

Enhancing the Atmosphere in Hybrid Restaurants: a Dining Experience Assessment with Mixed Reality

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Abstract. Dining is increasingly defined by an interplay of sensory, social, psychological, and environmental factors, with restaurants striving to create unique atmospheres that go beyond mere food consumption. Emerging digital technologies, such as eXtended Reality (XR), can significantly enrich these experiences. However, they are still understudied and a research gap remains in understanding how to leverage XR to integrate physical dining elements with digital augmentation. The present study reports on the development and preliminary evaluation of a Mixed Reality (MR) application aimed at enriching the dining experience within an Hybrid Restaurant. Deployed on the Meta Quest 3, the MR system integrates physical elements with digitally augmented settings, thereby providing an ecological platform for controlled dining research within hybrid environment. To assess the system, 12 participants were involved in a feasibility task within a Hybrid Restaurant. Both objective behavioural data (i.e., food and beverage consumption modalities) and self-report measures (i.e., perceived comfort, user experience, emotional response, cybersickness, and sense of presence) were collected. The findings suggest that the MR environment supports intuitive eating and drinking without disruption. Participants reported feeling comfortable eating with both cutlery and their hands, and a preference for drinking with a straw, which minimized interference with the head-mounted display. Furthermore, the immersive setup elicited a sense of presence with negligible adverse effects and positive overall user experience. The approach offers significant insights for researchers exploring multisensory interactions in dining while providing restaurateurs with innovative strategies for prototyping and enhancing customer engagement through digital augmentation.

Keywords: eXtended Reality · Dining experience · Hybrid environment · User eXperience · Mixed Methods

1 Introduction

Dining at a restaurant is far more than simply consuming food, it is a comprehensive and immersive experience that engages multiple senses and psychological dimensions. The dining experience encompasses a complex interplay of factors, including the quality of food, social interactions, service quality, and the atmosphere [13, 35]. Both researchers and restaurateurs have dedicated considerable attention in studying the role of the physical environment in shaping the dining experience [5, 32, 53, 56]. Previous research demonstrates the impact of a restaurant’s atmosphere, showing how interior elements such as ambient factors, design factors, and social factors [3, 20, 62] impact customers’ expectations and emotional states, thus influencing their overall experience [34, 60].

In recent years, there has been a growing trend toward hybridizing the physical and digital environments within dining contexts [24, 40]. This convergence aims to evoke richer emotional and multisensory experiences that integrate digital technologies to enhance or transform the traditional dining ambiance. Notable successful applications include *Le Petit Chef* [10], which employs projection mapping to turn the dining table into a dynamic, animated canvas that unfolds a captivating narrative throughout the meal [5]. Similarly, *The Fat Duck* [14] has become synonymous with multisensory gastronomy, artfully integrating unexpected soundscapes and imaginative presentation techniques to create an immersive culinary journey that transcends traditional dining [47]. Among the emerging technologies reshaping this landscape, eXtended Reality (XR) holds significant potential to increase customer experience [16, 5]. XR refers to an umbrella term that includes various technologies extending the physical reality (e.g., Augmented Reality, Mixed Reality) or replacing it with a completely virtual experience (e.g., Virtual Reality) [29]. The application of XR in the restaurant industry suggests its potential to foster deeper sensorial engagement and emotional involvement, thereby shaping customer perceptions in meaningful ways [57, 70]. Although XR holds great promise, its application in dining experience design remains relatively under-explored.

In this context, we aim to explore new approaches to enrich the dining experience through hybrid environments. To achieve this, we leverage XR technologies, which offer new opportunities for investigating environmental influences on dining by allowing controlled modifications while maintaining an ecological setting. In particular, we have developed a Mixed Reality (MR) application, as MR enables the seamless integration of physical and virtual elements. This approach preserves key tangible components of the dining experience within a restaurant, while allowing for the dynamic modification of selected environmental features. The system serves as a flexible research platform, enabling the controlled manipulation of different variables of interest to explore multiple aspects of the dining experience, including taste perception and food choices, social interactions, and behavioural and emotional responses. This paper presents the first phase of our research activity, focusing on the design and development of the MR-based Hybrid Restaurant and its preliminary evaluation through a user study. The study has a dual focus: assessing the comfort of food and beverage consumption while

wearing a HMD and examining multiple aspects of the experience within the Hybrid Restaurant, including user experience, affective response, sense of presence, and cybersickness. Participants were invited to consume a snack in an Hybrid Restaurant while experiencing different ways of eating and drinking. We adopted a mixed-methods approach, combining behavioural data (i.e., video-analysis) and self-report measures (i.e., questionnaires) to gain insights into both consumption dynamics and the overall user experience.

2 Background

2.1 The role of environment in shaping dining experience

Contemporary research demonstrates that the physical environment actively modulates consumers' sensory perceptions and behaviours in dining contexts [55]. Experimental studies have shown, for example, that color and lighting can enhance the perceived appetitiveness of dishes [53]. For instance, Spence and colleagues [56] demonstrated that targeted lighting modifications can intensify gustatory experiences, while Ulrich and colleagues [64] highlighted the restorative effects of well-lit, natural environments in reducing stress. Another critical aspect concerns the interaction between indoor materials and spatial layout [12, 45, 46]. Research by Zhang and colleagues [72] suggests that the use of carefully selected wall and furniture materials not only improves overall aesthetics but also changes affective state, creating spaces where customers feel welcomed and relaxed. Moreover, a multisensory approach to environmental design encompasses the management of auditory and olfactory cues [4]. For example, studies examining the impact of acoustic environments [8, 54, 71] have found that the introduction of calming sounds and the reduction of background noise promote greater meal concentration and lower stress levels.

In summary, an integrated environmental design that combines aesthetic and multisensory dimensions is essential not only for improving customer satisfaction, but also for fostering loyalty [9, 23]. When meticulously designed, the physical context becomes a dynamic component that transforms the simple act of dining into a high-quality culinary experience.

