MARTYR: Exploring Ingredients of Virtual Dining Experiences

Camilla Jaller [*] Aalborg University / MAKROPOL
Nicklas B. S. Andersen [†] Aalborg University
Niels C. Nilsson [‡] Aalborg University
Razvan Paisa [§] Aalborg University
Mads Damsbo [¶] MAKROPOL
Stefania Serafin [‖] Aalborg University

ABSTRACT

MARTYR is a dinner performance that explores food and collective virtual reality and premiered on October 22nd 2020. In this paper, we present the evaluation of two prototypes used to explore how virtual reality can affect dining experiences and how food can be used as an ingredient in virtual narratives. The results indicate that virtual reality can be used to affect perceived taste. However, the effect varied considerably between participants. Moreover, the participants appeared to accept food as an element of a virtual story, but it is unclear to what extent taste affected their experience of the narrative.

Index Terms: Human-centered computing—Human computer interaction (HCI)—Interaction paradigms—Virtual reality;

1 INTRODUCTION

Eating cannot be reduced to the act of satisfying one's hunger, the mechanical act of chewing, or taste sensations for that matter. When eating, multiple sources of sensory information become intertwined and produce complex perceptual experiences [23]. Such experiences may be pleasurable, revolting, and even aesthetic or artistic in nature. Virtual reality (VR) systems allow users to see, hear, and sometimes touch familiar, foreign, and fantastic virtual environments (VEs). However, VR systems rarely engage other senses such as taste and smell. For that reason virtual dining represents an interesting multisensory experience worth exploring.

MARTYR is a dinner performance that explores animal-human relationships through food and VR. The experience combines VR, a full tasting menu, lights, performance, and soundscapes to explore how audio-visual narratives affect our experience of food. It was conceptualized from the question: How can we by use of VR and additional sensorial stimuli, move restaurant guests to a stronger emotional experience of food? The final production premiered at Kunsthal Charlottenborg on October 22nd 2020. MARTYR is produced by the XR production company MAKROPOL who has developed, produced, and showcased quality experiences to audiences at theatres, festivals, and museums all over the world [13]. Together with Multisensory Experience Lab (ME-Lab) at Aalborg University and chef Frederik Bille Brahe at Restaurant Babylon, MARTYR was initiated in its pre-development phase as a part research and part artistic project. The collaboration involved the development and evaluation of the two prototypes presented in the current paper. These prototypes represent two potential dishes in a virtual dining experience: a starter and a dessert. The evaluations aimed to explore (1) how virtual dining experiences are affected by the congruence between taste and virtual content, (2) how virtual dining experiences are affected by positively or negatively valenced virtual scenarios, and (3) how gustatory stimuli can be used to support a virtual narrative. The research questions and evaluations were established by the university researchers based on the interests of the XR production company and the restaurant chef, to achieve a bottom-up effect relevant to the future production of MARTYR. All design decisions were attributed to the XR production company to reflect the context representative of the company's earlier works. Both studies were performed in locations meant to approximate real-world settings of restaurants, including multiple guests dining simultaneously.

[*]e-mail:caja@create.aau.dk
[†]e-mail:nba@create.aau.dk
[‡]e-mail:ncn@create.aau.dk
[§]e-mail:rpa@create.aau.dk
[¶]e-mail:mads@makropol.dk
[‖]e-mail:sts@create.aau.dk

2 RELATED WORK

In the context of entertainment, there has been a growing interest from the industry to explore business models that capitalize on the research of Human-Food Interaction (HFI) to create, modify, and enhance experiences of food [27]. Our project is one such experiment. Previous projects, including MetaCookie+ [17], focus to a lesser degree on existing foods or meals and more on creating pseudo-gustatory experiences where taste may be simulated by influencing visual and olfactory stimuli. Other projects including Project Nourished [12] eliminate food and strives to create proxies through 3D printed hydrocolloid cubes that taste, feel and smell like food. However, both projects share that the design of food experiences involve both intrinsic and extrinsic sensory factors, which is explored by other research projects as well [21, 27].

