TasteBud: Bring Taste Back into the Game

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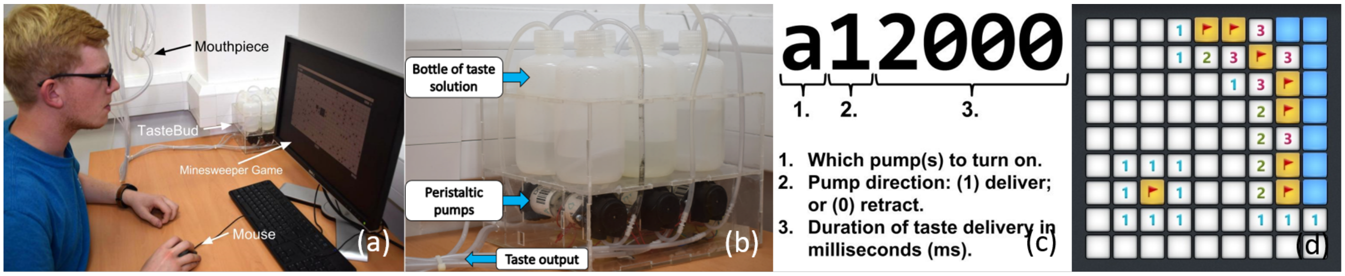

Figure 1: (a) A participant is playing a taste-enhanced Minesweeper game using TasteBud, our gustatory interface; (b) A TasteBud device composed of 6 peristaltic pumps controlling bottles of 5 basic tastes and water (neutral taste); (c) Message format of TasteBud; (d) An illustration of the Minesweeper game.

ABSTRACT

When we are babies we put anything and everything in our mouths, from Lego to crayons. As we grow older we increasingly rely on our other senses to explore our surroundings and objects in the world. When interacting with technology, we mainly rely on our senses of vision, touch, and hearing, and the sense of taste becomes reduced to the context of eating and food experiences. In this paper, we build on initial efforts to enhance gaming experiences through gustatory stimuli. We introduce TasteBud, a gustatory gaming interface that we integrated with the classic Minesweeper game. We first describe the details on the hardware and software design for the taste stimulation and then present initial findings from a user study. We discuss how taste has the potential to transform gaming experiences through systematically exploiting the experiences individual gustatory stimuli (e.g., sweet, bitter, sour) can elicit.

CCS CONCEPTS

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

KEYWORDS

Taste; taste-based technology; gaming experience; gustatory interface; interaction modality; multisensory design

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1 INTRODUCTION

Taste defines a final frontier in interaction design as it is the only sense that requires the user to actively accept the stimulation. Vision, hearing, touch, and smell can all be stimulated outside the human body, but taste requires the stimulation of the human tongue, where all of the receptors are located [23]. Motivating users to put things in their mouth, as we were used to as babies, is not easy unless a real added value to the users' experience is provided. Consequently, the value of taste experiences for human-computer interaction is still an uncharted field, and yet, initial steps towards an understanding of taste experiences for designing interactive systems has been made [13]. This is evidenced by a growing interest in exploiting the sense of taste for novel gustatory systems [2, 7, 8, 10, 12, 19, 21]. Khot et al. [7], for instance, designed EdiPulse that presents messages made of chocolate based on user's heart rate. Maynes-Aminzade [8] presented BeanCouter to deliver the taste in the form of jelly beans with different flavours (e.g., cherry, strawberry, lemon, etc.), with potential applications of memory profiling and network monitoring. Narumi et al. [12] presented Meta Cookies that simulated taste of the cookie based on the olfactory scent. Murer et al. [10] designed LOLLio, a taste-based game controller that makes, amongst all examples, best use of the qualities of taste as human decision-making system (e.g., sweet as reward, sour as punishment). However, the design space of these examples is limited due to the configuration of tastes to deliver, as well as the flexibility to connect to interactive applications [19].

