ViFeed: Promoting Slow Eating and Food Awareness through Strategic Video Manipulation during Screen-Based Dining

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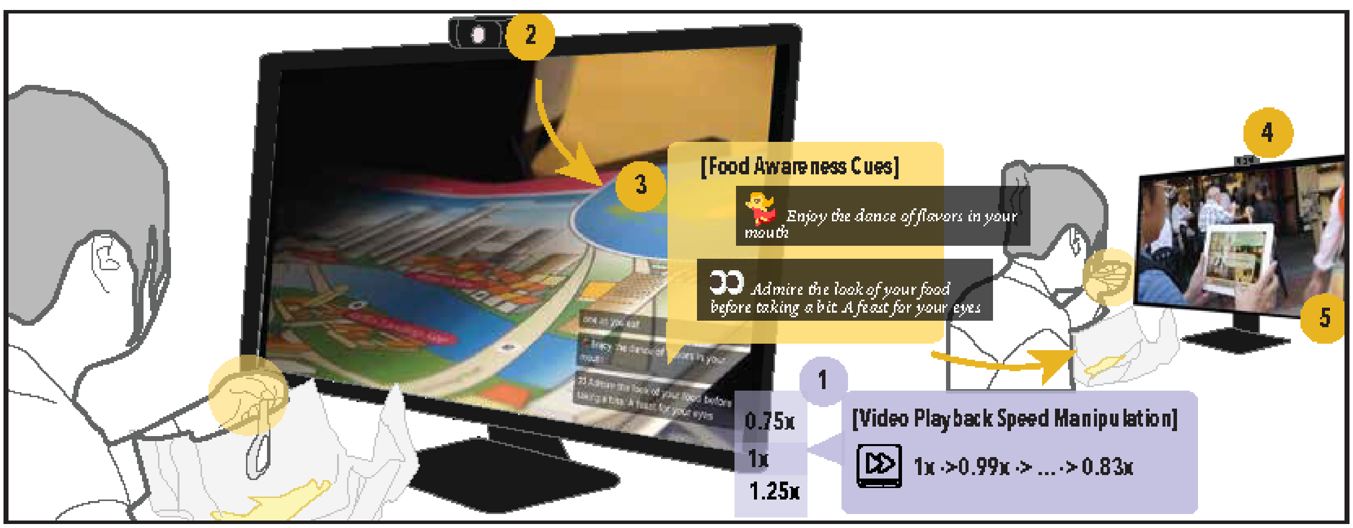

Figure 1: Interacting with *ViFeed* While watching videos, *ViFeed* subtly adjusts the video playback speed to encourage slower eating 1 and continuously detecting eating state using the camera 2. Once attention diversion (prolonged eating pauses with gaze on the screen) is detected, glanceable food awareness cues are displayed in the live stream format on the right corner of the screen to nudge 3. When the user resumes habitual eating behavior as detected by the camera, 4 The food awareness cues automatically disappear 5.

Abstract

Given the widespread presence of screens during meals, the notion that digital engagement is inherently incompatible with mindfulness. We demonstrate how the strategic design of digital content can enhance two core aspects of mindful eating: slow eating and food awareness. Our research unfolded in three sequential studies: (1). Zoom Eating Study: Contrary to the assumption that video-watching leads to distraction and overeating, this study revealed that subtle video speed manipulations—can promote slower eating (by 15.31%) and controlled food intake (by 9.65%) while maintaining meal satiation and satisfaction. (2). Co-design workshop: Informed the development of *ViFeed*, a video playback system strategically incorporating subtle speed adjustments and glanceable visual cues. (3). Field Study: A week-long deployment of *ViFeed* in daily eating demonstrated its efficacy in fostering food awareness, food appreciation, and sustained engagement. By bridging the gap between ideal mindfulness practices and screen-based behaviors, this work offers insights for designing digital-wellbeing interventions that align with, rather than against, existing habits.

CCS Concepts

• **Human-centered computing → Empirical studies in HCI**; **Interactive systems and tools**; • **Applied computing → Consumer health**.

Keywords

Mindful eating; Eating intervention; Behavior Change; Empirical study.

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1 Introduction

Mindfulness, defined as "the awareness that emerges through paying attention on purpose, in the present moment, and non-judgmentally to the unfolding of experience moment by moment" [79, 80], has gained significant attention in recent decades. Originally rooted in Buddhist meditation practices, mindfulness has been adapted for therapeutic and wellness applications, showing efficacy in reducing stress [78, 141], alleviating eating disorders [123] and improving general well-being [40].

However, maintaining mindfulness in our increasingly digital world presents significant challenges [17]. The omnipresence of screens and digital connectivity creates environments that inherently pull attention away from present-moment awareness. This tension is particularly evident in modern eating habits: digital devices have become a "third must-have" alongside cutlery and food [83, 119], with up to 88% of Americans regularly consuming meals while engaging with screens [101]. This trend fosters "zombie eating" [146] —automatic consumption without conscious awareness—disrupting physiological cues [39], potentially leading to overeating [88, 147] and, over time, contributing to long-term health concerns like obesity and metabolic disorders [51].

The application of mindfulness to eating practices offers potential solutions [77]. Research has identified five key principles of mindful eating: satiation awareness (recognizing hunger and fullness cues), food awareness (attending to food's sensory qualities), slow eating (eating pace regulation), avoiding distractions, and maintaining non-judgmental awareness [83, 160]. In this work, we approach mindfulness through the lens of these established mindful eating principles. Although screen use inherently conflicts with traditional mindful eating practices that emphasize distraction-free environments, we envision aspects such as slow eating—which supports better digestion and portion control—and food awareness—which enhances meal satisfaction and appreciation—can be maintained within modern screen-based dining contexts.

This perspective aligns with Niedderer's concept [120] of redesigning everyday objects to communicate mindfulness [151, 171], emphasizing that screens need not solely be viewed as barriers to mindfulness. Instead, they can be strategically repurposed to promote certain aspects of mindful eating during meals.

To investigate these possibilities, we conducted three studies (see Figure 2). In **STUDY 1**, we examined the extent to which screen-based eating deviates from mindfulness. In a simulated real-world setting with 24 habitual screen-based eaters, we found that screen-based eating did not inherently undermine mindfulness. Participants exhibited comparable levels of satiation awareness, perceived distraction, and consumption control compared to screen-free meals. Additionally, screen use naturally promoted slow eating, characterized by deliberate chewing. A subtle manipulation of video playback speed-imperceptibly and gradually slowed to 83% of the habitual playback rate-amplified this effect, reducing eating rate by 15.31% and food intake by 9.65%, while improving eating awareness without diminishing meal satisfaction. However, screen-based eating compromised food awareness—conscious attention to the multisensory aspects of food-prompting us to explore visual elements that could support this.

Through a participatory design workshop with 9 target users (**STUDY 2**), we developed *ViFeed* (Section 5.1), a video-watching system that strategically promotes real-time food awareness cues

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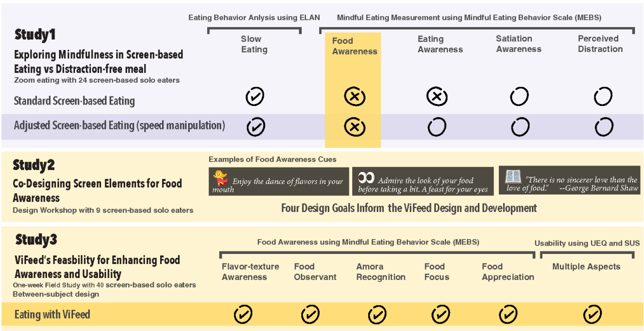

Figure 2: Study overview: Exploring mindfulness via two components - slow eating and food awareness - across three studies (Note: ◯ indicate maintenance, ⊗ indicates compromise, ✓ indicates enhancement)

within a live stream format based on attention shifts, complemented by subtle video playback speed manipulation refined in Study 1. A Subsequent one-week field study (**STUDY 3**) demonstrated *ViFeed* to be an effective, non-intrusive tool for promoting food awareness, particularly enhancing awareness of bodily cues, savoring, and food appreciation. User engagement exhibited an increasing trend over time, suggesting potential for sustained integration into regular meal routines.

While our primary focus was on fostering mindfulness itself during screen-based meals, the observed behavioral changes (e.g., slow eating and improved portion control) and attentional enhancements (e.g., heightened food sensory awareness) suggest potential long-term health benefits [77], such as mitigating overeating and addressing obesity [122]. These downstream effects, though beyond the immediate scope of this study, merit future research.

Our work contributes to the empirical understanding of how screen-based eating interacts with mindfulness. Through a semi-controlled study design, we demonstrated certain aspects of mindfulness can be maintained (i.e., satiation awareness) or even enhanced (i.e., slow eating) during screen-based meals, while also highlighting components requiring targeted support (i.e., food awareness). By exploring design mechanisms such as speed manipulation and subtle visual cues, we demonstrate how digital entertainment can be repurposed to bridge the gap between ideal mindfulness and the realities of screen-based cultures. By demonstrating how awareness and intentionality can be fostered in seemingly counter-intuitive contexts, we contribute to the field of digital well-being and offer actionable design strategies to integrate mindfulness techniques into the digital entertainment landscape.

2 Related Work

In this section, we first review the influence of video content on eating behaviors to inform strategies for repurposing screens as the medium for mindfulness. We then introduce the principles of mindful eating followed by a discussion of HCI approaches to mindful eating. Finally, we position our work by highlighting how mindfulness in eating, defined as the embodiment of mindful eating principles, can be adapted to screen-based dining context.

2.1 The Multifaceted Influence of Video on Eating

Research has extensively examined how various aspects of video content—sensory, emotional, visual, and auditory elements—influence food consumption patterns during watching. Studies demonstrate consistent relationships between content type and eating behavior: viewers consume significantly less food when watching comedies or happy-rated movies compared to tragedies or sad-rated films [31, 56, 158]. Specific visual elements, particularly depictions of eating in video significantly impact audience behavior[15, 129], driven by the behavioral mimicry—where individuals subconsciously imitate observed actions[170]—and priming effects, where exposure to food-related stimuli activates corresponding eating behaviors [64]. This effect extends to mukbang videos (people eating large quantities of food). While these videos can enhance viewers' flavor perception and create vicarious satisfaction [10, 72], they have been criticized for potentially inducing emotional eating and overeating [23, 81, 94].

Interestingly, even non-food-related video content might increase food consumption. For example, Bellisle et al. [15] demonstrated that environmental stimuli, such as television or recorded stories, significantly increased food intake compared to no-stimulus conditions. Moreover, television and audio-only content elicit similar eating patterns, suggesting that auditory elements may play a more prominent role than visual ones in influencing consumption.

Building on these insights, our research examines both auditory and visual components of video content with a distinct focus, aligning these dimensions with two key aspects of mindfulness—slow eating and food awareness—as detailed in Section 2.4.

2.2 Mindful Eating and Its Principles

The concept of mindfulness has found its place in HCI research [151], however, mindful eating-a specific application of mindfulness to eating context-has received comparatively less attention [59, 60, 83].

Although there is no universal definition of mindful eating, the literature consistently identifies foundational principles [83, 160]. In this work, we align our conceptualization of mindfulness with the core principles identified in mindful eating research, focusing on the following five key aspects:

- Satiation awareness: Being aware of the bodily triggers for initiating (hunger cues) and stopping eating (satiety cues)
- Food awareness: Savoring food through sensory engagement (e.g., presentation, taste, texture, and smell)
- Slow eating: Chewing each bite properly
- Avoiding distractions: Devoting full attention to food by avoiding all distractions
- Being non-judgmental: Acknowledging responses to food without any judgment

While primarily researched for managing eating disorders [155], mindful eating's benefits extend to promoting healthy eating behaviors in the general population, including facilitating slower meal consumption [160], enhancing awareness of and responsiveness to satiety cues [99], improving eating control [7, 123], increasing food enjoyment [11], and fostering a more conscious relationship with food [77].

A notable intervention that operationalizes these principles is the Mindfulness-Based Eating Awareness Training (MB-EAT) [89]. As a 12-week program rooted in mindfulness meditation, MB-EAT incorporates practices such as meditation, mindful eating exercises (e.g., the "mindful raisin" exercise), and structured reflections on eating habits. However, like most clinical interventions, MB-EAT requires significant time commitments (8–12 weeks) and in-person facilitation [160].

