Dining in XR: empirical study

Jee Youn Kim
KAIST
jounkimm@kaist.ac.kr

Andrea Bianchi
KAIST
andrea@kaist.ac.kr

Figure 1 Participant eating a real meal while wearing an XR HMD (Meta Quest 3).

Abstract

What does it actually feel like to eat in extended reality (XR)? As XR technologies enter daily life, this study examines how dining—one of the most fundamental human activities—is experienced through mediated perception. While prior work has explored cooking or sensory augmentation, eating itself remains underexplored in XR. Six participants ate while wearing a head-mounted display (HMD), and we analyzed their behaviors through video observation, think-aloud sessions, and interviews. Findings show that identical eating actions were experienced differently due to mismatches between visual immersion, bodily coordination, and interaction assumptions, leading participants to adapt their movements over time. These results reveal how XR mediation reshapes everyday sensory awareness and suggest design directions for interaction models that better align with everyday eating gestures.

Keywords

Extended Reality, Dining in XR, User Experience

1. Introduction

As extended reality (XR) technologies increasingly enter everyday life, researchers have explored how immersive systems can augment routine activities such as cooking, dining, and social eating. Prior work has investigated virtual recipe guidance, sensory augmentation, and remote dining environments that support social connection and engagement (Covaci et al., 2023; Santos-Torres et al., 2025; Velasco et al., 2018). Together, these studies illustrate the growing normalization of food-related experiences within XR across both domestic and social contexts.

However, eating itself presents a particularly demanding form of embodied interaction. Unlike many XR-supported activities, eating requires highly precise coordination between the hand, mouth, and visual field, while simultaneously involving safety-sensitive, intimate bodily actions. Small perceptual misalignments can lead not only to discomfort but also to hesitation, loss of control, or risk of spillage. These characteristics make eating a boundary case for XR interaction—one that places unusually strict demands on perceptual alignment, gesture interpretation, and bodily awareness.

Despite this, existing XR food research has largely focused on food preparation, sensory augmentation, or social dining experiences, treating eating primarily as a behavioral or contextual variable. Few studies have examined eating as an embodied interaction shaped by XR-specific constraints, such as restricted field of view, passthrough perception, or gesture-recognition assumptions. As a result, little is known about how XR mediation itself reconfigures everyday eating actions, sensory attention, and bodily adaptation during real meals.

To address this gap, we investigate how people eat within XR environments under a minimally augmented baseline condition, without virtual overlays or sensory actuators. We intentionally chose this setup to isolate the effects of XR mediation itself—specifically immersion, passthrough vision, and hand tracking—rather than added augmentation technologies. Through qualitative observation and interviews with six participants eating while wearing a head-mounted display (HMD), we identify (1) interaction- and perception-level failure modes that emerge during XR dining, (2) the adaptive processes through which users regain agency over time, and (3) design implications for XR input and interaction models intended for everyday embodied activities.

2. Related Work

2.1 Embodied Interaction in XR

Research on embodied interaction emphasizes that action, perception, and environment are inseparable in shaping interactive experience (Dourish, 2001; Loke & Robertson, 2013). In food-related contexts, prior work has explored remote or co-present dining systems using augmented tables or projection-based interfaces to support social presence and coordination (Wei et al., 2011). Other studies have used VR to examine eating behavior, reporting effects on meal duration, satiety, or comfort, as well as applications in clinical settings such as appetite regulation or eating disorder treatment (Alkyoni et al., 2017; Oliver & Hollis, 2021; Riva et al., 2021).

While these studies demonstrate XR's potential for studying eating, they largely frame eating as a behavioral or social variable. In contrast, our work examines eating as a situated embodied practice that becomes reorganized through XR mediation, focusing on how perceptual and interactional constraints reshape core eating actions rather than their outcomes.

2.2 Food and Sensory Design

Much of food-related XR and HCI research has focused on multisensory augmentation, exploring how taste, smell, and touch can be computationally manipulated to alter eating experiences (Obrist et al., 2016; Velasco et al., 2018). Many XR and HCI systems pursue this goal through actuator-based augmentation, including electrical taste stimulation (Ranasinghe et al., 2019; Ullah et al., 2022), olfactory interfaces, or augmented reality illusions that alter perceived food size and satiety (Narumi et al., 2012). These approaches demonstrate the richness of multisensory design in shaping eating experiences.

