# immersiTea: Exploring Multisensory Virtual Reality Environments to Enrich Bubble Tea Drinking Experiences


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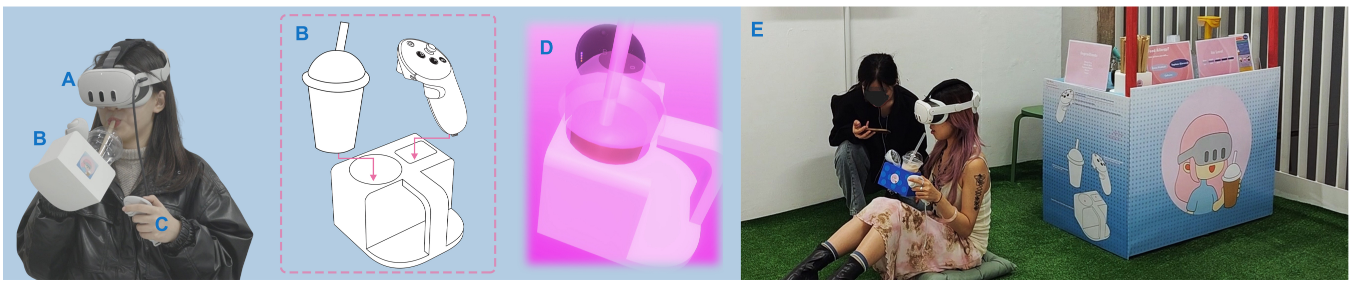


**Figure 1: User experience of immersiTea: A) virtual reality headset; B) immersiTea cup, including right hand controller; C) left hand controller; D) immersiTea cup's virtual counterpart; E) immersiTea in a "real-world" context.**


## ABSTRACT

HCI is increasingly interested in multisensory experiences; however, multisensory drinking seems to be underexplored. We introduce "immersiTea", a novel multisensory virtual reality (VR) system that aims to enrich the experience of drinking low-sugar bubble tea. Leveraging crossmodal correspondences between visual, auditory, and flavor stimuli, immersiTea integrates immersive VR environments with physical drinking actions to enhance sensory and emotional engagement. Through a mixed-method evaluation (n = 31), we found that the VR environments can elevate participants' enjoyment and sweetness perception while reducing reliance on sugar. Participants highlighted the role of playful interactivity and sensory congruence in drinking, making it a more engaging experience. These findings contribute to the growing field of Human-Food Interaction by showcasing the potential of immersive technologies to promote healthier and more enjoyable consumption practices. This work demonstrates the potential of immersiTea to not only enrich the drinking experience but also inspire future advancements in multisensory beverage design.



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## CCS CONCEPTS

• **Human-Centered Computing → Interaction Design**.

## KEYWORDS

Virtual Reality, Multisensory Experience Design, Human-food interaction, Cross-modal Correspondences, Food Science

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## 1 INTRODUCTION

Bubble tea, cherished worldwide for its joyful and engaging experience, has captivated a diverse consumer base [14]. However, as a sugar-sweetened beverage (SSB), it poses significant health risks, including obesity, diabetes, and cardiovascular diseases [17, 20]. This highlights the need for investigations into understanding how to reduce sugar intake without compromising the enjoyment of its taste experience. While efforts have been made to develop healthier alternatives and incorporate healthier sweeteners [7, 11, 20], limited attention has been given to leveraging interactive technologies to compensate for the reduced enjoyment due to lower sweetness.

We propose "immersiTea", a multisensory bubble tea drinking system that leverages Virtual Reality (VR) to enrich the enjoyment of low-sugar bubble tea. Drawing from the field of Human-Food

Interaction (HFI) [15], our work explores how multisensory VR could offer an innovative approach to dining, promoting healthier drinking habits without compromising the enjoyment of drinking. By leveraging the principles of cross-modal correspondences, which describe how sensory stimuli such as visuals and sounds influence taste perceptions, immersiTea integrates synchronized visual and auditory stimuli to amplify flavor experiences, such as sweetness and sourness [24, 26, 28]. The system comprises a specially crafted low-sugar bubble tea, immersive VR environments, and a custom-designed immersiTea cup that integrates physical drinking actions with virtual feedback. Through the integration of physical and virtual components, immersiTea aims to offer a novel and enjoyable drinking experience of low-sugar bubble tea.

To evaluate the system, we conducted a mixed-method study (n=31). Our findings highlight the potential of immersiTea to enhance the sensory experience of low-sugar bubble tea and reveal the sequence of virtual scenes in VR influences sensory perceptions.

As an initial exploration, our work makes several contributions. First, it introduces a multisensory VR drinking system that combines physical actions with synchronized virtual feedback. Second, the study provides insights into how such a system can affect flavor perception and enjoyment. Finally, it offers design implications for creating VR experiences that promote healthier beverage consumption without sacrificing enjoyment.

