Virtual Sweet: Simulating Sweet Sensation Using Thermal Stimulation on the Tip of the Tongue

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ABSTRACT
Being a pleasurable sensation, sweetness is recognized as the most preferred sensation among the five primary taste sensations. In this paper, we present a novel method to virtually simulate the sensation of sweetness by applying thermal stimulation to the tip of the human tongue. To digitally simulate the sensation of sweetness, the system delivers rapid heating and cooling stimuli to the tongue via a 2x2 grid of Peltier elements. To achieve distinct, controlled, and synchronized temperature variations in the stimuli, a control module is used to regulate each of the Peltier elements. Results from our preliminary experiments suggest that the participants were able to perceive mild sweetness on the tip of their tongue while using the proposed system.

CCS Concepts
•Human-centered computing → Interaction paradigms; Mixed / augmented reality; Interaction devices;

Author Keywords
Thermal taste; virtual sweet; sweet; virtual reality; multimodal interaction

INTRODUCTION
Sweetness, one of the five basic taste sensations, is typically produced by sugar dissolving on the tongue. However, excess consumption of sugar and sugar-based foods or beverages can have a detrimental effect on a human's health and lead to major health concerns, including obesity and diabetes [2]. By virtually simulating the sensation of sweetness, we will be able to introduce the sensation as a digitally controllable media and augment real-world flavors by virtually overlaying the simulated sweetness while users consume food and beverages. For example, having a similar system embedded on a personal glass or mug will enable a user to consume beverages with a lowered sugar content whilst maintaining the same sweet palatability of similar products with higher sugar content.

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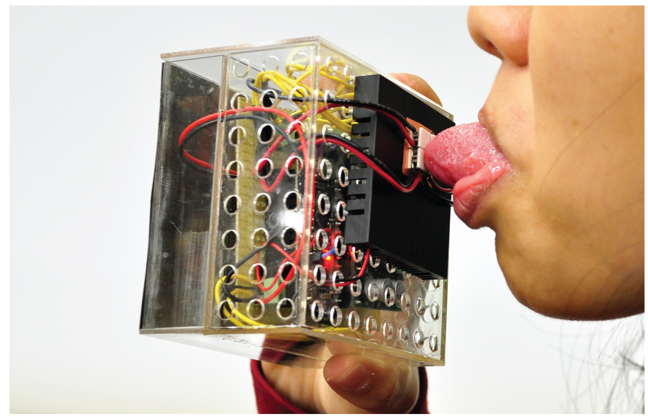

Figure 1. A participant places the tip of the tongue in the middle portion of the Peltier grid to simulate virtual sweetness.

As a solution, we have developed a digital instrument to simulate sweetness on the tongue. The proposed method is built on existing research that has highlighted the possibility of generating taste sensations by heating and cooling the human tongue [1, 3, 4]. Prior work has shown that controlled thermal stimulation not only simulates sweetness, but also enhances the perception of sweetness on the tongue due to the activation of TRPM5 ion channels, which have a key role in triggering the human perception of sweetness [1, 4]. This phenomenon will enable consumption of reduced sugar food and beverages while maintaining their palatability. Ranasinghe et al. have developed a control system to study the effects of thermal stimulation on the tongue with a single Peltier element. They have recorded evidence of simulated sour, minty, spicy, and sweet sensations when the temperature of applied thermal stimuli is changed during continuous heating and cooling [3].

The work presented in this paper explores the effects and perceptions of synchronous and simultaneous thermal stimuli on the tongue with a 2x2 grid of Peltier elements. Thus, the novelty of this work is the simultaneous utilization of two different thermal stimuli (synchronized heating and cooling) on the tongue. Figure 1 shows a participant interacting with the system by placing the tip of the tongue on the 2x2 grid Peltier elements.