2.3 Mindful Eating Interventions in HCI

Among limited, HCI research has explored various technological approaches to promote mindful eating, broadly categorized into three types: (1). Conversational agent-based: These comprehensive digital facilitators emulate traditional mindfulness instruction, guiding users through all aspects of mindful eating in both laboratory [126] and field settings [125, 168]. (2). App-based tools: Primarily focus on pre-meal and post-meal reflective practices, offering guided mindfulness meditations and food journaling inspired by MB-EAT [45, 60]. Meditations are often enhanced with multimedia elements such as calming music, videos, or animations to create engaging user experiences, while journaling encourages users to document meals using text or photos, self-report hunger and satiety, and reflect on associated emotions. Advanced apps like *Meditopia* [1] incorporate AI to analyze journal entries and provide personalized meditation recommendations. These apps also include goal-setting features supported by push notifications, progress tracking (e.g., progress bars, calendar views), and rewards such as milestone badges. Despite being widely adopted, this approach offers limited support for in-the-moment mindfulness during eating[60]. (3). Hardware-supported real-time intervention: Often focus on isolated aspects of mindful eating. Examples include wearable devices providing visual (light) and tactile (vibration) feedback to encourage slow eating [85], and utensils like shape-changing spoons to regulate bite size and eating pace [32]. Distraction prevention devices, such as SWAN [84], drop the food when focusing excessively on screens. Other innovations, like altering food perception to change satiation through 3D food printing [97] or AR/VR [117].

2.4 Integrating Mindfulness into Screen-Based Eating

Building on prior HCI efforts, we investigate how mindfulness support can be directly implemented within the act of video-watching during meals, aligning with contemporary dining practices. Unlike conversational agents, which may compete with video content's audio elements, or app-based tools that focus on pre- or post-meal reflection, our approach emphasizes in-the-moment mindfulness during the eating experience itself—an identified need in mindful eating research [55, 150]. While not aiming to fully replicate traditional mindful eating practices, our work seeks to support critical aspects of mindful eating principles within screen-based dining, striving for comparable mindfulness levels to those observed in distraction-free meals.

In **STUDY 1** (Section 3), we focus on the auditory dimension of video by examining the effects of playback speed manipulation—on encouraging slow eating, a behavioral aspect of mindfulness. Subsequently, in **STUDY 2** (Section 4), we design strategic visual cues to enhance food awareness, addressing this attentional component of mindfulness identified as compromised in **Study 1**. Finally, in **STUDY 3** (Section 5.2), we conducted a one-week field study to evaluate these combined interventions in naturalistic settings, contributing to the broader understanding of how food awareness can be reintroduced for real-world screen-based dining contexts [60, 83].

[1]https://meditopia.com/en

3 Study 1: Screen-Based Eating: Maintenance and Deviation with Mindfulness

A primary concern with the presence of video during meals is its potential to negatively affect eating, particularly by promoting overeating and reducing interoceptive awareness of hunger and satiety cues [15, 26, 39, 104]. However, the evidence regarding this relationship remains mixed [52, 74, 147], with most studies conducted in controlled laboratory settings that often focus on snack consumption [26, 51, 121] or ad libitum meal protocols [15, 52, 127]. While offer valuable insights, they may not capture the complexity and contextual factors of everyday eating experiences [130].

We first seek to develop a more ecological and nuanced understanding of how video watching influences both eating behaviors (e.g., food intake and eating pace) and adherence to mindful eating principles during meals. By framing our investigation through the lens of mindfulness, we aim to identify how screen-based eating may preserve or compromise specific aspects of mindfulness, while also addressing broader concerns about consumption control. This led to our first research question:

RQ1: How do eating behaviors and meal experiences—particularly aspects related to mindfulness—manifest in screen-based eating within simulated daily meal settings?

While screen use during meals is often associated with distraction, its inherently engaging nature presents an opportunity to explore whether certain characteristics of video watching could be repurposed to support mindfulness or mitigate undesired eating behaviors, such as overeating, if observed. This led to our second research question:

RQ2: Can subtle manipulations of video content, specifically slowing down playback speed, encourage mindfulness without diminishing the enjoyment of both the meal and the video content?

We focus particularly on slow eating for its dual significance: a key principle of mindful eating [160] and as a practical strategy to prevent overconsumption [87, 122]. This focus is further inspired by research showing audio tempo's influence on eating pace [33, 106], along with findings from our pilot study exploring slowed video playback (See 3.3.1), both of which informed the design of our main study.

To investigate these questions, we designed a remote Zoom study that simulated daily solo dining experiences while maintaining specific control to affect eating behavior [15, 27, 69]: standardized meal type across conditions, fixed dining time windows, and consistent video genres. These controls enabled reliable comparisons while preserving more natural elements of the dining experience (e.g., home environment, comfortable dining windows, a familiar standard meal, and participant-selected video content) than traditional laboratory studies. Participants completed three conditions in their own homes: 1) **Focused Eating** (no distractions), 2) **Standard Eating** (watching their usual videos), and 3) **Adjusted Video Playback Speed Eating** (watching videos at an imperceptibly slower speed).

3.1 Participants

We recruited 24 participants (12 males and 12 females) aged between 18 and 29 years (Mean= 23.6, SD=2.78), all with a healthy weight (body mass index: Mean= 21.58, SD=2.83) from the university's community for our formal study. Sample size determination was based on an a priori repeated measures ANOVA power analysis conducted using R, based on eating rate data from a pilot study (N = 6, generalized eta-squared = 0.315). The analysis indicated that 12-15 participants would provide 80% power to detect effects at $\alpha = 0.05$. We increased the sample size to 24 to account for potential dropouts, enabled complete counterbalancing across three conditions, and provided adequate power for more sophisticated analytical approaches, specifically linear mixed-effects modeling (LMM). To ensure reliable data, participants with medical conditions affecting eating (e.g., hyperphagia), those on specific diets, vegetarians, or with allergies to the test food were excluded. All participants reported frequently eating alone while watching videos, that the test food (i.e., fried rice) was similar to their regular diet, and indicated liking of it (scores of at least 7 on a 10-point Likert scale). Ownership of a kitchen scale was a prerequisite to measure food intake during the study. While we provided scales to participants on request, only 3 out of 24 required this accommodation. Participants gave informed written consent and the study protocol was approved by the University Research Ethics Committee.

3.2 Apparatus

3.2.1 Test Food. We selected fried rice as the standardized test meal, based on its: *Familiarity*: Common in many cultures, particularly Eastern cuisines[30, 118]. *Nutritional Profile*: Contains diverse ingredients and textures, providing a balanced meal. *Accessibility*: Easily purchased from local restaurants. To maintain ecological validity, participants were instructed to: 1. Purchase fried rice from a familiar local restaurant of their choice and 2. Choose any accompanying drink, maintaining consistency across all three meals. This approach reflected real-world dining habits while maintaining standardization across participants.

3.2.2 Test Video. To ensure ecological validity and experimental control, participants were asked to: 1. Choose their own videos, accommodating individual preference [16, 88, 112]. 2. Selected videos that are long enough to cover the entire meal duration for all conditions. 3. Maintained consistency in video genre and source across all three meals (e.g., different episodes from the same anime series, different segments from the same comedy show).

3.2.3 Video Playback Speed Manipulation. For the **Adjusted Video Playback Speed Eating** (in **RQ2**), we used VLC media player with its open-source extension (VLC Speed Controller) to manipulate the video playback speed. Specifically, the experimenter shared the Zoom screen to play the pre-selected videos chosen by participants and adjusted the playback speed according to predetermined settings. This Wizard of Oz approach enabled flexible and rapid testing of assumptions, allowing for quick iteration and refinement.

3.3 Testing Conditions

We designed three experimental conditions to investigate the effects of video watching on eating behavior:

- Focused Eating: In this condition, participants ate their meals without any digital distractions, focusing solely on their food.
- Standard Eating: Participants watched their usual videos while eating, replicating their typical meal-time viewing habits.
- Adjusted Eating: This condition involved participants watching videos at an imperceptibly slower speed while eating.

3.3.1 Pilot Study for Adjusted Eating: Determining Video Playback Speed. Before implementing the Adjusted condition in our formal study, we conducted a two-phase pilot study to establish the optimal slowdown rate parameters. Participants were selected based on the same criteria used in the main study to maintain consistency.

Phase1: Initial Testing. Six individuals (3 males, 3 females, aged 20-25, SD=1.8), from the university community participated in this phase. The procedure involved testing various incremental slowdown rates, starting from the standard speed (1x). It was determined that the minimal perceptible reduction interval of 1% per second was intuitively ideal, as it seamlessly integrated into the video-watching experience without noticeability.

Phase2: Refinement. This phase involved six new individuals (2 males, 4 females, aged 20-26, SD=1.6) to avoid participant bias from Phase 1. The tests focused on refining the previously identified slowdown rates. The findings indicated that a slowdown to 0.75x, commonly used on various platforms [93], was readily apparent to participants, thereby deemed "obvious". Conversely, a reduction to 0.83x was perceived as both natural and unobtrusive by five out of the six participants, and it demonstrated potential for subtly influencing eating behaviors.

Based on the outcomes of these exploratory phases, a 0.83x slowdown rate was adopted for the formal study. Note that some participants typically watched videos at faster speeds than 1.0, for those participants, we adjusted proportionally (e.g., 1.25x speed reduced to 1.04x).

This approach ensured a consistent relative slowdown effect across participants, allowing us to subtly influence eating behavior without compromising the viewing experience, addressing our **RQ2**.

3.4 Study procedure

The study was conducted over three days via Zoom, with each day focusing on one meal condition. To standardize satiety states, participants were instructed to: 1. Maintain the same diet across all three days. 2. Fast for four hours (except for water) before each meal. 3. Schedule meals at the same time each day (lunch: 11 am to

1 pm, or dinner: 5 pm to 8 pm) 4. Allow a three-day gap between sessions to prevent carryover effects and food fatigue [15].

Each meal session followed a structured procedure:

- **Pre-meal**: Participants completed a pre-meal questionnaire to rate their pre-meal appetite (Section 3.5). They also reported the weight of their food and drink using their own kitchen scales.
- **Meal session**: Participants were camera-recorded over Zoom during all sessions. They were instructed to eat as naturally as possible until comfortably full.
  For *Focused Eating*: Participants are required to avoid any tasks besides eating.
  For *Standard Eating*: The Experimenter remotely played participant-selected videos via screen share
  For *Adjusted Video Playback Speed Eating*: The experimenter discreetly adjusted the video playback speed to 0.83 times the participant's usual speed.
- **Post-meal**: Participants rated their appetite again and weighed the remaining food and drink. They also completed a post-eating questionnaire (see section 3.5). This was followed by a semi-structured interview designed to explore their preferences and habits during screen-based meals (e.g., plate-clearing tendencies), specific experiences in each session, and their priority during the meal (i.e., food, video, or both).

To validate the subtlety of video playback speed adjustments, after the third meal, participants were asked if they noticed differences between conditions. If no difference was noted, **Adjusted Video Playback Speed Eating** condition was repeated with a prompt to *"let us know if you notice something interesting happening"*. This time, the playback speed was decreased incrementally by 1% of the original speed every second, until the participant indicated a change. This assessed individual thresholds for perceiving speed adjustment. Lastly, participants were asked about their preference for slower video playback speeds while eating. To avoid any ordering effects, three meal conditions were counterbalanced.

3.5 Design

We used a within-subject design with CONDITION as the independent variable. Participants were asked to rate their *appetite* in terms of *hunger*, *fullness*, and *desire to eat* on 100mm visual analog scales [47] (0: not at all, 100mm=extremely) before and after each meal. Our dependent variables were (refer to Table 1 for details):

- *Eating Behavior*: Each recorded eating video was analyzed using the ELAN 6.1 software [2], following a coding scheme from previous studies [24, 46, 48] (definitions in Table 1).
- For subjective rating: We used a modified Mindful Eating Behavior Scale (MEBS), a validated instrument to measure mindful eating [103, 163, 164] across four domains: *Focused on food*, *Focused on hunger and satiety cues*, *Being unaware of eating*, *Being distracted*. Each domain, consisting of specific items, was measured on a 7-point Likert scale (1: strongly disagree, 7: strongly agree) and summed to compute a domain-specific score for analysis, following the instruction [164]. Using the same scale, we assessed additional aspects of meal experience including *Fun*, *Enjoyable*, *Entertaining* [21, 54]. To capture aspects of solo eating, *Lack of companionship*, *Boredom*, and the *Interest in daily inclusion* within each meal condition [22, 132, 148] were assessed.