## 2 RELATED WORK

Recent advancements in HFI and multisensory design [24, 27] have emphasized how technology can enrich food and beverage experiences, fostering healthier habits and creating enjoyable, interactive dining scenarios [15, 18]. A key area of focus within this domain is Multisensory Human-Food Interaction (MHFI), which examines how sensory stimuli—sight, sound, taste, touch, and smell—shape food perceptions and overall dining experiences [30]. For instance, auditory feedback has been shown to enhance the perceived crispiness of food [10], while visual cues like color [8, 9, 26, 28] and shape [9, 26] can alter taste perceptions. Beyond isolated sensory effects, researchers have explored how technologies can combine multiple sensory inputs to enrich drinking experiences. For example, the "Vocktail" system [22] integrates taste, smell, and visual stimuli through a digitally augmented glass to simulate diverse flavor profiles, showcasing the potential of technology to redefine beverage consumption.

The advent of VR has expanded the horizon of MHFI, providing researchers with tools to design highly immersive environments that influence sensory and emotional responses [25]. Unlike traditional visual tools, VR creates a sense of presence that emotionally connects users to virtual settings, enabling them to experience food and beverages in ways that defy physical and sensory constraints [29]. For instance, in the study by Wang et al., VR was used to manipulate the appearance of coffee, such as adding "virtual milk" by changing its color, which significantly influenced participants' flavor perception without altering the physical beverage itself [32]. Similarly, VR gamified eating experiences in the project "You Better Eat to Survive," where cooperative consumption was integrated into survival-based gameplay, demonstrated the potential of virtual worlds to influence eating behaviors [3]. These examples demonstrate VR's ability to merge multisensory design with immersive storytelling, offering opportunities to alter food perception [4], and modify eating behaviors [8]. However, much of the existing MHFI research focuses on creating novel sensory experiences rather than addressing broader goals like promoting healthier consumption habits.

One critical aspect of promoting healthier consumption habits is addressing the growing consumption of sugar-sweetened beverages (SSBs), which are closely linked to health issues such as obesity and diabetes[17, 20]. With global consumption of SSBs on the rise [20], bubble tea—one of the most popular SSBs [17]—has become especially popular [14]. Despite efforts to develop healthier alternatives, such as using alternative sweeteners [7, 11, 20], and the use of static multisensory designs like packaging [16] to enhance overall enjoyment, little research has explored the potential of integrating VR and multisensory design to promote healthier bubble tea drinking experiences.

Our research aims to explore this opportunity, positioning the overarching question as follows: How can interactive multisensory design, facilitated by VR, enrich the bubble tea drinking experience to reduce reliance on sugar while maintaining enjoyment and satisfaction?

## 3 DESIGNING IMMERSITEA

The immersiTea system is an interactive multisensory experience that combines specially crafted low-sugar bubble tea with virtual reality environments, using a custom 3D-printed cup equipped with a VR controller to synchronize physical actions and virtual feedback.

### 3.1 The design of the bubble tea

The bubble tea in this project is designed with health considerations at the forefront (for the process of making bubble tea, see Video Figure 2), aligning with recommendations from the Dietary Guidelines Advisory Committee [1]. The guidelines suggest a maximum daily sugar intake of 38 grams for men and 25 grams for women. A typical 473 mL serving of bubble tea contains up to 35 grams of sugar [17]. To address this, the sugar content of the bubble tea in this project is reduced to 12 grams per 473 mL serving, aiming to offer a healthier alternative. Our bubble tea aims to retain the essence of commercial offerings by combining black tea (313 mL per 473 mL serving), whole milk (160 mL per 473 mL serving), and tapioca pearls to recreate the iconic "bubbles".

### 3.2 The design of the VR environments

Within the system, we developed two distinct virtual environments to embody the contrasting themes of "sour" and "sweet." Each environment was crafted with unique visual and auditory cues to immerse participants in the corresponding sensory experience. The sour-themed scene, titled "Acid Boom," and the sweet-themed scene, titled "Sweet Sensation," were both built by using Unity 2022.3.15, with VR interactions managed through the XR Interaction Toolkit. The auditory stimuli—two soundtracks specifically designed to evoke the sensations of sourness and sweetness—were composed by Deng and Sun and used with granted permissions. Previous crossmodal studies have demonstrated that these soundtracks can successfully evoke the intended taste associations [31].

*3.2.1 Acid Boom.* Design choices for Acid Boom (Fig. 2A, Video Figure 3) were influenced by research on crossmodal perception and sensory associations [8, 26, 31]. This scene emphasizes quick, sharp movements to reflect how sourness is perceived—rapidly appearing and disappearing [19]. The scene is dominated by yellow and green tones and sharp, angular geometry, commonly associated with sour flavors [8, 19, 26]. The soundtrack, with high-pitched tones, staccato rhythms, and distorted effects, creates an atmosphere that mirrors sourness [31]. The particle system, VFX stripe bursts (Video Figure 00:21), and gravity shift effect (Video Figure 00:19-00:21) were inspired by the rapid, intense perception of sour flavors [13, 19], simulates the bursting sensation of lemon boba. Throughout, voice guidance directs participants, triggering specific experiences, effects, and music.