A defining feature of this body of work is the use of explicit sensory actuators to generate perceptual effects. In contrast, our study does not introduce additional sensory hardware. Instead, we investigate how XR mediation alone—through immersion, passthrough vision, and interaction models—alters real-food perception and bodily coordination during eating. This perspective shifts attention from sensory augmentation toward how XR systems implicitly shape bodily attention and action during everyday practices such as eating.

2.3 Mindfulness and Reflective Interaction

Beyond sensory augmentation, Mindful and reflective interaction frameworks emphasize bodily awareness and intentional attention over efficiency and task completion (Sengers et al., 2005; Tsaknaki & Fernaeus, 2016). Prior work suggests that constraints and subtle disruptions can serve as design resources, slowing interaction and foregrounding reflection (Gaver, 2002; Höök, 2018). In food-related domains, mobile systems have applied these ideas to regulate eating behavior or craving through feedback and self-monitoring (Mason et al., 2018), though such approaches typically lack spatial and bodily embodiment.

Recent XR research extends mindfulness into immersive dining contexts, where multisensory cues can heighten sensory awareness or shape reflective social presence (Apostolou & Liarokapis, 2022; Santos-Torres et al., 2025). Building on these perspectives, our study adopts a reflective lens to examine how XR-induced constraints—such as perceptual misalignment and gesture ambiguity—prompt users to attend more closely to their own bodily actions during eating. Rather than framing these disruptions solely as usability issues, we analyze how they become resources for adaptation and embodied reflection.

3. Method

This study employed a qualitative approach combining video observation, think-aloud protocols, and semi-structured interviews to explore how dining behaviors and sensory experiences are reshaped when eating while wearing a head-mounted display (Meta Quest 3). Each one-hour session was conducted during lunchtime (11:00–12:00, 12:30–13:30, 14:00–15:00), with participants provided balanced meals varying in size, texture, and utensil type (Figure 2).

A custom Quest 3 application utilized the passthrough function for real-time visibility of the physical environment while maintaining immersion. The hand-tracking feature remained active to reflect default XR interaction assumptions, though no virtual overlays were introduced, ensuring a baseline condition focused on XR mediation itself.

Both solo and lightly conversational dining situations were observed. To evoke a shared dining context and observe bodily and attentional adjustments, the first author engaged participants in light conversation during the meal. All sessions were video-recorded and followed by interviews capturing participants' reflective accounts of their sensory and embodied experiences.

Table 1. Participant Data

Index	Gender	VR Experience
P1	F	One time in VR
P2	M	One time in VR
P3	F	Used short time for work in VR
P4	F	One time in VR
P5	F	Usually work with VR
P6	M	Worked with VR in the past

