Enhancing Saltiness with Cathodal Current

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Abstract
Weak cathodal current applied to the tongue inhibits the taste of salt, but perceived saltiness tends to increase after the current is released. In this study, we propose a saltiness enhancer that uses this phenomenon. Our system applies weak cathodal current for a short time when the user eats or drinks. The user can thus perceive a salty taste without the use of salt.

Author Keywords
Taste; Cathodal current; Gustatory perception

ACM Classification Keywords
H.5.m. Information interfaces and presentation: Miscellaneous.

Introduction

Figure 1. Fries can taste saltier without adding salt.

Salt is necessary for life. However, we often tend to consume too much salt, leading to high blood pressure and other conditions. Most people find it difficult to decrease salt intake. However, it may be possible to reduce salt intake by increasing the perceived saltiness of food.

In recent years, psychology researchers have discovered that cathodal current applied to the tongue affects our perception of saltiness. In 2009, Hettinger found that cathodal current selectively inhibits salty and bitter-salty tastes [1]. He also revealed that saltiness tends to recover and increase after the release of current. This is remarkable because electricity tends to only add a slight metallic taste.

Using this phenomenon, we can non-intrusively control the taste of food (Fig 2). We use this knowledge to develop a saltiness enhancer that includes components to detect the eating or drinking action and to apply cathodal current to the tongue. We conduct an experimental trial to verify the effectiveness of our system.

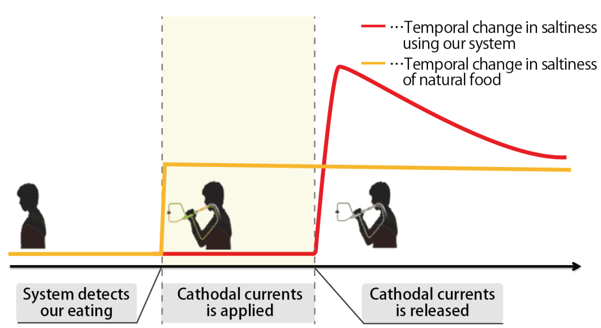


Figure 2. Saltiness expected by proposed system

Related work

Hettinger et.al examined the effects of cathodal current on the tongue [1]. They conducted human studies on the ion-specificity of cathodal inhibition of salts with salty, sour, bitter and sweet taste qualities, checking these taste qualities before, during, and after the application of current. Next, they investigated the effects of weak electric current applied through an ambient stimulating NaCl solution on the neural activity of the hamster chorda tympani nerve.

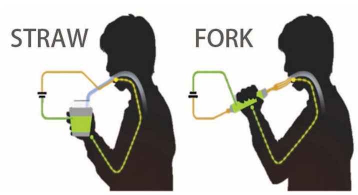
It was found that that the perception of saltiness was inhibited when current was applied. After the release of the current, flavor perception recovered and even increased. Electrophysiological experiments showed that inhibition of neural taste activity occured during cathodal current application in hamsters as in humans.

Many researchers have also distinguished the taste qualities of anodal and cathodal stimulus: anodal stimulus tends to feel salty, sour, and metallic, while cathodal stimulus tends to feel bitter [2]. In addition, some researchers have used this phenomenon to affect taste. Nakamura et al. devised systems to impart electric taste and proposed some applications [3], and Ranasinghee et al. proposed a system to control sourness and some tastes using electric current and temperature [4]. However, they did not focus on the effects of cathodal current.

System implementation

Detection system

We previously proposed a system that detects eating and drinking activities using electric taste adding apparatuses. Single-pole apparatuses have one electrode attached to the food and one electrode



Circuit of
Single-pole type apparatuses

attached to the subject’s body. The circuit is completed when the subject eats or drinks, allowing the detection of the activity and also of whether the taste has changed. The detection system monitors the voltage shifts in a circuit composed of battery and electric taste adding apparatuses (Fig 3). We use a voltage-dividing circuit whose output is fed into the AnalogIn port of the Arduino microcontroller. The user is deemed to be eating or drinking when this voltage exceeds a threshold. The threshold varies between individuals, and thus we require to calibrate the system.

