Development and Evaluation of Interactive System for Synchronizing Electric Taste and Visual Content

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ABSTRACT
Electric taste is a characteristic taste produced when the tongue is electrically stimulated. We have proposed apparatuses to add electric taste to food and drink. An interactive system could be developed to synchronize video contents using the reversibility and instantaneity of electric taste. However, to do so, the presentation time must be determined based on the different latency for the perception of each sense. We measured the latencies for electric taste and visual stimuli as a basic evaluation for a content presentation system in which electric taste and visual content are synchronized.

Author Keywords
Electric taste, gustatory presentation system, multimodal information system, latency difference of several sensations

ACM Classification Keywords
H.5.1 Multimedia Information Systems

General Terms
Design, Experimentation, Human Factors

INTRODUCTION
Humans perceive external stimuli through five senses: sight, hearing, smell, taste, and touch. Some sensory information can produce actions and feelings as a response. Many studies have proposed applications of multimodal information presentation for producing more realistic sensations and entertainment; some have proposed applications that use one of the five senses for more realistic sensation. However, whereas many applications use vision and audition, few use olfaction and gustation. This is because whereas the former senses require a physical structure, the acceptor reactions of the latter occur in response to chemical signals. Gustation, in particular, is attributed to taste buds located on top of the tongue. Treating gustatory information requires solutions to many complex problems. Chief among these is the fact that most foods and drinks are irreversible, that is, additives, once added, are very difficult to remove. Therefore, foods and drinks must be made anew to undo their taste. Some studies overcame this problem by using pseudo sensations and dietary environments; however, they only changed the feeling of taste, and not the taste itself. Furthermore, the sensing and detecting mechanisms involved were complicated.

In a recent study, we used electric taste to study the problem of irreversible change [6]. Humans perceive electric stimuli as a characteristic electric taste, which is used in gustatory testing. This taste is irreversible and is perceived immediately when the stimulus exceeds a certain threshold. Therefore, the addition of some electric stimulus in foods and drinks would constitute new and additional information, that is, an electric taste, that has not been perceived before and that can present reversibly and instantly. We can control this information using a simple electric circuit. Additionally, by detecting whether an electric circuit is completed, we can not only detect whether we eat or drink but also whether the taste has been changed. We can thus realize an interactive system triggered by our eating and drinking. The reversible change allows us to control our gustatory perception based on human–computer interactions. In addition, it may augment realistic sensations if utilized as an entertainment system in conjunction with other senses such as vision or audition.

In this study, we propose some apparatuses for adding electric stimuli to foods and drinks and introduce a method for using these apparatuses. We conducted an experiment to measure the latency between presentation and perception using visual and electric taste stimuli. We also analyzed the difference in perception and discussed a multimodal system using this method. Finally, we have discussed future possibilities arising from this study.

ELECTRIC TASTE APPARATUSES
We developed apparatuses that create circuits comprising some foods/drinks, metal cutleries, and our body and

tongue in order to add new gustatory information to food and drink based on electric taste. We have already proposed the polar opposite circuit [6], and we newly propose the single-pole circuit. Herein, we introduce these apparatuses.

When we eat and drink using these apparatuses, by presenting electric taste through food and drink, we get a greater impression of metallic, sour, or salty taste. This is consistent with findings of many previous studies that investigated electric taste using electrogustometry (directly touching an electrode on the tongue). Whether the change in taste change is considered positive depends on the food and drink.

Apparatuses for adding electric taste to drink

The apparatus for changing the taste of drink consists of a cup/bottle, electric circuit to present electric stimuli, and 1–2 straws to add stimuli to the drink. Stimuli are presented through a polar opposite or single-pole type circuit.

Polar opposite circuit for drink

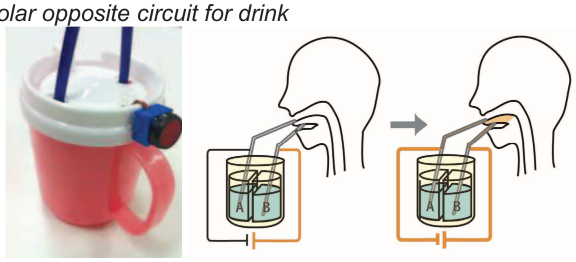

Figure 1. Polar opposite circuit to add electric taste to drink

This circuit consists of cup (separated from each other by smaller cups) and straws and a conducting wire. First, the user pours drinks into cups separately. Next, s/he inserts a negative electrode into one straw and a positive electrode into another (Figure 1). The circuit is switched on and off using the switch on the bottom.