A large body of work has explored the myriad of factors influencing gustatory perception and the general experience of eating (for comprehensive reviews see [21, 23]). Notably, research has shown that taste perception is not only based on physical factors like food ingredients but also factors including physiological states and moods, eating environments, cognitive and semantic understandings of the food, and previous experiences or memories related to food [1, 15, 16, 20, 30]. Visual stimuli are capable of altering the perception of taste, smell, and flavor [4]. Color is perhaps the most well-known [6, 22]. For example, studies on the crossmodal correspondences between colours and basic tastes indicate that orange, red, and pink are associated with sweetness, and blue, white and grey may be associated with saltiness [24]. However, learned associations including gloss, evenness, and shape have also been shown to influence the perception of taste [4]. For example, when participants are asked to match visual shapes and tastes, sweetness tend to be matched with round shapes and other tastes (e.g., bitterness, saltiness, and sourness) tend to be matched with angularity [28]. Notably, while such associations may affect expected taste, they need not affect the taste sensations reported after consuming food items [29]. Moreover, audition plays a central role for gustatory experiences, as evidenced by work showing that the crispness and staleness of potato chips can be manipulated by loudness and frequency composition of the sound produced when biting into the chips [31]. Finally, food experiences has been shown to include a range of factors unrelated to taste or flavor. Spence et al. [23] report, that factors including the color of the plate, the shape of the glass, the names used to describe the dishes, and the background music in the restaurant all influence the dining experience.

Immersive eating (i.e., eating inside a VE) is a relatively new area of study, and different technologies have been used to bring real food into VEs and to generate the VEs where the food is consumed. Korsgaard et al. [11] explored the utility of a video-based stereoscopic see-through display as a means of bringing real food into computer-generated environments and identified a number of limitations of this approach. Similarly, Perez et al. [19] used a video-based see-through display to enable immersive eating inside VEs presented using 360° video. More recent work by Korsgaard et al. [9, 10] relied on a depth sensor to generate dynamic meshes of users' hands and food items. This approach was used to explore whether immersive eating can improve eating habits of elderly people. That is, the authors explored what VEs elderly people prefer in regard to virtual dining experiences [9], and the effects of social immersive eating where users were virtually together but physically apart [10]. Stelick et al. [25] present a proof of concept study exploring the use of VR for sensory evaluation. Participants were served three identical cheeses in three different VEs (a sensory booth, a park bench, and a cow barn), and the results indicated that participants found the flavor more pungent when exposed to the barn compared to the sensory booth. Tuanquin et al. [26] used VR to study the effects of olfactory stimuli and VR on food cravings, and found that VR can elicit food cravings and the addition of olfactory cues seem to increase the effect. Finally, Arnold [2] used the act of eating, detected from chewing sounds, as an input for a VR game where players had to eat real food to survive and escape a virtual island.

This recent work points to immersive eating's broad range of applications. Not only does VR offer great potential as a vehicle for exploring the factors influencing gustatory perception, but it is also an exciting medium for offering restaurant guests with novel dining experiences. Our project aimed to examine how VR technologies and food function together, and how we may combine and create associations between taste and virtual environments in a way that evokes emotions in the context of restaurant-like settings.

3 Study 1 (S1): Sweet or Salty?

The aim of the first study was to investigate how sensory congruence and incongruence affect virtual dining experiences. Specifically, we explored how two types of oysters are experienced when eaten in a VE that either complements the taste or not. To meet this aim we compared four conditions presented using a within-subjects design: (1) *Salty oysters eaten in a salty VE*, (2) *Sweet oysters eaten in a sweet VE*, (3) *Salty oysters eaten in a sweet VE*, and (4) *Sweet oysters eaten in a salty VE*.

3.1 Setting and Stimuli of S1

The study was performed over three consecutive days in the café area of SPACE10; a Copenhagen-based research and design lab. This venue was chosen due to the similarity with a real restaurant setting. The café was open during the test sessions, which made the participants' experience more similar to being in a real restaurant, but necessarily also added noise and distractions from the other guests.

The oysters were French oysters prepared by chefs from Restaurant Babylon each morning and placed in containers with ice before the test sessions would begin. There were two taste versions of the oysters: a Salty Oyster and a Sweet Oyster. The Salty Oyster was a 'clean' oyster but enhanced with lemon juice to underline the saltiness. The Sweet Oyster had added elderflower syrup, which was not visibly detectable.

The two VEs were created in Unity. The salty environment was a dank stalactite cave with ocean sounds, while the sweet environment was a pink sky with candy and childish music (Figure 1). These design choices were made by the XR production company and are in line with previous work indicating that the color pink and round shapes are associated with sweetness, whereas grey and white colors and angled shapes are associated with other tastes, such as saltiness [24, 28]. The VEs were displayed through an Oculus Quest with an Intel Realsense depth camera mounted on the front. The camera's function was to key out all the pink from a table cloth, as seen on figure 2. The user would be left with a depth render representation of their hands and the tray with oysters. This approach was adopted from previous work by Korsgaard et al. [9] and allowed the users to eat the oysters even though they were "blinded" by the head-mounted display (HMD).

