a PC, and the electrodes were used as either the anode or cathode.

In total, we recruited 10 healthy participants (seven males and three females) for the experiment. The experiment was conducted in accordance with safety standards approved by the local ethics research committee of The University of Tokyo. The participants were briefed on the experiment and signed a consent form. These study protocols were performed in accordance with the ethical standards outlined in the Helsinki Declaration.

The concentration of NaCl solution in the mouth during the experiment was 1%, the current value was 2 mA, and the duration of one stimulus was 3 s.

After the participants received electrical stimulation with NaCl solution in their mouths, they participated in two trials: (A) stimulation intended to enhance the perceived taste, followed by a response to the position where the sense of taste became stronger, (B) stimulation intended to suppress the perceived taste, followed by a response to the position where the perceived taste became weaker. The common question was: *how did the perceived taste change during the experience (increased, decreased, or no change)?* In Case (A), after answering the above question about the perceived intensity of taste, the participants drew the area where they perceived the perceived taste to be stronger during the electric stimulation and the maximum point where they perceived the taste to be strongest on the illustration of a cross-section of the mandible including the

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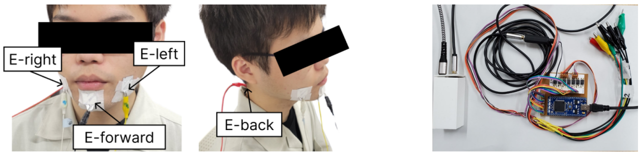
tongue. In Case (B), the same question was asked, and the participant drew the areas and points after the answer of the position where the perceived taste became weaker. The cathode in Case (A) and the anode in Case (B) were fixed at E-back, the position behind the neck, and the electrodes of the opposite polarity were set at E-right, E-forward, and E-left, as illustrated in the Figure 1. In both Case (A) and Case (B), there were three anode-cathode combinations, and each combination was randomly stimulated three times. The order of two cases were counterbalanced. After all trials were completed, participants completed an open-ended questionnaire.



(A) Electrode position (B) Devices

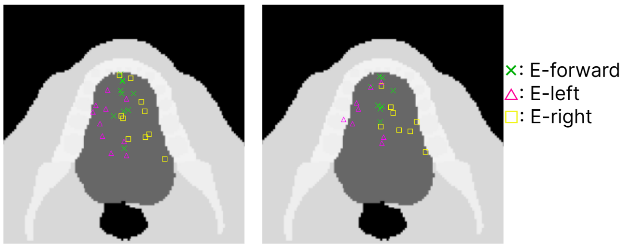
Figure 1: *Electrode position and the devices*

3. Results

Here, the participants were asked to draw the regions where the taste intensity changed and the maximum intensity point of the change. To clearly and shortly explain the discussion, only the maximum intensity regions of taste are presented in this paper.

In Case (A), anodes were placed around the tongue and stimulated to enhance the perceived saltiness. In total, 53% of all responses (57% for E-forward, 50% for E-left, and 53% for E-right anodes) responded that the saltiness became stronger and indicated the position where they felt the saltiness was enhanced. The positions of the most salty points in the drawn images were compared among the electrode conditions. In the left-right order, the Kruskal-Wallis test yielded $p = 2.3e-05$, rejecting the null hypothesis. The Steel-Dwass test results demonstrated that the null hypothesis was rejected for all electrode conditions: E-forward-E-left, E-forward-E-right, and E-left-E-right. In the forward-backward direction, the Kruskal-Wallis test yielded $p = 0.0039$, thereby rejecting the null hypothesis. The Steel-Dwass test rejected the null hypothesis between the E-forward-E-left and E-forward-E-right electrode conditions, while there was no significant difference between the E-right-E-left condition. In Case (A), the position at which the salty taste intensified differed depending on the electrode position, both in the left-right direction and in the front-back order.

In Case (B), the cathode was placed around the tongue to suppress perceived saltiness. In total, 22% (17% for E-forward, 27% for E-left, and 23% for E-right cathodes) responded that the saltiness became weaker, and the position where they felt the saltiness was suppressed was indicated. In the left-right direction, the Kruskal-Wallis test yielded $p = 1.4e-7$, thereby rejecting the null hypothesis. The Steel-Dwass test rejected the null hypothesis for all electrode conditions: E-forward-E-left, E-forward-E-right, and E-left-E-right. In the forward-backward direction, the Kruskal-Wallis test yielded $p = 0.014$, rejecting the null hypothesis. The Steel-Dwass test rejected the null hypothesis between the E-forward and E-right electrode conditions, whereas no significant difference exists between the E-forward-E-left and E-right-E-left conditions. In (B), the position of salty taste weakening differed depending on the electrode position in the left-right direction, but the difference was limited in the front-back order.



(A) The position where the saltiness was perceived to have **increased** the most.

(B) The position where the saltiness was perceived to have **decreased** the most.

Figure 2: *Point of most change in perceived saltiness (axial view of oral cavity)*

4. Discussion

In Case (A), there was a significant difference in the position where the taste sensation was most intensified in both the left-right and front-back directions. In Case (B), there was a significant difference in the position where the taste was weakened the most in the left-right direction. These results suggested the possibility of spatially selective control of salty taste intensity by altering the electrode arrangement.

However, the proportion of trials in which the participants perceived saltiness enhancement in Case (A) and saltiness suppression in Case (B) was relatively small. Participants commented that it was difficult to ascertain the overall impression of salty intensity because they felt both suppression and enhancement at the same time. There were also participants who only occasionally felt both enhancement and inhibition. Future challenges include estimating the optimal electrode placement based on electrophoretic simulation and devising an evaluation method for the intensity distribution when the sensations of salty enhancement and salty suppression are present simultaneously. By doing so, we aim to contribute to the presentation of taste changes that are close to the actual eating and drinking experience, and to the provision of a new taste experience in which the taste is perceived as it moves through the oral cavity.

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