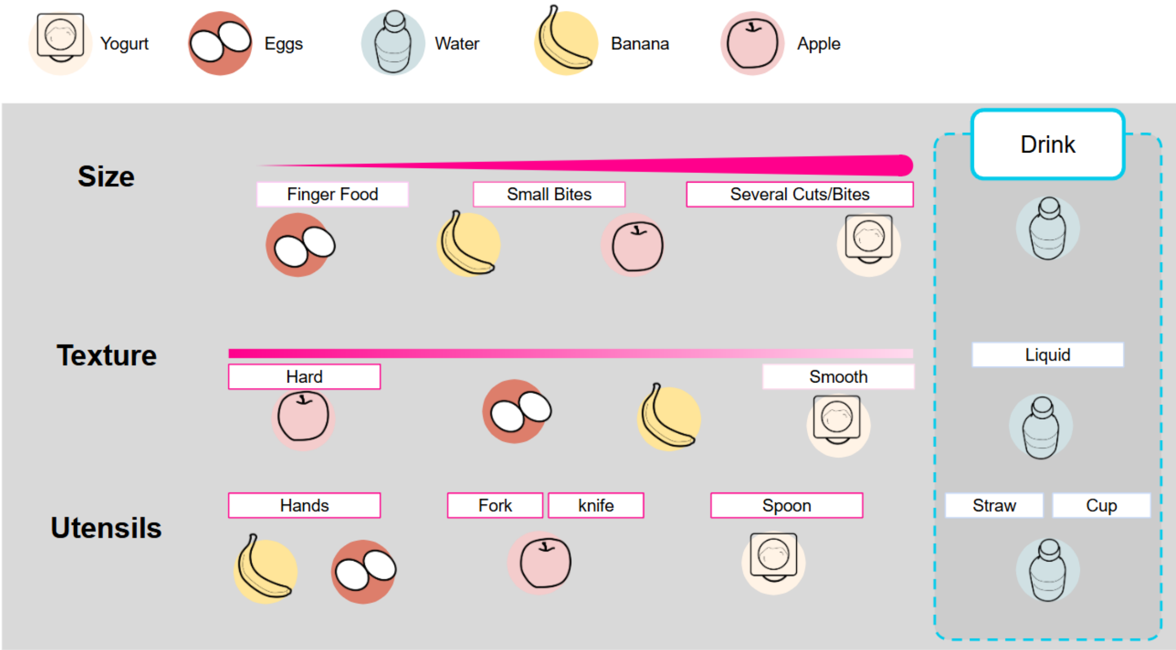

Figure 2 Overview of food items and their characteristics (size, texture, utensils, and drinks) used in the XR dining study. This illustration summarizes the physical eating conditions participants experienced while wearing the HMD.

3.1 Data Collection and Analysis

All sessions were video-recorded, and participants verbalized their thoughts and sensations during the meal to capture their immediate embodied experiences. Post-meal interviews were conducted to gather reflections on comfort, coordination, and sensory perception. All recordings were transcribed and analyzed following Braun and Clarke's (2006) six-phase thematic analysis through iterative cycles of familiarization, coding, and theme development. Thematic analysis was conducted by the author with iterative validation to ensure consistency. While no secondary coder was involved, repeated reviews and reflective memo-ing were employed to enhance analytical rigor and minimize potential bias. Four recurring patterns emerged—sense of agency, subjective perception, instrument selection, and eating strategies—which structure the discussion that follows.

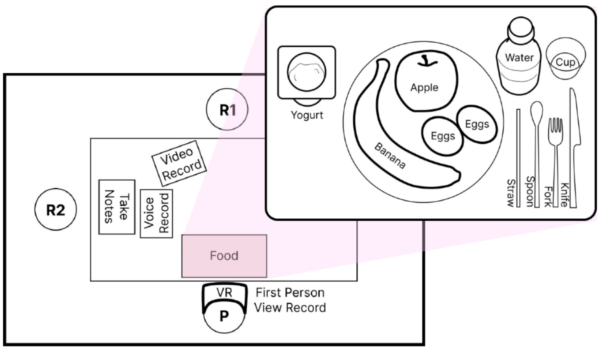

Figure 3 Study Settings with Food and Tool Orientation

4. Results: From Observation to Thematic Insights

Participants' experiences revealed how dining in XR reconfigured bodily control, sensory awareness, and vision–touch coordination, shaping how users negotiated physical and virtual eating.

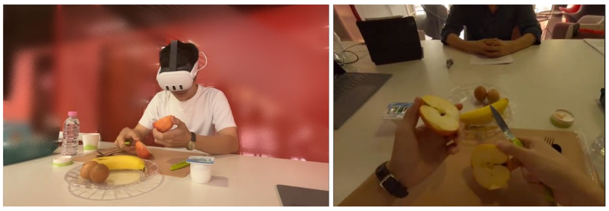

Figure 4 Video Analysis Scene. We analyzed both 3rd person view and 1st person view.

4.1 Bodily Disruption and Sensory Mismatch

Participants' initial reactions centered on the physical disruption caused by the headset. The occluded field of view and limited depth cues interfered with basic coordination between hand, mouth, and food. As one participant described, "I brought the spoon up, but the food disappeared right before my eyes. It was confusing—I froze for a second before I could eat" (P1). Others echoed similar disorientation: "It felt like the distance was off—my hand looked closer than it really was" (P3). This misalignment led to hesitation, pauses, and occasional unintended system-level reactions when mouth-directed eating motions were misrecognized as interaction gestures. The simple act of eating required constant recalibration between sight and touch, turning habitual behavior into deliberate action.