In a previous study, Obrist et al. [13] introduced a user and experience centred approach to taste. The authors presented a design framework that is based on three main characteristics of taste experiences: (1) temporality, (2) affective reactions, and (3) embodiment. The temporal dimension refers to the intensity, movement, and

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duration of the taste stimulus perceived by the user, and is further enhanced through descriptions of the affective reactions (pleasantness/ unpleasantness of the stimulus). The third characteristic refers to the mouthfeel of a taste stimulus. This empirical understanding is useful when designing for taste experiences as it provides us with a vocabulary to talk about taste beyond the surface level (e.g., it is just sweet). Moreover, these characteristics elucidate the potential design decisions a game designer can make with respect to the five basic tastes (sweet, bitter, sour, salty, and umami). For example, the above-mentioned LOLLio [10] could be improved in their design by providing designers with more fine-grain insights on the specific characteristics of taste experiences to be exploited in the gameplay. For example, when a person moves between related levels of a game, a continuing taste like bitter or salty is useful based on the "lingering effect" and thin (straight through your mouth to the back) characteristics of those tastes [13]. Whereas in a challenge, an explosive taste like sour might be more suitable.

Based on such research and an increased interest in multisensory experience design [14, 15], it is now possible to think of a variety of design and research directions. Here, we aim to make a small but necessary first step towards a more semantically grounded use of taste in interaction design, exemplified in the context of game experience design. More specifically, we used the insights presented by [13] to inform the design of a taste-enhanced Minesweeper game [9]. This game was selected for various reasons: first it is available as an open source project, enabling us to augment the gameplay for specific features in the game; second it is simple and yet engaging for users, who have to find the best strategies to manoeuvre around the mine field. Here, we will first describe how our work relates to prior research and design efforts on taste-enhanced gaming, then move on to describe the design and implementation of the game. Finally, we provide insights into a first exploratory study on the effect of the taste stimuli on users' gaming experience and discuss possibilities for future work. We advocate the creation of new interactive experiences based on an understanding of the hardwired characteristics of the human gustatory system [18].

In sum, the contribution of this paper is threefold: (1) Design and implementation of TasteBud, a gustatory interface; (2) Demonstration of the use of TasteBud in a gaming context augmenting the classic Minesweeper game; and (3) Discussion on the future potentials to augment gameplay experiences.

2 TASTEBUD: GUSTATORY INTERFACE

Here we present TasteBud, a gustatory interface aiming to address the challenges of providing an interactive and flexible interaction in a gameplay using taste stimuli. The key design challenges are:

1. C1: Enable the stimulation of all five basic tastes (sweet, bitter, sour, salty, and umami).
2. C2: Easy to integrate and customize taste stimuli for an interactive task, e.g., control over the volume/ intensity of each taste stimulus to be delivered.
3. C3: Providing a mechanism to interactively and flexibly deliver taste (a single or combinations).

In the following sections, we present the hardware and software design to address these challenges. Challenge C1 relates to the design of the hardware whereas C3 is related to the software design and C2 is focused on the hardware and software integration.

2.1 Taste stimulation used

In a previous work, Vi et al. [19] argued that the chemical stimulation of taste is the only approach that enables us to stimulate all five basic tastes and can cover the complete design spectrum of taste experiences, as opposed to electrical taste stimulation. Therefore, TasteBud is based on the use of a chemical stimulation approach using taste stimuli in a liquid form. Such an approach has been used in previous works of gustatory interfaces in HCI (i.e. [8, 10]) as well as in the investigation of the experiential characteristics of taste [13, 22]. The latter is following the ISO specifications of taste concentrations [1]. However, recent works suggest the use of higher taste concentrations to ensure detectability (see [5, 6, 17, 22]).

2.2 Hardware design

The hardware design of TasteBud must satisfy the two challenges C1 & C2. Specifically, the device must be able to: (i) Deliver a taste stimulus at a variable speed. The reaction time must be minimized to have the feeling of instantaneous delivery of taste. (ii) Designed to allow a non-interruptive, hand-free user interaction. The user does not need to hold the device to interact with it. (iii) Act as a standalone unit that can be connected and controlled by any interactive applications.