3.2 Participants and Procedure of S1

A total of 25 participants (11 males and 14 females) aged between 20-44 years (M=29.6, SD=6.6), participated in the study. Out of the 25, 19 reported having experience with VR, and 19 had eaten oysters before. The participants were recruited using mailing lists of MAKROPOL and ME-Lab as well as from the guests visiting SPACE10. All participants gave written informed consent. Participation occurred in groups of 2-3 people, and the study lasted approximately one hour per group. After being introduced to the study, the participants were asked to eat a single oyster without wearing the HMD and fill out the questionnaire administered after exposure to each condition. This was done to ensure that the participants had a fresh memory of the sensations of eating an oyster under normal circumstances, they understood the questionnaire items, and they were aware of what gustatory sensations we wanted them to attend to when eating oysters in VR. The members of each group were exposed to the four conditions in the same order. However, to mitigate potential order effects, the condition order was counterbalanced between groups using a Latin square. The participants were offered bread and water between conditions to neutralize the taste of the oyster eaten during the previous condition.

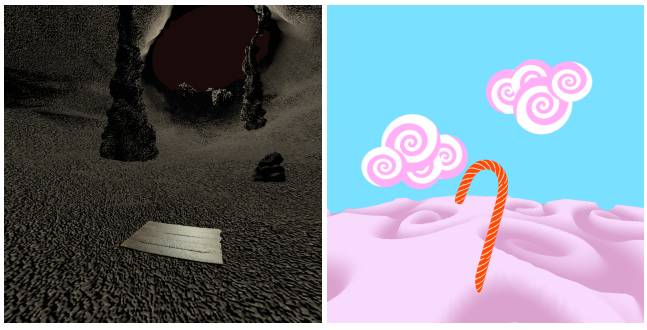

Figure 1: The VEs of the salty scenario (left) and the sweet scenario (right).

Figure 2: A group of users during exposure to the VE in S1.

3.3 Measures of S1

The participants' experiences were evaluated using a combination of quantitative and qualitative self-reported measures. A questionnaire was administered after each condition, and after all four conditions the participants took part in focus group interviews. The questionnaire included eight items answered on 10-point scales ranging from 1 to 10. The first five asked the participants to rate the intensity of the five taste sensations *saltiness*, *sweetness*, *sourness*, *bitterness*, and *umami* (1 = 'not detectable' and 10 = 'strongest imaginable' relative to taste sensation experienced in daily life). These anchors were adapted from Green et al. [8]. The sixth item asked the participants to rate the degree to which they *liked* the experience of eating oysters in VR (1 = 'strongly dislike' and 10 = 'strongly like'). The last two items asked about the *valence* (1 = 'very unpleasant' and 10 = 'very pleasant') and *arousal* (1 = 'very calming' and 10 = 'very exciting') associated with the experience. The focus group interviews asked the participants to discuss what condition they preferred, their thoughts about the tastes of the different oysters, and any perceived connections between the oysters and the VEs.

3.4 Results of S1

3.4.1 Post-exposure questionnaire

The results of the eight questionnaire items are presented in Figure 3. The analyses were performed using non-parametric Friedman tests and pairwise comparisons were performed with Bonferroni correction for multiple comparisons (IBM SPSS Statistics 25). The Friedman tests found a marginally significant difference between conditions with respect to *saltiness*, $\chi^2(3) = 6.491, p = .090$. Moreover, a statistically significant difference was found with respect to *sweetness* $\chi^2(3) = 10.841, p = .013$, and the pairwise comparison indicated that the participants found the condition where both the oyster and VE were salty (SaOy&SaVR; $Mdn = 3$) significantly less sweet, than the condition involving a salty oyster and a sweet VE (SaOy&SwVR; $Mdn = 6$), $p = .019$. No other statistically significant differences between conditions were identified.

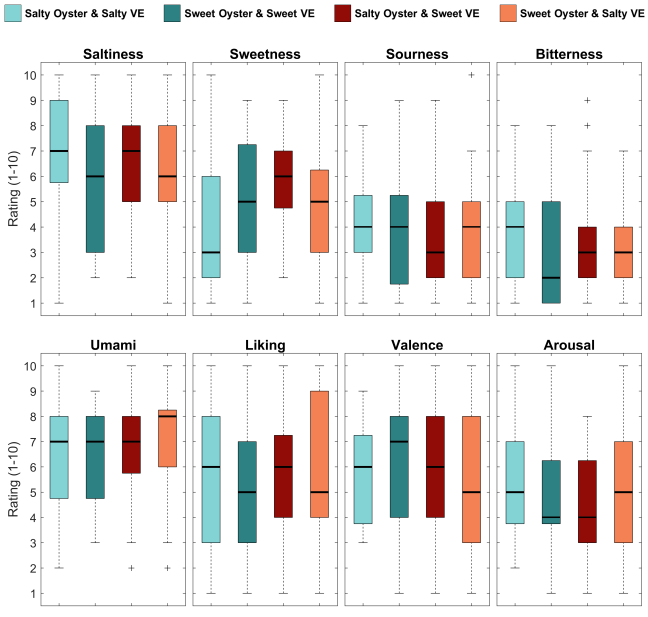

Figure 3: Boxplots visualizing rating scale data (S1) in terms of medians, interquartile ranges, minimum and maximum ratings, and outliers.

