Thermal Sweet Taste Machine for Multisensory Internet

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ABSTRACT

This paper presents a new taste interface for multisensory communication called "Thermal Sweet Taste Machine". We developed this interface in order to create sweet sensations, by manipulating the temperature on the tongue, without using chemicals. This device device changes the temperature on the surface of the tongue (from 20°C to 40°C) within a short period of time using a computer controlled circuit. Our preliminary user studies suggested that this device would be effective in two ways; producing the sweet sensations without the aid of chemicals, and enhancing the sweetness of the food and drinks. Here we discuss our concept, development of the interface, and some preliminary studies that has been carried out. We believe our technology would enhance the experiences and capabilities in future multisensory communication in different disciplines such as Human-Computer Interaction, human robot interactions, gaming and interacting with artificial agents.

ACM Classification Keywords

H.5.m. Information Interfaces and Presentation (e.g. HCI): Miscellaneous; See http://acm.org/about/class/1998/ for the full list of ACM classifiers. This section is required.

Author Keywords

Thermal Sweet Taste Machine; Multisensory Communication; Digital Taste; HCI; TRPM5.

INTRODUCTION

The five most fundamental tastes are sweet, sour, bitter, salty and umami (savory). Probably sweet taste is the most pleasant out of all the basic tastes [2]. Considering about the multisensory communication, sensing and actuating sweet taste digitally is an extremely important requirement. Once we reached that goal, people will be able to experience the sweetness digitally through the internet (as illustrated in Figure 1) like we experience text, audio and visuals in our daily life.

The early sweet taste taste interfaces developed in the field of Human-Computer Interaction primarily used chemicals to generate sweet sensations [4, 5, 10]. However, some previous studies suggested that by rising the temperature on the tongue within few seconds resulted sweet sensations without chemicals [3] and enhance the sensitivity for sweetness [9]. Using this concept, we have developed a computer controllable user interface that can change the temperature of the surface of the tongue rapidly within safe margins and produce sweet sensations without using chemicals.

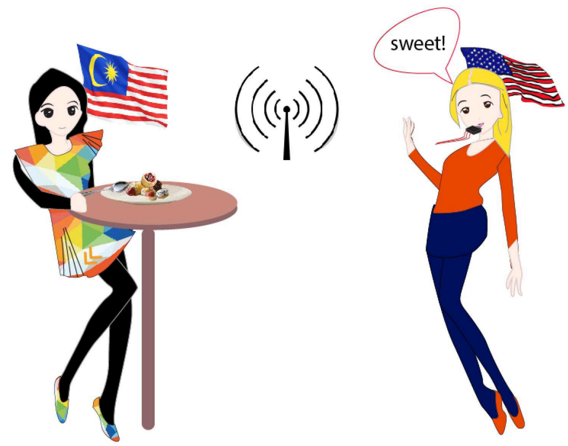

Figure 1. Concept image of people that are able to communicate and experience sensations digitally

RELATED WORKS

The "Thermal stimulation of taste" [3] experiment has first showed that heating the tip of the tongue from a cold temperature resulted phantom sweet taste sensations. The temperature limits used for the experiment was from 20°C to 35°C and varied at approximately at 1.5°C/s using a Peltier module. This research has discussed the concept of 'Thermal Tasters', the kind of people who can perceive different tastes by stimulating their tongue with temperature.

According to the study conducted by Talavera et al. [9], increasing the temperature resulted in activation of TRPM 5 channel (which triggers for sweet, umami and bitter tastes) that generates a depolarizing potential in the taste receptor cells. This effect causes both the enhancement of sweetness perception at high temperatures and the 'thermal taste' (the phenomenon whereby heating or cooling of the tongue evoke sensations of taste in the absence of chemical tastants).

As above mentioned papers, in medicine and neuroscience fields, the thermal effect with TRPM 5 channel has well studied and discussed. However, in HCI, still there is no user interface that can effectively reproduce sweet sensations on tongue digitally. The "Digitally Stimulating the Sensation of Taste Through Electrical and Thermal Stimulation" [6] presented a system that is able to stimulate taste sensations on

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human tongue. By changing the temperature and inverted current, some participants reported that they were able to percept sweetness. However, this technology has never developed as a sweet interface although the author and other researchers in the field has developed digital interfaces that are able to produce sour and salty tastes more robustly [1, 7]. "Affecting Tumbler" [8] is an another interface that can affect human perceive of different flavor, without changing the food and drinks ingredients itself. The study is done by applying thermal sensations (heating up) to the skin around the nose while drinking. Based on the user study, it is suggested that the flavor perception is improved after applying thermal to the nasal skin.

Results of the previous studies suggest that still there are many studies left to be done in this research area to build a robust, controllable and repeatable sweet interface (e.g. find the suitable parameters such as temperature levels, intensity, speed, user experience studies such as compare organic and digital tastes, and study short term and long term effects).