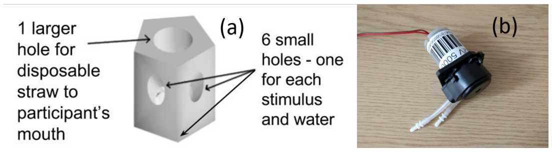

Figure 2: The mouthpiece design (a) and peristaltic pump (b).

TasteBud is designed using 6 peristaltic pumps controlling bottles of 5 basics tastes and a neutral bottle for water (see Figure 1b). A bottle of taste can be created by mixing taste ingredient (i.e. sugar for sweet, MSG for umami, and so on) with water. The TasteBud device can push the taste liquid from the taste solution bottle to participant's mouth. Multiple tastes can also be mixed and delivered together with a single output to participant's mouth using a mouthpiece (see Figure 2a for the design of the mouthpiece).

Figure 2b shows a peristaltic pump, chosen to control each bottle of taste stimulus. It has been widely used for pumping variety of fluids without exposing those fluids to contamination from exposed pump components. Additionally, the flow rate can be customized by controlling the rotation per minute (RPM) of the pump head.

Each taste can be stored in a single and separated bottle. Each bottle is controlled by a peristaltic pump (Figure 2b) to push the taste liquid from the bottle into a plastic tube connecting the bottle (input) and the participant's mouth (output). This results in each taste having its own tube to deliver that taste. To ensure that there is only a single tube at the endpoint (the mouth), we designed a mouthpiece (Figure 2a) to join all tubes into a single output. However, after each taste delivery, the taste chamber inside the mouthpiece is contaminated by the leftover of previous taste stimulus. To clean it, a control taste solution (e.g., mineral water) is used to clean the taste chamber by pumping it up after each taste delivery. This water can be consumed by the participants following each taste to clean the previous taste sensation and ready for the next taste delivery.

The operating mechanism is controlled by an Arduino unit to make it operate as a standalone unit. In the next section, we present the software design of TasteBud, focusing on the communication between this Arduino unit and the controlling application.

2.3 Software design

Once TasteBud is connected to a PC, it can be controlled by receiving messages via a serial port. This makes the communication of TasteBud with interactive applications convenient and independent of the software platform (e.g., writing to serial port can be done in all programming language - C, C++, C#, Java, etc.). Figure 1c shows the message format, sent by the controlling application to TasteBud, specifying which pump(s) to activate, direction of delivery (deliver/ retract), and delivery duration.

Combining together the design of hardware and software, TasteBud provides a mechanism to interactively and flexibly deliver all basic tastes. It can easily be integrated to provide a single or mixture of taste for an interactive task (see Figure 1a for the illustration of the complete integration).

3 SAMPLE IMPLEMENTATION: TASTE-ENHANCED MINESWEEPER GAME

To test the use of TasteBud in a real interactive experience, we augmented the classic Minesweeper game through taste stimulation. Below we describe in detail the design and integration of taste in the gameplay, followed by a description of the experiment, to compare traditional and taste-enhanced gameplay experiences.

3.1 Gameplay augmentation

Minesweeper is a classic game that is pre-installed with Microsoft Windows. Players are presented with a board of different grid sizes (9x9, 16x16, or 16x30 cells). The goal of the game is to open all the cells of the board which do not contain a bomb (or a mine). Players lose the game if they set off a bomb cell. Each non-bomb cell opened will reveal the total number of bombs in the eight neighbouring cells (Figure 1d). If players are sure that a cell contains a bomb, they can right-click to put a flag it on it as a reminder. Players win the game when all the non-bomb cells are opened.

Most implementations of the game of Minesweeper use a timer that starts at zero and increases in seconds until the player wins the game. This acts as a scoring mechanism that allows the player to compare their score against others. Nevertheless, a countdown timer would cause the player to think on their feet and act quickly, leading to more opportunities to deliver taste to the player (i.e. when time is running out).

Following Obrist et al. [13], sweet and bitter were used as rewards and punishments due to their affective attribute of pleasantness and unpleasantness. In addition, as sour was shown to be experienced as "explosive" and "punchy", it should be delivered to the player at the very start of the game to get them enthused for the game. Figure 3 shows the mapping between these tastes and game scenarios.