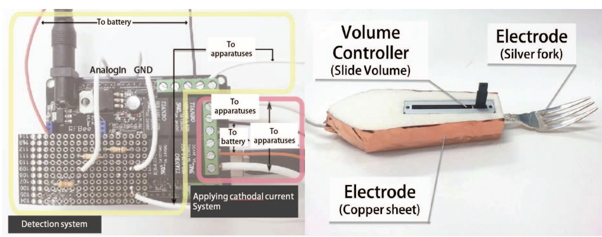


Figure 3. Proposed System

Applying cathodal current

This system applies cathodal current briefly when the user eats or drinks. The circuit uses a relay shield for Arduino (made by SeeedStudio) between the battery and the taste-adding apparatuses. When the detecting system detects eating or drinking, the relay is triggered and completes the circuit. Shortly afterwards, the relay switches back to the open state to turn off the current. The duration of cathodal current can be adjusted by the user. The detecting system can malfunction if it detects the voltage applied by the cathodal current system. Hence, we deactivate the detecting system while cathodal current is applied, putting a relay into the line between detection system and battery.

We made the apparatuses look like eating utensils (cups and forks) for greater acceptability. For safety, the electrode in contact with the food and drink a silver fork and silver pole and the side of electrode attached to the body surface uses a copper foil sheet. These apparatuses have a potentiometer to control output voltage individually. We can use a DC battery, waveform output system (post-amplifier), and polarity reversion circuit to control the output voltage and pattern without a potentiometer.

Experimental trial

We designed an experimental trial for testing the effectiveness of our system. We investigated whether the subject could feel the differences in taste during the application and release of cathodal current. We also investigated whether the subject could taste increased saltiness after the release of cathodal current. We conducted this experiment with 14 subjects (13 males, ranging in age between 21 and 25), who had given prior consent for electric stimulus. Before the subjects began the trial, they drank water to clean their palates.

Experimental design

Calibration trial (about 3 times): we activated only the detecting system in order to ensure that participants did not perceive effects associated with the main trial (maximum voltage was 1.5V, 40μA). We gave the subject a fork with food on it, and instructed him to bring the food into contact with his tongue. The food and tongue were in contact for 6 seconds. We also conducted a 2^{nd} and 3^{rd} trial to verify that participants did not feel any change in taste.

Main trial (3 times): we gave the subject a fork with food on it, and instructed him to bring the food into contact with his tongue. During contact (6 seconds), the system applied cathodal current for the first 3 seconds (maximum voltage was about -5.1V, 250μA). After that, the system released the cathodal current and emitted a beep. Participants removed the food 3 seconds after the beep.

After each trial, we asked the subject if he could perceive any change of taste when the food was in contact with the tongue. If he did, we asked when the taste and saltiness felt stronger. We also asked about the features of taste verbally as a free answer question. After main trial, we enlightened participants attached food with fork, without applying cathodal current. We asked which taste was stronger, the taste after the release of cathodal current or the food’s natural taste.

Results

natural<after current was released	10
natural=after current was released	1
natural>after current was released	3

Table 1. Comparison of taste intensity between natural and proposed systems

Participants could perceive a difference in taste in 39 trials (92.9%). 11 participants could perceive the difference every time, and 3 participants could perceive it 2 times. In all of the trials where they perceived the difference, they felt that the taste after the release of current was stronger and saltier than that during the application of current. Furthermore, 10 participants felt that the taste after the release of current was stronger than the natural taste of the food (Table 1).
In the free answer, 7 participants commented on the saltiness of the food. 1 participant felt that the saltiness resembled that of Japanese pepper. Furthermore, 2 participants felt a difference in texture, and 1 participant each felt a difference in sourness and in temperature between during and after current was released. In addition, 1 participant said that the taste became stronger after the current was released, and decreased in intensity with time. Furthermore, 3 participants commented that the 2nd and 3rd trial gave a more natural flavor than the 1st trial.

Discussion

We found that we can control the perception of saltiness. Every participant felt a difference in taste between the current-on and current-off states at least twice, and 11 participants felt these differences every time. In addition, in 88.0% of trials, they felt that the saltiness of foods increased after the release of the current compared to during the application of current. Furthermore, 10 participants felt that the saltiness of foods after current was released was stronger than its natural taste. This result implies that we can avoid adding salt when we feel foods are under-salted.

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