*3.2.2 Sweet Sensation.* The Sweet Sensation scene (Fig. 2B, Video Figure 4) embodies the smooth, calming nature of sweetness through visual and auditory elements inspired by crossmodal perception research [8, 26, 31]. Sweet tastes are linked to smooth, continuous stimuli, such as rounded geometries and slow movements [8, 13, 26]. The design features soft, curved geometric models, a spiral pathway, and a soothing flow, bathed in soft pink hues often associated with sweetness [8, 9, 26, 28]. Particles gently fade in and out, enhancing the tranquil atmosphere. The soundtrack, with harmonious melodies, high piano notes, and bells [31], reinforces the calming, sweet perception. A low-gravity effect at the top of the spiral allows the participant to float down slowly, mimicking a feather drifting gently to the ground and amplifying the sensation of smoothness and serenity, reinforcing the experience of sweetness. The participant is guided along the spiral pathway, with voice cues directing them to their next destination.

## 3.3 The user interaction of immersiTea

The immersiTea experience aims to seamlessly integrate physical and virtual interactions to create a highly immersive and enjoyable VR experience (Video Figure 5). Participants wear the Meta Quest 3 headset (Fig. 1A) to enter a virtual environment while holding the left-hand controller (Fig. 1C) to navigate the scene with the joystick and interact with the user interfaces by pressing the trigger button. In their right hand, they hold the 3D-printed immersiTea cup (Fig. 1B), which not only accommodates a bubble tea cup but also integrates the right-hand VR controller for tracking. As participants lift the immersiTea cup to drink, this action is mirrored in the VR environment (Fig. 1D). Additionally, we explored situating immersiTea in a "real-world" context by presenting it as a stall in a food market within our university graduate exhibtion (Fig. 1E, Video Figure 1).

# 4 USER STUDY

## 4.1 Participants

We recruited 31 participants aged between 18 and 45 years, with a mean age of 24.08 years (standard deviation ±4.89 years). The gender distribution included 26 participants identifying as female, 2 as male, 1 as non-binary, and 2 preferring not to disclose their gender. All participants were regular consumers of bubble tea or self-identified as bubble tea connaisseurs [23]. They confirmed no known allergies or intolerances to our bubble tea ingredients, including black tea, milk, tapioca pearls, water, and sugar. Participants were also required to have normal or corrected-to-normal vision and no reported impairments in taste perception. This study protocol received approval from the university's ethics review board. Participants received small gifts, such as project-related fridge magnets, keychains, and clips.

## 4.2 Measurements

To assess the impact of immersive VR environments on the enjoyment and flavor perception of low-sugar bubble tea, both quantitative and qualitative measures were employed. Participants rated their overall enjoyment using a 9-point Likert scale (1 = "Dislike Extremely," 9 = "Like Extremely") and assessed sweetness, sourness, and bitterness on a 9-point sensory scale (1 = "None," 9 = "Extremely") to capture the key dimensions of flavor commonly associated with bubble tea. Each drink was presented in identical cups labeled A and B, with participants unaware of the identical bubble tea contents. The goal was to convince them that A might be distinct from B. To mitigate order effects, the sequence of VR environments was randomized, and participants rinsed their palate with water between conditions. Qualitative data were collected through semi-structured interviews using the micro-phenomenology technique [21], conducted immediately after tasting sessions. These interviews, ranging from 15 to 20 minutes in duration, were audio-recorded, transcribed for thematic analysis [6], and analyzed using NVivo software. Transcripts were coded to identify patterns and themes. Coding was conducted independently by two researchers to enhance reliability.

## 4.3 Procedure

The study was conducted as a one-on-one session in a controlled laboratory environment, ensuring consistency and minimizing external influences on the participants' sensory experiences. Each participant completed the experiment individually, following a structured sequence of steps designed.

The session began with an introduction to the study, obtaining informed consent, and a brief health screening to confirm no allergies or sensitivities to bubble tea ingredients. Participants then received a tutorial on using the VR headset (Meta Quest 3) to ensure comfort and familiarity with the equipment.