3.4.2 Focus group interviews

Quotes from the focus group interviews were broken down into codes, using content analysis (CA) [18]. In what follows, we present codes associated with the broad category *connections between oysters and VEs*. Based on the transcripts we identified three general codes named *clear connection*, *mixed connection*, and *no connection*. Each of the three codes consists further of condensed meaning units based on the participants' statements [7].

Clear connection: 36% (9/25) of all participants stated explicitly that they perceived a connection between the taste and the presented VEs. Four of these participants thought the Salty VE influenced the taste of the oysters, and five thought the Sweet VE influenced the taste. For example, one noted *"I had a feeling that it was more salty. And I think that was the point you were trying to convey with the underwater"*, while another remarked that *"by the third one [Sweet Oysters & Sweet VE] it became really obvious that it had some psychosomatic effect on the way the oyster tasted sweet suddenly."* Notably, three of these participants thought the environments brought out tastes opposite of expectations (i.e., the Sweet VE increased perceived saltiness and the Salty VE made the taste sweeter).

Mixed connection: 44% (11/25) of all participants were not sure whether they could sense a connection between the oysters and the VEs. For example, three stated that they were uncertain about whether the tastes varied across VEs or if the perceived difference was simply a placebo effect, and two explicitly stated that the audiovisual stimuli contributed to the overall experience, but they were not sure if the taste was different (e.g., *"I'm not saying it radically changed what the oyster tasted like, but it made me look at other aspects of it."*

No connection: Finally, 20% (5/25) of the participants did not perceive a connection between the VEs and oysters' taste.

4 Study 2 (S2): My First Ice Cream

The second study aimed (1) to explore how gustatory stimuli can be used actively as part of a narrative, and (2) to explore how dining experiences are affected when the virtual scenario is either positively or negatively valenced. To meet this aim, we performed a study requiring participants to eat an ice cream during exposure to virtual scenario where they assumed the role of a small child observing a conversation between its parents. The study relied on a between subjects design and compared three conditions: a *happy* scenario where the parents showed clear signs of affection toward each other, a *sad* scenario where the parents were fighting, and a *control* condition where the participants ate the ice cream without exposure to VR.

4.1 Setting and Stimuli of S2

The lab was setup with five reclining garden chairs and another chair in between them, which served as a table for the questionnaire, a dishtowel, and to hang the VR equipment and headphones. Each test participant would sit on the garden chairs. Reclining garden chairs were chosen so the test participant could get a close feeling of sitting in a baby carriage. The dishtowel helped the users become comfortable with eating whilst being "blinded" by the HMD, as it covered their clothes against dripping and falling ice cream. This setup can be seen in figure 4.

The ice cream was specially developed by Skarø Is according to chef Frederik Bille Brahe's design and recipe. The ice cream was a sorbet made from a combination of grapefruit and chili. Flavors that are not normally associated with ice cream were deliberately chosen with the aim of eliciting an unexpected flavor experience (i.e., like a child tasting ice cream for the first time, the participants encounter a novel taste experience).

A happy and sad scenario were filmed with an Insta360 Titan camera in Frederiksberg Gardens, Copenhagen. The films were

Figure 4: A group of users during exposure to the VE in S2.

exported to a stereoscopic 5120x2560 resolution and the happy and sad versions were color graded in a warm and cold temperature respectively. A baby carriage was modelled in 3D and placed in the VE. The scenarios depict the two parents, who are either on great terms or near divorce. Both scenarios lasted approximately 5 minutes. What the parents were talking about was slurred to make it incomprehensible for the *child*, as only a few general words would be clear.

Inside the VEs, subjects had two hands where the right hand held an ice cream. The ice cream was a photogrammetry model of the real ice cream the participants ate. Figure 5 shows the two scenarios from the user's perspective. The VE was displayed using an Oculus Quest and the real ice cream was mounted on a Quest controller, to ensure that the real and virtual ice creams were co-located.

