Gustatory Interface: The Challenges of 'How' to Stimulate the Sense of Taste

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ABSTRACT

Gustatory interfaces have gained popularity in the field of human-computer interaction, especially in the context of augmenting gaming and virtual reality experiences, but also in the context of food interaction design enabling the creation of new eating experiences. In this paper, we first review prior works on gustatory interfaces and particularly discuss them based on the use of either a chemical, electrical and/or thermal stimulation approach. We then present two concepts for gustatory interfaces that represent a more traditional delivery approach (using a mouthpiece) versus a novel approach that is based on principles of acoustic levitation (contactless delivery). We discuss the design opportunities around those two concepts in particular to overcome challenges of "*how*" to stimulate the sense of taste.

CCS CONCEPTS

• **Human-centered computing** → **User interface design**; *Interaction design*;

KEYWORDS

Taste; Taste Experience; Food Interaction Design; Acoustic Levitation; Food Delivery System; Taste Perception

1 INTRODUCTION

The field of Human-Computer Interaction (HCI) has mainly focused on the use of visual and auditory modalities when designing user interfaces. This has changed through the proliferation of haptic technologies and will in the future be further transformed through the exploration of the sense of smell and taste [24]. The chemical

senses are particularly of interest in the context of food-interaction design, linked to the study of food in everyday life (e.g., [3][5]), investigating the ecologies of domestic food consumption [6], product and package design [22], but also with respect to the exploration of novel interaction concepts (e.g., shape-changing food [26], edible screen/interface [2]).

When it comes to the design of food interaction and gustatory interface design, HCI is still facing various challenges related to the "how" of stimulating the sense of taste. Within HCI, taste stimulation is mainly achieved through the use of chemical stimulation (e.g., solutions for basic tastes [11][14]) or through electrical and/or thermal stimulation of the users' tongue (e.g., [12][18][19]).

A systematic review and discussion of the possibilities and pitfalls around stimulating the chemical senses (taste and smell) was recently presented by Spence et al. [23], providing a solid foundation for future work. Here, we extend the discussion by reviewing the specificities of gustatory interfaces using both chemical and electrical/thermal stimulation approaches. We then move on and introduce two concepts of gustatory interfaces we were actively involved designing and developing. The first concept refers to a device that involves five basic tastes that can be flexibly controlled, and is inspired by LOLLio, a taste-based gaming interface [11]. The second concept presents a new interaction concept for human food interaction exploiting principles of acoustic levitation.

We conclude with a reflection on the emerging design opportunities around the sense of taste and discuss how particularly the two concepts we introduce could provide new approaches in food experience design.

2 GUSTATORY INTERFACES

Current gustatory interface developed within the field of HCI can be categorized into two main groups based on their ***stimulation approach*** to create a taste sensation on the users' tongue: (1) chemical stimulation, and (2) electrical and/or thermal stimulation. Below we review and classify prior works on gustatory interfaces (see Table 1 below for an overview) based on the following three criteria:

- Materials used in the specific gustatory interface (e.g., cartridges, pumps)
- Interaction method used for the human interaction with the gustatory interface (e.g., passive vs. active)
- Capability of the gustatory interface (e.g., how many tastes can be stimulated, combination of taste stimuli)

Table 1: Overview on gustatory interfaces in HCI, divided by chemical and electrical/thermal stimulation, clustered along the 3 main criteria