METHOD
The virtual sweet instrument has three main submodules for power, control, and the output of stimuli. A 9V battery is used

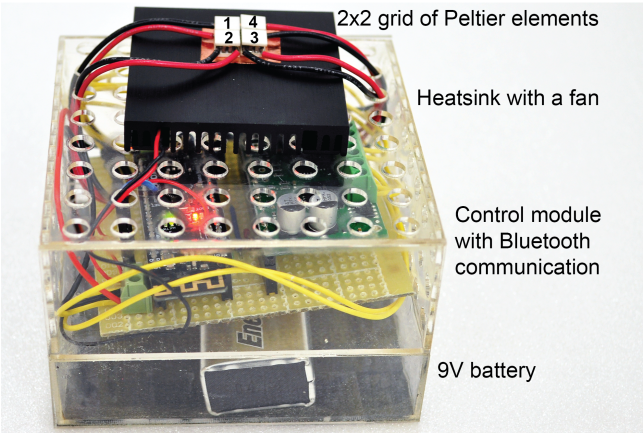

Figure 2. Different components of the Virtual Sweet instrument.

as the power source and a control system has been developed to manage the thermal stimuli. A dual channel DC motor driver, based on full H-bridge configuration, is used to control the flow of current through the Peltier elements. The technique of Pulse-Width Modulation (PWM) is then used to control the time required to achieve a distinct temperature change. By utilizing this method, the instrument is calibrated to achieve a 5°C degree of change within approximately 4 seconds.

To stimulate the tip of the tongue, a 2x2 grid of Peltier elements, each individually mounted on a heatsink, is used to achieve efficient and accurate temperature control. The dimensions of each Peltier element are 6mm x 6mm. This setup is shown in Figure 2, and as labeled on the Peltier elements, simultaneous thermal stimuli are applied as 1) heating, 2) cooling, 3) heating, and 4) cooling on different Peltier elements.

EXPERIMENTAL RESULTS

A preliminary experiment has been conducted with 15 participants (8 males and 7 females with an average age of 24) to explore the effectiveness of this approach, with a focus on the use of simultaneous thermal stimuli. The experiments were performed in a dark and quiet room that had a temperature that was constantly maintained at 20°C. The thermal stimuli are controlled within 20°C - 35°C and continuously fluctuate between these minimum and maximum boundaries. Participants were asked to place the tip of their tongue in the middle portion of the Peltier grid. Each participant was provided with three sessions and each session had three cycles of 20°C-35°C-20°C and 35°C-20°C-35°C stimuli. In between each session, participants were given a 5 minutes resting period; also providing time to correctly reset the temperature of the Peltier elements and the control system in order to provide accurate control of thermal stimuli. To obtain feedback after each session, participants were asked to report their perceived level of sweetness intensity on a 5-point rating-scale of: barely detectable, mild, medium, strong, and very strong. Only the feedback after the final session for each participant was recorded as their final perception.

Preliminary results indicate that, although some of the participants perceive the sweet sensation (53% - 8 out of 15), the intensity of the simulated sweetness was only at mild or barely detectable levels. Feedback also highlighted that some participants did not consistently experience singularly distinctive taste sensations but, instead, perceived mixtures of sensations such as sweet and minty. These results indicate the need for further sets of controlled experiments. We also observed several limitations: 1) manually aligning the placement of the tongue in the middle of the Peltier grid, 2) absorption of heat by the human tongue during the stimulation, which leads to poor performance, and 3) salivation due to the tongue is in contact with the instrument out of the mouth for an extended period. In addition to these points, due to the subjective nature of the sense of taste and sensory adaptation to stimuli, the presence of different sensory phenomena must be considered and tackled through the individual calibration of the instrument for every single user.

DEMO EXPERIENCE

During the interactive demonstration, users will experience the aforementioned virtual simulation of the sensation of sweetness on the tongue. Also, they may select different combinations of thermal stimuli, for example, contrasting thermal stimuli vs. similar stimuli (synchronized heating and cooling vs. separated heating and/or cooling) and different speeds of heating and cooling. With regards to hygiene considerations within the demonstration, we will use two different modules and clean the Peltier elements using alcohol swabs and deionizedăwater before each new trial.

CONCLUSION

In summary, this work demonstrates a novel instrumentation for providing controllable virtual sweet sensations that may be incorporated into interactive computer systems. Here, thermal stimulation is used to simulate sweetness, and employs synchronous heating and cooling of the tongue, via a 2x2 grid of Peltier elements.

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