4.2 Participants and Procedure of S2

The study was performed over the course of three consecutive days at Aalborg University, Copenhagen, and participants were recruited using mailing lists of MAKROPOL and from the student body at Aalborg University. A total of 33 people (9 females and 24 males) aging from 20-52 years (M=29.5, SD=8.3) participated in the study. Out of the 33, 27 reported having prior experience with VR. All participants gave written informed consent. Participation occurred in groups of 3-5 people, and the study lasted approximately 40 minutes per group. After being introduced to the study, the participants in the happy and sad VR conditions put on the HMDs and the ice creams were mounted on the Oculus Quest controllers. The participants assigned to the control condition ate their ice creams without wearing any VR equipment.

4.3 Measures of S2

As in S1, the participants' experiences were assessed using a combination of questionnaires and focus group interviews. After exposure to the three conditions the participants were asked to fill out the same questionnaire used for S1. Before the focus group interviews, we administered an adapted version of the Microsoft Desirability Toolkit (MSDT) [3]. Because we administered these product reaction cards with the aim of exploring the participants' aesthetic experience, we removed all words that were only relevant for functionality or performance, as recommended by Moran [14]. The final deck included 33 cards (14 which were negative words) and the participants were asked to choose the three cards that best described the virtual dining experience. During the focus group interviews the participants were asked to elaborate on their choice of cards, the taste of the ice cream, and how they felt while eating it. The two groups exposed to VR were also asked to reflect on how the virtual experience made them feel, the connection between the taste of the ice cream and the virtual scenario, and any associations elicited by the experience.

Figure 5: The happy scenario (left) and the sad scenario (right) as seen from the perspective of a user.

4.4 Results of S2

4.4.1 Post-exposure questionnaire

The results of the questionnaire items are shown in Figure 6. The data was analyzed using Kruskal-Wallis H tests and pairwise comparisons were performed using Dunn's procedure with Bonferroni corrections for multiple comparisons (IBM SPSS Statistics 25). The Kruskal-Wallis H test indicated that the distributions of scores differed significantly with respect to *arousal*, $\chi^2(3) = 11.483, p = .003$. The pairwise comparisons indicated that the self-reported arousal was significantly higher with respect to the sad condition (*meanrank* $= 24.9$) compared to the happy condition (*meanrank* $= 13.2$), $p = .011$, and the control condition (*meanrank* $= 12.9$), $p = .009$.

4.4.2 Product reaction cards and Focus Group

The focus group interviews were analysed through the same CA process as in S1. However, the analysis focused on the feelings experienced by the participants, and the perceived connection between the ice cream and the VE during exposure to the sad and happy conditions. Figure 7 presents a Venn diagram showing what words from the MSDT the participants chose after exposure to each condition.

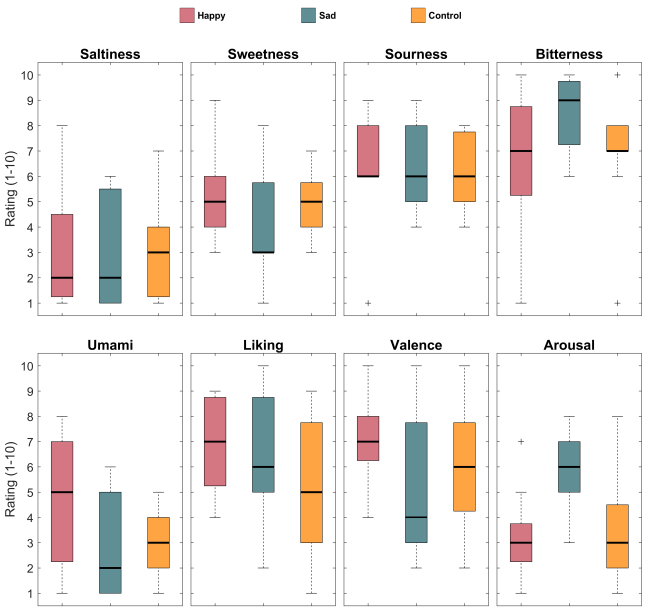

Figure 6: Boxplots visualizing rating scale data (S2) in terms of medians, interquartile ranges, minimum and maximum ratings, and outliers.