2.2 XR in dining experience

The integration of digital technologies in the dining experience has garnered increasing attention, particularly in relation to immersive solutions [57]. These range from projection-based systems [5, 65], to 360° videos [36, 48, 50], AR and MR [33, 63], and VR [19, 41]. Interest in these technologies is driven by their potential to help modify the dining experiences and hopefully enhance the sensory perception, influencing consumer behaviour and enhancing user engagement [57]. For instance, Pennanen and colleagues [43] used a CAVE system to explore how immersive environments impact consumer emotions and food evaluations, showing that an environment that elicits positive emotion (i.e., a picnic in a sunny

environment) positively shaped consumer perceptions of food and encouraged healthier choices, compared to a sudden rainstorm and a neutral control. Similarly, Chen and colleagues [11] found that VR visual stimuli (displayed using a Samsung Gear VR headset) have crossmodal effects on sweetness perception: participants rated the same beverage as sweeter in a congruent environment (i.e., pink and red colours, round shapes, soft/smooth visual textures) and less sweet in an incongruent one. Another study explored whether MR systems (Oculus Rift HM), could recreate the illusion of dining in a living room, either alone or in the presence of familiar others. Although no significant changes in energy intake were observed, the findings indicated that this immersive experience positively contributed to the overall meal experience, with the virtual environment rated as having a more pleasant atmosphere and the food perceived to be of higher quality. Importantly, the MR social conditions significantly reduced feelings of loneliness and improved mood [28]. Finally, 360° technology [48] was adopted to examine the impact of the congruency of the VR environments (displayed using an Oculus Go) with consumed food on product liking. Participants rated food more favourably in seasonally congruent VR settings (e.g., watermelon in a summer context, truffles in a winter one).

The diversity of XR technologies used in research stems from their varying levels of immersion and isolation from the physical environment. Each technology presents specific strengths and limitations. While projection-based systems allow diners to see their food, they fail to create immersive environments. On the other hand, VR provides a higher degree of immersion but inherently isolates users, obstructing their view of the food and restricting natural social interactions that are fundamental to dining experiences. Moreover, many studies have primarily focused on small, handheld food items such as chocolate [43], bread [50], and watermelon [48] due to the constraints imposed by VR and 360° technologies—namely, excessive immersion that prevents interaction with utensils and obstructs the diner’s view of the table.

In contrast, MR emerges as the most versatile solution for dining experiences, seamlessly integrating virtual and physical elements within the same environment. Although no universally accepted definition of MR exists, Speicher and colleagues [52] identify six distinct conceptualizations, one of which defines MR as an alignment of environments—the synchronization of physical and virtual spaces to create a cohesive experience. In this framework, MR serves as a bridge between real and digital elements, ensuring that virtual content is accurately positioned and interacts meaningfully with the physical world. In our study, MR integrates virtual elements, such as the restaurant setting, with physical components, including the hands, table setting, utensils, and plates. This hybrid environment maintains the inherently social nature of dining, enhancing both immersion and interaction and positioning MR as a promising tool for crafting more natural and engaging dining experiences.

3 MR application for Hybrid Restaurant

The system developed employs MR to establish a hybrid environment wherein physical and virtual elements coexist, thereby enriching and personalising the dining experience beyond conventional approaches. Specifically, the dining room is integrated with a virtual immersive environment that surrounds the user, while preserving visibility of the physical elements in the immediate interaction area when one is seated, such as the table, tableware, food, and the user’s hands, thanks to passthrough technology (Fig. 1). This approach encourages spontaneous, natural, and immersive interactions, effectively balancing the benefits of fully virtual or immersive room solutions [67].

3.1 System development and implementation

The MR application was developed using the Unity engine (version 6000.1.0a2) and compiled into an APK format for deployment on the Meta Quest 3, a device selected for its advanced hardware capabilities. An interaction zone was implemented to integrate a physical table within the virtual environment, utilizing the official Meta XR All-in-One SDK (version 69.0.1). The virtual environment was constructed using assets derived from the ArchvizPRO Interior Vol.8 package, complemented by custom 3D models created with Blender (version 4.2). The design employed baked global illumination instead of real-time lighting to optimize device performance and enhance visual realism, thus reducing the rendering load. Spatial anchors were employed to allow an initial calibration to align the physical table with the virtual environment. This process makes the system adaptable to tables of varying sizes, as well as rooms with different layouts. Additionally, spatial audio was integrated to enhance immersion by positioning specific audio sources within the virtual space.

3.2 Description of the Hybrid Restaurant

The virtual environment simulates a restaurant with a panoramic sea view of Venice, comprising a main dining area measuring approximately $10 \times 7.5 \times 3.5$ meters (Fig. 1A). The environment is designed to evoke elegance and tranquility, featuring minimalist and sophisticated interior décor. Large windows overlooking the sea provide visual depth and realism to the virtual scene [22]. During the experience, participants are expected to remain seated at a physical table, continuously visible through the passthrough functionality of the headset, maintaining direct contact with physical elements, such as tableware, food, and their hands. The auditory environment is carefully composed of two distinct audio sources: ambient sea sounds [39] from the virtual exterior and subtle background music [61], enhancing the realism and immersion of the dining scenario [21, 37]. This setup serves as a versatile experimental platform, providing a controlled yet adaptable foundation for future research into dining experiences, seamlessly integrating tangible elements within a customizable virtual environment (Fig. 1C).



Fig. 1. The Hybrid Restaurant setup. The central panel shows a participant dining at a physical table (B), with their POV on the sides. On the left (A), the Hybrid Restaurant used in this study is shown. On the right (C), a version with altered environmental features is shown, maintaining the same experimental setup

4 Material and Methods

In the following the experimental tools and setting are described.

4.1 Experimental design

The study followed a within-participants design, in which two independent variables were manipulated: eating modality (using cutlery vs. with hands) and drinking modality (using a straw vs. without a straw).

4.2 Settings and equipment

The evaluation took place in a living lab within the university premises, ensuring consistent and stable lighting conditions throughout the day, specifically during the typical mid-afternoon snack time. The Hybrid Restaurant was experienced through the Meta Quest 3 (section 3.2). Participants were offered a banana, which was chosen for its versatility in being consumed by hand or with cutlery. The fruit was served with the peel intact to ensure hygiene by minimizing direct contact with the edible portion before consumption. For the beverage, they were served half a glass of still water (33 cl total capacity). The physical setup included a wooden table with a chair, arranged with a placemat, a stainless steel fork and knife in a cutlery holder, straws, and a paper napkin to replicate a typical dining environment. The experimental session was recorded using both an ambient camera (VHD-V61CL) and the screen recording of the Meta Quest 3.

4.3 Data collected

Behavioural data. All videos were imported into a dedicated analysis software, i.e., Behavioral Observation Research Interactive Software [17], to run the

video analysis. The analysis relied on a coding scheme following a top-down approach. Initially, two of the authors identified the significant events during the XR dining experience, including all the explicit behaviours that participants performed during the interactions with the tableware: eating with cutlery, eating without cutlery (using hands), drinking with a straw, and drinking without a straw. Subsequently, the two researchers reviewed the videos and identified situational triggers indicating the beginning and the end of each event included in the coding scheme, resulting in a list of physically-based events [2]. A trained coder reviewed and evaluated the recorded videos. In addition, action breakdowns were analyzed. More specifically, we considered breakdowns as any aspect that could slow down or interrupt the eating or drinking process while wearing the headset, in line with our research objectives and previous studies [18, 27]. In addition to assessing the smoothness of the experience, we also considered disruptions related to the need for manual adjustments of the HMD. A complete description of the various types of possible breakdowns can be found in Table 1.