Table 1: Coding scheme for measures regarding eating behavior

MEASURES	DEFINITION
Food intake	
Total consumption (g)	kitchen scales were used to measure the weight difference of total food and drink consumption before and after eating.
Food oral processing behavior	
Meal duration (s)	Time between the first pick up spoon and the last drop of the spoon.
Oral exposure time (s)	Cumulative time food spent in the mouth between the bite and the swallow throughout the meal.
Bite size (g/bite)	Total amount consumed divided by the total number of bites.
Number of Chews	Total number of chews within the meal.
Eating rate (g/s)	Total amount of food consumed divided by the total oral exposure time.
Average length of pause/interval (s)	Total non-active eating duration divided by the total number of intervals.
Food gaze	
Percentage of gaze on food (s)	Total duration of people looking at their food divided by the total meal duration.

3.6 Results

We first analyzed the pre-meal appetite ratings using Friedman test tests, (all $p > 0.05$). This indicated that baseline satiation levels were consistent and controlled across the different experimental days. Subsequently, we applied Linear Mixed-Effects Models (LMM), a popular alternative to repeated-measures ANOVA, which allowed us to specify random effects, explicitly partitioning the variance associated with individual differences [75, 161].

The model specification for all measures of eating behavior was as follows:

$$EATING\ BEHAVIOR_{ij} = \beta_0 + \beta_1 CONDITION_{ij} + \beta_2 \Delta HUNGER_{ij} + \beta_3 \Delta FULLNESS_{ij} + \beta_4 \Delta DESIRE_{ij} + u_i + \epsilon_{ij} \quad (1)$$

where:

- $EATING\ BEHAVIOR_{ij}$: The dependent variable (e.g., eating rate, food intake) for participant i in measurement j.
- β_0: The fixed intercept.
- $CONDITION_{ij}$: The experimental condition (**Focused**, **Standard**, **Adjusted**), treated as a categorical fixed effect (β_1).
- $\Delta HUNGER_{ij}, \Delta FULLNESS_{ij}, \Delta DESIRE_{ij}$: Changes in satiation states from pre- to post-meal, included as continuous fixed-effect covariates ($\beta_2, \beta_3, \beta_4$).
- u_i: The participant-level random intercept, assumed to follow a normal distribution ($u_i \sim N(0, \sigma_u^2)$), accounting for variance due to individual differences.
- ϵ_{ij}: The residual error term ($\epsilon_{ij} \sim N(0, \sigma_\epsilon^2)$).

Model fitting was performed using the `lme4` [91] package in R. Pairwise comparisons between conditions were conducted using the `emmeans` [95] package with Bonferroni correction for multiple comparisons. For subjective rating, the Friedman test was employed, followed by post hoc pairwise comparisons performed using the Wilcoxon signed-rank test with Bonferroni correction.

Food Intake. Fixed effects estimates indicated that neither the ADJUSTED eating ($\beta = -15.57$, $p = 0.481$) nor the STANDARD eating ($\beta = 40.95$, $p = 0.069$) significantly affected total food intake compared to the FOCUSED eating. Similarly, *hunger* ($\beta = 0.66$, $p = 0.745$), *fullness* ($\beta = -1.13$, $p = 0.568$), and *desire to eat* ($\beta = -1.28$,

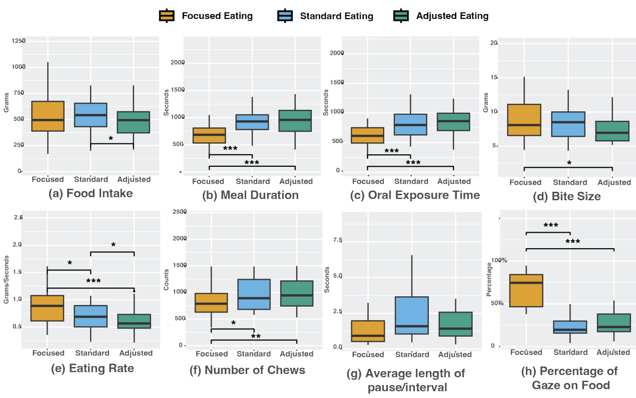

Figure 3: Eating behavior in terms of food intake, food oral processing behavior and gaze on food across three meal conditions (Yellow: FOCUSED, Blue: STANDARD, Green:ADJUSTED

$p = 0.360$) were not significant predictors of total *food intake*. However, there was a significant difference between the ADJUSTED and STANDARD eating ($t(43.7) = -2.606$, $p = 0.037$). Particularly, participants who watched videos with adjusted playback speed (496.0 ± 167) ate 9.65% less than those who watched videos at normal speed (549.0 ± 228).

Food Oral Processing Behavior. Fixed effects estimates revealed that *fullness*, *hunger*, and *desire* to eat were not significant predictors of all measures (all $p > 0.05$). Detailed results for each specific food oral processing behavior are as follows (refer to Figure 3).

Meal duration. Meal duration were significantly longer in both the ADJUSTED (999.0 ± 400) and STANDARD eating (924.0 ± 271) compared to the FOCUSED eating (666.0 ± 211) (FOCUSED vs. ADJUSTED : $\beta = -345.0$, SE = 58.2, $t(45.4) = -5.923$, $p < 0.0001$; FOCUSED vs. STANDARD: $\beta = -268.7$, SE = 58.1, $t(45.5) = -4.621$, $p = 0.0001$). There was no significant difference between the ADJUSTED and STANDARD eating ($t(44.7) = 1.319$, $p = 0.5817$).

Oral exposure time. Both the ADJUSTED (882.0 ± 351.2) and STANDARD (807.0 ± 235.6) eating significantly prolonged *oral exposure time* compared to the FOCUSED eating (609.0 ± 192.7) (FOCUSED vs. ADJUSTED: $\beta = -285.8$, SE = 50.3 $t(45.4) = -5.679$, $p < 0.0001$; FOCUSED vs. STANDARD: $\beta = -211.4$, SE = 50.2, $t(45.5) = -4.209$, $p = 0.0004$). There was no significant difference between the ADJUSTED and STANDARD eating ($t(44.6) = 1.488$, $p = 0.4317$).

Bite size. Participants in the ADJUSTED eating (7.61 ± 2.12) took smaller bite size compared to the FOCUSED eating, (8.95 ± 3.19) $\beta = -1.35$, SE = 0.53, $t(45.3) = -2.551$, $p = 0.043$. There was no significant difference between the STANDARD (8.67 ± 3.14) and either the FOCUSED ($t(45.5) = 0.636$, $p = 1.000$) or the ADJUSTED eating ($t(44.5) = -1.927$, $p = 0.181$).

Eating rate. Participants significantly slow down their eating in both the ADJUSTED eating (0.640 ± 0.239) and the STANDARD eating (0.756 ± 0.446) compared to the FOCUSED eating (0.895 ± 0.365) (FOCUSED vs. ADJUSTED: $\beta = -0.3017$, SE = 0.0580, $t(45.2) = 5.195$, $p < 0.0001$; FOCUSED vs. STANDARD: $\beta = -0.1543$, SE = 0.0580, $t(45.4) = 2.660$, $p = 0.0323$). Additionally, participants who watched videos in ADJUSTED speed further slowed down their eating rate by approximately 15.31% than those who watched videos with normal speed ($t(44.4) = -2.560$, $p = 0.0418$).

Number of chews. Both ADJUSTED (1027.0 ± 407) and STANDARD (958 ± 308) eating led to a significant increase in *number of chews* compared to the FOCUSED eating (823 ± 308) (FOCUSED vs. ADJUSTED : $\beta = -211.0$, SE = 55.0, $t(45.1) = -3.826$, $p = 0.0012$; FOCUSED vs. STANDARD: $\beta = -143.0$, SE = 55.0, $t(45.4) = -2.593$, $p = 0.0383$). There was no significant difference between the ADJUSTED and STANDARD eating ($t(44.3) = 1.247$, $p = 0.6572$).

Average length of pause/interval. Neither the ADJUSTED eating ($\beta = 0.962$, SE= 0.482, $t(45.7) = -1.994$, $p = 0.156$) nor the STANDARD eating ($\beta = 1.156$, SE= 0.482, $t(45.5) = -2.399$,$p = 0.062$) significantly affected *Average length of pause/interval* compared to the FOCUSED eating. However, participant tends to pause longer in ADJUSTED (2.30 ± 2.13) and STANDARD (2.50 ± 2.27) eating compared to FOCUSED (1.31 ± 0.954). There was no significant difference between the ADJUSTED and STANDARD eating ($t(45.3) = -0.402$, $p = 1.000$).

Percentage of Gaze on Food. Fixed effects estimates indicated that Both ADJUSTED eating ($\beta = -0.414$, SE= 0.035, $t(45.6) = -11.777$, $p < 0.0001$) and the STANDARD eating ($\beta = -0.439$, SE= 0.035, $t(45.5) = -12.518$, $p < 0.0001$) significantly lowered the *percentage of gaze on food* compared to the FOCUSED eating ($67.6 \pm 20.7\%$) . While *fullness* ($\beta = -0.0002$, $p = 0.471$) was not a significant predictor, *hunger* ($\beta = 0.0004$, $p = 0.048$) and *desire to eat* ($\beta = 0.0004$, $p = 0.028$) had significant but small effects. There was no significant difference between the ADJUSTED ($26.7 \pm 13.8\%$) and STANDARD ($24.7 \pm 13.2\%$) eating ($t(45.0) = 0.720$, $p = 1.000$).

3.6.1 *Subjective Rating.* (Refer to Figure 4)

Mindful eating perception. There were significant effects of CONDITION on *Focused on food* $\chi^2(2) = 20.273, p < 0.0001$. Particularly, participants reported being more focused on food in FOCUSED ($Mdn = 30$) condition as compared to ADJUSTED ($Mdn = 23.5$), ($p = 0.0018$) and STANDARD ($Mdn = 23$), ($p = 0.0052$). However, there was no significant difference between the ADJUSTED and STANDARD conditions ($p = 1.0000$). There was a significant effect of CONDITION on *Being unaware of eating*, $\chi^2(2) = 12.156, p = 0.002$. Namely, participants were significantly more unaware of their eating in the STANDARD condition ($Mdn = 6$) compared to the FOCUSED condition ($Mdn = 3$) ($p = 0.0029$) and the ADJUSTED condition ($Mdn = 4.5$) ($p = 0.0319$). There was no significant difference between the FOCUSED and ADJUSTED conditions ($p = 0.5162$). There were no significant effects of CONDITION on *Focused on hunger and satiety cues* ($\chi^2(2) = 3.493, p = 0.1744$), or *Being distracted* ($\chi^2(2) = 2.189, p = 0.335$).

Eating Experience. There were significant effects of CONDITION on *Fun* ($\chi^2(2) = 29.948, p < 0.0001$), *Enjoyable* ($\chi^2(2) = 38, p < 0.0001$), *Entertaining* ($\chi^2(2) = 36.816, p < 0.0001$), *Lack of companionship* ($\chi^2(2) = 17.93, p = 0.0001$), *Boredom* ($\chi^2(2) = 34.842, p < 0.0001$), and *Interest in daily inclusion* ($\chi^2(2) = 33.13, p < 0.0001$). Post-hoc pairwise comparisons revealed that participants found both video-watching eating conditions to be more fun, enjoyable,

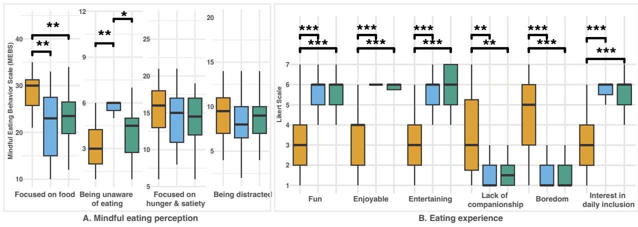

Figure 4: Subjective feedback regarding A. mindful eating B. Various aspects of eating experience (Yellow: FOCUSED, Blue: STANDARD, Green:ADJUSTED)

and entertaining, and less lonely or boring than eating without videos. Consequently, they were more inclined to incorporate video-watching into their daily eating routines.

3.7 Discussion

Given the breadth of measures employed, we first present overview findings to **RQ1** and **RQ2**. We then provided a more detailed discussion on how video and its playback speed manipulation influence eating in real-world settings.

***RQ1**: How do eating behaviors and meal experiences—particularly aspects related to mindfulness—manifest in screen-based eating within simulated daily meal settings?*

Video watching enhanced meal experiences by increasing entertainment, pleasure, and reducing boredom and loneliness, making it a part of daily routines [22, 119, 138, 166]. Contrary to the widely held belief that video-watching promotes overeating by distorting hunger and satiety perception [15, 26, 39, 104], we observed satiation awareness, perceived distraction, and food consumption levels compared to distraction-free eating contexts. This suggests that screen-based eating does not inherently compromise mindfulness in terms of maintaining satiation awareness.