Feelings while eating in the sad condition: 54.5% (6/11) of the participants who experienced the sad condition described that the act of eating ice cream while immersed in the VE affected their experience (e.g., *"the ice cream and this extra taste, suck you more into the experience"*). Moreover, some participants appear to have gotten some sense of being a helpless child. That is, 45.5% (5/11) expressed that they felt trapped because they felt stuck in the middle of the parents' argument and had no control of what was happening. Interestingly, one participant described that the experience of eating the ice cream changed as the parents' fight intensified, *"I felt it was quite bitter in the beginning, but then when they were fighting I felt that I at least have my ice cream. Then it tasted much better because it's the only thing you can do, so it has a lot of impact."*

Feelings while eating in the happy condition: 36.5% (4/11) of participants in the happy condition described that the combination of being a child in VR and eating an actual ice cream made the experience more stimulating. However, 45.5% (5/11) expressed that a scenario taking place on a summer day or at an ice cream store would have fitted the taste of the ice cream better and it would have made them more interested in eating the ice cream. On the other hand, one participant justified the presence of the ice cream by referring to their role as a child: *"Usually I eat ice cream in the summer. So, that was a bit contradictory. But in general it was fitting, because you were a little kid who likes ice cream."*

Perceived connections in the sad condition: 63.6% (7/11) thought the taste matched the experience, and some even thought that the taste changed over time (e.g., *"...it was kinda sour or sweet in the beginning and, at least for me, it kind of got salty or bitter by the end, and that very much mirrors the experience"*). Notably these participants were unsure if the change in perceived taste reflected an actual change in flavor of if they were influenced by the virtual experience. 27.3% (3/11) found no clear connection and one explicitly noted that there was a disconnect between the ice cream's flavor and the type of ice cream children would enjoy. One participant thought the experience negatively influenced the taste.

Perceived connections in the happy condition: 72.7% (8/11) stated that they found no apparent connection between the VR experience and the ice cream, and 63.6% (7/11) expected and wanted a different taste because they felt the taste would be better suited for a warmer environment. Moreover, some felt that the flavor was disconnected because a child was unlikely to enjoy it. Finally, 27.3% (3/11) thought that the color of the virtual ice cream had a big impact on the expected taste, which caused them to be surprised by the actual taste.

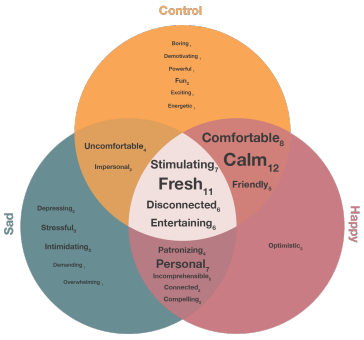

Figure 7: Venn diagram showing what product reaction cards were unique to each condition and what cards were shared between conditions. The size of each word indicates how frequently it was chosen and the numbered subscript indicate the exact frequency.

5 Discussion

The first study explored how the congruence between taste and virtual content affected virtual dining experiences, including flavor perception. Most of the questionnaire items did not reveal significant differences between conditions. However, the item pertaining to perceived sweetness indicated that the salty VE may have caused the participants to find the oyster less sweet. Moreover, the combination of the salty VE and salty oyster appear to be perceived as more salty than the remaining conditions. However, this result was not statistically significant. The qualitative data obtained from the focus group interviews corroborate these indications and suggest that the VEs did affect some participants' perception of the oysters. The effect appeared most pronounced during exposure to incongruent stimuli, specifically, when eating a salty oyster in a sweet VE. Some participants noted that the VEs increased their appreciation of the taste and texture, and each VE helped bring forth different aspects. The majority of the test participants found there to be a connection between the taste of the oyster and the VEs. That is, the cave in the salty VE was associated with saltiness or umami, and the pink clouds and candy canes of the sweet VE were associated with sweetness. This indication is inline with previous work on the associations between tastes and visual attributes such as colors and shapes [24, 28]. Nevertheless, less than half of the participants reported that the oysters' taste was affected. This also appears to be in line with previous work suggesting that even though visual attributes may affect expected taste, they need not affect actual taste sensations [29]. Interestingly, some participants noted that incongruent VEs emphasized the flavor of the oyster rather than biasing them toward the flavor suggested by the VEs (e.g., the sweet VE made the participants increasingly aware of the salty taste of the oyster, rather than making it seem sweeter). This suggests that the effect of VEs on flavor perception may vary considerably between individuals, and it helps explain the large spread in the data.