The experiment consisted of two phases: a baseline tasting phase without VR and an experimental phase with VR. In the baseline phase, participants tasted two identical cups of low-sugar bubble tea, labeled A and B, in a neutral, non-VR environment to establish baseline ratings for enjoyment and flavor perception. After tasting each sample, participants provided verbal feedback, and the researcher recorded the ratings. In the experimental phase, participants experienced two VR environments—"Sweet Sensation" and "Acid Boom"—while tasting the same bubble tea samples from the baseline phase. Each VR condition lasted about five minutes, with verbal ratings for enjoyment and flavor perception recorded by the researcher. After each condition, participants rinsed their palate

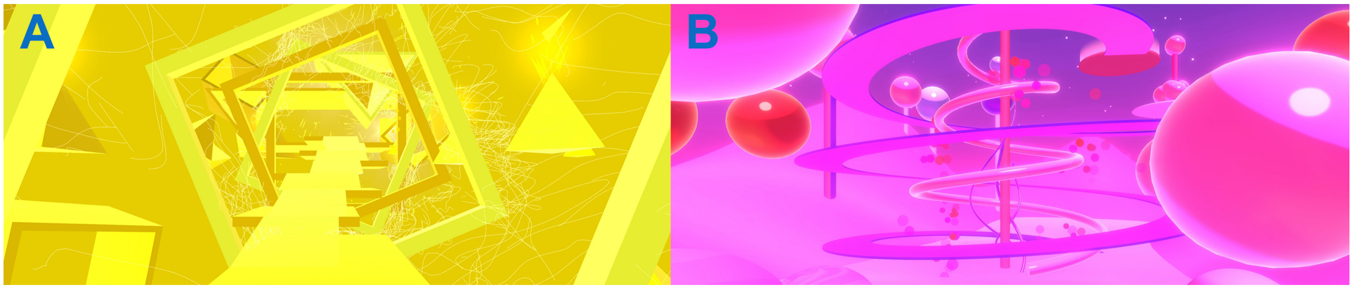


**Figure 2: VR environments: A) Acid Boom VR scene; B) Sweet Sensation VR scene.**

with water to minimize sensory carryover effects. The order of VR environments was randomized.

Finally, participants took part in a 15–20-minute semi-structured interview, reflecting on their experiences in both baseline and VR conditions.

# 5 RESULTS

## 5.1 Quantitative Analysis

The analysis examined the main effects of the VR conditions. Shaprio-Wilk test for normality confirmed that "Enjoyment" and "Sweetness" are normally distributed, but not "Sourness" and "Bitterness". A repeated-measures ANOVA was conducted in SPSS Statistics for "Enjoyment" and "Sweetness". As shown in Figure 3, participants reported higher enjoyment of the drinks in the Sweet Sensation VR condition (Mean ± SE: 7.1 ± 0.2) compared to the Acid Boom VR condition (5.7 ± 0.3), with the main effect of VR environments significant for "Enjoyment" ($F(1, 30) = 25.013, p < 0.001, \eta^2 = 0.455$). Similarly, the VR conditions significantly influenced "Sweetness" ($F(1, 30) = 11.382, p = 0.002, \eta^2 = 0.275$), with drinks rated as sweeter in the Sweet Sensation VR condition (5.5 ± 0.3) than in the Acid Boom VR condition (4.6 ± 0.3). A Wilconxon Signed Ranks tests was performed for "Sourness" and "Bitterness". A significant result was found for "Sourness" ($Z = -3.72, p = 0.000$), suggesting a strong and consistent influence of VR on participants' sourness ratings, with the Acid Boom VR eliciting higher sourness ratings ($1.8 \pm 0.1$) compared to Sweet Sensation VR ($1.3 \pm 0.1$). The effect of VR on "Bitterness" ($Z = -2.79, p = 0.005$) was also significant, with participants perceiving drinks in the Acid Boom VR condition as more bitter (2.0 ± 0.2) than those in Sweet Sensation VR (1.5 ± 0.1).

## 5.2 Thematic analysis

*5.2.1 Theme 1: Progressive Trajectory in VR Scenes.* Participants highlighted the impact of VR environments on their overall bubble tea drinking experience, with most agreeing that VR enriches the experience. Specifically, participants described the Sweet Sensation scene as "dreamy" (n=13), evoking feelings of comfort and relaxation (n=15) and offering a soft and enjoyable ambiance (n=19). In contrast, the Acid Boom scene elicited predominantly negative emotions (n=21), with descriptions such as "tension"(n=5) and "discomfort"(n=7). For instance, Participant 11 remarked: *"It didn't feel like a place for enjoying bubble tea."*

Interestingly, several participants noted a trajectory-like experience [5] that contributed to a more playful and dynamic interaction. Participants described a sequential unfolding of elements within the VR scenes, creating a sense of linear progression that added a narrative quality to their experience. They often began noticing visual features like color schemes, followed by geometric shapes, then music triggered by interactions, and finally, object movement, which became more apparent after extended time in the environment. For instance, P9 highlighted how music significantly impacted her mood, enriching her enjoyment of the bubble tea: *"With the addition of music, the effect was even more pronounced."* Exploration of different areas in the VR environment also led to fragmented yet meaningful experiences, with specific scenes evoking distinct emotional responses. For example, P19 noted that the sweetness of her drink felt more intense when she was positioned at the top of a slope in the pink-themed scene: *"It was all about the perspective and mood."* Additionally, some participants observed that the immersive quality of the VR experience deepened over time. P5 reflected on this progression, stating: *"The effects become more noticeable"* as she stays in the scene longer.