Single-pole circuit for drink

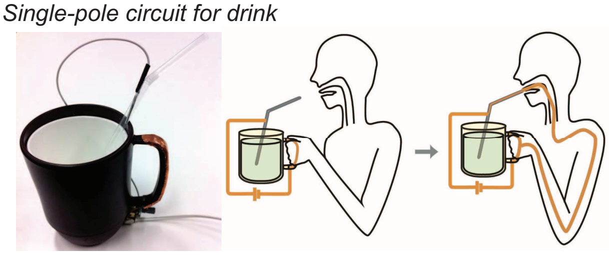

Figure 2. Single-pole circuit to add electric taste to drink

This circuit utilizes the human body as a part of the circuit. Hence, we use a cup/bottle and two electrodes—one in contact with the body and the other with the straw (Figure 2). We can drink the beverage with electric taste using the straw when we touch one electrode. To do so, a wristband can be attached to the skin surface; attaching a copper foil seat on the grip of the cup/bottle is easier. This apparatus includes a miniature potentiometer for voltage adjustment.

Apparatuses for adding electric taste to food

The apparatus for changing the taste of food consists of metal cutlery through which electric stimuli are presented using one of the two circuits mentioned above.

Polar opposite circuit for food

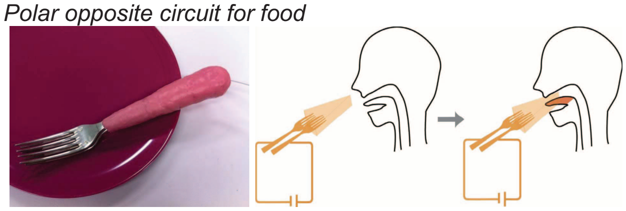

Figure 3. Polar opposite circuit to add electric taste to food

This circuit consists of a conducting wire and two metal cutleries, say, two forks, one of which is connected to the positive electrode and the other to the negative electrode (Figure 3). The right and left tines of the fork are connected to the negative and positive electrodes, respectively. The user has to break the connection between the two tines.

Single-pole circuit for food

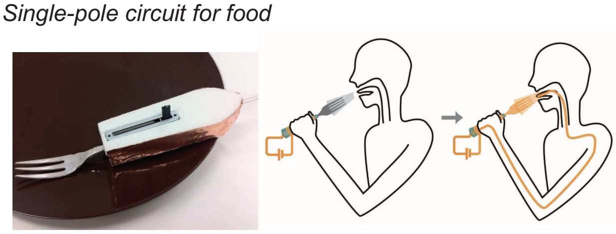

Figure 4. Single-pole circuit to add electric taste to food

This circuit, too, utilizes the human body as a part of the circuit. One electrode is connected to our body using copper foil and the other is connected to metal cutlery (Figure 4). We can eat the food with electric taste using the metal cutlery when we touch one electrode. This apparatus, too, includes a miniature potentiometer.

Method for presenting electric stimulus

These apparatuses use two 9V batteries to present electric taste. However, batteries provide a flat sensation of electric stimulus because they use direct current. Therefore, we tried other electric stimuli such as a pulsating voltage or one with time series variations (such as an auditory signal) to change the taste and we found that it produces greater and noticeable variation in taste. Such voltages are amplified and outputted using an amp. Our preliminary investigation suggested that most subjects could distinguish the difference in frequency with such signals. For example, one subject described coarse and keen feelings at lower and higher registers, respectively. There were individual variations in how subjects felt depending on the type of signal. Nevertheless, saw tooth waves were commonly considered harsh, and noise felt harsher than a saw tooth wave.

EXPERIMENTS

Mutually synchronized multimodal media provide a wholesome feeling, and it would be beneficial for content such as games and visual content to be more realistic and expressive. However, the latency time between presentation and perception depend on the organ and sensation.

We should measure these latencies and adjust them to realize effective multimodal presentation. Some studies have already done so; for example, Kim et al. developed the Aroma-Chip based Olfactory Display and measured the latency between the start (end) of diffusion and the start (end) of perception [3]. Similarly, we measured the latency of visual and electric taste stimuli and analyzed the perceptual traits of electric taste using our apparatuses.

Experimental method

We used the color change of a rectangle to measure visual stimulus latency and the gustatory change with DC and varying voltage to measure electric taste stimulus latency.

For the latter, we used the polar opposite drink apparatus. Subjects could indicate when they perceived a stimulus using a switch. Before starting the experiment, we allowed the nine subjects (excluding the experimenter) to familiarize themselves with our apparatus (the time required depended on the subjects). This method required subjects to keep drinking before we presented the electric taste stimulus, and we informed them about how long they had to drink before we added the stimulus.

The experimental program was developed using Max/MSP. We measured 14 visual stimuli followed by 14 gustatory ones. Subjects were previously informed of which stimulus would be presented first. We repeated each experiment 14 times but excluded the top and bottom two results because subjects occasionally could not perceive the electric taste stimulus. Voltages of 0.3–0.5 V were presented, and all subjects could perceive this electric stimulus as electric taste. When we measured the latency of visual/electric taste stimulus, we verified whether the stimuli were felt by subjects on a separate display monitor. Subjects were asked to report if they did not feel any stimulus.

