Controlling Temporal Change of a Beverage's Taste Using Electrical Stimulation

Saraha Ueno
Meiji University
Nakano, Tokyo, Japan
cs182011@meiji.ac.jp

Kazuma Aoyama
The University of Tokyo
Tokyo, Japan
aoyama@cyber.t.utokyo.ac.jp

Hiromi Nakamura
Meiji University
Nakano, Tokyo, Japan
hirominakamura.b@gmail.com

Homei Miyashita
Meiji University
Nakano, Tokyo, Japan
homei@homei.com

ABSTRACT

In this paper, we discuss concepts for improving beverage experience using electrical stimulation in terms of the requirements for the procedure (design space), previous study (completion), and limitations of conventional technologies. To improve beverage experience, electrical stimulation has been indicated as a method for changing a beverage's taste. However, the taste of a beverage changes temporally—a beverage's taste during drinking is different from its taste after swallowing. There are methods of evaluating the taste of a beverage based on time-series, such as the Time-Intensity (TI) method and the Temporal Dominance of Sensations (TDS) method. Therefore, it is important to focus on the temporal change in a beverage's taste for improving the beverage experience. Thus, we focused on the taste before and after swallowing as a first step. Based on

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this review, we propose the concept of controlling the temporal change of a beverage's taste using electrical stimulation.

CCS CONCEPTS

• **Applied computing** → **Health care information systems**; • **Human-centered computing** → *Human computer interaction (HCI)*.

KEYWORDS

Beverage Experience; Temporal Change of Beverage; Electrical Stimulation; Electric Taste.

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INTRODUCTION

Beverages are indispensable for not only physical but also mental health of human beings. To improve beverage experience, it is necessary to make a beverage's taste satisfying. Although adding chemicals to enhance taste to the drinks is one solution, one risk involved is that it undermines physical health because of the overuse of these substances (e.g. sweeteners). Several studies have proposed electrical stimulation of the tongue or inner mouth as a method to improve the taste of beverages [1, 6, 8]. Since this method has a short time response and its effect is reversible, it can modulate and induce taste sensation with the simple application of electrical stimulation.

However, the taste of a beverage changes temporally. There are two important parts of taste in the beverage experience; the taste of the beverage before swallowing and the aftertaste which is experienced after swallowing. It is said that beverages with an unpleasant aftertaste tend to be avoided [4]. In addition, there are also methods for evaluating the taste of a beverage based on time-series such as the Time-Intensity (TI) method [5] and the Temporal Dominance of Sensations (TDS) method [7]. TI and TDS methodology starts by recording the change in the intensity of a given sensory attribute over time and recording the sensory attributes that are perceived as the most striking perception at a given time. By recording this data, a graph (TI curve and TDS curve) can be plotted with intensity and dominance rate as the vertical axis and time as the horizontal axis.

For these reasons, we believe that it is important to focus on the temporal change of a beverage's taste in order to achieve an appealing beverage experience. Thus, in this paper, we propose the first concept for controlling temporal change of a beverage's taste by using electrical stimulation.

Electrical stimulation is a suitable approach for focusing on temporal change because this method can affect taste immediately and its effect is reversible, as mentioned previously. In this paper, we are focusing on the effect of electric stimulation on taste by inducing and modulating taste sensory perception before and after swallowing separately.

Before proposing the concept, we reviewed the conventional studies for electrical stimulation to induce and modulate the taste sensation in each sequence of the beverage experience; before and after swallowing. Then, we explained what should be done for the approach to improve the overall beverage experience in the Design Space. In the "Completion" section, we have described our observations and the additional problems that exist with using electrical stimulation (Limitations). Based on this review, we propose the initial concept of controlling temporal change of a beverage's taste using electrical stimulation.

A REVIEW OF THE TASTE BEFORE AND AFTER SWALLOWING

Before Swallowing

Design Space. The taste of a beverage before swallowing is the taste that is perceived by the tongue in the inner mouth. It is necessary to both enhance and inhibit all the five basic taste sensations (sweetness, bitterness, saltiness, sourness, and umami) of the beverage. Although not included in the five basic taste groups, it is rational to enhance and induce hot and spicy sensations of a beverage's taste as well.

Completion. Previous methods of electrical stimulation involved using a cathodal electrode that gets attached near the tongue to enhance and inhibit the taste of a beverage. Hettinger et al. demonstrated that such an electrical stimulation can inhibit the salty and bitter-salty tastes induced by a solution [3]. They also found that this method enhanced the taste, bitter-saltier, after the cathodal current was released than before and during the stimulation. We established that the mechanism of the taste suppression is due to ion migration and we demonstrated that all five basic tastes that were induced by the electrolyte water solution were inhibited [2]. Furthermore, we developed the continuous square current stimulation which can enhance taste during the stimulation [1]. We used a cathodal electrode attached in a straw or the inner side of a cup, and anodal electrodes at the surface of the cup, forehead, or at the back of the neck to obtain these effects [1, 3, 6]. Although this electrode arrangement can stimulate during the natural drinking process, users were required to touch the tableware during a beverage experience. Therefore, we invented the stimulation method without attaching the electrodes to the inner mouth [1]. This stimulation is called galvanic chin stimulation and uses cathodal electrodes attached on the chin.

Figure 1: The method for enhancing the intensity and extending the duration of the aftertaste in the throat

Figure 2: We provided an exhibit at a Japanese domestic conference

Limitation. The taste suppression has no effect for non-electrolyte solutions such as sucrose, because ionic migration does not occur [2]. Therefore, we should further explore methods for changing the taste induced by non-electrolyte molecules. Furthermore, no method has been found to induce and modify the hot and spicy sensations, and further research to explore this issue should be done. Sometimes electrical stimulation can cause painful sensations; this may be useful for reproducing pungent hot and spicy sensations.