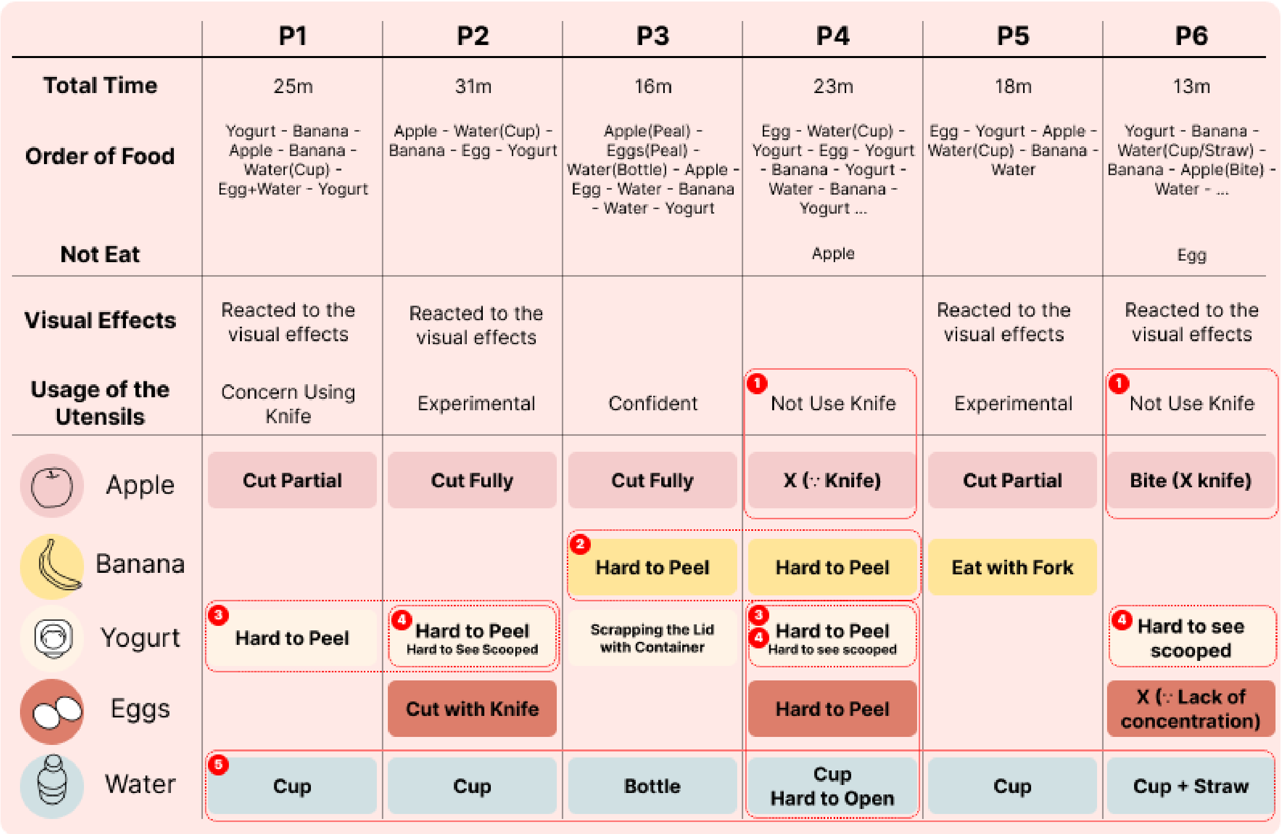

Figure 5 Summary of participants' eating behaviors in the XR dining study. The XR environment influenced utensil use (1, 4), affected interactions with food (2, 3), and led to diverse ways of drinking water (5).

4.2 Adaptive Eating Strategies

Despite early frustration, participants quickly began developing coping strategies. They altered body posture, leaned closer to the plate, or even switched tools. One participant said, "I could kind of see it under my nose, but the spoon looked slightly displaced—it made me feel a bit dizzy" (P5). Another noted, "I tilted my head and the cup slowly until I could feel it at my lips" (P2). The video analysis showed that participants progressively minimized head motion and stabilized their arms to reduce perceptual error and avoid triggering gesture-based interactions during eating. Some participants used their non-dominant hand to assist alignment, creating a new coordination pattern. These strategies suggest a learning process in which sensory mismatch prompted bodily recalibration rather than disengagement.

4.3 From Frustration to Curiosity

Emotional responses evolved throughout the session. Early moments were characterized by irritation and confusion, but these emotions often transformed into curiosity and playfulness. "It was frustrating at first—I couldn't find my food—but later I laughed at myself. It was like a mini game," one participant explained (P6). Another reflected, "I got used to it. It felt like training—trying to understand how my body works in this weird space" (P3). This emotional progression from struggle to discovery was mirrored in our observations: participants' movements became more deliberate over time, suggesting growing confidence and adaptation. Rather than resisting the constraints, they explored them.

4.4 Reflective Awareness of Eating

A recurring theme was heightened self-awareness of action. Participants often described a sense of observing themselves from outside. "I could see myself eating—it was strange, like watching my own habits," said P4. Others connected the slower pace with introspection: "Usually, I just eat without thinking, but here I had to think about every step. It made me realize how automatic I am" (P2). This reflective awareness transformed the XR environment from a frustrating medium into a mirror of embodied behavior. For some, it even led to appreciation: "I became more careful, more aware of the taste and act itself" (P5). What began as a breakdown evolved into reflective engagement.