Right after the player starts the game, they receive the sour taste. They can then start to click or mark unopened cells on the game board to search for mines. When the player clicks on a cell in the game board, if that cell reveals a mine, the player lost the game and they receive their "punishment" of a bitter taste. If the cell reveals a free space, then the game continues. If that cell also revealed a large free space on the game board (≥ 10 cells), then the player is "rewarded" with a sweet taste. If the game is still ongoing when 10 seconds remain on the timer, then the player will experience another sour taste as an "explosive" warning to encourage the player to speed up as time is running out. If the timer expires and the game is not won, then the player receives a bitter taste and the game is lost. If the player wins the game within the time limit, then they get a final sweet taste and the game is won.

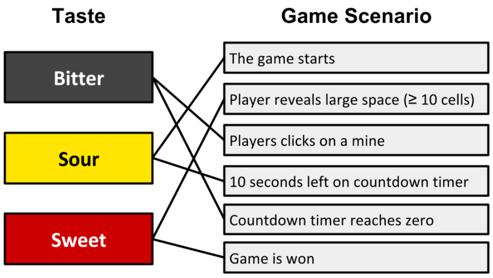

Figure 3: The mapping of tastes to game scenarios.

3.2 User study on taste-enhanced gaming

We conducted a within-subject experiment comparing the traditional with the augmented Minesweeper game experience. We combined quantitative and qualitative to understand the effect of taste on users' gameplay experience.

Taste stimulus: The concentration of taste stimuli used in this study are based on previous works using basic tastes in the field of psychology and neuroscience ([5, 6, 17, 22]). Specifically, we used sucrose (75.31 mg/ml), caffeine (0.97mg/ml), and citric acid (1.92 mg/ml) for sweet, bitter, and sour correspondingly.

Participants: Sixteen participants, who were students and staff at the local institutions, volunteered to take part in this study. By self-report, 25% claim to be beginners at Minesweeper, 50% claim to be intermediate players, and the remaining 25% claim to be expert players. All participants confirmed (verbally) that they did not have any food allergy and did not eat or drink 1h prior to the experiment. Participants gave informed consent to the study before starting. The study was approved by the local ethics committee (ER/DHA23/1).

Procedure and method: Participants sat comfortable in front of a table and about 100cm from the computer screen. The Minesweeper game was programmed in Java and displayed at the centre of the screen. The disposable mouthpiece for the TasteBud device was suspended from the ceiling on a piece of string (see Figure 1a). Participants put the end of the mouthpiece into their mouth.

Participants were given 10 minutes each to play the Minesweeper game with and without TasteBud in a counterbalanced order. After that, they were interviewed using pre-determined questions to gain qualitative data on how they feel their user experience changed both with and without the involvement of taste. Quantitative data was collected using short questionnaires including the following four elements: easy to play, easy to navigate, satisfying, and enjoyable. Participants were asked to rate each element on a Likert scale from 1 to 5 (1 being the lowest rating and 5 the highest for the respective question, e.g., 1 for "not easy to play at all", versus 5 for "very easy to play"). Finally, participants were asked for further comments and feedbacks on their gameplay experience enhanced through taste.

3.3 Results

Questionnaire data: Questionnaires results showed that 81.25% of participants found the Minesweeper game more difficult to play with the TasteBud device. Surprisingly however, despite these difficulties, 68.75% of participants were more satisfied with their performance whilst playing the taste-enhanced game compared to the traditional game. Most participants (81.25%) enjoyed the game as much or more when playing enhanced through taste.

We performed repeated-measure ANOVA with each of the four questions (Q1: Easy to play, Q2, Easy to navigate, Q3: Satisfy, Q4: Enjoyable) as the dependent variable. The results show that participant found playing with the game with taste is more difficult to play and to navigate. On the other hand, they found that incorporating taste made the game more satisfying and more enjoyable. However, we could not find significant differences (p>0.05) between the two conditions (with and without taste) in all variables (Figure 4).