Stimulation Approach	Gustatory Interface	Materials used	Interaction Method	Capabilities
Chemical (e.g., cartridges with flavouring agents or basic tastes)	TasteScreen [9]	A USB device contains 20 small plastic flavour cartridges, mounted on top of the screen.	Users lick the screen to sample the taste.	Deliver liquid in the cartridges (e.g., lemonade, milk, coffee, wines).
	BeanCounter [9]	Rods (made from transparent acrylic), each is filled with a flavour of jelly beans. The bottoms of the rods are sealed with electronically controlled valves.	Map information with the colour of jelly beans. Users can pick up and eat the jelly beans.	Tastes of jelly beans: cherry, strawberry, orange, lemon, liquorice, grape.
	LOLLio [11]	A small spherical handheld device and a spherical lollipop with a plastic stick. Hardware: tiny pump, taste compound, Arduino.	User tastes the actual lollipop. Small amounts of a sour liquid are pumped from the grip to the outlet of the candy.	Sweet and sour.
	EdiPulse [7]	A chocolate printer. A heart rate monitor device.	A message made of chocolate is printed based on the user's heart rate data. The user is free to taste or share the printed chocolate.	Chocolate.
	Meta Cookies [13]	Plain cookies with AR marker (printed using branding iron).	User select a type of cookie (chocolate, strawberry, tea, etc.) and have the scent dispensed to the nose.	Simulated taste of the cookie based on the olfactory scent.
Electrical and/or Thermal	Digital Lollipop [17]	Tongue interface (two electrodes) Control system (control and dispense an electrical current).	User holds the device to the tips of their tongues.	Sour, bitter, salty.
	Augmented gustation using electricity [12]	A positive and a negative straw inserted into two cups of electrolyte drink.	User drink the solution from both cups using the two straws.	Electric taste.
	Virtual Lemonade [18]	pH sensor, RGB sensor, LEDs. Mouth piece with two silver electrodes. Control module with Bluetooth communication.	User select the colour then have the lemonade taste electrically simulated.	Sour (800Hz, 160ÂţA current).
	Thermal Sweet Taste Machine [21]	An electronic controller circuit, Electrode that connects to the Peltier, and a software module.	User put the taste strip on the surface of their tongue to perceive taste.	Sweet, (possible) bitter, and (possible) umami

Chemical Based Stimulation Approaches

Traditionally, tastes are given to users through a chemical compound, either in a solid or liquid form. Example ingredients for the five basic tastes (sweet, bitter, sour, salty, and umami) are: glucose for sweet, citric acid for sour, caffeine/quinine for bitter, sodium chloride for salt, and monosodium glutamate for umami [14].

This chemical based approach was, for instance, used by Maynes-Aminzade [9], who delivered the taste in form of jelly beans with different flavours (e.g., cherry, strawberry, lemon, etc.), with potential applications of memory profiling and network monitoring. The author also presented TasteScreen, a set of small transparent plastic cartridges that can be placed on a screen [9]. These cartridges release a flavouring agent if a user lick the screen.

Additionally, Murer et al. [11] presented LOLLio, a taste-based game interface. The taste dispensing mechanism is inspired by daily objects that people put in their mouth, such as a lollipop or a baby milk bottle (in the first prototype). The metaphor of a lollipop is

then further developed into a working prototype, where users can experience either sweet or sour throughout a gameplay experience depending on how well or bad they are playing. In a similar vein, Ranasinghe et al. [17] designed a device in the form of a lollipop, however used electrical stimulation to create taste simulations, which we discuss further below.

In another attempt, Narumi et al. [13] introduced the concept of MetaCookie, a system that creates customized tastes with the same plain cookie by dispensing an olfactory scent to user's noses. Users can select between different types of cookies (e.g., strawberry, chocolate, tea).

Electrical and/or Thermal Stimulation Approaches

It has been shown that people can perceive taste qualities without administering a chemical compound on the tongue, by stimulating the tongue papillae using electrical [15] or thermal [4] stimulation. Plattig [15] stimulated the sweet, sour, and bitter tastes in participants by placing a silver wire (0.4 mm tip diameter) on the tip of the tongue and a reference electrode on the left wrist of the subject. Cruz and Green [4] showed that a sweet sensation can be created by warming the anterior (front) edge of the tongue, and a sourness and/or saltiness can be evoked by cooling it. Recently, these findings have been harnessed by HCI designers who demonstrated how to design an application with electrical and thermal stimulation of taste.

Ranasinghe et al. [17] designed a lollipop shaped gustatory device that delivers electricity on the users' tongue. Users hold two electrodes on two sides of the tip of their tongue to perceive the simulated taste. Their results show that participants tasted sourness the most (90%), then saltiness (70%), bitterness (50%), and sweetness (5%). In a follow up design, Ranasinghe et al. [18][19] integrated this stimulation approach into a bottle that augments the taste sensation by: (1) superimposing virtual colours onto the drink using Light Emitting Diodes (LED) and (2) applying weak and controlled electrical stimulation on the tongue.

Similarly, Amira Samshir et al. [21] presented a concept that can create different tastes by thermal stimulation. Their design includes an electronic controller circuit, electrode that connects to the Peltier, and a software module. Users can perceive tastes that are thermally stimulated by the Peltier attached with a silver strip. This device was shown to create sweet taste in participants.