Interestingly, screen-based eating naturally facilitated slower eating—a key principle of mindful eating—by prolonging oral exposure time and encouraging more deliberate chewing. However, it reduced attentional engagement, with fewer gazes at food and lower self-reported mindfulness regarding food and eating awareness.

Portion Control through Daily Practice. Contrary to controlled laboratory studies often associating screen use with overconsumption, our findings suggest it may not be the case in more semi-controlled settings. In our study, participants consumed meals with pre-determined, standardized portions either purchased from familiar stores or prepared by themselves, naturally limiting their food intake. This approach unlike the ad libitum or buffet-style meals typical in laboratory settings, which can encourage overeating "artificially" [15, 52, 127]. This control over portion sizes, as highlighted by P11 who noted, "I make a conscious decision on how much to eat when I buy the food," demonstrates how structured meal environments in everyday settings can naturally mitigate the risk of mindless overeating during the screen-based meals.

Time Extension Effect [42]: Our findings suggest that video-watching prolongs meal durations and food consumption, as individuals often synchronize their eating pace with the video length, using it as a natural mealtime "timer." P9 expressed, "If video is 10 min, I can eat within 10 min; if it's video is 30 min, I can still eat for 30 min. " This contrasts with **Focused Eating**, which, while aimed at creating a distraction-free environment, is often perceived as *"lacking engagement"*, *"boring"*, and *"a waste of time"*, resulting in *"a rush to finish the food"*. Despite concerns that prolonged eating might lead to increased energy intake [66], our study found that slower eating rate and fixed portion sizes typically seen in real-world settings counteract this risk. This synchronization of eating pace with video length suggests that video-watching can serve as a natural regulator of meal duration. As P6 highlighted, *" When I eat with videos, I chew many times before swallowing so that I can watch more video content while eating. "* The repetitive nature of chewing and the engagement provided by videos create a balanced mealtime experience, where eating is extended but not excessive.

Cultural Norms and Eating Habits: A notable behavior among participants (16 out of 24) is the tendency to clear the plates while eating. This behavior may stem from a cultural aversion to food waste[114, 133], a habit instilled during childhood ("A habit from young."), rather than relying on internal cues of satiety. This highlights the significant role that social norms play in regulating portion sizes and potentially contributing to overeating. While previous research has often linked media consumption with overconsumption and obesity, our study suggests that video-watching may not be the direct cause of these issues. Instead, factors like exposure to food advertising [137, 162], increased preference for unhealthy food choices (e.g., fried foods, processed meat, and sugar-sweetened beverages) [70, 71, 74, 157, 162] could also contribute to these patterns. The influence of specific video content, like mukbang [81, 86], impaired memory of prior food intake [51], and overall sedentary lifestyles and inactivity physical activity linked with prolonged media consumption [71, 140], also likely factor into unhealthy eating behaviors and outcome. In line with Bellisle et al. [15], Wiecha et al. [162], we propose that this combination of elements may have a more significant impact on eating patterns than mere act of video-watching itself.

***RQ2**: Can subtle manipulations of video content, specifically slowing down playback speed, encourage mindfulness without diminishing the enjoyment of both the meal and the video content?*

Our result suggests that subtle video playback adjustments enhanced mindfulness during screen-based eating. By leveraging the natural tendency of video watching to support slow eating, speed adjustment amplified this effect, leading to a 15.31% decrease in eating rate and a 9.65% reduction in food consumption, while maintaining satiation levels. This pattern aligns with established research on speed-consumption relationships [50] and the documented consistency of eating rate's effects across multiple daily meals [67] suggests potential for sustained impact beyond our single-meal observations.

Additionally, the playback adjustment partially addressed attentional engagement deficits observed in standard video-watching contexts, supporting eating awareness while preserving enjoyment of both the meal and video content. However, food awareness, particularly attention to food's sensory aspects, remained relatively limited compared to distraction-free meals.

Unconscious synchronization of chewing. There was more pronounced thorough chewing in the slower video speed condition, as participants unconsciously synchronized their bodily rhythmic patterns (i.e., chewing) with external auditory stimuli (i.e., slower video speeds)[34, 106]. This audio-motor synchronization aligns with the theory of entrainment [37], a well-established concept in chronobiology, where biological rhythms adjust to match external rhythms. While entrainment has been extensively studied in music therapy [36, 134], our findings suggest its extended applicability to eating behavior regulation. This synchronization effectively decelerates the eating pace and consequently reduces food intake [33].

Increased cognitive capacity for eating awareness. The limited capacity model of mediated message processing [92] suggests that individuals have restricted cognitive resources for concurrent tasks. By controlling the information density within the same duration, the adjusted playback speed reduces the cognitive load required to process video content, allowing participants more bandwidth to focus on their food. In our post-study interviews, participants highlighted this shift in attention allocation, with a notable increase—from 5 participants during normal video speed to 14 during adjusted video—reporting effective management of both eating and video-watching. As P19 observed, "Somehow, I didn't feel as distracted; I could focus on both the video and my food without feeling like I was juggling them." Interestingly, participants unaware of the speed adjustment attributed their improved eating awareness to external factors. Some referenced content characteristics (P6: "The content seemed less demanding today"), personal states (P21: "I felt more relaxed, so I could focus better"), or environmental factors (P12: "The pacing felt more natural, maybe because the video was simpler"). These findings highlight the imperceptible nature of such intervention and its enhanced mental availability enabling greater *eating awareness.*

Challenges of maintaining mindfulness. Our empirical findings, in alignment with [83] revealed that maintaining mindfulness during meals is challenging across all conditions, even in supposedly distraction-free scenarios. Notably, 20 out of 24 participants reported perceived distractions in **Focus Eating** condition, primarily due to boredom-induced mind wandering or heightened attention to environmental stimuli (e.g., Someone is talking, honking). This suggests that attention diversion is a pervasive issue in daily eating contexts, regardless of screen presence. Given the prevalence of screen use during meals in modern society, our findings demonstrate that strategic video manipulation can support certain aspects of mindfulness. Specifically, adjusted playback speed promoted slower eating and enhanced general eating awareness by reallocating attention to the act of eating. However, while promising, this approach alone does not fully replicate the mindfulness potential of distraction-free eating, especially sustained attention to food's sensory qualities. This limitation suggests the need for additional strategies to reallocate attention to food awareness within screen-based dining contexts.

4 Study 2: Co-Designing Screen Visual Elements to Enhance Food Awareness

Mindfulness, by its very nature, requires reflection and conscious awareness-aspects that temporal adjustments (i.e., video playback speed manipulation) alone cannot fully address. Participants' sustained screen focus (Sec 3.6) suggested an opportunity to leverage visual elements for directing attention. This led us to explore explicit visual strategies to enhance food awareness during screen-based eating.

While limited in mindful eating, prior research has demonstrated the efficacy of visual elements in other mindfulness interventions: swimming jellyfish for breath guidance [145], lung visualizations in VR therapy for breathing regulation [1], and geometric patterns promoting general mindfulness during walks [149]. However, adapting these approaches to screen-based eating poses unique challenges, as these cues must coexist with video content in a way that supports food awareness without disrupting the eating or watching experience. This led to the following research question:

RQ3: What design principles can guide visual elements design to support food awareness during screen-based eating?

To explore this, we conducted a participatory design workshop, a method widely used in HCI research. This technique engages participants as both informants and co-designers, facilitating diverse perspectives and co-created solutions aligned with individual practices [143]. We invited 9 typical users who met specific criteria: frequent video consumption during meals (self-rated ≥ 7/10), similar meal durations (2̃0 minutes), and diverse professional backgrounds including computing, business, medicine, and design to offer diverse perspectives on how visual elements can convey food awareness.

4.1 Methodology

4.1.1 Workshop Material. Besides the common workshop materials such as colored markers and papers, we developed two cultural probes [57]:

- *Paper-based design probe* We used an A3 format paper probe (see Figure 5) to guide participants in deconstructing the design task into three parts: 1. Concept visualization space for initial design ideation. 2. Targeted questions to prompt detailed design. 3. Open-ended inquiries addressing non-visual aspects (e.g., how it has been triggered). Participants were encouraged to use these probes as a starting point but were not restricted to them. They were free to engage in free-form sketching, drawing user journeys or storyboards for more vivid representations of their ideas.
- *Mindful eating principles cards* We adapted mindful eating principles [29, 59]—awareness of the sensory properties of food, awareness of hunger and satiety, awareness of triggers to eat, awareness towards eating behavior, and attitude—into inspiration cards [62]. Each card provided instructions on mindfulness (e.g., pay attention to the taste, texture, and smell of the food) and practice examples (e.g., notice if the food is crunchy, sweet, or salty) to help participants translate mindful eating concepts into actionable design elements.

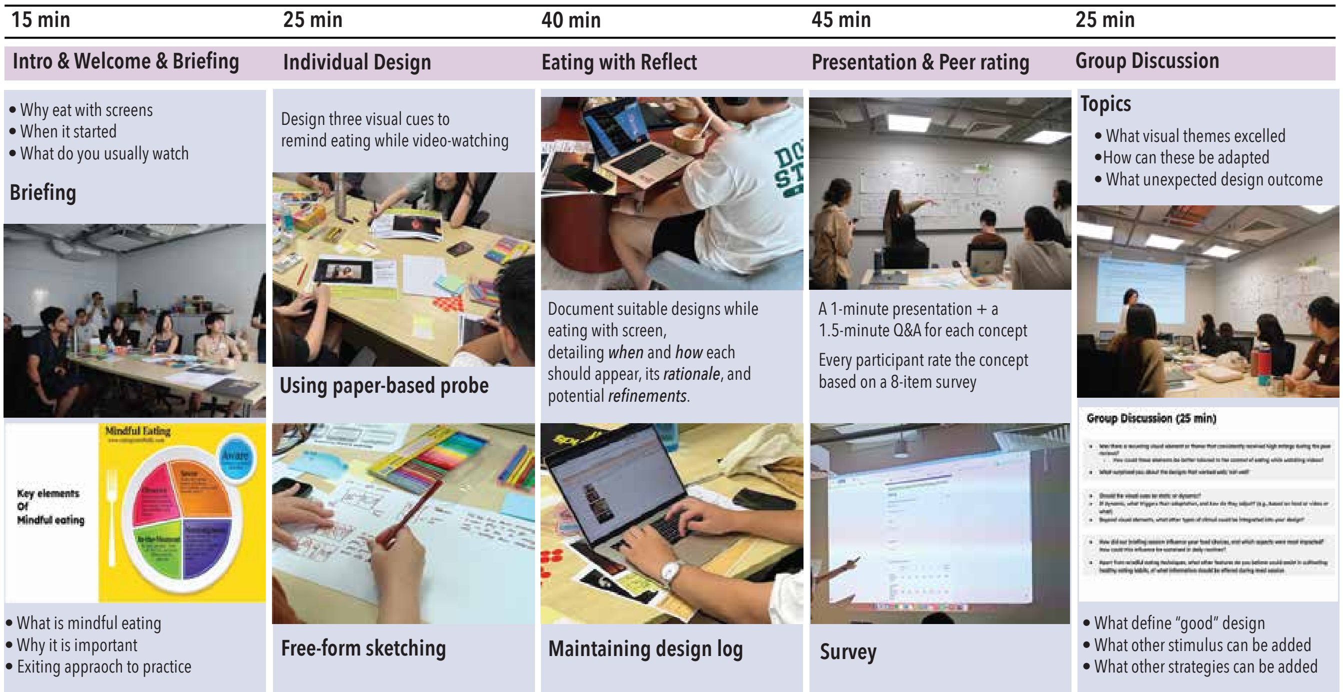

Figure 5: Participatory design workshop procedure: The workshop began with an introductory session, after which participants took part in a hands-on individual session tailored to the workshop's specific objectives. This was followed by an "eating with reflection" phase where participants ate lunch while refining their design and documented changes via a design log. Next is presenting their designs and engaging in peer evaluation through a survey. The workshop concluded with a group discussion.