5. Discussion

5.1 XR Dining as a Mismatch Between Everyday Gestures and XR Interaction Assumptions

Our analysis shows that XR dining difficulties arise less from the HMD itself than from a mismatch between everyday eating gestures and the task-oriented interaction assumptions embedded in current XR systems. As illustrated in Figure 6, participants' breakdowns arose from the interplay of physical constraints, unintended system responses, and altered social conditions, which together shaped their subsequent adaptations and reflections.

Current XR input models—particularly hand tracking and gesture recognition—largely assume intentional, task-oriented hand movements designed for manipulation, pointing, or command execution. In contrast, eating gestures are intimate, mouth-directed, and safety-sensitive, requiring precise coordination between vision, touch, and proprioception. Similar to prior accounts of presence disruption caused by sensory misalignment (Lombard & Ditton, 1997), this mismatch became evident when routine actions such as lifting food or adjusting utensils were misinterpreted as system commands, triggering unintended UI responses and amplifying perceptual confusion.

Social coordination further intensified this mismatch. In shared dining situations, participants wearing the HMD often failed to perceive or correctly interpret non-verbal cues from non-HMD users, resulting in brief but noticeable communication breakdowns. Such asymmetries resonate with earlier observations in mediated co-presence (Wei et al., 2011; Santos-Torres et al., 2025), positioning XR dining as a boundary case for ordinary bodily practices rather than goal-driven tasks.

5.2 Adaptation as Calibration: From Disruption to Regained Agency

While initial encounters with XR dining were marked by hesitation and disorientation, participants' experiences followed a process of calibration, in which bodily adaptation gradually restored a sense of agency. Sensory and spatial disruptions rendered normally unconscious actions—reaching, grasping, chewing—newly visible, prompting attention to the micro-temporal sequencing of movement. This reflects Suchman's notion of situated action, where agency emerges through ongoing negotiation with material conditions (Suchman, 2006).

Across the session, participants developed micro-strategies to cope with perceptual mismatch, such as stabilizing posture, reducing head movement, slowing down utensil use, or relying more heavily on tactile feedback. These adjustments transformed XR dining into a learnable interaction space and parallel accounts of somatic learning and bodily attunement (Höök, 2018; Schiphorst, 2011), where friction invites active reconfiguration rather than passive error correction (Benford et al., 2012).

This adaptive trajectory was accompanied by an emotional shift from frustration to playful curiosity, where uncertainty became a resource for exploration rather than failure. Such engagement echoes ambiguity as a design resource (Gaver, 2002; Gaver et al., 2003).

5.3 Design Implications: XR Dining as a Boundary Case for Everyday Embodied Computing

Rather than framing XR dining difficulties solely as usability problems to be eliminated, our findings suggest that everyday embodied activities demand interaction paradigms distinct from conventional XR task models. XR dining thus serves as a boundary case that reveals broader design challenges for immersive systems intended to enter daily life, particularly those involving safety-sensitive and fine-grained bodily coordination.

First, XR systems may benefit from eating-safe interaction modes, in which gesture recognition is suppressed or selectively constrained during dining to prevent unintended system responses. Recognizing eating as a high-risk activity calls for interaction layers that prioritize bodily safety and comfort over responsiveness, aligning with reflective design perspectives that caution against over-automation (Sengers et al., 2005; Benford et al., 2012).

Second, perceptual alignment aids—such as subtle depth cues, stabilized passthrough rendering, or micro-guides—could support coordination between vision and touch without introducing overt augmentation. Unlike actuator-based multisensory systems that directly manipulate taste or smell (Obrist et al., 2016; Velasco et al., 2018; Narumi et al., 2012), such supports would leverage XR mediation itself as a resource for bodily calibration while preserving user agency.

Third, XR dining highlights the need to address social asymmetry in mixed HMD/non-HMD settings. Explicit interaction conventions or cues could help bridge perceptual gaps, reducing miscommunication and supporting shared awareness during co-present activities. This implication extends prior XR dining research on coordination and mutual visibility (Wei et al., 2011; Santos-Torres et al., 2025) to everyday, co-located contexts.

Taken together, these implications shift the design focus from seamless immersion toward supporting everyday bodily negotiation. Consistent with slow and reflective technology perspectives (Hallnäs & Redström, 2001; Sengers et al., 2005), XR dining demonstrates that friction and constraint—when carefully managed—can support reflective engagement rather than detract from experience.