Table 1. Video-analysis coding scheme of breakdowns during dining experience with HMD.

Behaviour	Breakdown	Description
Eating	Contact with the HMD	The food touches the HMD during the eating action.
	Trajectory adjustment	Participants need to correct their movements to ensure proper arm-to-mouth coordination.
	Food dropping	The participant drops the food while bringing it close to their mouth.
Drinking	Contact with the HMD	The glass or straw touches the HMD during the drinking action.
	Trajectory adjustment	Participants need to correct their movements to ensure proper arm-to-mouth coordination when bringing the glass or straw to the mouth.
Smoothness of the experience	Adjustment of the HMD	The participant engages in manual manipulation of the HMD to regulate fit, or move the lens area.

Self-report data. A total of 3 purposefully devised questionnaires and 3 standardized questionnaires were employed. Users’ backgrounds and dining habits were collected with a socio-demographic questionnaire which included items on gender, age, nationality, occupation, and dominant hand. Additionally, participants were asked to report any known allergies or food intolerances. The questionnaire also assessed participants’ liking for the snack presented in the study,

the frequency with which they dine at restaurants, and their previous experiences with HMD.

Comfort and ease of eating and drinking with an HMD were assessed using a 12-item questionnaire. The items evaluated their perceived comfort, ease, and the extent to which the headset interfered with eating or drinking. Specifically, participants rated statements such as *“It was comfortable to eat food using cutlery”*, *“It was easy to eat food using cutlery”*, and *“The headset did not obstruct the act of eating with cutlery”*. Equivalent items were included for the different eating and drinking conditions (cutlery vs. hands for eating, straw vs. no straw for drinking). Participants had to answer on a 7-point Likert scale (1 = “I strongly disagree”, 7 = “I strongly agree”).

Participants’ UX within the Hybrid Restaurant was evaluated using a 10-item questionnaire rated on a 7-point Likert scale. It measured 6 dimensions, including: overall satisfaction, ease of interaction with the physical tableware, physical HMD comfort, atmosphere, desire to stay longer, and repatronage intention. Overall satisfaction measures the feeling experienced when performing a required or desired action and perceiving its outcomes [44, 49] by two items. Ease of interaction with the physical tableware refers to the perceived effortlessness when handling and using elements in the table setting area, and it was assessed with one item. Physical HMD comfort refers to the degree of comfort individuals experience while wearing the headset and was assessed using two items adapted from Spagnolli and colleagues [51]. The overall perceived pleasantness of the restaurant atmosphere was evaluated using two items adopted from Erraja and colleagues [15]. Desire to stay longer is an affective state of attraction to the environment that motivates the customer to remain in the environment for an extended period of time [66], explored with an item adapted from Amin and colleagues [1]. Repatronage intention, referring to taking benefit of the service again in the future, was evaluated with 2 items adapted from Oliver and Swan [42].

Participants’ emotional responses during the dining experience were measured using the Self-Assessment Manikin (SAM) [7] which assesses three affective dimensions: valence, measuring the degree of pleasantness of an experience; arousal, describing the degree of psychophysiological activation elicited by a stimulus; and dominance, reflecting the perceived sense of control over the emotional experience or stimulus. The SAM relies on stylized figures that visually represent different levels of emotional intensity (9-point scale). Cybersickness is a condition that may occur during or after exposure to a virtual environment and it can induce symptoms such as headache, eye strain, nausea or vomiting in extreme cases, reducing the likelihood that VR users will ever use it again [26, 30, 31]. Cybersickness symptoms were assessed through the Simulator Sickness Questionnaire (SSQ) [25], which includes 16 items covering dimensions of nausea, oculomotor discomfort, and disorientation on a 4-point scale (0 = Not at all; 3 = Very much). Sense of presence is defined as *“the subjective experience of being in one place or environment, even when one is physically situated in another. Indeed, presence refers to experiencing the computer-generated environment rather than the actual physical locale”* [69]. It was measured using an

adapted Presence Questionnaire (PQ) [68], excluding the controller-related item. The 7-point scale assessed involvement, sensory fidelity, quality of interface, and adaptation/immersion.

Experimental procedure. Participants signed the informed consent form before beginning the experimental session. Subsequently, they completed the pre-experience questionnaire about socio-demographic aspects. After this initial step, participants were invited to sit at the table and instructed to wear the Meta Quest 3 headset, with the MR system already running. The experimenter ensured the HMD was fitted comfortably and functioning before proceeding with the experimental task. The experimental task simulated a dining experience in the MR-based Hybrid Restaurant. Participants were asked to perform four sequential actions: first, they drank the water from the glass using a straw; second, they ate half a banana with their hands (without using cutlery); third, they drank the water again, this time without the straw; finally, they ate the remaining half of the banana after cutting it with fork and knife. Notably, the sequential actions involving different eating and drinking modalities were counterbalanced across participants to prevent ordering effects. A printed sheet detailing the phases and their order was placed on the table beside the dining area, allowing participants to consult it in case of need. The session was video recorded, as detailed above. Upon finishing their experience in the Hybrid Restaurant, participants were asked to complete the post-experience questionnaires. All questionnaires were administered online through the Qualtrics platform. The entire experimental session lasted approximately 20 minutes. The experiment was approved by the local Ethical Committee.

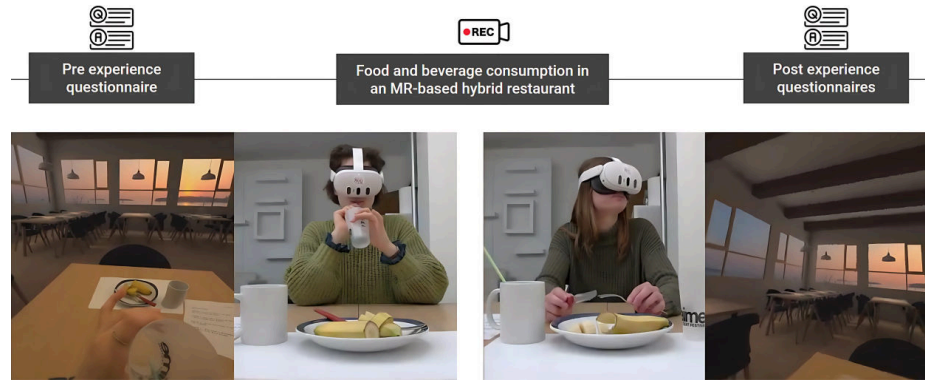


Fig. 2. Experimental conditions and task procedure. The figure displays the participants POV of the restaurant atmosphere and the two immersive dining conditions of the steps of the task, one for drinking and the other for eating.