4.1.2 Workshop Format. The workshop was facilitated by a mindfulness psychology specialist and three co-facilitators with design backgrounds, followed a four-step sequence (Figure 5):

- *Individual Ideation (25 min)* Participants were tasked with creating at least three distinct visual cues for on-screen display during video-watching to remind and engage them of food eating. This phase was supported by mindful eating principle cards for inspiration.
- *Eating with Reflection (40 min)* To contextualize and refine design concepts, participants engaged in a real-world exercise: Participants watched self-selected videos while eating lunch, pausing at moments they deemed suitable for their visual cues. They documented these insights in a design log. This in-situ approach allowed participants to refine their concepts based on immediate, real-world experiences, grounding the ideation process in a practical context.
- *Presentation and peer rating (45 min)* Each participant presented their two most promising designs in a 1-minute presentation, followed by a 1.5-minute Q&A. Each design was then evaluated by all participants using an adapted 8-item usability questionnaire [96, 144], rated on a 7-point Likert scale, assessing dimensions such as food awareness, eating enthusiasm, and visual appeal.
- *Group Discussion (25 min)* The workshop concluded with a group discussion synthesizing insights from the peer-rating process. Topics included recurring elements in highly-rated designs, practicality concerns, and potential implementation challenges. The discussion also touched on the potential complementary stimuli for food awareness cues in multitasking scenarios.

The workshop lasted around 2.5h and each participant was reimbursed with a 15 USD voucher, alongside a complimentary lunch as part of the workshop task.

4.1.3 Workshop Analysis. Throughout design workshops, we documented the activities using field notes, audio recordings, video footage, and photographs. For initial analysis first author identified the top 50% of design concepts based on peer ratings, yielding 9 preferred designs. Each selected concept was additionally labeled to highlight strengths and areas for improvement, determined by comparing median scores to the overall average. To ensure a comprehensive interpretation, we triangulated this quantitative evaluation with qualitative data from workshop discussion transcripts and field notes. Four research team members collaboratively identified commonalities and overarching themes.

4.2 Workshop Findings

In this section, we present the design implications extracted from the ideas generated by participants in response to **RQ3**. Rather than detailing each idea, we focus on synthesizing the principles that illuminate how such concepts could be effectively designed for real-world usage, with emphasis on the principles of glanceability (See Table 2). Findings are referenced using labels D1-D9 for design concepts and P1-P9 for participant quotes.

Prioritizing Glanceable Eating-related Cues. The concept of glanceability [38] emerged as a critical design consideration for visual cues aimed at prompting food awareness during video watching. Glanceability emphasizes designs that allow users to quickly and seamlessly extract pertinent information from a visual display with minimal interruption to their primary task [107]. Achieving high glanceability requires striking a delicate balance between information density and perceptual efficiency. Supported by existing work, workshop-generated designs suggest, firstly, that this can be accomplished through abstraction, which conveys essential information in a simplified form that can be quickly absorbed through with users' peripheral attention, thus enabling efficient processing [58, 108]. Secondly, workshop-generated designs touch upon strategies for positioning cues in peripheral vision to ensure glanceability and noticeability. Thirdly, workshop participants suggested the development of an adaptive system, triggering cues with personalized timing and frequency.

a. Levels of Abstraction Our workshop explored food awareness cues across a spectrum of abstraction levels, ranging from explicit text-based notifications to abstract visual representations. This exploration highlighted the delicate balance between information richness, explicitness, and cognitive demands required to create effective prompts[20, 107].

At the concrete level, text-based notifications (e.g., "Look at your food") mirror traditional system pop-ups by offering clear and direct instructions. However, they were often perceived as lacking in visual appeal and persuasive power. As P8 noted: "I'd probably just dismiss it like any other pop-up. It tells me what to do, but doesn't really make me want to do it." This reflects existing findings in peripheral display design, where text, although efficient for conveying information, may fail to engage users in multitasking environments, as compared to visual presentations [144].

Moving towards abstraction, iconic representations (D3, D4, D5, D8) attempted to balance information richness and visual appeal. For example, the hunger face emoji changing its color to indicate fullness (D3) leveraged the quick interpretability of high-symbolism icons in glanceable displays [107]. However, these designs required strong semantic links to eating behaviors to avoid being dismissed as distractions [28]. Examples such as sparkling sun emojis (D4) or clock scales (D5) revealed that misalignments between the icon and the action could confuse users, highlighting the need for meaningfulness and clarity in icon-based representations [111].

At the most abstract end, designs like color-based cues (D6), such as adding a food-related hue around the video frame, created subtle ambient awareness of eating behavior [159]. P7 appreciated this intuitiveness, stating, "It's subtle but still makes you aware of something; it feels natural and instinctive." However, without clear, actionable prompts, the ability of such cues to promote sustained behavior change remains in question [3].

This analysis suggests that the challenges of iconic representation stem not just from design but from the inherent limitations of using abstract visualizations for conveying food awareness. Based on these findings, we propose three design recommendations for visual cue design in screen-based eating contexts, listed in Table 2.

b. Peripheral Awareness and Noticeability Peripheral positioning emerged as a key strategy for designing glanceable visual cues, a core principle of peripheral display design [107]. Participants consistently favored designs that leveraged peripheral vision while employing various attention-capturing mechanisms. This approach directly addresses a fundamental consideration in peripheral displays [136]: balancing quick information acquisition (glanceability) with the capacity to draw attention when necessary (noticeability). Workshop designs revealed three primary categories based on peripheral placement and attention-capture techniques:

- **Traditional notification placements (D1, D2):** Banner-style cues at the top of the screen, or pop-up windows, featuring tickering (scrolling text) or fading animations, relied on users' familiarity with existing alert systems.
- **Corner placements (D3, D4, D5, D8,D9):** Cues placed in screen corners, using color changes or blinking effects to capture attention, were designed to be noticeable yet minimally disruptive.
- **Seamless integration (D6, D7):** Cues blended directly into the video content itself. For example, D7 linked eating behavior to video color, where unhealthy eating led to a monochrome video display. This strategy made the cue feel like a natural part of the viewing experience, subtly changing over time.

These designs align with the concept of glanceable feedback [13], indicating that well-placed cues enhance information uptake without significantly increasing cognitive load. The chosen attention-capture mechanism is essential for balancing noticeability with non-intrusiveness. Bartram et al. [14] demonstrated that motion-based cues are more effective at drawing attention to the periphery compared to static color or shape changes. Building on this, McCrickard et al. [109, 110] found that while different animations (fading, tickering, and blasting) didn't significantly disrupt the primary task, blasting (an abrupt onset) was most effective at capturing attention. Based on these insights, we propose two design recommendations in Table 2.

c. Adaptive Timing and Frequency Food awareness cues, can be disruptive if triggered simply by a user glancing at the screen. To avoid this, cues should align with the principles of Just-In-Time Adaptive Interventions (JITAI) [116], which suggest tailoring cue timing to each user's unique patterns to increase their effectiveness. Our workshop findings revealed a strong preference for dynamic, context-aware cues over static, fixed-interval reminders. Participants found static cues, like those tied to standard advertisement breaks, to be predictable and often ignored. These cues lacked the contextual relevance needed for impactful interventions. As P12 shared, "If the system could learn when I'm more likely to get distracted by the video and adjust the reminders accordingly, it might actually change how I eat." This preference aligns with research on mobile notifications, where adaptive, context-sensitive approaches have been shown to improve receptivity [131]. Users are more likely to engage with prompts that appear at opportune moments rather

Table 2: Workshop Findings Summary. Outlines key design principles extracted from the workshop

Design Principle	Key Insights	Examples from Workshop	Design Recommendations
Glanceability			
a. Levels of Abstraction	Designing visual cues that are quickly processed with minimal interruption.	Cues ranged from explicit text-based (D1: "Are you full?") to abstract visual representations such as hungry emoji (D3) and color-based cues around the video frame (D6).	1. Develop semantically aligned visual language. 2. Leverage familiar visual paradigms to reduce cognitive load. 3. Ensure clear, actionable prompts.
b. Peripheral Awareness and Noticeability	Cues placed in peripheral vision to maintain attention without being intrusive.	Motion-based banner-style notifications (D1, D2), corner placements (D3, D4, D5, D8, D9), and color blending into video (D6: color frame, D7: gradual monochrome scale).	1. Implement motion-based cues in peripheral areas. 2. Use adaptive saliency (e.g., color, flashing, or abrupt onset) to capture attention.
c. Adaptive Timing and Frequency	Context-aware cues that adjust timing based on user behavior.	Concerns about fixed-interval reminders being too predictable; preferred adaptive systems that anticipate user distraction.	1. Learn and predict individual eating rhythms. 2. Monitor attention states for heightened distraction. 3. Adjust cue timing to enhance user receptivity.

than at set intervals. We propose a behavioral JITAI for screen-based eating interventions with three key features listed in Table 2 as design recommendations.

4.3 Design Goals

Drawing from the insights generated during our participatory design process together with study 1 findings, we propose four design goals to guide the development of our proof-of-concept system.

G1: Leverage the familiar notifications with enhanced emotional cues Our solution aims to build on routine reminders by incorporating icon-based visual elements that infuse subtle touches on humanity and humor [63]. To ensure clarity, these cues will incorporate concise, straightforward textual prompts that guide users toward specific actions, striking a balance between intuitive recognition with actionable instruction.

G2: Repurpose existing video formats for seamless Integration. Our solution aims to adapt familiar video formats to subtly embed intuitive food awareness cues. By building upon users' pre-existing viewing habits (e.g., live stream) and combining them with innovative elements like food awareness cues, our solution is designed to minimize cognitive load and maximize user acceptance.

G3: Implement continuous, context-aware interventions. In line with habit formation theories [116], our solution aims to provide continuous, real-time cues to gradually transform unconscious eating habits into active food awareness through strategic 'dishabituation'. The system will demonstrate contextual awareness, delivering the right support at the ideal times, and integrating seamlessly into individual eating behaviors.

G4: Implement covert auditory manipulation for behavioral nudging. Based on study1 (Section 3), our solution incorporates a hidden feature of incremental playback speed manipulation, setting the video speed to 0.83x of users' habitual viewing pace. This subtle adjustment seeks to promote slow eating-one behavioral aspect of mindfulness without users' explicit awareness.

5 Study3: ViFeed- Promoting Food Awareness in Real-World Screen-Based Eating

5.1 *ViFeed*: System Design and Development

We designed *ViFeed*, a system that provides real-time food awareness cues with subtle playback speed manipulation (G4) to help those who habitually watch videos while eating to infuse mindfulness (Figure 1). *ViFeed* features icon-augmented notifications [73] that present straightforward instruction to refocus user food awareness (G1). These cues are integrated into a live stream video format, mimicking continuous user comments, thus fitting seamlessly into a common video-watching experience (G2). The system triggers these cues during extended periods of non-eating that deviate from the individual's natural eating rhythm, which may indicate potential attention diversion from the meal during the video-watching session (G3).

5.1.1 Food Awareness Cues. We initially used GPT-4 to develop two distinct styles for mindfulness instruction: icon-augmented notifications [73] and proverb-based reminders. The prompts instructed GPT-4 to create messages in different tones (e.g., encouraging, playful, gentle) and to incorporate sensory-focused content (e.g., noticing flavors, textures, aromas), attentional focus, or motivational elements (e.g., famous quotes, emojis). Detailed examples of the prompts are provided in Appendix A. This process yielded over 60 potential food awareness cues. The three authors then reviewed, voted, and refined the cues, ultimately selecting 25 that best aligned with *ViFeed* development (referred to Appendix B). Both

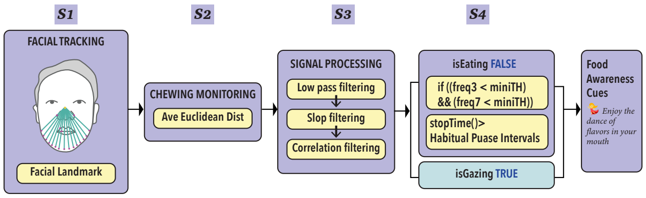

Figure 6: System pipeline to trigger prompts

styles leverage emojis and concise instructions to communicate sentiment, enhance understanding, and introduce a touch of humor to humanize the interaction [63, 90] encourage users to approach their meals mindfully. For example, icon-augmented prompts like 💃 *Enjoy the dance of flavors in your mouth* provide clear actionable instructions, while proverb-based reminders such as 💁‍♀️ *Food for the body is not enough. There must be food for the soul. – Dorothy Day* offers deeper, reflective insights, tapping into the spiritual aspects of mindfulness [151].

5.1.2 Personalized Attention Diversion. Our method for detecting attention diversion during screen-based meals is grounded in the recognition that video-watching and eating can coexist. Participant observations revealed that screen-based distractions frequently manifest as forgetting to eat or losing track of the meal while being engrossed in video content. This insight informed our decision to use *Habitual Pause Intervals* between chews, rather than pure predetermined gaze durations (e.g., 2-5 min [84]) as a more personalized and context-sensitive indicator of attention shifts. This baseline is established using average pause intervals, defined as *Total non-active eating duration divided by the total number of intervals* [24, 46, 48], providing a tailored metric for each individual. Attention diversion is inferred when eating pauses exceed this personalized threshold while the visual focus is simultaneously directed toward the screen. By acknowledging that brief screen glances are a natural part of screen-based eating, our method minimizes unnecessary interruptions by focusing on deviations from the user's established eating rhythm.