After Swallowing

Design Space. In terms of the taste after swallowing, enhancing and inhibiting the aftertaste of a beverage is required. The intensity of aftertaste is one of the most important elements in a beverage experience, especially one involving full-bodied coffee and wine, which consists of multiple taste qualities. In these cases, sometimes it is necessary to enhance not only the pleasant tastes such as sweetness but also the unpleasant tastes such as bitterness. Similarly, it may be required to inhibit pleasant tastes in order to cleanse the taste of a beverage. For example, we can change the taste of wines from light-bodied to full-bodied. Since not only the intensity but also the duration of aftertaste would be important, it is necessary to extend and shorten the duration of the experience. The important aspects of modulating the taste of a beverage involve not only modifying the intensity of the aftertaste, but also reducing the duration of the aftertaste. Although the beverage has already been removed from the mouth after swallowing, we can induce taste in order to prolong the sensation of the taste.

Completion. There have been no techniques proposed in this field to modulate aftertaste without involving chemical materials. However, we invented a novel method to enhance the intensity and extend the duration of the aftertaste in the throat. In this method, the anodal electrode is attached on the inferior part of the chin and cathodal electrode is attached to the back of the neck (see Figure 1). We demonstrated the effect in an experiment using commercially available beverages and exhibited this method at a Japanese domestic conference (see Figure 2). At the exhibition, 44 participants were tested and approximately 30 of them responded positively to the experience. In addition, our method can control sweetness, which has been challenging previously.

Limitation. Although we can enhance and extend aftertaste, we still have not been able to inhibit or reduce its duration. We need to investigate the mechanisms controlling aftertaste sensations both to enhance and prolong, and to inhibit and shorten the duration of the aftertaste.

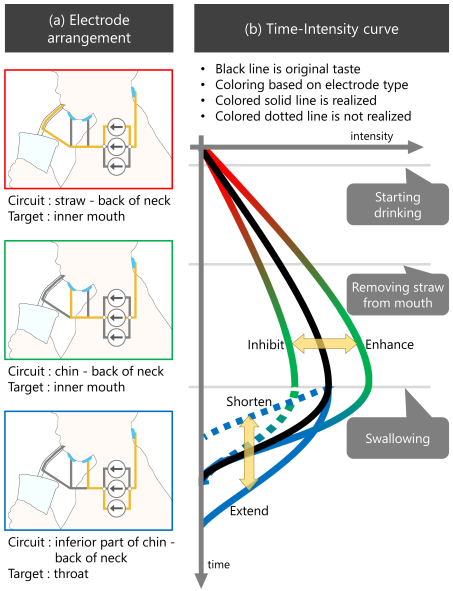

Figure 3: How we can control temporal change of taste using electrode arrangement. (a) Electrode arrangement (b) Time-intensity curve

THE INITIAL CONCEPT FOR CONTROLLING THE TEMPORAL PATTERN OF THE TASTE OF A BEVERAGE USING ELECTRICAL STIMULATION

Following overall review of taste before and after swallowing, we proposed the initial concept for controlling the temporal pattern of the taste of a beverage using electrical stimulation.

As described above, electrode positions are mainly classified into three types in conventional technologies (i.e., the straw, the chin, and the inferior part of the chin). The benefit of the straw electrode method is that the straw can be stimulated during the natural drinking process. Additionally, the chin electrode method is an effective location for stimulation while the taste is in the mouth, and the inferior part of the chin method can be used to enhance and extend the aftertaste in throat.

Incorporating all of these benefits, we propose the electrode arrangement that is shown in Figure 3 (a) which has four electrodes (i.e., in the straw, on the chin, on the inferior part of the chin, and on the back of the neck) and three bipolar constant electrical stimulation circuits (i.e., straw - back of neck, chin - back of neck, inferior part of chin - back of neck). Figure 3 (b) shows how we can control the original taste (black line) with our method using electrodes, i.e., the straw (red), the chin (green), inferior part of the chin (blue). When the drink is sucked into the mouth, the stimulation using straw modifies taste immediately. The stimulation electrodes position can also control the aftertaste by using the electrode at the inferior part of the chin and at the back of the neck after swallowing.

In addition, by using three independent circuits, the system can not only switch stimulation between the electrodes, but also crossfade between them, providing the participant with a smoother transition between sensations (represented in the gradation of each color). In the previous section, we focused on the taste before and after swallowing, but taste is complex and can gradually change over time from the first impression when the subject begins drinking through the aftertaste.

We also can measure impedance in the inner mouth by voltage and current measurement with a weak stimulation because the constant current circuits are used for the system, implying that it is assumed that we are able to estimate where the beverage is located. By combining these functions, we can control the sensation of taste beginning immediately when the participant starts drinking and continuously until the aftertaste after swallowing with only electrical stimulation circuits.

By using all the circuits, the system can be an effective approach for improving the beverage experience. When each element is complete, we will establish and evaluate the overall system.

CONCLUSION

In this paper, we focused on the taste of a beverage before and after swallowing, by reviewing each portion of the sensory experience during beverage consumption and have realized the limitations

of conventional technologies for this analysis. Based on our overall review, we propose the initial concept of controlling the temporal change of taste using electrical stimulation. Our concept uses four electrodes and three bipolar electrical circuits to control taste based on time-series by switching and cross-fading these electrodes.

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