Sample. A total of 12 international participants volunteered to take part in the study (all females). They did not receive any compensation for participation. The only inclusion criteria were the absence of any allergies or intolerances to the food item provided as a snack. The average age of the sample was 27.33 years ($SD = 4.93$, range 21-53). Regarding handedness, 11 participants were right-handed and only 1 was left-handed. All participants reported the absence of allergies, except for one individual who reported an intolerance to anise. As for dietary habits, all participants reported consuming bananas at least once a month. Regarding prior experience with HMDs, 75% of participants reported using one for the first time, while the remaining 25% had used an HMD less than once per year.

4.4 Data Analysis.

All statistical analyses were performed using RStudio Team (2024). Non-parametric tests were employed to evaluate participants' behavioural and self-report data across all conditions. Given the limited sample size, the ordinal nature of most variables, and the violation of normality assumptions, non-parametric methods were deemed most appropriate. Consequently, the Wilcoxon signed-rank test was employed to compare average scores between experimental conditions and to determine whether participants' responses significantly deviated from the mid-point of the response scale, which indicates a neutral attitude. For composite dimensions consisting of multiple items, mean scores were computed to obtain a single representative value. In addition, descriptive statistics, including medians (Mdn), means (M), and interquartile ranges (IQRs), were provided to summarize the data.

5 Results

5.1 Behavioural data

Wilcoxon signed-rank tests were performed to compare eating (with hands vs. using cutlery) and drinking (with a straw vs. without a straw) modalities in terms of breakdowns and duration. The ratio of food manipulation actions was calculated relative to the total number of such actions performed. Furthermore, the descriptive analysis indicated that participants, on average, completed their meal in 3 minutes and 36 seconds. Notably, headset adjustment never emerged as a breakdown, as no participant needed to reposition it at any point during the experiment. Table 2 summarizes the occurrence of behavioral breakdowns during eating and drinking tasks performed while wearing the HMD.

Eating with HMD. None of the participants touched the HMD while eating with cutlery or with hands. Analysis showed that the rates of trajectory adjustments per bite did not significantly differ between eating with cutlery ($Mdn = 0.00$, $M = 0.15$, $IQR = 0.00-0.27$) and with hands ($Mdn = 0.00$, $M = 0.00$,

IQR = 0.00–0.00; $V = 10$, $p = 0.10$). Similarly, the rates of food drops per bite were minimal in both conditions, with cutlery (Mdn = 0.00, $M = 0.15$, IQR = 0.00–0.15) and hands (Mdn = 0.00, $M = 0.00$, IQR = 0.00–0.00), showing no significant difference ($V = 15$, $p = 0.06$). Instead, participants took significantly more time when using cutlery (Mdn = 105.35 s, $M = 104.82$ s, IQR = 84.27–125.49) compared to eating with hands (Mdn = 73.80 s, $M = 65.26$ s, IQR = 50.31–79.30; $V = 73$, $p = 0.005$).

Drinking with HMD. No collisions between the HMD and the glass occurred when participants drank using a straw. In contrast, most participants ($n = 9$) experienced at least one collision between the HMD and the glass when drinking without a straw. This difference was significant according to a Wilcoxon test ($V = 0$, $p = 0.008$). Notably, none of the participants needed to adjust their movements to achieve proper arm-to-mouth coordination when bringing the glass or straw to their mouth. Drinking duration was slightly longer with a straw (Mdn = 23.98 s, $M = 23.92$ s, IQR = 14.88–30.49) compared to drinking without a straw (Mdn = 21.91 s, $M = 21.59$ s, IQR = 14.35–26.17), though this difference was not significant ($V = 45$, $p = 0.677$).

Table 2. Summary of action breakdowns during eating and drinking with HMD.

Eating Breakdown	With cutlery		With hands	
	% participants	% per bite	% participants	% per bite
Contact with the HMD	0%	0%	0%	0%
Trajectory adjustment	33%	14%	0%	0%
Food dropping	25%	5%	0%	0%
Drinking Breakdown	With straw		Without straw	
	% participants		% participants	
Contact with the HMD	8%		75%	
Trajectory adjustment	0%		0%	

5.2 Self-report data

Comfort and ease of eating and drinking with HMD. Wilcoxon signed-rank tests were performed to compare eating (hands vs. cutlery) and drinking (straw vs. no straw) modalities 3.

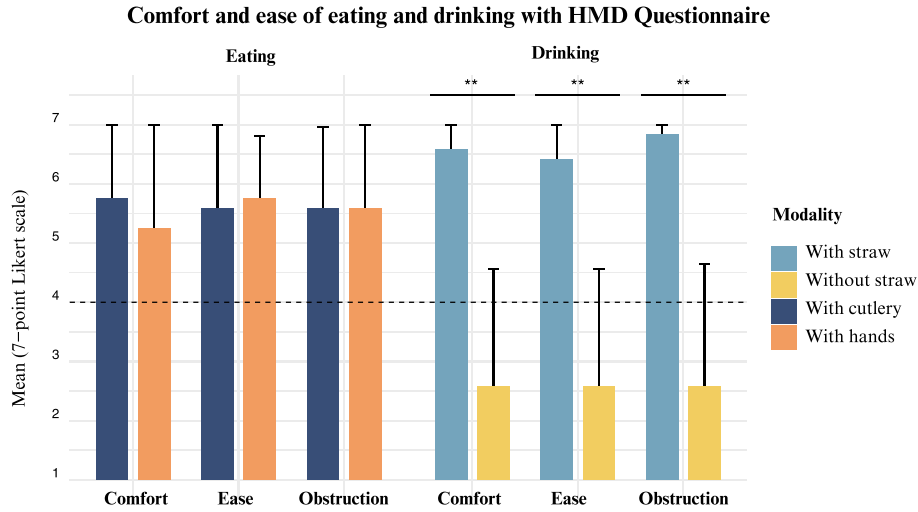
For eating, comfort was rated higher with cutlery than with hands though no significant difference emerged ($V = 23$, $p = 0.526$). Similarly, no significant differences were found in perceived ease of eating between cutlery and hands ($V = 16$, $p = 0.832$), nor in obstruction ratings ($V = 13$, $p = 0.930$).

For drinking, comfort was rated significantly higher when using a straw compared to drinking without one ($V = 66$, $p = 0.003$). The same pattern was observed for ease of use, with drinking via straw rated significantly easier than without a straw ($V = 66$, $p = 0.004$). Obstruction was also rated significantly lower with a straw ($V = 0$, $p = 0.004$).

Table 3. Comfort and ease ratings of eating and drinking with HMD.