The second study explored how a positively or negatively valenced virtual scenario affects virtual dining experiences, and how gustatory stimuli can support virtual narratives. The analysis of the questionnaire data did not find a significant effect of scenario valence on perception of the five basic tastes. Bitterness appears to have been the most dominant of the five basic tastes, and the sad condition received the highest bitterness ratings. This is in line with previous work indicating that exposure to mild stressors before eating saccharin, may lead to higher ratings of bitterness and lower ratings of sweetness [5]. We similarly observed lower sweetness ratings in regard to the sad condition. However, this difference was not statistically significant. We did find a significant influence on arousal. That is, the participants found the sad scenario significantly more exciting than the happy scenario and the control condition. Even though no significant difference was found with respect to perceived valence, the distribution of scores suggests that the participants generally found the sad scenario more unpleasant. This indication is supported by the words chosen by the participants to describe their experience post exposure (Figure 7). That is, after exposure to the sad condition participants generally chose negatively valenced words and explained these with reference to the sensation of being a child, the actions of the virtual parents, and their own inability to act. Contrarily, after exposure to the happy scenario the participants generally chose positively valenced words reflecting the atmosphere of that scenario. In case of both virtual scenarios, some participants choose the word "personal" and several explicitly referred to the sensation of being a child. Moreover, the participants exposed to the two VR conditions appeared to like the experience more compared to the participants exposed to the control conditions. However, this difference was not statistically significant.

The focus group interviews indicated that many participants who experienced the happy scenario felt that the bitter taste did not match the experience because that type of ice cream was better

suited for a summer day, and a child would be unlikely to enjoy that flavor. The majority of participants who were exposed to the sad condition perceived a connection between the bitterness and the unpleasant experience. Some participants even had taste experiences that changed over time, seemingly in response to the unfolding events (i.e., they thought the ice cream became more bitter over time). A few participants did not find a clear connection between the flavor and the sad scenario, and they gave similar reasons as the participants who did not experience a connection during the happy scenario. Nevertheless, the ice cream contributed positively to the experience of some participants who felt that it helped pull them into the experience, and the combination of the real and virtual helped them connect with the scenario.

6 Conclusion

This paper detailed two user studies performed as part of a collaboration between an XR production company, a chef, and a research lab. The results of the first study indicate that the VEs did affect taste perception on behalf of some participants. However, the effect varied considerably between individuals. In some cases incongruent VEs made the participants find sweet oysters more salty and salty oysters more sweet. Other participants found that the contrast between the taste and the VE emphasized the taste instead. This suggests that VEs can affect the taste during virtual dining experiences, but it is difficult to predict the effects of incongruent audiovisual stimuli. The results of the second study indicated that the sad scenario produced higher arousal. The participants exposed to the happy scenario did not feel that the bitter taste of the ice cream matched the scenario. Conversely, most of the participants exposed to the sad scenario did perceive a meaningful connection between the bitter taste and the unpleasant experience, and a few even perceived increased bitterness as the narrative grew increasingly unpleasant. Finally, the lack of agency and the experience of eating ice cream contributed to some participants' sensation of being a child. However, it remains unclear to what extent the taste played a role in this regard.

Acknowledgments

This work was supported by Future Food Innovation and Innovation Fund Denmark.

References

[1] R. I. Allison and K. P. Uhl. Influence of beer brand identification on taste perception. *Journal of Marketing Research*, 1(3):36–39, 1964.

[2] P. Arnold. You better eat to survive! exploring edible interactions in a virtual reality game. In *Proceedings of the 2017 CHI Conference Extended Abstracts on Human Factors in Computing Systems*, pp. 206–209, 2017.

[3] J. Benedek and T. Miner. Measuring desirability: New methods for evaluating desirability in a usability lab setting. *Proceedings of Usability Professionals Association*, 2003(8-12):57, 2002.

[4] J. F. Delwiche. You eat with your eyes first. *Physiology & behavior*, 107(4):502–504, 2012.

[5] N. K. Dess and D. Edelheit. The bitter with the sweet: the taste/stress/temperament nexus. *Biological psychology*, 48(2):103–119, 1998.

[6] C. N. DuBose, A. V. Cardello, and O. Maller. Effects of colorants and flavorants on identification, perceived flavor intensity, and hedonic quality of fruit-flavored beverages and cake. *Journal of Food Science*, 45(5):1393–1399, 1980.

[7] C. Erlingsson and P. Brysiewicz. A hands-on guide to doing content analysis. *African Journal of Emergency Medicine*, 7(3):93–99, 2017.

[8] B. G. Green, P. Dalton, B. Cowart, G. Shaffer, K. Rankin, and J. Higgins. Evaluating the 'labeled magnitude scale'for measuring sensations of taste and smell. *Chemical senses*, 21(3):323–334, 1996.

[9] D. Korsgaard, T. Bjøner, and N. C. Nilsson. Where would you like to eat? a formative evaluation of mixed-reality solitary meals in virtual environments for older adults with mobility impairments who live alone. *Food research international*, 117:30–39, 2019.