METHOD

During the development of the proposed device we were primarily focused on heating up the surface of the tongue and stimulate the heat receptors with in a short time period. The operating temperature of the device is limited from of 20°C to 40°. Typically, the body temperature of a human is approximately 36.5°C. Therefore, in terms of the operating temperature range, this interface can be considered as safe to be applied with humans. The latest prototype of the thermal sweet taste machine is shown in the Figure 2. Thermal Sweet Taste machine consists of an electronic controller circuit, Electrode that connects to the Peltier, and a software module. Figure 3 shows the the design of the circuit. Temperature of the tongue is adjusted by the Peltier attached with a silver strip (tongue interface).Peltier module is a special kind of semiconductor whereby one side becomes cool and other side become hot when current flows through it. This Peltier has operating temperature in between -40°C to 80°C and consumes up to 8.5A. Therefore, high power motor driver is used to drive high current Peltier module up to 10A continuously and support sign magnitude PWM operation.

We used copper strips for the first prototype and silver strip in the latest version. We found that silver provides faster temperature change as it has low specific heat capacity, which is 0.057kcal/kg°C, 0.035kcal/kg°C lower than copper. We designed the silver strip to a smaller surface area for a faster heating and cooling process and made it as thin as possible (0.5mm thickness). Silver strip is attached using a high thermal conductivity in order to provide efficient heat transfer between two surfaces. Further, silver does not provide any metallic taste sensations.

By improving heating and cooling process of the peltier, faster change of temperature can be achieved. Therefore, a liquid cooler is attached together with the cooling side of the peltier to overcome the inconsistent heating. A series of technical experiments have been conducted to identify the most suitable rise time of the silver strip from 25°C to reach 40°C using a PID controlling. The best rise time we achieved with a good stability was 7.25s with a PID parameter of (20,10,25). We have also modified our system to start the temperature rise from 20°C. We have also found out three different rise times which provide different stimulation speeds to use in user experiments.

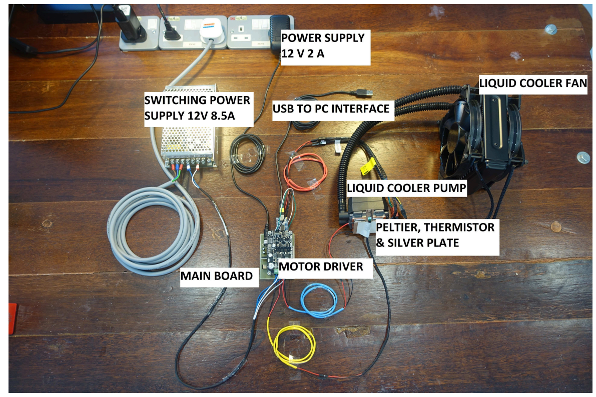

Figure 2. This figure shows the detailed component view of the thermal sweet taste machine second prototype .

DISCUSSION

The preliminary studies of the Thermal Sweet Taste device shows quite significant results in achieving the objectives. Series of user experiments has been conducted to prove the effectiveness of the device. During the first experiment with 36 volunteers (12 females, Mage = 25.88, SD = 5.75, Age range = 20-44) participants were asked to place the interface on top of their tongue and sense the temperature change and requested to describe their experiences. Six participants felt the sweet sensation purely from the device. These participants are recognized and was asked to do the next experiment, which is based on three different speeds (the rise times for the three speeds was 6 seconds , 10 seconds and 15 seconds) of temperature change. We found out that the medium and fast temperature changes produce more intense sweet sensations.

The second experiment was done with 20 volunteers (5 females, Mage = 25.30, SD = 5.43, Age range = 20-44) from another institute. We were studying the effect using the thermal sweet interface (two modes : device is switched ON and OFF) with two sucrose solutions and water (water, 3 g/l sucrose, and 24 g/l sucrose). As shown in the Figure 4, the result shows that when the device is switched on it is able to enhance the intensity and sweetness of the solutions.

In future, we would continue to identify more thermal tasters. With a large group of thermal tasters (at least more than 40) we will be able to run out more user experiments to improve the Thermal Sweet Taste Machine. We are planing to identify parameters for controlling intensity, repeatability and controllability of sweet sensations. Also we are looking forward to develop new prototypes which will be suitable for different applications such as spoons, cups, and bottles. We believe that this interface would be very useful in the future of multisensory applications for the fields like human-computer interaction, man-machine interactions, virtual reality and medicine.