Eating Dimensions	With Cutlery			With Hands			Wilcoxon test	
	Mdn	M	IQR	Mdn	M	IQR	V	p-value
Comfort	6.50	5.75	5.00–7.00	5.50	5.25	4.50–7.00	23	0.526
Ease	6.00	5.58	4.75–7.00	6.00	5.75	5.00–6.25	16	0.832
Obstruction	2.00	2.42	1.75–3.00	2.00	2.42	1.00–3.00	13	0.930
Drinking Dimensions	With Straw			Without Straw			Wilcoxon test	
	Mdn	M	IQR	Mdn	M	IQR	V	p-value
Comfort**	7.00	6.58	6.75–7.00	2.00	2.58	1.00–3.00	66	0.003
Ease**	7.00	6.42	6.00–7.00	2.00	2.58	1.00–3.00	66	0.004
Obstruction**	1.00	1.17	1.00–1.00	6.00	5.42	4.75–7.00	0	0.004

** Indicates statistically significant differences ($p < 0.01$).

**Fig. 3.** M and SD of eating and drinking by different modalities with HMD.

User eXperience within the Hybrid Restaurant. Wilcoxon signed-rank tests were performed to compare the average scores against the scale median value (Mdn = 4). Results indicated significantly higher scores across all subscales: overall satisfaction ($V = 78$, $p = 0.002$; Mdn = 6.25, $M = 6.21$, $IQR = 6.00-6.63$), ease of interaction with the physical tableware ($V = 73.5$, $p = 0.006$; Mdn = 6.00, $M = 6.00$, $IQR = 6.00-7.00$), physical HMD comfort ($V = 55.5$, $p = 0.049$; Mdn = 5.25, $M = 5.04$, $IQR = 3.75-6.13$), atmosphere ($V = 78$, $p = 0.002$; Mdn = 6.25, $M = 6.29$, $IQR = 5.88-7.00$), willingness to extend the duration of the experience ($V = 40$, $p = 0.040$; Mdn = 5.00, $M = 5.17$, $IQR = 4.00-7.00$), and repatronage intention ($V = 78$, $p = 0.002$; Mdn = 6.00, $M = 6.13$, $IQR = 5.50-7.00$).

Emotional Responses. To evaluate the emotional responses, subscales including valence, arousal, and dominance were analyzed. Wilcoxon signed-rank tests were conducted to compare the scores against the scale’s median value (Mdn = 4). Results indicated significantly higher scores for valence ($V = 55$, $p = 0.005$; Mdn = 7.00, $M = 7.10$, IQR = 6.00–8.00), and dominance ($V = 55$, $p = 0.006$; Mdn = 6.50, $M = 6.70$, IQR = 5.25–8.00), while no significant difference was found for arousal ($V = 14.5$, $p = 0.457$; Mdn = 4.00, $M = 4.50$, IQR = 4.00–5.75).

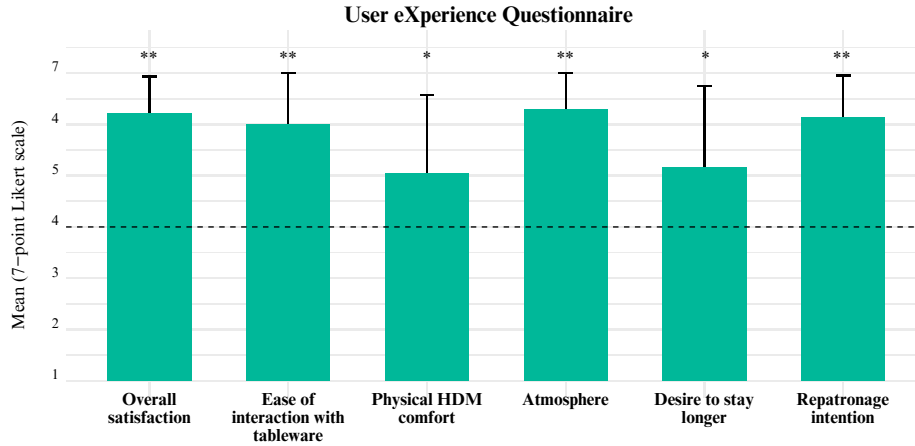


Fig. 4. M and SD of User eXperience Questionnaire scores by subscale.

Cybersickness. To evaluate the scores, subscales including disorientation, nausea, and oculomotor were analyzed [58]. Wilcoxon signed-rank tests were conducted to compare the scores against the scale’s median value (Mdn = 1.5). Results indicated significantly lower scores across all subscales: disorientation ($V = 2.5$, $p = 0.005$; Mdn = 0.286, $M = 0.5238$, IQR = 0.00–0.786), nausea ($V = 0$, $p = 0.002$; Mdn = 0.143, $M = 0.298$, IQR = 0.00–0.4286), and oculomotor ($V = 9$, $p = 0.020$; Mdn = 0.517, $M = 0.788$, IQR = 0.107–1.500).

Sense of Presence. Subscales including involvement, sensory fidelity, quality of interface, and adaptation/immersion were analyzed. Wilcoxon signed-rank tests were conducted to compare the scores against the scale’s median value (Mdn = 5). Results indicated significantly higher scores in all scales: involvement ($V = 68$, $p = 0.005$; Mdn = 5.31, $M = 4.97$, IQR = 4.98–5.48), sensory fidelity ($V = 74$, $p = 0.007$; Mdn = 5.25, $M = 5.13$, IQR = 4.33–5.71), quality of interface ($V = 49$, $p = 0.003$; Mdn = 5.25, $M = 5.04$, IQR = 4.00–6.00), and adaptation/immersion ($V = 78$, $p = 0.032$; Mdn = 5.25, $M = 5.42$, IQR = 5.00–6.06).

6 Discussion

This study investigated two main aspects: the feasibility and comfort of eating and drinking while wearing an HMD, as well as key factors influencing the dining experience in an MR-based Hybrid Restaurant. Specifically, we examined UX, emotional response, sense of presence, and cybersickness, providing a comprehensive preliminary evaluation of the designed and developed MR application. To explore these aspects, participants consumed a snack both with and without cutlery and drank from a glass both with and without a straw. We collected both behavioural data (i.e., video-analysis) and self-reported measures (i.e., questionnaires). In the following, we discuss the results for each of these aspects.