Results

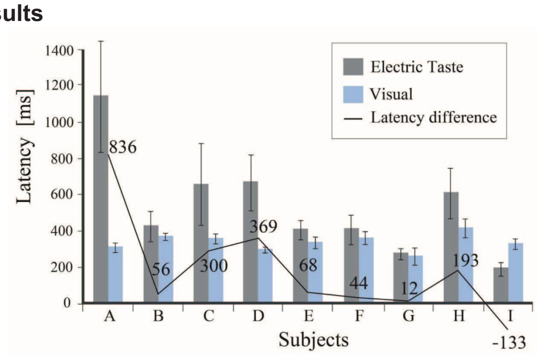

Figure 6. Average latency during perception stimulus change

For most subjects, the latency for electric taste stimulus was greater than that for visual stimulus. The difference between latencies ranged from 13 to 837 ms (Figure 6). Only one subject perceived electric taste stimulus before visual stimulus, with the difference between latencies being 134 ms; this subject's visual perception was not anomalous, with the latency for visual stimulus agreeing with that of other subjects.

DISCUSSION

Our results show that if visual and electric taste stimuli are presented simultaneously, most people perceive the latter last. However, the subjects showed greatly varying electric taste stimulus latencies, and only one perceived the latter first. Therefore, we should adjust the presentation time of each stimulus according to each subject's perception latency. However, for subjects B, E, F, and G, the difference between latencies was small, so we did not adjust the presentation times if the visual and electric taste stimuli were presented realistically. Toward this end, we performed comparative experiments and adjusted the presentation times using examples from our experiments. We used very simple changes in stimuli because we needed to measure the ordinary change in each stimulus. We intend to perform comparative experiments using more complex stimuli in order to utilize our system to enjoy games and visual contents more richly.

In this experiment we required subjects to keep drinking before we presented the electric stimulus. However, such a compulsion might cause users some mental stress and reduce the entertainment derived from content. We considered this method impractical for lengthy content and variable use. Therefore, we proposed a method for detecting whether the electric circuit is complete. We added a circuit and program for measuring the voltage change. In addition, we added a very low voltage that cannot be perceived as taste in order to measure whether the user drinks, based on the voltage change. This method can also be applied to control the presentation time of other senses by checking the latency of each sense and adjusting the time. This enables multi-synchronized presentation using electric taste and other sensations.

A limitation of our work is that the electric taste is currently limited to metallic, sour, and salty tastes. Therefore, we should carefully select the foods used.

In future work, we will conduct experiments on the latency of haptic, olfactory, and auditory senses in conjunction with the gustatory sense. This will enable richer and varied experiences when enjoying entertainment content.

RECENT WORK

Many studies have focused on the structure of taste. The perception of and reaction to taste is generally attributed to taste buds located on top of the tongue. Mouth orifice side cells perceive a chemical agent and depolarize to generate a potential. This potential is delivered from the bottom side cells to the gustatory nerve. Depolarization is attributed to direct ion influx into cells, interface potential difference between sapid substances and the tongue surface, and receptor attachment due to a reaction with sapid and protein substances [10].

Electric taste was discovered by Sulzer in 1754 when he placed two different metals on his tongue. Volta later hypothesized that this taste was attributable to an electric stimulus flowing from one metal to the other metal through taste sensors on the tongue [9]. Many studies analyzed the quality of electric taste and its thresholds. Tomiyama et al. reported that the threshold increased with age, and they reported no significant variation with bilateral differences, sexual differences, smoking history, artificial dentition, and dental metallic crowns. They reported that the most commonly perceived tastes were, in order, metallic and salty and sour tastes, and that humans can perceive AC stimuli [11]. Another study reported that the quality of metallic taste using AC stimuli is stronger than that of copper pennies [5]. One study determined the condition of taste buds using electric taste in a gustatory test [8]. BrainPort, a tongue output system, was proposed to convert visual images to strengthen electric stimuli and provide an output to the tongue [1]. This system enables a visual image to be seen based on the strength of the electric stimulus. It can also be used in evaluation experiments to support surgery [12]. In these studies, an electrode was directly attached to the tongue to present electric taste; in contrast, we add electric taste to food and drink.

Some studies reported that other senses and dietary environment affect gustatory perception. Therefore, Toko et al. presented a chart affected to build daintiness. Olfaction and texture are considered essential to gustation, whereas vision and audition have lesser influence. Therefore, tastes can be changed through pseudo sensations such as a sense of vision or smell. Narumi et al. proposed Meta Cookie, a method to change taste using augmented reality (AR) and scent [7]. This system changes the perceived taste of a cookie based on cross-modal effects evoked by overlaying visual information (texture) and scent onto a real cookie using an AR marker. Food Simulator [2] and ChewingJockey [4] were proposed to add food textures using haptic or auditory information. The former uses a haptic and sound interface to apply pressure to the tongue and produces a biting sound to enhance virtual taste. The latter measures biting using a photo reflector and presents a filtered and designed sound effect through a bone-conduction speaker. Our work presents taste directly, allowing us to use other perceptions for multimodal and unrealistic expressions.

Some studies described how humans visualize feelings of taste and quantity of taste. Flavor visualization is a co-cooking interface system that presents unique tastes through graphical information. Electric taste can be visualized easily because we can manipulate it using electrical circuits and a computer. However, the quality of taste depends on each individual, and therefore, we should design the system to represent a subjective taste.

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