5.1.3 Real-time Eating State Analysis. Figure 6 depicts the workflow of *ViFeed*'s real-time eating state detection, which identifies the attention diversion moment using live video streams.

S1 ***S2*** Our system uses the laptop's webcam to detect and analyze eating behaviors in real-time. It begins by identifying key points on the user's face, focusing on areas that move during chewing. By tracking the movement of these facial points, particularly around the jaw and lips, the system can detect chewing motions.

S3 To ensure accuracy, we apply several filtering techniques. These help distinguish actual chewing from other facial movements and reduce "noise" in the data. The system then looks for specific patterns in facial movements that correspond to chewing cycles, capable of identifying both quick and slow chewing rates.

S4 Combined with gaze detection, the system can identify moments when the user's attention shifts away from eating and towards the screen for longer than usual. When it detects a pause in eating combined with prolonged screen focus, it triggers food awareness cues.

We tested the system's ability to detect non-eating states using 80 minutes of video from four participants across two meals, following a similar approach [115]. The system successfully identified most non-eating instances, achieving an average 72% recall and 79.5% F1 score. For a detailed technical explanation of the algorithms and equations used in this process, please refer to Appendix C.

5.1.4 System Implementation. The *ViFeed* system was developed using `React.js` for the front-end interface to ensure a responsive user experience. While future integration with platforms like YouTube is envisioned, we developed a standalone web application using the `react-youtube` component for enhanced control over video playback functionality and eating state detection customization. Upon user consent, *ViFeed* accesses the device's camera feed via the browser. Real-time eating behavior detection is achieved using the `useFaceMesh` hook and `@tensorflow-models/face-landmarks-detection/mediapipe` library. The detection algorithm triggers food awareness prompts when `isEating state is false` and `isgazing state is true` for a duration exceeding the individual's `Habitual Pause Intervals`. These prompts disappear after a 3-second delay (implemented with `setTimeout`) once chewing resumes, ensuring smooth and timely transitions.

5.2 Field Study of *ViFeed*

To evaluate *ViFeed*'s potential for enhancing food awareness in everyday contexts, we conducted a one-week field study. Unlike typical day-long, lab-based mindful studies that focus on immediate effects [160], our approach integrated *ViFeed* into participants' daily routines. This naturalistic design allowed participants to use *ViFeed* during any meal (breakfast, lunch, dinner, or snacks), in various locations, and with any food or video content of their choice. This naturalistic design shifted the focus from the behavioral aspects of mindfulness (i.e., slow eating) assessed in Study 1 to the attentional aspects identified as compromised (i.e., food awareness).

We aimed to explore two key research questions:

RQ4: How does *ViFeed* affect food awareness during screen-based eating in daily contexts, and how does this effect evolve over multiple exposures throughout the week?

RQ5: What is the user experience when interacting with *ViFeed* during screen-based eating in daily contexts, and how does this experience change over multiple exposures throughout the week?

5.3 Participants

We recruited 40 participants (20 female) through the university forum aged 18-30 (mean= 22.48, SD=3.44), across a spectrum of Body Mass Index (BMI) categories from 17.17 to 29.86 (1 underweight, 10 overweight) to ensure the presentation of diverse body composition, enhancing the generalizability of our findings to a broader population. Participants were selected based on self-reported behaviors, specifically those who identified as engaging in mindless eating during screen use (scoring above 7/10 on a Likert scale) and reported at least one screen-based meal per day. To maintain the study's focus, we excluded individuals with medical conditions affecting eating behaviors and those actively engaged in mindful meditation practices. However, expanding on our previous study, we included

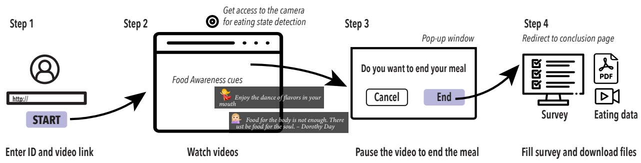

Figure 7: Four-step of system interaction: 1.*System Access*: Participants logged in and entered a YouTube video link. 2. *Video Playback*: Users watched videos while eating, receiving cues if part of the *ViFeed* group. *Meal Completion*: To end the session, participants paused the video and confirmed meal completion through a pop-up window.*Feedback and Data Collection*: After confirming meal completion, participants were directed to a page to fill out a questionnaire on their experience.

participants following specific diets or vegetarian lifestyles to understand our system's impact across a broader range of dietary preferences. All participants provided informed consent, and the study protocol was approved by the university's Institutional Review Board. Participants received compensation of approximately 20 USD for their involvement.

5.4 Procedure

Participants were then randomly assigned to either the *ViFeed* group or the control group. Both groups accessed a unique webpage with identical functionality; however, only the *ViFeed* group received food awareness cues during video playback. The study procedure followed these key steps:

- **Pre-study Session**: The study began with a pre-study Zoom eating session, mirroring the **Focused Eating** session from Study 1 (Section 3). This session served two purposes: determining each participant's *Habitual Pause Intervals* (Section 5.1.2) for personalized prompts and briefing participants on the study procedure to ensure their understanding and commitment.
- **Daily Meal Interaction**: Participants engaged with the system daily, following a four-step interaction process (See Figure 7). After each meal, participants were asked to complete a survey, focusing their feedback solely on the video-watching functionality, disregarding current setup limitations (e.g., manual video link input) to align with future YouTube integration.

The experimenter reminded participants daily to use the system at least once a day to ensure consistent data collection. Zoom interviews were conducted on the first and last days to capture participants' initial experiences, explore any changes in attitudes or perceptions over the week, and gather suggestions for system improvement.

5.5 Design

Following established protocols for field studies of eating interventions [35, 98], we analyzed pre-post comparisons between initial (D1) and final (D7) measurements. Specifically, we used a mixed design, with Time (two levels: D1 for immediate effect and D7 for prolonged effect) as a within-subject independent variable and Group (two levels: ViFeed and Control) as a between-subject independent variable. In terms of dependent variables, we measured the following:

- *Food awareness*: To assess *ViFeed*'s ability to compensate for the lack of food awareness identified in Study1 (3.6), we employed five measures: *Flavor-texture Awareness*, *Food Observance*, *Aroma Recognition*, *Food Focus* and *Food Appreciation*. These items collectively assess various aspects of sensory engagement with food (consistent with our previous measures in Study 1) and the overall value placed on the eating experience, which might be enhanced by increased mealtime attention. All items were measured on a 7-point Likert scale (1: strongly disagree, 7: strongly agree).
- For system interaction, we adapted the User Experience Questionnaire (UEQ) [142], focusing on four domains: *Attractiveness* (the overall impression), *Perspicuity* (easy of use and followability), *Efficiency* (addressing attention diversion without unnecessary effort) and *Stimulation* (the hedonic aspect of motivating use). Each domain comprised specific items measured on the same 7-point Likert scale (see Figure 9 for more details). Additionally, we incorporated an adapted System Usability Scale (SUS), particularly focusing on the glanceable system design [96, 144], to assess the system's *unobtrusiveness* and its ability to balance attention between video watching and eating. This evaluation also included measures of *perceived usefulness* and interest in *daily inclusion*, providing insights into *ViFeed*'s practical applicability and long-term adoption potential.

This design allowed us to explore *ViFeed*'s potential for enhancing food awareness and its usability in real-world contexts, rather than repeating behavioral measurements that are less reliable under free-living conditions (e.g., varying food types, portion sizes, eating times, and settings) [33].

5.6 Results

An aligned rank transform (ART) ANOVA, a nonparametric alternative for mixed design analysis, was performed [165]. This approach was chosen because our data consisted of ordinal Likert scale responses, which did not meet normality assumptions (Shapiro-Wilk tests, $p > .05$) required for parametric tests like Repeated Measures ANOVA. For post hoc comparison, either Wilcoxon signed-rank tests for within-subject factors (D1 and D7) or Mann-Whitney U tests for between-subject factors (ViFeed and Control) were employed with Bonferroni corrections. To address the non-normal distribution characteristic of Likert data, we report median values as measures of central tendency [19].

5.6.1 Food Awareness. There was a significant main effect of Group on *Flavor-texture Awareness* ($F_{1,38} = 107.94$, $p < 0.001$, $\eta^2_G = 0.74$), *Food Observance* ($F_{1,38} = 64.90$, $p < 0.001$, $\eta^2_G = 0.63$), *Food Focus* ($F_{1,38} = 28.32$, $p < 0.001$, $\eta^2_G = 0.43$) and *Food appreciation* ($F_{1,38} = 6.50$, $p = 0.015$, $\eta^2_G = 0.15$). Specifically, Post-hoc comparisons revealed that participants in the ViFeed group consistently reported higher levels of consciousness regarding food flavor and texture, increased attention to food appearance, greater food focus, and enhanced food appreciation compared to those in Control group.

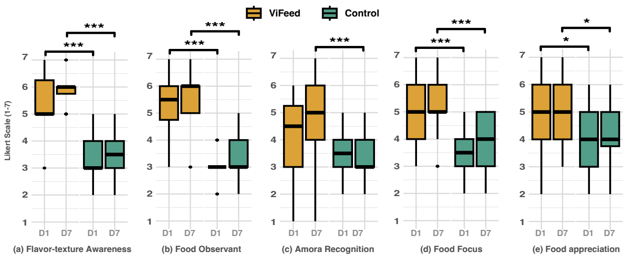

Figure 8: Comparison of food awareness between ViFeed and Control on D1 (immediate effect) and D7 (prolonged effect)

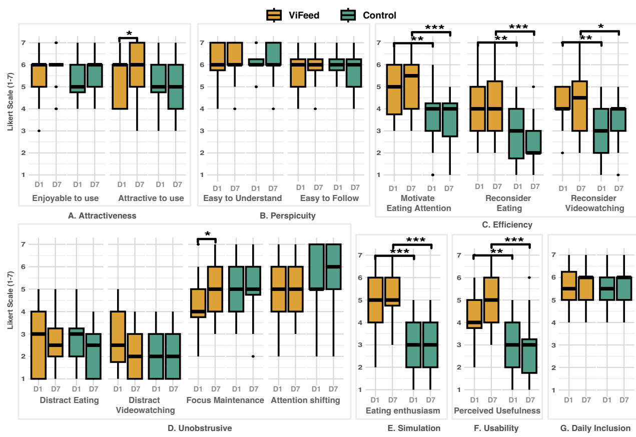

Figure 9: Comparison of system interaction experience between ViFeed and Control on D1 (immediate effect) and D7 (prolonged effect)

These differences were evident both immediately after implementation (D1) and persisted through the end of the study (D7). For *Amora Recognition*, There was a significant main effect of Group ($F_{1,38} = 16.79$, $p < 0.001$, $\eta^2_G = 0.31$) and a significant Group × Time interaction ($F_{1,38} = 4.86$, $p = 0.034$, $\eta^2_G = 0.11$). While no significant difference was observed on D1 between the two Group (ViFeed: *Mdn* = 4.5; Control:*Mdn* = 3.5) ($U = 268$, $p = 0.060$), by D7, ViFeed participants (*Mdn* = 5) reported significantly more attentive to smells and aromas of the food they ate compared to those in the Control (*Mdn* = 3) ($U = 334$, $p < 0.001$). See Figure 8 for details.

Addressing RQ4, these findings demonstrate *ViFeed*'s significant immediate and 7-day positive impact on food awareness and appreciation. While most aspects show consistent effects throughout the week, the delayed improvement in aroma recognition suggests cumulative benefits with continued use.

5.6.2 System Interaction. Key findings for each aspect are detailed below (Figure 9):

A. Attractiveness. There was no significant main effect of Group, Time or Group x Time interaction on *Enjoyable to Use* and *Attractive to Use* (all p>0.05). However, ViFeed group reported increased attractiveness of system use over time from D1 (*Mdn* = 6) to D7 (*Mdn* = 6), ($U = 4.5$, $p = 0.025$).

B. Perspicuity. There was no significant main effect of Group, Time or Group x Time interaction on *Easy to Understand* and *Easy to follow* (all p>0.05).

C. Efficiency. There was a significant main effect of Group on *Motivate Eating Attention* ($F_{1,38} = 18.79$, $p < 0.001$, $\eta^2_G = 0.33$), *Reconside Eating* ($F_{1,38} = 32.86$, $p < 0.001$, $\eta^2_G = 0.46$) and *Reconsider Videowatching* ($F_{1,38} = 14.85$, $p < 0.001$, $\eta^2_G = 0.28$). Specifically, the ViFeed group reported higher motivation to pay attention to food eating, and were more likely to reconsider their eating and video-watching habits compared to the control group on both D1 and D7.