6.1 Food and beverage consumption with HMD

The results indicate that eating a snack with HMD does not pose significant challenges. All participants were able to consume their snacks, with behavioural measures showing no differences in food drops or trajectory adjustments between conditions, and overall disruptions remained low in both modalities. These findings align with self-reported evaluations in which participants rated eating as easy and comfortable, with minimal obstruction caused by the headset, regardless of whether they used their hands or utensils. Taken together, our findings suggest that participants could eat comfortably while wearing the headset, expanding upon earlier evidence of generally positive MR dining experiences by Koesgaard and colleagues [27]. While their work noted issues such as headset collisions and mismatched sensory cues, these disruptions were minimal in our preliminary evaluation of the MR system, likely due to the integration of new passthrough technology. Moreover, the longer duration of food consumption with utensils than eating by hand suggests that this modality may encourage a more prolonged engagement with the Hybrid Restaurant. This should be interpreted cautiously, as various factors could contribute to differences in the time spent at the restaurant [38] or affect consumption based on type of utensil [6]. Instead, drinking behaviours differed significantly between conditions. Participants experienced obstruction when drinking from a glass (e.g., collision with the HMD), whereas no such issue occurred with a straw. This aligns with Koesgaard and colleagues [27] who reported similar issues with glasses colliding with the Oculus Rift. This was reflected in self-reported data, as participants rated drinking with a straw more comfortable and less obstructive than drinking directly from a glass. Notably, drinking duration did not differ significantly between conditions, suggesting that the consumption mode affected perceived comfort rather than the time spent drinking. On one hand, this result provides clear indications for the design of future experiments. On the other hand, it raises a question regarding the consistency between drinking with a straw and being in an elegant environment.

6.2 User eXperience within Hybrid Restaurant and Affective Responses

Overall, the UX within the Hybrid Restaurant was positive. Participants expressed high satisfaction, ease of interaction with physical tableware, and physical comfort while using the headset. The behavioural data corroborated these findings, as no participants adjusted their headsets during the session, indicating sustained comfort throughout the experience. The atmosphere was perceived as pleasant, with participants expressing a desire to extend their time in the Hybrid Restaurant and a willingness to repeat the experience.

Affective responses further supported the positive reception of the MR dining experience. Arousal levels were moderate, suggesting that the experience was engaging without being overly stimulating. This balance is beneficial, as excessive arousal could lead to discomfort, while very low arousal might indicate a lack of engagement. Furthermore, the high levels of positive valence and dominance suggest that participants experienced positive emotions and a sense of control during the meal [7]. These emotional responses align with the reported overall satisfaction and willingness to repeat the experience, reinforcing the feasibility of MR dining applications.

6.3 Cybersickness and Sense of Presence

Cybersickness symptoms were minimal across all dimensions (nausea, oculomotor discomfort, and disorientation), indicating that the MR application did not induce significant discomfort. This is a key finding, as cybersickness can be a significant barrier to adopting XR technologies in real-world applications [59]. The absence of severe symptoms suggests that the MR system is well-suited for dining experiences, allowing users to interact with physical and virtual elements without adverse effects.

Presence was also consistently high across all measured dimensions, including involvement, sensory fidelity, quality of interface, and adaptation/immersion. These findings indicate that participants felt highly engaged in the XR environment, perceiving it as a cohesive and immersive dining space. The strong sense of presence supports the viability of MR as a platform for studying dining behaviours, as it ensures that users feel embedded within the virtual setting while maintaining interactions with physical elements such as food and tableware [22].

7 Conclusion

With this contribution, we introduced and evaluated an MR-based system designed to investigate factors that enhance dining experiences through hybrid environments. Overall, the findings demonstrate the potential of MR to create ecologically yet controllable hybrid environments bridging the gap between controlled experimental settings and real-world dining scenarios. Our results further support the feasibility of dining while wearing an HMD, with eating proving to be comfortable and unobstructed regardless of whether participants used their

hands or utensils. However, drinking from a glass presented challenges due to collisions with the headset, whereas using a straw was rated as more comfortable. The evaluation of our system confirmed its effectiveness in providing a positive and engaging dining experience. Participants reported high satisfaction, seamless interaction with tableware, and overall comfort while using the headset. The pleasant atmosphere and high sense of presence suggest MR’s potential for enhancing dining experiences, with minimal cybersickness and balanced affective responses supporting its applicability in future research on immersive dining behaviours. Additionally, this study highlights MR as a cost-effective tool for testing and optimizing dining environments before physical implementation, while also demonstrating its potential for designing immersive XR dining experiences that extend beyond traditional architectural constraints.

This study has some limitations. First, our sample was small and composed only of female participants, mostly young adults. To improve generalizability, future research should include a more heterogeneous sample. Moreover, since dining is inherently a social experience, and this study focused on solo dining, future studies should explore how MR affects shared meals and social interactions. Additionally, this research focused solely on snack consumption. Future studies should extend this approach to full meals, not only to explore the impact of MR across diverse culinary contexts but also to assess how prolonged exposure to XR influences user experience, comfort, and engagement over time. Finally, while this study focused on tableware, different types of dining tools are known to influence the overall eating experience [6]. Future investigations should explore a broader range of utensils and dining setups to determine their compatibility with MR dining settings and their potential impact on user behaviour and comfort.

Regarding future research directions, the system functions as a versatile research platform, allowing controlled manipulation of key variables related to ambient, design, and social factors. Future studies could further investigate various psychological aspects of the dining experience, including taste perception, food choices, social interactions, and behavioural and emotional responses. These investigations could provide deeper insights into optimizing dining environments to enhance diners’ experience. The findings from this first phase highlight MR’s potential as a research tool for studying dining behaviours in immersive settings. Expanding research to diverse user populations and assessing prolonged exposure effects will be essential for understanding the broader applicability of MR dining environments.