Opportunities and Challenges

In summary, each stimulation approach has its advantages and disadvantages. While the chemical approach is less invasive than the electrical and thermal stimulation of the tongue, it has the disadvantage of requiring continuous fresh preparation and refill of taste stimuli. Electrical and thermal stimulation allow for more control and replication of taste stimuli over a long period of time and over distance (e.g., such as in Taste/IP [16] or virtual lemonade [18]). However, the spectrum of potential taste sensations that can be stimulated through this approach are still limited. Hence, in the early stage of using taste as stimulation approach in HCI, chemical stimulation has the advantage of covering the broad range of taste experiences [14].

3 NEW CONCEPTS OF GUSTATORY INTERFACES

In this section, we introduce two concepts for gustatory interfaces employing a chemical stimulation approach. Our intention is not to present each concept in detail (specific technical or perceptual abilities) as each idea is worth a dedicated paper in itself. Our intention is to systematically reflect upon those two concepts in the context of the other devices from prior work. Thus, we will highlight how the complete spectrum of all five basic tastes can be covered (concept 1, we refer to as TasteBud) and how a totally new delivery mechanism can be exploited (concept 2, we refer to as TastyFloats, see [25] for more details).

First Concept: TasteBud

TasteBud is composed of six bottles of solution (see Figure 1), each contains one basic taste and one with water as neutral solution. The solution is pumped from each bottle using a peristaltic pump at a controllable speed. Out of each bottle is a tube for the taste solution to be transported. The six tubes for six bottles converges into a single tube (or straw), using a mouthpiece, making it convenient for the user to hold in the mouth during the interaction.
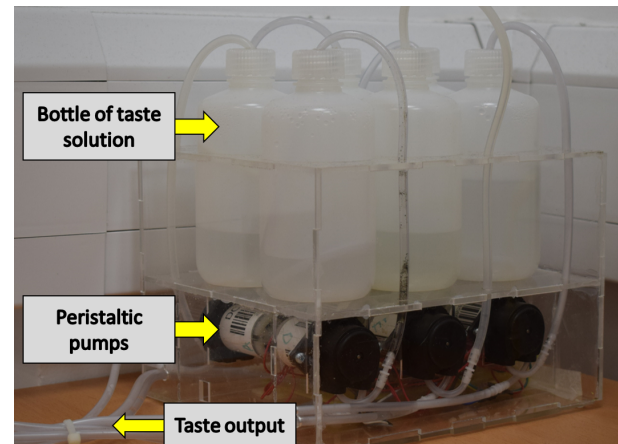

Figure 1: Overview of the TasteBud concept with bottles of taste solutions and six peristaltic pumps controlling delivery of five basic tastes and water.

TasteBud pumps taste solution from one or more bottles into the tubes connecting to participant's mouth. The taste delivery is controlled using an Arduino that allows the delivery of one or multiple tastes at a time, enabling an interactive and flexible gustatory interface. Compared to previous gustatory interfaces, TasteBud, as a standalone unit, offers the capability of delivering single or a combination of multiple taste in one trial. In addition, it offers a plug-and-play interface which allows interactive applications to send control commands to the Arduino board via a serial port to specify the taste delivery (a single or a combination of taste and the amount to deliver). This provides the flexibility and cross-platform ability necessary to stimulate taste in users.

TasteBud can deliver a customizable amount of taste stimuli to the user's mouth whilst they are interacting with the application

(e.g., playing a game) on a computer connected to the device. The taste stimuli are in a liquid form delivered to the user's mouth. This minimizes the interaction required by hand allowing them to focus on the task at hand. This first concept aims to (a) provide a single taste or a mixture of five basic tastes though a single input device into participant's mouth and (b) can be interactively and flexibly controlled by a computer program. This guarantees a wide design space for potential applications in HCI.

Second Concept: TastyFloats

TastyFloats is a novel system that uses acoustic levitation to deliver food morsels to the users' tongue (see Figure 2). The technical implementation and first insights into its effect on users' taste perception are described in Vi et al. [25].
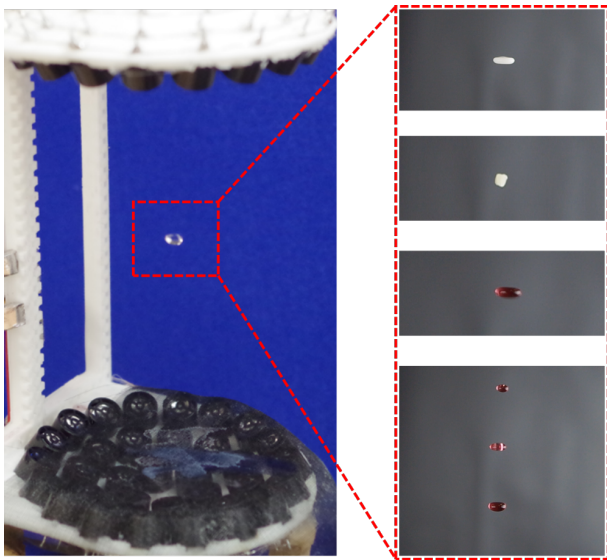