D. Unobtrusiveness. There was no significant main effect of Group, Time or Group x Time interaction on *Distracting Eating*, *Distracting Video-watching* and *Attention Shifting* (all p>0.05). However, There was a significant main effect of Time ($F_{1,38} = 7.01$, $p = 0.012$, $\eta^2_G = 0.16$) on *Focus Maintenance.* Post-hoc comparison showed that the ViFeed group reported increased attention maintenance during multitasking over time from D1 (*Mdn* = 4) to D7 (*Mdn* = 5), ($U = 2$, $p = 0.0282$).

E. Stimulation. There was a significant main effect of Group ($F_{1,38} = 55.12$, $p = 0.015$, $\eta^2_G = 0.59$) on *Eating Enthusiasm.* Post-hoc comparison indicated that participants consistently rated ViFeed (D1: *Mdn* = 5; D7: *Mdn* = 5) as promoting a fresher and more enthusiastic approach to eating compared to the Control (D1: *Mdn* = 3; D7: *Mdn* = 3) on both D1 ($U = 328$, $p < 0.001$) and D7 ($U = 368$, $p < 0.001$).

F. Usability. There was a significant main effect of Group ($F_{1,38} = 25.80$, $p < 0.001$, $\eta^2_G = 0.40$) and Group × Time interaction ($F_{1,38} = 4.11$, $p = 0.050$, $\eta^2_G = 0.10$) on *Perceived Usefulness.* Post-hoc comparison indicated that participants in ViFeed (D1: *Mdn* = 5; D7: *Mdn* = 5) consistently considered it as more useful toward food awareness compared to the Control (D1: *Mdn* = 3; D7: *Mdn* = 3) on both D1 ($U = 304$, $p = 0.0041$) and D7 ($U = 347$, $p < 0.001$).

G. Daily Inclusion. There was no significant main effect of Group ($F_{1,38} = 0.017$, $p = 0.896$, $\eta^2_G = 0.0005$) or Time ($F_{1,38} = 1.296$, $p = 0.262$, $\eta^2_G = 0.03$), nor was there a significant Group × Time interaction ($F_{1,38} = 0.201$, $p = 0.656$, $\eta^2_G = 0.005$) on *daily use.*

Addressing RQ5, participants found *ViFeed* to-be a motivating and effective tool for promoting food awareness in daily settings, without being intrusive. The attractiveness of *ViFeed* and its capability to maintain focus during multitasking improved with continued use, underscoring its potential for regular integration into daily routines.

6 Discussion

The ubiquity of digital entertainment in modern life presents both challenges and opportunities for shaping daily behaviors. Our research suggests that, rather than viewing digital content solely as a distraction, it can be strategically repurposed as a pathway toward mindfulness. Using *ViFeed* as a proof-of-concept, we demonstrate how careful manipulations of digital content—specifically, slight speed adjustments and subtle visual cues—can foster slow eating and food awareness during screen-based eating without disrupting the primary entertainment experience. Our one-week field study provided empirical insights into *ViFeed*'s practical application and effectiveness. By integrating these findings, we examined how simple interventions can drive behavioral and attentional change, identified potential avenues for *ViFeed*'s refinement and adoption, and more importantly, informed how its core principles—subtle manipulation within existing digital activities can be broadly applied to other mindfulness practices.

6.1 The Impact of *ViFeed* Beyond Mindfulness

Beyond enhancing the sensory awareness and sensory exploration of food [103, 163], *ViFeed* incorporated "entertaining" emojis with actionable instruction, tapping into the benefits of gamification in health interventions[76]. This approach created a "fun and interactive" (P17) eating environment, which helped sustained user engagement throughout the week. This gamified approach not only improved system adherence but also fostered a sense of emotional and social support during meals, aligning with the concept of digital commensality [22]. This was especially valuable for solitary eaters, as highlighted by P9's sentiment of having "someone eat with me." While *ViFeed* primarily promotes food awareness through explicit visual cues, participants demonstrated reflection beyond immediate sensory engagement. The system's prompts to savor each bite unexpectedly encouraged awareness of broader eating behaviors. For example, P14 became aware of their fast eating and adjusted their behavior to eat more slowly after encountering the prompts. This suggests that by fostering self-awareness, explicit food awareness cues may still catalyze broader behavioral reflection during screen-based meals, potentially supporting multiple aspects of mindful eating simultaneously.

6.2 User Engagement and Motivation Transformation

ViFeed facilitated natural adoption by integrating food awareness support into existing screen-based dining practices. This familiarity fostered a sense of perceived volition [61], as participants retained meaningful control over decisions, such as when to eat, what to eat, and how to engage with the cues. Participants appreciated this flexibility, which ensured mindfulness practices aligned with their personal preferences. As P4 expressed, "I didn't feel forced to follow the prompts; they were there if I wanted them, but I could still ignore them." By automatically prompting cues, *ViFeed* alleviated the cognitive effort required for self-monitoring, particularly in relation to food sensory engagement. As P17 described: "They were like training wheels for mindfulness.".

Over time, user engagement with *ViFeed* demonstrated a shift from extrinsic to intrinsic motivation. Initially, curiosity, daily information habits, and novelty of experience drew participants to *ViFeed*. According to P1, "I was just curious about the study and thought it wouldn't hurt to follow instructions". This external motivation deepened, as influenced through positive reinforcement, such as focusing on the sensory aspects of the meal (P1) deepened the motivation to follow the prompts. Similarly, P6 indicated a growing appreciation for eating, reporting that eating slowly allowed for a "greater appreciation of the food" and the overall dining experience.

However, the effectiveness of *ViFeed* was not uniform across all participants. Those who (P10) had self-identified as a mindful eater reported less benefit, indicating a potential ceiling effect. This implies that interventions may be less impactful for individuals at more advanced stages of behavior change. This corresponds with the maintenance stage of the Transtheoretical Model of behavior change [105], characterized by the consistent practice of new habits, leaving less room for additional interventions to drive further change. These observations highlight the necessity of identifying and adapting to varying levels of mindful eating proficiency, ensuring broader applicability and sustained benefit across a diverse spectrum of users.

6.3 Adapting to *ViFeed*

The week-long engagement with *ViFeed* showcased an interesting trend of growing user attachment, countering typical technology adoption patterns where engagement diminishes after initial novelty. This trend can be encapsulated through two key observations:

6.3.1 Mere Exposure Effect. Mere Exposure Effect suggests that repeated exposure to a stimulus increases an individual's liking for it [167]. In the case of *ViFeed*, the seven-day engagement appeared sufficient for fostering familiarity, without causing habituation or fatigue[113]. One plausible explanation is the inherent repetition in mindfulness practices[25, 156]. As P6 noted, "It's okay to do the same thing and have the same instruction. It's just like other mindfulness practices—you breathe in, breathe out." However, *ViFeed* extends beyond simple repetition by introducing dynamic cue delivery, balancing familiarity with unpredictability. Dynamic cue presentation and delivery likely contribute to user interest, leading to anticipation of cues becoming part of the experience.

Initially, some participants underestimated *ViFeed*'s potential impact, reflecting a cognitive bias rooted in overconfidence about their existing eating habits. P4 exemplified this sentiment, saying "The very first time I try it, I think it doesn't really affect me because I already had it in me." Over repeated use, however, the added value of external prompts became apparent, leading to a growing appreciation for the system's utility. This shift to an appreciation of external support for maintaining mindfulness represents the next stage of adaptation and integration with *ViFeed*. As the system became a habitual part of the mealtime experience, its absence was notably felt. P9's reaction to a prompt-free meal on 3rd day of study, expressed as "no prompt day 😟", underscored how quickly the system had become ingrained in users' daily practices.

6.3.2 Interruption Management in Daily Life. Research on interruption management [154] suggests that people are accustomed to dealing with interruptions in their everyday lives. This inherent ability provided a foundation for participants to adapt to *ViFeed*, eventually reframing food awareness cues from potential distractions to valuable refocusing aids. Unlike typical "quite technical"

(P18) notifications that often fragment attention [41], *ViFeed* seamlessly incorporated relevant information (i.e., food awareness) into ongoing activities (i.e., screen-based eating). These cues served as informative interruptions, enhancing rather than hindering the primary activities of eating and video watching. P11 highlighted this benefit, noting, "I think I've gotten more aware of the food I eat... I got to appreciate more of the food I eat while still enjoying the videos." Continued engagement over the week allowed users to leverage their existing interruption management skills while experiencing *ViFeed*'s multifaceted benefits.

Over time, some participants developed adaptive strategies to balance attention between video watching and prompt reading when interacting with *ViFeed*. Those who initially read each prompt meticulously gradually streamlined their interactions. P1 explained this transition: "Initially, I'm trying to read every word... but now I know whenever I see this shows up, I should have been focusing on my eating." This shift from careful reading to efficient scanning allowed for quicker processing of prompts without disrupting the video-watching experience. Similarly, participants optimized their interaction with *ViFeed* based on the cognitive demands of their primary task. They learned to engage more with prompts during less visually demanding video segments, allowing for better integration during multitasking. This progressive adaptation enhanced their ability to maintain focus while multitasking (i.e., screen-based eating with cues checking).

6.4 Future Research Directions

6.4.1 Enhancing ViFeed for Commercial Integration.

Diverificaiton of Mindfulness Cues. *ViFeed*'s two types of prompts - icon-augmented and proverb-based - cater to diverse user preferences, with 60% favoring icon-augmented cues for their simplicity and directness and 25% valued proverb-based prompts for their depth and reflective nature. Building on these findings, to enhance long-term effectiveness, future research could explore:

- Content-specific variation: Incorporating educational elements ranging from food-specific content (e.g., nutritional facts, food origins) to general wellness information (e.g., mindfulness tips) could transform reminders into tools for enhancing health literacy. A balanced approach, highlighting both the benefits and pitfalls of eating habits, may support deeper self-reflection [60].
- Emotional, temporal, and contextual awareness: Personalizing prompts based on users' emotional states or daily routines could significantly enhance their relevance and effectiveness [171], consequently improving users' receptivity[128].
- Interactive and reflective elements Introducing engaging questions and post-meal reflections could foster active mindfulness, potentially increasing user engagement and the depth of mindful practices.

Privacy and Ethical Consideration. Despite 65% of the participants prioritizing functionality over privacy, viewing eating as a relatively public activity, and valuing the benefits of camera-based Automatic Dietary Monitoring, addressing privacy concerns remains crucial for widespread adoption [6, 153]. Future development should focus on:

- Enhanced data management: User acceptance of mindful eating apps depends heavily on data security concerns [60]. While *ViFeed* mitigates risks through on-device processing [9, 44], technical safeguards alone don't fully establish trust. Social settings introduce privacy complexities. Future iterations should explore advanced techniques to limit data transmission and storage.
- User control: Developing granular control mechanisms, such as temporary camera deactivation options, could address privacy concerns in various social contexts.
- Ethical implementation: Creating clear, context-specific privacy agreements tailored to different application scenarios (e.g., research, personal use, commercial deployment) is crucial for maintaining user trust and ethical standards [82].
- Alternative detection methods: While *ViFeed* uses camera-based detection [18], less intrusive methods like wearables [68], smart utensils [169], and audio sensors [124] offer viable alternatives. These methods, enhanced by techniques like CNNs, could improve accuracy while balancing privacy and real-world applicability [153].

6.4.2 From Screen-Based Mindfulness to Broader Health Impact.

Our focus is on university community members—predominantly young adults who have grown up with screens as integral parts of daily meal rituals—as an initial population for exploring the potential of screen-based eating interventions like *ViFeed* [5]. Their familiarity with integrating technology into mealtimes, combined with flexible eating habits and high digital literacy, created favorable conditions for early adoption.

The immediate effects observed in this population demonstrate *ViFeed*'s potential in two mindful eating aspects: eating behavioral regulation (i.e., reduced eating rate and food consumption in Study 1) and attentional enhancement (i.e., improved food awareness in Study 3). These findings align with established relationships between mindful eating and improved health markers [77]. For instance, practices like slower eating and controlled food intake are recognized strategies in obesity management interventions [48, 65, 122], while enhanced mindfulness during meals may reduce emotional eating and mitigate eating disorders [160].