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References

1. Amin, M., Ryu, K., Cobanoglu, C., Rezaei, S., Wulan, M.M.: Examining the effect of shopping mall attributes in predicting tourist shopping satisfaction and behavioral intentions: Variation across generation X and Y. *Journal of Quality Assurance in Hospitality & Tourism* **22**(3), 367–394 (2021)
2. Bakeman, R., Quera, V.: Behavioral observation. In: *APA handbook of research methods in psychology, Vol 1: Foundations, planning, measures, and psychometrics*, pp. 207–225. American Psychological Association, Washington (2012)
3. Baker, J.: The role of environment in marketing services: the consumer perspective”. American Marketing Association, Chicago, IL (1986)
4. Bangcuyo, R.G., Smith, K.J., Zumach, J.L., Pierce, A.M., Guttman, G.A., Simons, C.T.: The use of immersive technologies to improve consumer testing: The role of ecological validity, context and engagement in evaluating coffee. *Food Qual. Prefer.* **41**, 84–95 (Apr 2015)
5. Batat, W.: How augmented reality (AR) is transforming the restaurant sector: Investigating the impact of “le petit chef” on customers’ dining experiences. *Technological Forecasting and Social Change* **172** (2021)
6. Bolhuis, D.P., Keast, R.S.J.: Assessment of eating rate and food intake in spoon versus fork users in a laboratory setting. *Food Qual. Prefer.* **49**, 66–69 (Apr 2016)
7. Bradley, M.M., Lang, P.J.: Measuring emotion: the self-assessment manikin and the semantic differential. *Journal of behavior therapy and experimental psychiatry* **25**(1), 49–59 (1994)
8. Bravo-Moncayo, L., Reinoso-Carvalho, F., Velasco, C.: The effects of noise control in coffee tasting experiences. *Food Quality and Preference* **86** (2020)
9. Çetinsöz, B.C.: Influence of physical environment on customer satisfaction and loyalty in upscale restaurants. *J. Tour. Gastron. Stud.* **7**(2), 700–716 (Jul 2019)
10. Chef, L.P.: Le petit chef - the dining experience (2025), <https://lepetitchef.com/>, accessed: 2025-03-03
11. Chen, Y., Huang, A.X., Faber, I., Makransky, G., Perez-Cueto, F.J.A.: Assessing the influence of visual-taste congruency on perceived sweetness and product liking in immersive VR. *Foods* **9**(4), 465 (Apr 2020)
12. Cheng, M.H., Zheng, M.C., Chen, C.Y.: Arrangements design of the congregate meal site to promote elderly interactive behavior. *J. Asian Archit. Build. Eng.* **22**(4), 2033–2046 (Jul 2023)
13. Counihan, C.: Food consumption and food activism in Italy. In: *Italians and Food*, pp. 101–125. Springer International Publishing, Cham (2019)
14. Duck, T.F.: The fat duck restaurant (2025), <https://thefatduck.co.uk/>, accessed: 2025-03-03
15. Errajaa, K., Legohérel, P., Daucé, B., Bilgihan, A.: Scent marketing: linking the scent congruence with brand image. *International Journal of Contemporary Hospitality Management* **33**(2), 402–427 (2021)
16. Flavián, C., Ibáñez-Sánchez, S., Orús, C.: The impact of virtual, augmented and mixed reality technologies on the customer experience. *Journal of business research* **100**, 547–560 (2019)
17. Friard, O., Gamba, M.: Boris: a free, versatile open-source event-logging software for video/audio coding and live observations. *Methods in Ecology and Evolution* **7**(11), 1325–1330 (2016)

18. Gamberini, L., Spagnoli, A., Prontu, L., Furlan, S., Martino, F., Solaz, B.R., Lozano: How natural is a natural interface? an evaluation procedure based on action breakdowns. *Personal and ubiquitous computing* **17**, 69–79 (2013)
19. Gouton, M.A., Dacremont, C., Trystram, G., Blumenthal, D.: Effect of perceptive enrichment on the efficiency of simulated contexts: Comparing virtual reality and immersive room settings. *Food Research International* **165** (2023)
20. Grayson, R.A.S., McNeill, L.S.: Using atmospheric elements in service retailing: understanding the bar environment. *J. Serv. Mark.* **23**(7), 517–527 (Oct 2009)
21. Guedes, D., Vaz Garrido, M., Lamy, E., Pereira Cavalheiro, B., Prada, M.: Cross-modal interactions between audition and taste: A systematic review and narrative synthesis. *Food Qual. Prefer.* **107**(104856), 104856 (Apr 2023)
22. Han, D.I.D., Boerwinkel, M., Haggis-Burridge, M., Melissen, F.: Deconstructing immersion in the experience economy framework for immersive dining experiences through mixed reality. *Foods* **11**(23), 3780 (Nov 2022)
23. Han, H., Ryu, K.: The roles of the physical environment, price perception, and customer satisfaction in determining customer loyalty in the restaurant industry. *J. Hosp. Tour. Res.* **33**(4), 487–510 (Nov 2009)
24. Huang, T., Lin, K.Y., Wang, Y.T., Chen, C.: Promoting customers' augmented reality immersion in restaurants (2022)
25. Kennedy, R.S., Lane, N.E., Berbaum, K.S., Lilienthal, M.G.: Simulator sickness questionnaire: An enhanced method for quantifying simulator sickness. *The international journal of aviation psychology* **3**(3), 203–220 (1993)
26. Kolasinski, E.M.: US army research institute for the behavioral and social sciences **1027** (1995)
27. Korsgaard, D., Nilsson, N.C., Bjørner, T.: 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)
28. Korsgaard, D., Bjørner, T., Bruun-Pedersen, J.R., Sørensen, P.K., Perez-Cueto, F.J.A.: 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). IEEE (Mar 2020)
29. Koumou, K.O., Isafiade, O.: Asset Management Trends in Diverse Settings Involving Immersive Technology: A Systematic Literature Review. *IEEE Access* (2024)
30. LaViola, J.J.: A discussion of cybersickness in virtual environments. *SIGCHI Bull.* **32**(1), 47–56 (Jan 2000)
31. Lawson, B.D., Kass, S., Muth, E., Sommers, J., Guzy, L.: Development of a scale to assess signs and symptoms of motion sickness in response to mild or nonsickening motion stimuli. In: Proceedings of the 72nd Annual Meeting of the Aerospace Medical Association. Reno, NV (2001)
32. Leong, A.M.W., Chen, K.Y., Chen, H.B., Chiang, T.E., Huan, T.C.: Exploring the effects of customers' assessments of a restaurant's atmospherics and emotional assessments on a fine-dining experience and intentions to return. *Tourism Management Perspectives* **47** (2023)
33. Li, S., Ding, Y., Gao, Z.: Sensory cravings: A mixed reality installation enhancing psychological experiences through multisensory interactions. In: SIGGRAPH Asia 2024 Posters. pp. 1–2. ACM, New York, NY, USA (Dec 2024)
34. Lin, I.Y., Mattila, A.S.: Restaurant servicescape, service encounter, and perceived congruency on customers' emotions and satisfaction. *Journal of hospitality marketing & management* **19**(8), 819–841 (2010)