These findings suggest how VR environments can facilitate progressive trajectories that enrich user engagement. Whether through sequential narratives, fragmented explorations, or the deepening effects of prolonged immersion, participants experienced the drinking environment in ways that enriched their sensory and emotional engagement.

*5.2.2 Theme 2: Association between scene elements and taste perception.* The associations formed with specific elements in the VR scenes constituted the most immediate and tangible aspect of participants' sensory experiences. In the Sweet Sensation scene, the pink color evoked a sense of joy (n=19), while the rounded and smooth geometric elements conveyed softness (n=21). Relaxing music further contributed to feelings of calm and inner peace (n=15), and the slow motion of spherical animations combined with particle effects appeared to deepen the overall comfort of the scene (n=9). In contrast, the Acid Boom scene's yellow-green tones left an impression of liveliness and excitement (n=9). However, its sharp, angular geometric objects conveyed a sense of danger (n=3), while the chaotic and jarring music induced tension and discomfort (n=11). The rapid motion of the VFX stripes was often described as unsettling and overwhelming (n=13), although a small number of participants found it exciting and playful (n=2).

Beyond emotional associations, these elements also shaped participants' perceptions of taste. A majority of participants (n=17) reported that the Sweet Sensation scene enhanced the perceived

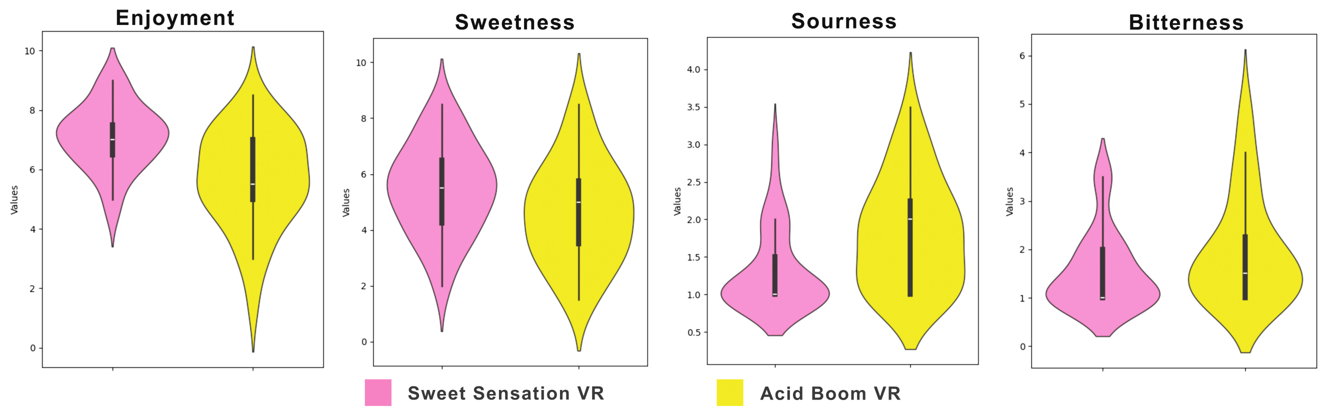


**Figure 3: Violin plots of ratings (Enjoyment, Sweetness, Sourness, and Bitterness) for Sweet Sensation VR and Acid Boom VR.**

sweetness of their drinks. For example, calming music (P6) and soft pink visuals (n=6) contributed to an intensified sweetness. Some participants, like P1, associated the scene's spherical and translucent reflective materials with the imagery of a lollipop, which further reinforced this perception. Similarly, the Acid Boom scene often triggered associations with sour flavors (n=11), primarily through visual and dynamic elements. As P12 explained, the yellow-green tones evoked thoughts of lemon-flavored candies, described as "soft and lemony." Additionally, the yellow particle burst animations reminded some participants of the sensation of lemon juice bursting in the mouth (n=5).

These findings highlight the ways in which VR environments can shape perceptions of sweetness and sourness.

*5.2.3 Theme 3: Sequential Influence on Sensory and Emotional Perception.* Switching between contrasting environments also played a significant role in shaping participants' perceptions. Drinks often tasted sweeter in the pink scene after leaving the tense yellow scene, as the stark difference between the two settings accentuated the drink's flavors. *"Coming from the yellow scene, which felt bitter in comparison, the contrast made the sweetness stand out even more"* (P30). However, prolonged exposure to repetitive or visually intense scenes, particularly the yellow scene, led to sensory fatigue. As one participant explained, *"The yellow scene, after walking it a few times, got a bit boring. The pink scene felt more engaging because of the spiral staircase—you could see the spirals above, and it felt like I still had a long way to go"* (P23). These findings suggest that sequential exposure to contrasting or repetitive environments can influence sensory and emotional responses in complex ways.