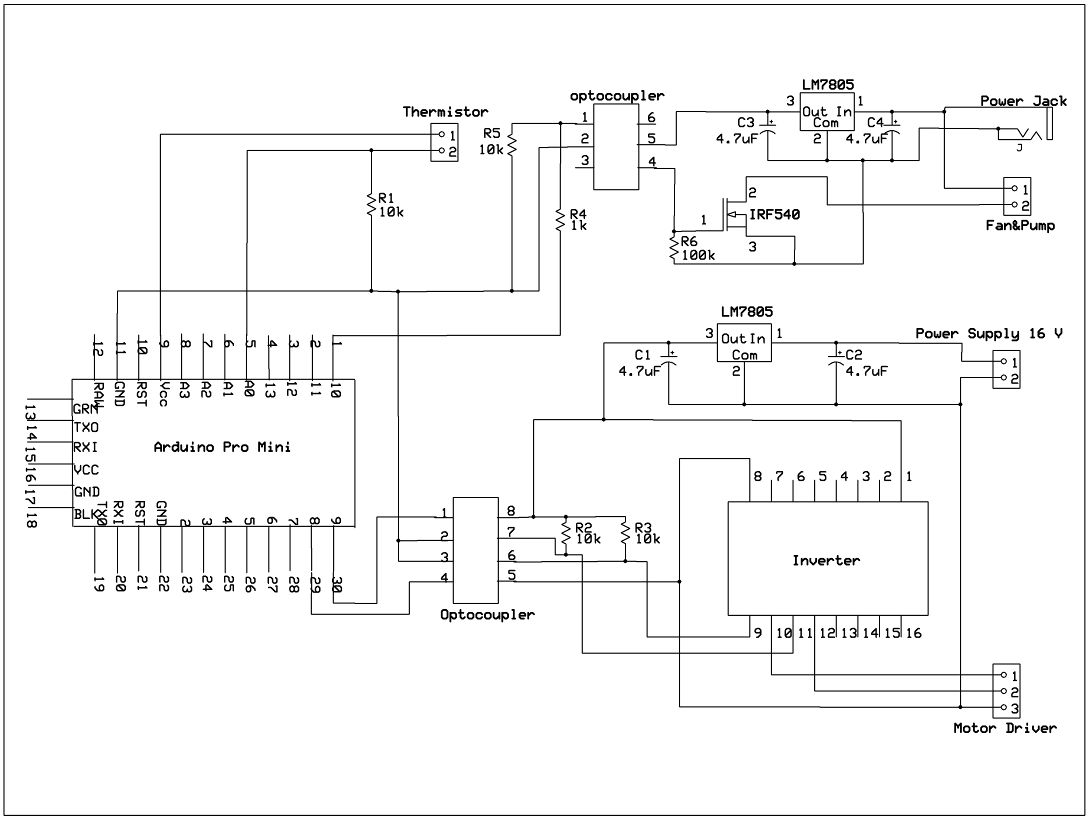

Figure 3. This figure shows the detailed component view of the thermal sweet taste machine second prototype.

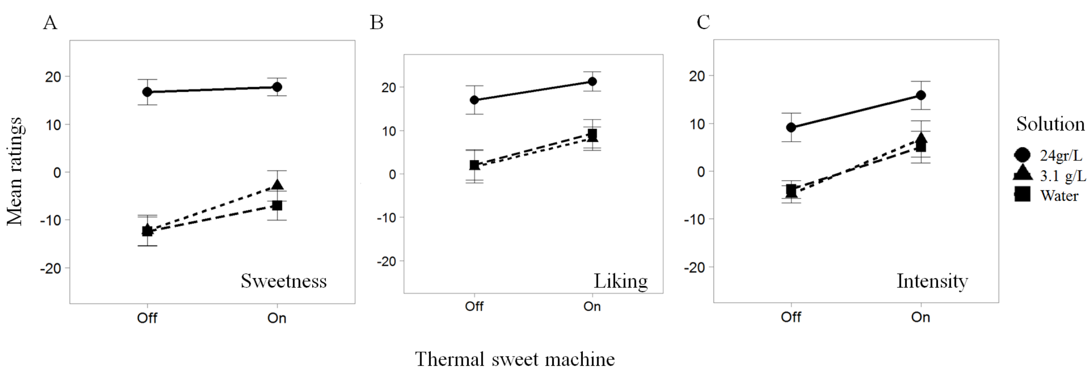

Figure 4. Experiment results for the user evaluation on enhancement of sweet taste

CONCLUSION

This paper presented the research and development of a new user interface which reproduce and enhance sweet sensation by applying thermal stimulation to the surface of the tongue. Our concept, development of the prototype and some preliminary user experiment results were discussed in the above sections. In summary, by using this device, 'Thermal Tasters' are able to obtain the sweet sensation purely from the device and in another scenario, enhancement of sweet sensations was reported while tasting sucrose after using the device. By carefully improving this technology further and finding the proper stimulation parameters, we will be able to digitally actuate sweet sensations meaningfully for future internet communication.

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