35. Lukito, Y.N., Xenia, A.P.: Café as third place and the creation of a unique space of interaction in UI campus. *IOP Conf. Ser. Earth Environ. Sci.* **99**, 012028 (Dec 2017)
36. Man, K., Patterson, J.A., Simons, C.: The impact of personally relevant consumption contexts during product evaluations in virtual reality. *Food Quality and Preference* **109** (2023)
37. Mathiesen, S.L., Hopia, A., Ojansivu, P., Byrne, D.V., Wang, Q.J.: The sound of silence: Presence and absence of sound affects meal duration and hedonic eating experience. *Appetite* **174**(106011), 106011 (Jul 2022)
38. Mathiesen, S.L., Mielby, L.A., Byrne, D.V., Wang, Q.J.: Music to eat by: A systematic investigation of the relative importance of tempo and articulation on eating time. *Appetite* **155**, 104801 (2020)
39. Mixkit: Free sea sound effects (2025), <https://mixkit.co/free-sound-effects/sea/>, accessed: 2025-03-03
40. Motowilowa, J., Vergari, M., Kojić, T., Warsinke, M., Möller, S., Voigt-Antons, J.N.: Exploring Augmented Table Setup and Lighting Customization in a Simulated Restaurant to Improve the User Experience (2024)
41. Oliver, J.H., Hollis, J.H.: Virtual reality as a tool to study the influence of the eating environment on eating behavior: A feasibility study. *Foods* **10** (2021)
42. Oliver, R.L., Swan, J.E.: Consumer perceptions of interpersonal equity and satisfaction in transactions: A field survey approach. *Journal of Marketing* **53**(2), 21–35 (1989)
43. Pennanen, K., Närväinen, J., Vanhatalo, S., Raisamo, R., Sozer, N.: Effect of virtual eating environment on consumers' evaluations of healthy and unhealthy snacks. *Food Qual. Prefer.* **82**(103871), 103871 (Jun 2020)
44. Poushneh, A., Vasquez-Parraga, A.Z.: Discernible impact of augmented reality on retail customer's experience, satisfaction and willingness to buy. *J. Retail. Consum. Serv.* **34**, 229–234 (Jan 2017)
45. Presti, P., Ruzzon, D., Avanzini, P., Caruana, F., Rizzolatti, G., Vecchiato, G.: Measuring arousal and valence generated by the dynamic experience of architectural forms in virtual environments. *Sci. Rep.* **12**(1), 13376 (Aug 2022)
46. Robson, S.K.A., Kimes, S.E., Becker, F.D., Evans, G.W.: Consumers' responses to table spacing in restaurants. *Cornell Hosp. Q.* **52**(3), 253–264 (Aug 2011)
47. Salim, P.: Immersive Technology Study As A Science Innovation to Enhance Modern Dining Experience (2022)
48. Schouteten, Joachim and Van Severen, Arthur and Dull, Danielle and De Steur, Hans and Danner, Lukas: Congruency of an eating environment influences product liking : a virtual reality study. *Food and quality and preference* **113**, 6 (2024)
49. Shee, D.Y., Wang, Y.S.: Multi-criteria evaluation of the web-based e-learning system: A methodology based on learner satisfaction and its applications. *Computers & Education* **50**(3), 894–905 (2008)
50. Song, X., Pérez-Cueto, F.J.A., Bredie, W.L.P.: Food desires and hedonic discrimination in virtual reality varying in product-context appropriateness among older consumers. *Foods* **11**(20) (2022)
51. Spagnolli, A., Guardigli, E., Orso, V., Varotto, A., Gamberini, L.: Measuring user acceptance of wearable symbiotic devices: validation study across application scenarios. In: *Symbiotic Interaction: Third International Workshop, Symbiotic*, vol. 3, pp. 87–98. Springer International Publishing, Helsinki, Finland (2014)
52. Speicher, M., Hall, B.D., Nebeling, M.: What is mixed reality? In: *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*. p. 1–15. CHI '19, Association for Computing Machinery, New York, NY, USA (2019)

53. Spence, C.: On the manipulation, and meaning (s), of color in food: A historical perspective. *Journal of Food Science* **88**(S1), A5–A20 (2023)
54. Spence, C.: Noise and its impact on the perception of food and drink. *Flavour* **3**(1) (Dec 2014)
55. Spence, C.: Multisensory flavor perception. *Cell* **161**(1), 24–35 (Mar 2015)
56. Spence, C.: Gastrophysics: Getting creative with pairing flavours. *International Journal of Gastronomy and Food Science* **27**, 100433 (2022)
57. Spence, C.: Digitally enhancing tasting experiences. *International Journal of Gastronomy and Food Science* **32**, 100695 (2023). <https://doi.org/https://doi.org/10.1016/j.ijgfs.2023.100695>
58. Stanney, K.M., Kennedy, R.S., Drexler, J.M.: Cybersickness is not simulator sickness. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* **41**, 1138–1142 (1997)
59. Stanney, K., Lawson, B.D., Rokers, B., Dennison, M., Fidopiastis, C., Stoffregen, T., Weech, S., Fulvio, J.M.: Identifying causes of and solutions for cybersickness in immersive technology: Reformulation of a research and development agenda. *Int. J. Hum. Comput. Interact.* **36**(19), 1783–1803 (Nov 2020)
60. Stroebele, N., De Castro, J.M.: Effect of ambience on food intake and food choice. *Nutrition* **20**(9), 821–838 (Sep 2004)
61. Studios, F.: Closed curtains - royalty free music (2025), <https://www.fesliyanstudios.com/royalty-free-music/download/closed-curtains/2209>, accessed: 2025-03-03
62. Turley, L., Milliman, R.: Atmospheric effects on shopping behavior: a review of the experimental evidence". *Journal of Business Research* **49**, 193–211 (2000)
63. Ueda, J., Spence, C., Okajima, K.: Effects of varying the standard deviation of the luminance on the appearance of food, flavour expectations, and taste/flavour perception. *Sci. Rep.* **10**(1), 16175 (Sep 2020)
64. Ulrich, R.S., Simons, R.F., Losito, B.D., Fiorito, E., Miles, M.A., Zelson, M.: Stress recovery during exposure to natural and urban environments. *Journal of environmental psychology* **11**(3), 201–230 (1991)
65. van Bergen, G., Zandstra, E., Kaneko, D., Dijksterhuis, G., de Wijk, R.: Sushi at the beach: Effects of congruent and incongruent immersive contexts on food evaluations. *Food Quality and Preference* **91**, 104193 (2021)
66. Wakefield, K.L., Blodgett, J.G.: The importance of servicescapes in leisure service settings. *J. Serv. Mark.* **8**(3), 66–76 (Sep 1994)
67. Wang, Q.J., Barbosa Escobar, F., Alves Da Mota, P., Velasco, C.: Getting started with virtual reality for sensory and consumer science: Current practices and future perspectives. *Food Research International* **145**, 110410 (2021)
68. Witmer, B.G., Jerome, C.J., Singer, M.J.: The factor structure of the presence questionnaire. *Presence: Teleoperators & Virtual Environments* **14**(3), 298–312 (2005)
69. Witmer, B.G., Singer, M.J.: Measuring presence in virtual environments: A presence questionnaire. *Presence: Teleoper. Virtual Environ.* **7**(3), 225–240 (Jun 1998)
70. Wu, X., Lai, I.K.W.: The use of 360-degree virtual tours to promote mountain walking tourism: stimulus–organism–response model. *Inf. Technol. Tour.* **24**(1), 85–107 (Mar 2022)
71. Xu, Y., Hamid, N., Shepherd, D., Kantono, K., Reay, S., Martinez, G., Spence, C.: Background soundscapes influence the perception of ice-cream as indexed by electrophysiological measures. *Food research international* **125** (2019)
72. Zhang, X., Lian, Z., Wu, Y.: Human physiological responses to wooden indoor environment. *Physiol. Behav.* **174**, 27–34 (May 2017)