6. Conclusion

6.1 Limitations and Future Works

This study provides foundational insights into embodied dining in XR but has several limitations. The small participant pool (n = 6) restricts generalizability, as personal habits and XR familiarity likely shaped adaptation; future work should recruit more diverse participants to examine how cultural

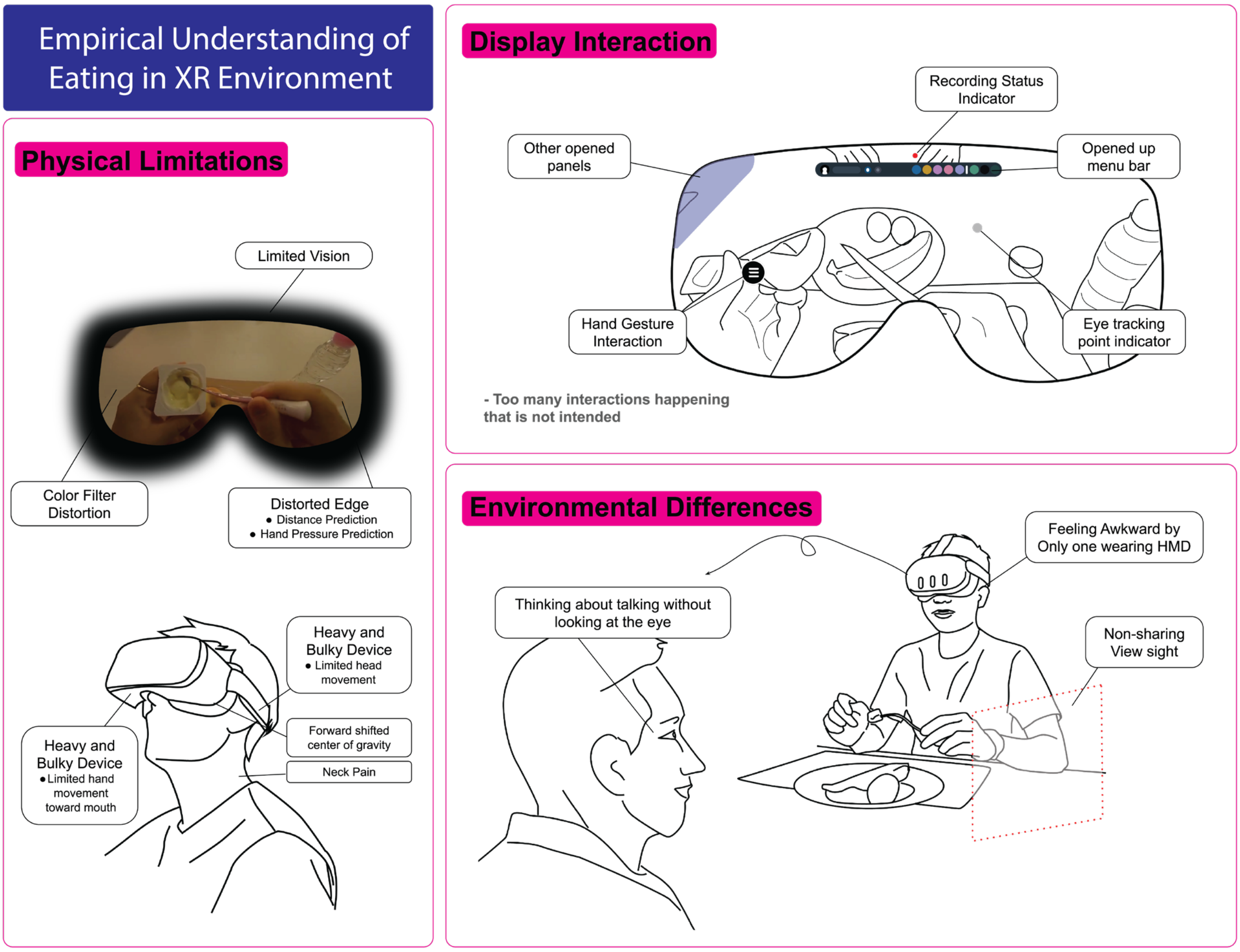

Figure 6 Empirical understanding of eating in XR environments, summarizing users' experiences of (a) physical limitations, (b) unintended display interactions, and (c) environmental or social differences while dining in XR.

background, food type, and XR experience influence embodied awareness. Methodologically, reliance on qualitative observation and self-reports limits depth, and incorporating biometric or behavioral sensing—such as eye tracking, motion capture, or physiological data—would strengthen understanding of attention, adaptation, and cognitive load. The standard HMD also constrained sensory realism, suggesting that future systems could integrate multisensory cues informed by prior research (Obrist et al., 2016; Velasco et al., 2018; Ullah et al., 2022; Narumi et al., 2012) to expand perception–action possibilities. Finally, because the analysis was conducted by a single researcher, multi-coder validation and longitudinal observation would improve reliability and clarify how reflective adaptation unfolds over time, ultimately supporting more holistic XR dining systems that balance bodily autonomy with reflective, meaningful engagement.