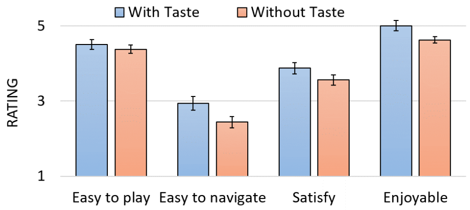

Figure 4: Comparison of the two conditions (with taste and without taste) for each question. Bars represent SD.

The performance data captured from the participants' sessions showed that only 18.75% of participants actually managed to win a game, but out of those participants, 100% matched their win percentage or attained a higher win percentage whilst playing the taste-enhanced version of Minesweeper than playing it without the TasteBud. The captured data also showed that 75% of participants took longer on average to take each turn when playing with the TasteBud than when they did playing the game by itself.

Qualitative data: The qualitative feedback and comments from participants at the end of the study, revealed additional insights into the game experience. Participants described their experiences with TasteBud as "interesting" [P3, P9, P11, P12, P14] and "very fun" [P5, P11, P12, P13, P16]. However, some participants [P2, P8] did not enjoy the experience, stating that they found the chemical stimulation of taste "intrusive".

Whilst most of the participants enjoyed their experience, some felt that taste-enhanced gaming was more of a "novelty" [P1], than something they could see being a thing of the future. Yet, participants were generally stimulated by this novel approach to gaming and wanted to see taste-enhanced gaming beyond one-off experiences, so the initial novelty effect could be overcome. Specifically, it is necessary to make taste more than just an 'interesting' experience. Participants emphasized the need to understand better the mapping between taste and their action. Furthermore, among the implemented tastes, sour was commented as the most unclear one.

4 DISCUSSION AND FUTURE WORK

TasteBud advocates a new way of interacting with a system and engaging our sense of taste. We documented a sample implementation in a taste-enhanced Minesweeper game. Users' feedback provided preliminary insights on the effect of taste on the gaming experience, encouraging more research into the balance between perceived difficulty and enjoyment. Although, the results from our study did not demonstrate significant differences between conditions, which could be due to the small sample size, we believe that increasing the number of participants in each condition accounting for different user's expertise (i.e., novice, intermediate, expert user) could increase the statistical power and reveal more specific insights into the experienced challenges and enjoyment of the game. Flow theory, which aims to identify the right balance between skills and challenges [3, 11], could provide the theoretical framework for future investigation into the use of taste in a gameplay and balancing the difficulty and enjoyment level for different skilled users.

Moreover, it is intriguing to note that despite the low completion rate in the Minesweeper game, participants who successfully completed the game, had a 100% match in their win percentage or attained a higher win percentage whilst playing the taste-enhanced version of Minesweeper game. While this is an initial observation, it indicates a potential for further investigations of games performance with respect to taste-enhanced gaming, as well as the effect of taste-based interaction in general. The gustatory system is known to be very powerful in helping people make decisions about the ingestion and rejection of food [18]. Hence, we could speculate that by using the appropriate taste stimuli, higher performance could be achieved through the hardwired and instinctive reaction to specific tastes: for instance, sweet encourages ingestion (reward) and bitter elicits aversive reactions (punishment) [16]. Taking advantage of TasteBud's capabilities in delivering multiple tastes, further studies can investigate the mapping of all five basic tastes to the narrative of a gameplay (i.e. the CandyCrush game where a candy is mapped to a taste). Furthermore, the integration with other senses (i.e. smell and touch), to create flavour interfaces, can be imagined [4, 15, 20].

5 CONCLUSIONS

Taste is not just relevant in the context of eating, it can be part of whatever you want it to be, gaming, a communication tool, a new type of movie experience, or art. Here we presented TasteBud, a gustatory interface to enhance gaming experiences. TasteBud provides a simple hardware and software integration that can however be easily used and shared with HCI designers and researchers interested in transforming user's interactions and experiences with technology. By bringing taste back into the game, we can start thinking beyond the dominance of existing interaction as well as create completely new experiences (e.g., by making taste part of the narrative of the gameplay).

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