# 6 DISCUSSION

## 6.1 Enriching drinking experience in VR

The study revealed a significant impact of VR environments on participants' enjoyment of drinking bubble tea (Theme 1). Participants consistently reported higher levels of enjoyment in the "Sweet Sensation" environment, attributing this to its calming visuals, harmonious music, and interactive elements. The immersiTea experience was perceived as more engaging compared to consuming the beverage in a neutral setting. Additionally, the interactive narrative embedded within the VR environment contributed to a trajectory-like experience, encouraging participants to view the process of drinking bubble tea as an engaging and cohesive journey, which enriched their drinking experience and resulted in significantly higher enjoyment ratings ($p < 0.001$). These findings align with previous research suggesting that user experiences can be enriched through designed trajectories [5].

Interestingly, the sequence of VR environments emerged as a critical finding (Theme 3). This sequential influence aligns with theories of sensory contrast [12], underscoring the potential of dynamic VR transitions to modulate taste perceptions. While much of the existing research minimize such effects in their studies [2], our study raises the possibility of harnessing order effects to create richer sensory and narrative dimensions in drinking experiences. We propose that future designs might deliberately incorporate order effects as a mechanism within VR experiences, shaping participants' perceptions and enhancing their overall engagement.

## 6.2 Promoting healthier bubble tea consumption through multisensory design

To address the health concerns associated with the high sugar content of bubble tea, immersiTea was designed to offer a low-sugar alternative. Drawing from findings in crossmodal theory related to sweetness perception (Theme 2), the VR environments were designed to evoke the sensation of sweetness, enabling participants to enjoy the beverage despite its reduced sugar content. Alternatively, the VR experience aimed to enrich the overall drinking experience, allowing participants to derive enjoyment from the bubble tea even when it was perceived as less sweet.

Our findings suggest that VR environments can potentially reduce reliance on sugar while maintaining or even enhancing the sensory enjoyment of beverages. Enjoyment and Sweetness ratings showed a significant increase under VR conditions with large effect sizes (Enjoyment: $\eta^2 = 0.455$ ; Sweetness: $\eta^2 = 0.275$). Participants frequently highlighted the role of the VR environment in amplifying their perception of sweetness. For instance, calming music (P6) and soft pink visuals (n=6) were specifically noted as contributing to the sensation of enhanced sweetness. These results align with previous research in crossmodal perception [8, 13, 19, 26, 28], while also extending its application toward user experience design. However, several critical limitations warrant consideration. The study's intervention only demonstrates short-term effectiveness, leaving open questions about sustained impact across days or weeks of repeated use. Furthermore, the absence of rigorous control groups and long-term dietary tracking prevents direct claims about actual sugar intake reduction. While our results suggest VR's potential as a sugar-reduction adjuvant, longitudinal studies with physiological measures are needed to validate its practical efficacy in public health contexts.

## 7 CONCLUSION AND FUTURE WORK

Despite its strengths, this study also has limitations. The design is hindered by limited interactivity, with issues like positional inaccuracies from the controller disrupting immersion. Future iterations should integrate advanced tracking technologies to improve precision and alignment. Another limitation arises from the constrained ecological validity of current headset-controller-based VR systems. Bubble tea is typically consumed in dynamic real-world contexts (e.g., while walking, socializing), yet our stationary setup restricted natural movement and contextual congruence. This discrepancy between experimental conditions and naturalistic consumption environments may reduce the generalizability of findings. Developing contextually congruent multisensory environments that align with natural drinking behaviors may further optimize crossmodal effects while preserving experiential authenticity. Moreover, individual differences in sensory and emotional responses suggest that personalized VR environments could further enhance the user experience. Future research could explore adaptive VR systems that dynamically adjust visual and auditory elements based on user preferences and responses.

In conclusion, our work introduced immersiTea, an interactive drinking system that incorporates multisensory VR to enrich the experience of consuming low-sugar bubble tea. By examining the crossmodal correspondences among visual, auditory, and flavor stimuli, our findings suggest that immersiTea can amplify perceived sweetness and elevate overall enjoyment. This demonstrates its potential to transform beverage consumption into a more engaging and health-conscious activity. We hope this work inspires further advancements in the design of multisensory drinking experiences.

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## REFERENCES


[1] 2025 Dietary Guidelines Advisory Committee. 2024. Scientific Report of the 2025 Dietary Guidelines Advisory Committee: Advisory Report to the Secretary of Health and Human Services and Secretary of Agriculture. https://doi.org/10.52570/DGAC2025. https://doi.org/10.52570/DGAC2025

[2] Gastón Ares and Sara R. Jaeger. 2013. Check-all-that-apply questions: Influence of attribute order on sensory product characterization. *Food Quality and Preference* 28, 1 (April 2013), 141–153. https://doi.org/10.1016/j.foodqual.2012.08.016

[3] Peter Arnold, Rohit Ashok Khot, and Florian Floyd Mueller. 2018. "You Better Eat to Survive": Exploring Cooperative Eating in Virtual Reality Games. In *Proceedings of the Twelfth International Conference on Tangible, Embedded, and Embodied Interaction*. 398–408. https://doi.org/10.1145/3173225.3173238