Beyond behavioral and attentional components, mindful eating encompasses attitudinal formation—particularly non-judgmental awareness—which presents distinct challenges [83]. Our cognitive patterns naturally tend toward evaluative categorization of food as "good" or "bad". While *ViFeed* did not explicitly address this dimension, the increased food appreciation observed in our field study signals a promising avenue. Research indicates that cultivating deeper relationships with food through enhanced sensory, cultural, and nutritional appreciation can facilitate the development of non-judgmental attitudes [160]. This presents an opportunity for future investigations to explore how digital interventions like *ViFeed* could support this attitudinal development in mindful eating practices, further amplifying their impact on health and well-being.

Although our investigation centered on solo diners, the increasing integration of screens into family mealtimes, particularly in households with young children [135], presents opportunities for broader application. Adapting *ViFeed* for communal dining contexts could extend its impact beyond individual mindfulness to support family-wide healthy eating practices. However, such adaptation requires careful consideration of complex familial dynamics, including managing diverse age groups, varying family roles, privacy concerns, and potential interpersonal conflicts [139]. For instance, while socially-oriented prompts (e.g., "What memory does this meal bring to mind?") could facilitate family discussions and enhance collective food appreciation, their successful implementation depends on addressing these familial complexities.

6.4.3 Expanding Digital Mindfulness Beyond Eating. The concept of digital mindfulness [171] has evolved from standalone applications on devices (e.g., mobile phones[60], smart glasses [149], VR devices [12]) to integrated approaches in everyday digital interactions. *ViFeed* embodies this shift by leveraging screens as conduits for mindfulness interventions in screen-based eating settings.

Our empirical exploration of *ViFeed* uncovered a key insight: for complex mindfulness practices like mindful eating, purely unobtrusive interventions (i.e., video playback speed adjustments) may be insufficient. To address this, *ViFeed* introduced explicit food awareness cues that prompted conscious reflection and engaged multiple principles of mindful eating. This dual strategy aligns with the dual-process theory of cognition, which distinguishes between two systems: System 1 (fast, automatic, and unconscious) and System 2 (slow, deliberate, and conscious) [53]. The integration of dual-process theory in digital mindfulness, as demonstrated by *ViFeed*, opens avenues for broader digital mindfulness beyond eating contexts:

- Cross-domain Applications: For instance, in the realm of mindful breathing, applications could be developed to subtly adjust background visuals or sounds to synchronize with optimal breathing rhythms, while periodically providing explicit prompts for breath awareness. Similarly, mindful walking could be promoted through apps that use accelerometer data to subtly adjust audio cues based on walking pace, paired with occasional reminders to focus on the sensations of movement. The concept could even be applied to traditional practices like body scan meditation, where wearable devices could use gentle haptic feedback to guide attention through different body parts, complemented by voice prompts encouraging deeper awareness of bodily sensations.
- Multi-sensory Approaches: Expanding beyond visual interventions, future research could explore multi-sensory approaches to deliver mindfulness cues or behavior change prompts. Olfactory cues present an intriguing avenue, given the strong connection between smell, memory, and emotional regulation [102]. Tactile feedback through haptic technologies could provide unobtrusive mindfulness reminders while serving as a form of tactile attention capture. Even thermal stimuli could be examined for their potential in creating immersive mindfulness experiences. However, these multi-sensory approaches, while promising, present challenges in hardware requirements and practical integration that warrant careful investigation.
- Theoretical Implications and Future Research: Integrating dual-process theory into digital mindfulness research offers promising avenues for understanding the interplay between unconscious and conscious processes in cultivating mindfulness. This approach allows us to examine the evolution of mindful behaviors, particularly how conscious, effortful practices transition into intuitive, habitual behaviors. Drawing from emerging research in digital behavior change [100], the transition from System 2 to System 1 processes holds the key to developing interventions with lasting impact, potentially reshaping how individuals interact with digital environments on a daily basis. Moreover, recognizing individual differences and contextual factors in mindfulness practices paves the way for personalized interventions [60]. By investigating *when* and *why* single-system approaches might outperform dual-process strategies, we can develop a more nuanced understanding of digital mindfulness and technology-mediated behavior change in the digital age.

7 Limitations

Our focus on video watching, while representative of a prevalent screen-based activity during meals, captures only one aspect of digital entertainment in eating contexts. Future studies should explore the applicability of ViFeed's principles to other screen activities such as social media browsing, messaging, or digital commensality [83]. This expansion could provide a more comprehensive understanding of such design strategies for promoting mindfulness across diverse digital interactions.

From a technical perspective, our current implementation, using a webpage rather than integrating with popular streaming platforms, also leaves room for expansion and user adoption. While our computer vision-based eating detection achieved a reasonable F1 score (67%-92%), the latency (800ms-3000ms) in detecting real-time chewing and facial movements indicates room for improvement. Individual variations in chewing patterns and potential confounds like speaking movements suggest the need for more advanced or multi-modal detection methods. Future research could explore sensor fusion techniques or deep learning approaches to enhance detection accuracy and reduce latency. Moreover, validating attention diversion markers through extended habitual eating pauses and gaze tracking could further refine the system's empirical foundation.

Methodological limitations include demographic constraints (university community focus), potential self-selection bias in Study 3 (self-reported mindless eating), accessibility limitations (kitchen scale requirement) and a single trial nature in Study 1, which restricts the generalizability of our findings. Future studies should prioritize diverse sampling, incorporating individuals with varying body weights (e.g., those with obesity) and groups who may derive the most benefit from mindful eating interventions (e.g., individuals with eating disorders). While *ViFeed*'s deployment on common digital devices might enhance its scalability, real-world eating contexts are inherently complex. Factors such as time-constrained meals, cultural norms around technology use during dining, and individual differences in eating styles (e.g., restrictive vs. non-restrictive eaters) warrant further investigation to adapt *ViFeed* effectively for diverse settings. Moreover, comparative analysis between *ViFeed*'s food-focused design and non-food visual cues (e.g., general wellness prompts) could elucidate whether the observed effects stem specifically from food awareness or general attention modulation.

Lastly, given that behavioral change and habit formation occur over extended periods, future research is recommended to examine *ViFeed*'s impact across different temporal scales: from more granular patterns of user awareness and engagement progression to longitudinal studies spanning several months to understand its efficacy in establishing sustained mindful eating practices during screen-based meals, and if such mindfulness could contribute to more general health impact.

8 Conclusion

In this paper, we explored how mindfulness principles can be strategically integrated into screen-based eating, transforming potential digital distractions into opportunities for positive health outcomes. *ViFeed*, a video playback system designed to facilitate mindfulness through two core mechanisms: subtle video playback speed adjustments for eating rate regulation and context-aware food awareness cues for attentional enhancement. These features were developed and refined through a series of empirical studies. In a semi-controlled zoom eating (Study 1), we provided an empirical understanding of how screen-based eating both diverts and maintains mindfulness compared to distraction-free meals. Subtle manipulations, such as video playback speed adjustments, emerged as effective strategies to enhance eating awareness, slow down eating, and control food consumption without compromising satiation. Through participatory design (Study 2), we identified and implemented key design strategies—particularly glanceability—to enhance food awareness during screen-based meals. A subsequent week-long field deployment (Study 3) validated *ViFeed*'s efficacy in promoting sustained mindfulness, with participants demonstrating enhanced food awareness and appreciation coupled with increasing engagement over time.

Positioned as a step toward mitigating the challenges of a distraction-filled digital environment, *ViFeed* illustrates how implicit mechanisms (e.g., subconscious speed adjustment) and explicit prompts (e.g., reflective cues) can maintain digital engagement with mindfulness. Future research should examine how these immediate benefits could be sustained and potentially amplified over time, suggesting opportunities for digital health interventions to achieve broader health impacts beyond mindfulness across diverse real-world settings.

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A Examples of GPT-4o prompts for generating food awareness cues

Generate 15 simple, intuitive reminder messages that can be used to encourage mindful eating during a video-watching session. The messages will show up timelily on the screen to help align eaters with the principles of mindful eating, and be in the tone of an encouraging facilitator. You can include emojis or other methods to make the messages engaging. (You can provide relevant famous quotes to accompany these reminder messages.)

Now generate similar messages that cover specific aspects of mindful eating, such as noticing ingredients, flavors, textures, taste, and aromas of the food. Messages can also be relevant to self-awareness and attentional focus.

Provide versions of the message in different tones and styles.

B A list of food awareness cues in ViFeed

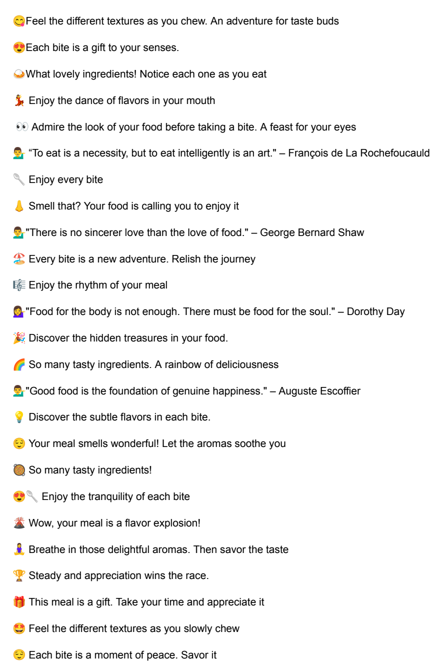

Figure 10

C System development

S1 The system captures real-time video streams through the users' laptop webcam. Using TensorFlow Face Landmark Detection Model by MediaPipe, together via the npm TensorFlow module, it identifies 19 facial landmark points related to chewing activity, where the nose point serves as a central reference [8].

S2 The **Average Euclidean Distance** between the nose point and oval jaw and lip points is calculated to monitor oscillations in facial geometry indicative of chewing, using Equation(1).

$$\textbf{Average Euclidean Distance} = \frac{1}{n}\sum_{i=1}^{n}\sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2} \tag{1}$$

where n is the number of points on the jaw and lips.

S3 The system applies a *Low Pass Filtering* using Equation(2) to smooth the final and reduce noise:

$$\textbf{Low Pass Filtering Value} = \alpha \times \text{Euclidean Distance Calculated} + (1 - \alpha) \times \text{Previous Value} \tag{2}$$

where: $\alpha = \frac{dt}{dt+RC}$ with $dt = \frac{1}{\text{Sample Rate}}$ and $RC = \frac{1}{2\pi \times \text{Cutoff Frequency}}$

Following this, the system applies the slop filtering [8], utilizing a cutoff frequency of 1 Hz. The sample rate is determined in real-time, based on the time intervals between consecutive signal captures :

(1) **Identify Local Maxima:** A peak is identified if:

$$\text{Signal}[i] > \text{Signal}[i-1] \text{ and } \text{Signal}[i] > \text{Signal}[i+1]$$

(2) **Calculate Slopes:** For each identified peak, the slopes on both sides are calculated:

$$\text{Left Slope} = \text{Signal}[i] - \text{Signal}[i - \text{Offset}]$$
$$\text{Right Slope} = \text{Signal}[i + \text{Offset}] - \text{Signal}[i]$$

where i represents the index of identified peaks, utilizing an offset of 2.

(3) **Filter Peaks Based on Slope Threshold:** A peak is retained if:

$$\text{Left Slope} > \text{Threshold and } |\text{Right Slope}| > \text{Threshold}$$

The threshold value of 0.14 was determined based on empirical testing to optimize the detection of subtle chewing activities while minimizing the capture of incidental facial movements.

Correlation filtering further refines the process by aligning detected peaks with established chewing cycles using a Pearson correlation coefficient (Equation 3), setting a threshold of $r = 0.8$ [4]. This optimal correlation value was established through empirical testing ranging from 0.4 to 0.95, avoiding potential false positives.

$$r = \frac{\sum\left(\frac{(\text{arr1}[i]-\text{Mean}_{\text{arr1}})\times(\text{arr2}[i]-\text{Mean}_{\text{arr2}})}{\text{StdDev}_{\text{arr1}}\times\text{StdDev}_{\text{arr2}}}\right)}{N} \tag{3}$$

Where $\text{Mean}_{\text{arr}} = \frac{\sum \text{arr}}{N}$ and $\text{StdDev}_{\text{arr}} = \sqrt{\frac{\sum(\text{arr}-\text{Mean}_{\text{arr}})^2}{N}}$

S4 Finally, the system defines chewing cycles with dual time windows: a 3-second window [49, 152] for immediate chewing post-pause and a 7-second window to smooth out the frequency to capture slow chewing rate (i.e., 1.96s per chew). Combined with the gaze detection model[43], the system actively identifies attention diversion moments - when the participant's chewing frequency falls below a predefined threshold and gaze fixes on the screen for longer than the *Habitual Pause Intervals*, triggering mindful eating cues.