6.2 Conclusion

This study examined how dining behaviors and perceptions are reconfigured in XR. Through qualitative observation and interviews, we identified recurring themes—bodily recalibration, emotional adaptation, instrumental negotiation, and reflective awareness—that show how sensory and spatial disruptions turn ordinary eating into a site of learning. Participants' transitions from frustration to curiosity exemplify dynamic agency (Suchman, 2006), highlighting how users renegotiate control through bodily adaptation. These adjustments align with reflective design (Sengers et al., 2005), somatic learning (Höök, 2018; Schiphorst, 2011), and playful engagement where friction and ambiguity foster awareness (Gaver, 2002; Gaver et al., 2003; Benford et al., 2012). Taken together, the findings position XR dining as a practice of reflective embodiment—a process of learning-through-friction in which the body becomes both instrument and subject of reflection. Rather than removing discomfort, designers can integrate subtle, reflective frictions that cultivate attentiveness, sensory curiosity, and mindful pacing. By using disruption as a design resource, XR dining can move beyond simulation toward embodied encounters that foreground bodily awareness in everyday eating.

Acknowledgement

This work was supported by the IITP(Institute of Information & Communications Technology Planning & Evaluation)-ITRC(Information Technology Research Center) grant funded by the Korea government(Ministry of Science and ICT)(IITP-2026-RS-2024-00436398)

Reference

1. Velasco, C., Obrist, M., Petit, O., & Spence, C. (2018). Multisensory technology for flavor augmentation: A mini review. *Frontiers in Psychology*, 9, 26.
2. Covaci, A., Alhasan, K., Loonker, M., Farrell, B., Tabbaa, L., Ppali, S., & Ang, C. S. (2023). *No Pie in the (Digital) Sky: Co-Imagining the Food Metaverse.* In Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems (CHI '23), Article 501, 1–17. ACM.
3. Dourish, P. (2001). *Where the Action Is: The Foundations of Embodied Interaction*. The MIT Press.
4. Phoebe Sengers, Kirsten Boehner, Shay David, and Joseph 'Jofish' Kaye. 2005. Reflective design. In Proceedings of the 4th decennial conference on Critical computing: between sense and sensibility (CC '05). Association for Computing Machinery, New York, NY, USA, 49–58.
5. Tsaknaki, V., & Fernaeus, Y. (2016). *Expanding on Wabi-Sabi as a Design Resource in HCI.* In Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems (CHI '16), 5970–5983. ACM.
6. Lian Loke and Toni Robertson. 2013. Moving and making strange: An embodied approach to movement-based interaction design. ACM Trans. Comput.-Hum. Interact. 20, 1, Article 7 (March 2013), 25 pages.
7. Wei, J., Peiris, R. L., Koh, J. T. K. V., Wang, X., Choi, Y., Martinez, X. R., Tache, R., Halupka, V., & Cheok, A. D. (2011). Food Media: Exploring interactive entertainment over telepresent dinner. In Proceedings of the 8th International Conference on Advances in Computer Entertainment Technology (ACE '11), Article 26, 1–8.
8. Andrés Santos-Torres, Patricia de Torres Coll, Tamás Bukits, Ramón Perisé, and Sergio Cabrero Barros. 2025. The XR Table: Envisioning The Future of Remote Dining Experiences Using Immersive Telepresence. In Proceedings of the 2025 ACM Designing Interactive Systems Conference (DIS '25). Association for Computing Machinery, New York, NY, USA, 1674–1690.
9. Glympi, Alkyoni et al. "Eating Behavior and Satiety With Virtual Reality Meals Compared With Real Meals: Randomized Crossover Study." JMIR serious games vol. 11 e44348. 10 Aug. 2023, doi:10.2196/44348
10. Oliver, J. H., & Hollis, J. H. (2021). Virtual Reality as a Tool to Study the Influence of the Eating Environment on Eating Behavior: A Feasibility Study. Foods (Basel, Switzerland), 10(1), 89.
11. Riva, G., Malighetti, C., & Serino, S. (2021). Virtual reality in the treatment of eating disorders. Clinical psychology & psychotherapy, 28(3), 477–488.
12. Obrist, M., Velasco, C., Vi, C. T., Gopalakrishnakone, P., Ranasinghe, N., Israr, A., Martinez, X. R., & Cheok, A. D. (2016). Touch, Taste, & Smell User Interfaces: The Future of Multisensory HCI. In Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems (CHI EA '16), 3285–3292. ACM.
13. Xiuxin Xia, Yuchao Yang, Yan Shi, Wenbo Zheng, and Hong Men. 2024. Decoding human taste perception by reconstructing and mining temporal-spatial features of taste-related EEGs. Applied Intelligence 54, 5 (Mar 2024), 3902–3917.
14. Ranasinghe, N., Tolley, D., Nguyen, T. N. T., Yan, L., Chew, B., & Do, E. Y. (2019). Augmented Flavours: Modulation of Flavour Experiences Through Electric Taste Augmentation. Food research international (Ottawa, Ont.), 117, 60–68.
15. Ullah, A., Liu, Y., Wang, Y., Gao, H., Wang, H., Zhang, J., & Li, G. (2022). E-Taste: Taste Sensations and Flavors Based on Tongue's Electrical and Thermal Stimulation. Sensors, 22(13), 4976.
16. Takuji Narumi, Yuki Ban, Takashi Kajinami, Tomohiro Tanikawa, and Michitaka Hirose. 2012. Augmented perception of satiety: controlling food consumption by changing apparent size of food with augmented reality. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '12). Association for Computing Machinery, New York, NY, USA, 109–118.
17. Gaver, W. (2002). Designing for homo ludens. I3 Magazine.
18. Höök, K. (2018). Designing with the Body - Somaesthetic Interaction Design. Anais Estendidos do XVII Simpósio Brasileiro de Fatores Humanos em Sistemas Computacionais (IHC).
19. Mason, A. E., Jhaveri, K., Cohn, M., & Brewer, J. A. (2018). Testing a Mobile Mindful Eating Intervention Targeting Craving-Related Eating: Feasibility and Proof of Concept. JMIR mHealth and uHealth, 6(9), e10256.
20. Halabi, O., Saleh, M. Augmented reality flavor: cross-modal mapping across gustation, olfaction, and vision. Multimed Tools Appl 80, 36423–36441 (2021).