[4] Ronald G. Bangcuyo, Kacey J. Smith, Jamie L. Zumach, Alex M. Pierce, Gretchen A. Guttman, and Christopher T. Simons. 2015. The use of immersive technologies to improve consumer testing: The role of ecological validity, context and engagement in evaluating coffee. *Food Quality and Preference* 41 (2015), 84–95. https://doi.org/10.1016/j.foodqual.2014.11.017

[5] Steve Benford, Gabriella Giannachi, Boriana Koleva, and Tom Rodden. 2009. From interaction to trajectories: designing coherent journeys through user experiences. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (Boston, MA, USA) *(CHI '09)*. Association for Computing Machinery, New York, NY, USA, 709–718. https://doi.org/10.1145/1518701.1518812

[6] Virginia Braun and Victoria Clarke. 2006. Using thematic analysis in psychology. *Qualitative Research in Psychology* 3, 2 (2006), 77–101. https://doi.org/10.1191/1478088706qp063oa

[7] Lining Chen, Wei Wu, Na Zhang, Kathrine H. Bak, Yuhao Zhang, and Yu Fu. 2022. Sugar reduction in beverages: Current trends and new perspectives from sensory and health viewpoints. *Food Research International* 162 (Dec. 2022), 112076. https://doi.org/10.1016/j.foodres.2022.112076

[8] Yang Chen, Arya Xinran Huang, Ilona Faber, Guido Makransky, and Federico J. A. Perez-Cueto. 2020. Assessing the Influence of Visual-Taste Congruency on Perceived Sweetness and Product Liking in Immersive VR. *Foods* 9, 4 (2020). https://doi.org/10.3390/foods9040465

[9] Patricia Cornelio, Christopher Dawes, Emanuela Maggioni, Francisco Bernardo, Matti Schwalk, Michaela Mai, Steve Pawlizak, Jingxin Zhang, Gabriele Nelles, Nadejda Krasteva, and Marianna Obrist. 2022. *Virtually tasty*: An investigation of the effect of ambient lighting and 3D-shaped taste stimuli on taste perception in virtual reality. *International Journal of Gastronomy and Food Science* 30 (Dec. 2022), 100626. https://doi.org/10.1016/j.ijgfs.2022.100626

[10] Rafael de Liz Pocztaruk, Jan Hendrik Abbink, René A. de Wijk, Luis Carlos da Fontoura Frasca, Maria Beatriz Duarte Gavião, and Andries van der Bilt. 2011. The influence of auditory and visual information on the perception of crispy food. *Food Quality and Preference* 22, 5 (July 2011), 404–411. https://doi.org/10.1016/j.foodqual.2010.11.008

[11] Jennifer Erickson and Joanne Slavin. 2015. Total, Added, and Free Sugars: Are Restrictive Guidelines Science-Based or Achievable? *Nutrients* 7, 4 (April 2015), 2866–2878. https://doi.org/10.3390/nu7042866 Number: 4 Publisher: Multidisciplinary Digital Publishing Institute.

[12] F. A. Hayek. 2012. *The Sensory Order: An Inquiry into the Foundations of Theoretical Psychology*. University of Chicago Press. Google-Books-ID: ZY9PYuxhOfwC.

[13] Gijs Huisman, Merijn Bruijnes, and Dirk K. J. Heylen. 2016. A Moving Feast: Effects of Color, Shape and Animation on Taste Associations and Taste Perceptions. In *Proceedings of the 13th International Conference on Advances in Computer Entertainment Technology* (Osaka, Japan) *(ACE '16)*. Association for Computing Machinery, New York, NY, USA, Article 13, 12 pages. https://doi.org/10.1145/3001773.3001776

[14] Istijanto and Indria Handoko. 2021. What approach and avoidance factors drive Gen-Z consumers to buy bubble tea? An exploratory study. *Young Consumers* 23, 3 (Dec. 2021), 382–396. https://doi.org/10.1108/YC-08-2021-1376 Publisher: Emerald Publishing Limited.

[15] Rohit Ashok Khot and Florian Mueller. 2019. Human-Food Interaction. *Foundations and Trends® in Human–Computer Interaction* 12, 4 (2019), 238–415. https://doi.org/10.1561/1100000074

[16] Deng Lujie, Liang Lizhu, and Li Jiang. 2022. Multi-Sensory Experience in Food and Beverage Packaging Design. *International Journal of Advanced Research in Technology and Innovation* 4, 1 (2022), 85–96. https://myjms.mohe.gov.my/index.php/ijarti/article/view/17822

[17] Jae Eun Min, David B. Green, and Loan Kim. 2017. Calories and sugars in boba milk tea: implications for obesity risk in Asian Pacific Islanders. *Food Science & Nutrition* 5, 1 (2017), 38–45. https://doi.org/10.1002/fsn3.362