Figure 2: The pick-up unit using acoustic levitation with a drop of water (left) and (right, from top to bottom) milk, cheese, red wine (1 drop) and red wine (3 drops).

Prior attempts of levitating food have been made by chefs such as Fernando Canales at Etxanobe (Bilbao) [1] and Anthony Martin at Morimoto (New York) [10] who are serving dishes on top of a levitating plate. In these examples, magnetic levitation is used and food is placed on a levitating but static dish where customers have to take the foods using cutlery. TastyFloats is using acoustic levitation that not only allows to levitate the food item itself, but also facilitates a contactless delivery of food into users' mouth without the need for cutlery. Such an approach has been demonstrated in prior attempts to levitate water [8] and salad ingredients [20]. The TastyFloats concept takes those ideas a step further and not just allows static but also dynamic levitation of food items. This type of food delivery has the hygienic advantages as the whole process of food pick-up and delivery is in mid-air. In addition, this mechanism enables rich and interactive user experience by manipulating the combination of food items being levitated and transported into the users' mouth in a pre-defined order (e.g., chefs could specify which food item(s) is released first to user).

4 DISCUSSION AND DESIGN OPPORTUNITIES

When using a taste delivery device in an HCI application scenario, one important question is "*how*" it will affect users taste perception and interaction experience. When using novel technologies, such as acoustic levitation, there are still a lot of unanswered questions on how the size of a stimulus, choice of stimuli (be it a basic taste stimulus or a food item, such as cheese or wine) would influence a users' perception and can ultimately be used in an interaction scenario. Both concepts we presented in this paper, on top of reviewing prior gustatory interface approaches, are using a chemical stimulation approach, covering the whole spectrum of basic taste stimulation. The first concept TasteBud is inspired by LOLLio [11], but extends the previous design by allowing for the stimulation of all five basic tastes. Moreover, TasteBud is designed for a single-user interaction, with one mouthpiece, however, can be extended to multiple users by multiplying the mouthpiece to deliver the same or different tastes to more than one user at time. This system can be integrated into a variety of interactive applications (e.g., notification system, gaming).

The second concept, TastyFloats is a novel approach with high relevance for food interaction design, as it does not only allow the delivery of food morsels (liquid and solid items) from one place to the users' tongue but also opens up new design opportunities for HCI, such as enhance gaming experiences for single and multiple users (see [25] for more discussion on application scenarios). Moreover, TastyFloats has the potential to change user's taste perception and dining experiences. For example, food items being levitated may change their properties (e.g., heating up while transported) due to the continuous induced energy and offer inspiration for chefs, you are interested in creating surprising new food serving experiences. Moreover, chefs can explore new food and flavours combinations (e.g., non-existing menu creations). In summary, our concepts can be used in combination with other senses to enhance user experiences while interacting. However, designers should consider the moment of when to deliver the taste to create an optimal experience. Moreover, different taste have different temporal properties, making the synchronisation crucial [14]. Further research with the sense of taste can explore this cross-sensory integration.

5 CONCLUSION

Gustatory interfaces are fascinating and challenging for HCI in general and for food interaction design research in particular. The success of such interfaces depends ultimately from the end user, and if they are willing to accept the stimulus to be delivered into their mouths. In contrast to any other sensory stimulation, the sense of taste is best stimulated inside the human body, in a user's mouth. Hence, the question of "how" to stimulate taste sensations is extremely important to discuss, study, and investigate with respect to the various stimulation approaches and purposes of a stimulation. Only if it is made meaningful and implicitly integrated into an interaction and application, the likelihood that users will accept it and enjoy it, will increase. Here we only started to review existing efforts and directions for gustatory interface designs hoping to inspire future research that will transform we will eat, experience food, and interact with technology in the future.

ACKNOWLEDGMENTS

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