[10] D. Korsgaard, T. Bjørner, J. R. Bruun-Pedersen, P. K. Sørensen, and F. J. Perez-Cueto. Eating together while being apart: A pilot study on the effects of mixed-reality conversations and virtual environments on older eaters' solitary meal experience and food intake. In *2020 IEEE Conference on Virtual Reality and 3D User Interfaces Abstracts and Workshops (VRW)*, pp. 365–370. IEEE, 2020.

[11] D. Korsgaard, N. C. Nilsson, and T. Bjørner. Immersive eating: evaluating the use of head-mounted displays for mixed reality meal sessions. In *2017 IEEE 3rd Workshop on Everyday Virtual Reality (WEVR)*, pp. 1–4. IEEE, 2017.

[12] K. Lab. Project nourished – a gastronomical virtual reality experience [online]. `http://www.projectnourished.com/`, 2015. Accessed: 2010-09-30.

[13] Makropol. Previous projects [online]. `https://makropol.dk/#projectssection`, 2020. Accessed: 2020-02-03.

[14] K. Moran. Using the microsoft desirability toolkit to test visual appeal [online]. `https://www.nngroup.com/articles/microsoft-desirability-toolkit/`, 2016. Accessed: 2020-01-25.

[15] A. Nanri, Y. Kimura, Y. Matsushita, M. Ohta, M. Sato, N. Mishima, S. Sasaki, and T. Mizoue. Dietary patterns and depressive symptoms among japanese men and women. *European journal of clinical nutrition*, 64(8):832–839, 2010.

[16] T. Narumi. Multi-sensorial virtual reality and augmented human food interaction. In *Proceedings of the 1st Workshop on Multi-sensorial Approaches to Human-Food Interaction*, p. 1. ACM, 2016.

[17] T. Narumi, S. Nishizaka, T. Kajinami, T. Tanikawa, and M. Hirose. Meta cookie+: an illusion-based gustatory display. In *International Conference on Virtual and Mixed Reality*, pp. 260–269. Springer, 2011.

[18] K. A. Neuendorf. *The content analysis guidebook*. sage, 2016.

[19] P. Perez, E. Gonzalez-Sosa, R. Kachach, J. Ruiz, I. Benito, F. Pereira, and A. Villegas. Immersive gastronomic experience with distributed reality. In *2019 IEEE 5th Workshop on Everyday Virtual Reality (WEVR)*, pp. 1–6. IEEE, 2019.

[20] P. Rozin. Family resemblance in food and other domains: the family paradox and the role of parental congruence. *Appetite*, 16(2):93–102, 1991.

[21] C. Spence. *Gastrophysics: The new science of eating*. Penguin UK, 2017.

[22] C. Spence, C. A. Levitan, M. U. Shankar, and M. Zampini. Does food color influence taste and flavor perception in humans? *Chemosensory Perception*, 3(1):68–84, 2010.

[23] C. Spence and B. Piqueras-Fiszman. *The perfect meal: the multisensory science of food and dining*. John Wiley & Sons, 2014.

[24] C. Spence, X. Wan, A. Woods, C. Velasco, J. Deng, J. Youssef, and O. Deroy. On tasty colours and colourful tastes? assessing, explaining, and utilizing crossmodal correspondences between colours and basic tastes. *Flavour*, 4(1):23, 2015.

[25] A. Stelick, A. G. Penano, A. C. Riak, and R. Dando. Dynamic context sensory testing–a proof of concept study bringing virtual reality to the sensory booth. *Journal of food science*, 83(8):2047–2051, 2018.

[26] N. M. B. Tuanquin, S. Hoermann, C. J. Petersen, and R. W. Lindeman. The effects of olfactory stimulation and active participation on food cravings in virtual reality. In *2018 IEEE Conference on Virtual Reality and 3D User Interfaces (VR)*, pp. 709–710. IEEE, 2018.

[27] C. Velasco, K. Karunanayaka, and A. Nijholt. Multisensory human-food interaction. *Frontiers in psychology*, 9:796, 2018.

[28] C. Velasco, A. T. Woods, O. Deroy, and C. Spence. Hedonic mediation of the crossmodal correspondence between taste and shape. *Food Quality and Preference*, 41:151–158, 2015.

[29] Q. J. Wang, F. R. Carvalho, D. Persoone, and C. Spence. Assessing the effect of shape on the evaluation of expected and actual chocolate flavour. *Flavour*, 6(1):2, 2017.

[30] B. Wansink, K. Van Ittersum, and J. E. Painter. How descriptive food names bias sensory perceptions in restaurants. *Food quality and preference*, 16(5):393–400, 2005.

[31] M. Zampini and C. Spence. The role of auditory cues in modulating the perceived crispness and staleness of potato chips. *Journal of sensory studies*, 19(5):347–363, 2004.