21. Apostolou, A., & Liarokapis, F. (2022). A Systematic Review: The Role of Multisensory Feedback in Virtual Reality. In 2022 IEEE 2nd International Conference on Intelligent Reality (ICIR) (pp. 39–42). IEEE.
22. Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. Qualitative Research in Psychology, 3(2), 77–101.
23. William W. Gaver, Jacob Beaver, and Steve Benford. 2003. Ambiguity as a resource for design. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '03). Association for Computing Machinery, New York, NY, USA, 233–240.
24. Lombard, M., & Ditton, T. (1997). At the Heart of It All: The Concept of Presence. Journal of Computer-Mediated Communication, 3(2).
25. Suchman, L. (2006). Human-Machine Reconfigurations: Plans and Situated Actions (2nd ed.). Cambridge: Cambridge University Press.
26. Thecla Schiphorst. 2011. Self-evidence: applying somatic connoisseurship to experience design. In CHI '11 Extended Abstracts on Human Factors in Computing Systems (CHI EA '11). Association for Computing Machinery, New York, NY, USA, 145–160.
27. Ingold, T. (2011). Being Alive: Essays on Movement, Knowledge and Description (1st ed.). Routledge.
28. Benford, S., Greenhalgh, C., Giannachi, G., Walker, B., Marshall, J., & Rodden, T.A. (2012). Uncomfortable interactions. Proceedings of the SIGCHI Conference on Human Factors in Computing Systems.
29. Kirsten Boehner, Rogério DePaula, Paul Dourish, and Phoebe Sengers. 2007. How emotion is made and measured. Int. J. Hum.-Comput. Stud. 65, 4 (April, 2007), 275–291.
30. Hallnäs, L., & Redström, J. (2001). Slow Technology – Designing for Reflection. Personal and Ubiquitous Computing, 5, 201-212.
31. Wiberg, M. (2018). The Materiality of Interaction: Notes on the Materials of Interaction Design. MIT Press.
32. Stolterman, E. (2008). The nature of design practice and implications for interaction design research. International Journal of Design, 2(1), 55–65.