[18] Florian 'Floyd' Mueller, Marianna Obrist, Soh Kim, Masahiko Inami, and Jialin Deng. 2023. Eat-IT: Towards Understanding Interactive Technology and Food (Dagstuhl Seminar 22272). *Dagstuhl Reports* 12, 7 (2023), 19–40. https://doi.org/10.4230/DagRep.12.7.19

[19] Marianna Obrist, Rob Comber, Sriram Subramanian, Betina Piqueras-Fiszman, Carlos Velasco, and Charles Spence. 2014. Temporal, affective, and embodied characteristics of taste experiences: a framework for design. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (Toronto, Ontario, Canada) *(CHI '14)*. Association for Computing Machinery, New York, NY, USA, 2853–2862. https://doi.org/10.1145/2556288.2557007

[20] Barry M. Popkin and Corinna Hawkes. 2016. Sweetening of the global diet, particularly beverages: patterns, trends, and policy responses. *The Lancet Diabetes & Endocrinology* 4, 2 (2016), 174–186. https://doi.org/10.1016/S2213-8587(15)00419-2

[21] Mirjana Prpa, Sarah Fdili-Alaoui, Thecla Schiphorst, and Philippe Pasquier. 2020. Articulating Experience: Reflections from Experts Applying Micro-Phenomenology to Design Research in HCI. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems (CHI '20)*. Association for Computing Machinery, New York, NY, USA, 1–14. https://doi.org/10.1145/3313831.3376664

[22] Nimesha Ranasinghe, Thi Ngoc Tram Nguyen, Yan Liangkun, Lien-Ya Lin, David Tolley, and Ellen Yi-Luen Do. 2017. Vocktail: A Virtual Cocktail for Pairing Digital Taste, Smell, and Color Sensations. In *Proceedings of the 25th ACM International*

*Conference on Multimedia* (Mountain View, California, USA) *(MM '17)*. Association for Computing Machinery, New York, NY, USA, 1139–1147. https://doi.org/10.1145/3123266.3123440

[23] Thecla Schiphorst. 2011. Self-evidence: applying somatic connoisseurship to experience design. In *CHI '11 Extended Abstracts on Human Factors in Computing Systems* (Vancouver, BC, Canada) *(CHI EA '11)*. Association for Computing Machinery, New York, NY, USA, 145–160. https://doi.org/10.1145/1979742.1979640

[24] Charles Spence. 2015. Multisensory Flavor Perception. *Cell* 161, 1 (2015), 24–35. https://doi.org/10.1016/j.cell.2015.03.007

[25] Charles Spence. 2023. Digitally enhancing tasting experiences. *International Journal of Gastronomy and Food Science* 32 (June 2023), 100695. https://doi.org/10.1016/j.ijgfs.2023.100695

[26] Charles Spence. 2023. Explaining Visual Shape–Taste Crossmodal Correspondences. *Multisensory Research* 36, 4 (2023), 313 – 345. https://doi.org/10.1163/22134808-bja10096

[27] Charles Spence and Alberto Gallace. 2011. Multisensory design: Reaching out to touch the consumer. *Psychology & Marketing* 28, 3 (2011), 267–308. https://doi.org/10.1002/mar.20392 _eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1002/mar.20392.

[28] Charles Spence, Xiaoang Wan, Andy Woods, Carlos Velasco, Jialin Deng, Jozef Youssef, and Ophelia Deroy. 2015. On tasty colours and colourful tastes? Assessing, explaining, and utilizing crossmodal correspondences between colours and basic tastes. *Flavour* 4, 1 (July 2015), 23. https://doi.org/10.1186/s13411-015-0033-1

[29] Carlos Velasco, Francisco Barbosa Escobar, Olivia Petit, and Qian Janice Wang. 2021. Impossible (Food) Experiences in Extended Reality. *Frontiers in Computer Science* 3 (Aug. 2021). https://doi.org/10.3389/fcomp.2021.716846 Publisher: Frontiers.

[30] Carlos Velasco, Qian Janice Wang, Marianna Obrist, and Anton Nijholt. 2021. A Reflection on the State of Multisensory Human–Food Interaction Research. *Frontiers in Computer Science* 3 (Dec. 2021). https://doi.org/10.3389/fcomp.2021.694691 Publisher: Frontiers.

[31] Qian Wang, Andrew Woods, and Charles Spence. 2015. "Whats Your Taste in Music?" A Comparison of the Effectiveness of Various Soundscapes in Evoking Specific Tastes. *i-Perception* 6 (12 2015). https://doi.org/10.1177/2041669515622001

[32] Qian Janice Wang, Rachel Meyer, Stuart Waters, and David Zendle. 2020. A Dash of Virtual Milk: Altering Product Color in Virtual Reality Influences Flavor Perception of Cold-Brew Coffee. *Frontiers in Psychology* 11 (Dec. 2020). https://doi.org/10.3389/fpsyg.2020.595788 Publisher: Frontiers.